Digital capture and transfer of tacit knowledge embedded in craft objects

A thesis submitted in partial fulfilment of the requirements for the degree of

Doctor of Philosophy

by

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DECLARATION

I hereby declare that the work contained in this thesis entitled "**Digital capture and transfer of tacit knowledge embedded in craft objects**" is my own work done under the supervision of Professor Pradeep G. Yammiyavar, at the Department of Design, Indian Institute of Technology Guwahati (IITG), Assam. I hereby declare that to the best of my knowledge, it contains no materials previously published or written by another person, or substantial proportion of material which have been accepted for the award of any other degree or diploma at IITG or any other educational institute, except where due acknowledgement is made in this thesis. Any contribution made to the research made by others, with whom I have worked at IITG or elsewhere, is explicitly acknowledged in the thesis. I also hereby declare that the intellectual content of this thesis is the product of my own work, and as per general norms of reporting research findings, due acknowledgements have been made wherever the research findings of other researchers have been cited in this thesis.

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CERTIFICATE

This is to certify that the work contained in this thesis entitled "**Digital capture and transfer of tacit knowledge embedded in craft objects**" submitted by Mr. Sai Prasad Ojha to the Indian institute of Technology Guwahati, Assam (India) for the award of the degree of Doctor of Philosophy has been carried out under my supervision. This work has not been submitted elsewhere for the award of any other degree or diploma.

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Synopsis

Crafts industry is largely dependent on skills of highly proficient employees. Art Craft and to some limited extent Design Traditions and practices are transferred from one generation to another by internship and are often confined to families or communities. Even though there has been modernization in the crafts industry the requirements and supply for highly skilled craftsmen has not kept pace with demand. Several instances of a line of crafts having died out because there being very few craftsmen willing to continue or train new interns which has come to light. Continuing the traditions is becoming difficult besides gaps in documentation. With decrease in artisan numbers and onslaught of mechanization & mass production crafts, accompanying skills and more important tacit knowledge surrounding them are likely to lose out.

The above scenario is leading to loss of Knowledge in crafts that has been traditionally handed down through generations of crafts families. This thesis work posits that if there is a way to capture and preserve as well as transfer tacit knowledge of the craftsmen into some form of reusable digital documentation it is possible to replicate and preserve such knowledge and use it in the future especially so in the absences of expertise that resides in the human body mind and spirit. When masters die. If 'Tacit knowledge' can be captured into digital form it is expected to remain safe for centuries, besides become a knowledge base for generations to come.

Such a tacit knowledge repository is expected to help in wide ranging knowledge engineering activities ranging from conservation to heritage mapping including anthropology as well as engineering and manufacture domains.

Two specific problems arose during this research.

1) How to capture Tacit knowledge and

2) How to transfer tacit knowledge from human knowledge domain to machine knowledge domain.

To answer the above several studies to observe craftsmen in the act of creation were documented using available mediums such as photography and videography. Interviews were conducted to understand and bring out thought process behind the tacit thinking of the craftsman.

Another set of experiments have been attempted to capture, transfer and reproduce some aspects of tacit knowledge using digital tools.

This eventually led to a method for capturing, documenting and transferring Tacit Knowledge. The outcome is in the form of a fuzzy model, which binds the knowledge/skills of the craftsman embedded in his creation. The proposed fuzzy-based model accesses the craft products in terms of various design elements like colour, shape, pattern, size and texture value. This fuzzy model developed is a step forward towards categorization of the craft product uniquely in terms of tacit knowledge of craftsman and craft product. Also an extension of the crafts knowledge was made using an transfer learning algorithm which is one of the advancement in Artificial Intelligence.

The experiments to prove certain assumptions and hypothesis that have been carried out in this work involved local craftsman working in the bamboo and craft and clay items making enterprises.

Initial result indicates that to capture the many hues of tacit knowledge, an in-depth and cyclic study needs to be conducted in the form of dialogues and video documentation with the craftsperson while they are either practicing or are training other craftsperson. The mental maps of a craftsperson's thinking while practicing need to be developed. These mental maps will also act as conduits and sinks of the local culture and traditions where the crafts thrive.

It is possible to machine code tacit knowledge that goes into making, and deciding a product during its birth.

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Chapter-1 Introduction

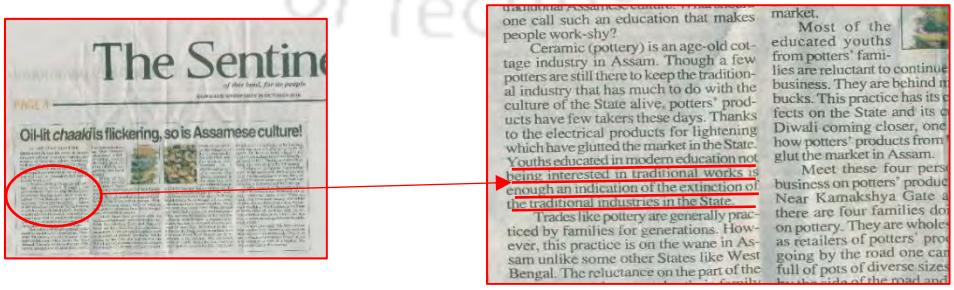
***Abstract**: This chapter introduces the background and context of the research covered this thesis. It outlines the aims, objectives, and purpose of the research. The research tries to capture and preserve the knowledge acquired during the craft making process. It describes the framework around which the research plan is formulated. The overall methodology, followed along with definitions of terms used, has been outlined. Research gaps of the thesis are highlighted, which lead towards the formulation of research questions. The chapter concludes with summaries of all the chapters.*

1.1 Introduction

The history of craft and art dates back to several thousand years in which the human civilization has been practicing art and craft to display their talent as well as produce daily needed products. The traces of craft items can be found in the Harappa and the Indus valley civilization. The older civilization crafts (Miller et al., 1997) depict the different ways of producing pottery, cups, utensils, etc.

Fig.1.1 Different firing Kilns of the Indus valley civilization (Miller et al., 1997)

According to the Ministry of Arts and Crafts, India (retrieved from www.india-exports.com, Feb. 2, 2018), India has been a major contributor to the distribution of handicraft since ages. In the ancient times, handicrafts were exported to far of East, Europe, West Asia and Africa via the 'Silk Route'. During recent times there has been a drastic decline of the trade due to very less craftsman getting involved in the production of the crafts, Fig. 1.2.


The Sentinel

Oil-lit *chaaki* is flickering, so is Assamese culture!

one call such an education that makes people work-shy?

Ceramic (pottery) is an age-old cottage industry in Assam. Though a few potters are still there to keep the traditional industry that has much to do with the culture of the State alive, potters' products have few takers these days. Thanks to the electrical products for lightening which have glutted the market in the State. Youths educated in modern education not being interested in traditional works is enough an indication of the extinction of the traditional industries in the State.

Trades like pottery are generally practiced by families for generations. However, this practice is on the wane in Assam unlike some other States like West Bengal. The reluctance on the part of the

market.

Most of the educated youths from potters' families are reluctant to continue business. They are behind m bucks. This practice has its e fects on the State and its c Diwali coming closer, one how potters' products from glut the market in Assam.

Meet these four pers business on potters' produc Near Kamakshya Gate there are four families do on pottery. They are whole as retailers of potters' pro going by the road one ca full of pots of diverse sizes

Fig. 1.2: The news report of depleting craft. (The Sentinel, 2016).

1.2 Scenario of Craft Sector in India

More than half of the craft industries of India are on a declining stage as the modernizing is increasing in India. Fig. 1.3 shows the approximate craft distribution in various parts of India.

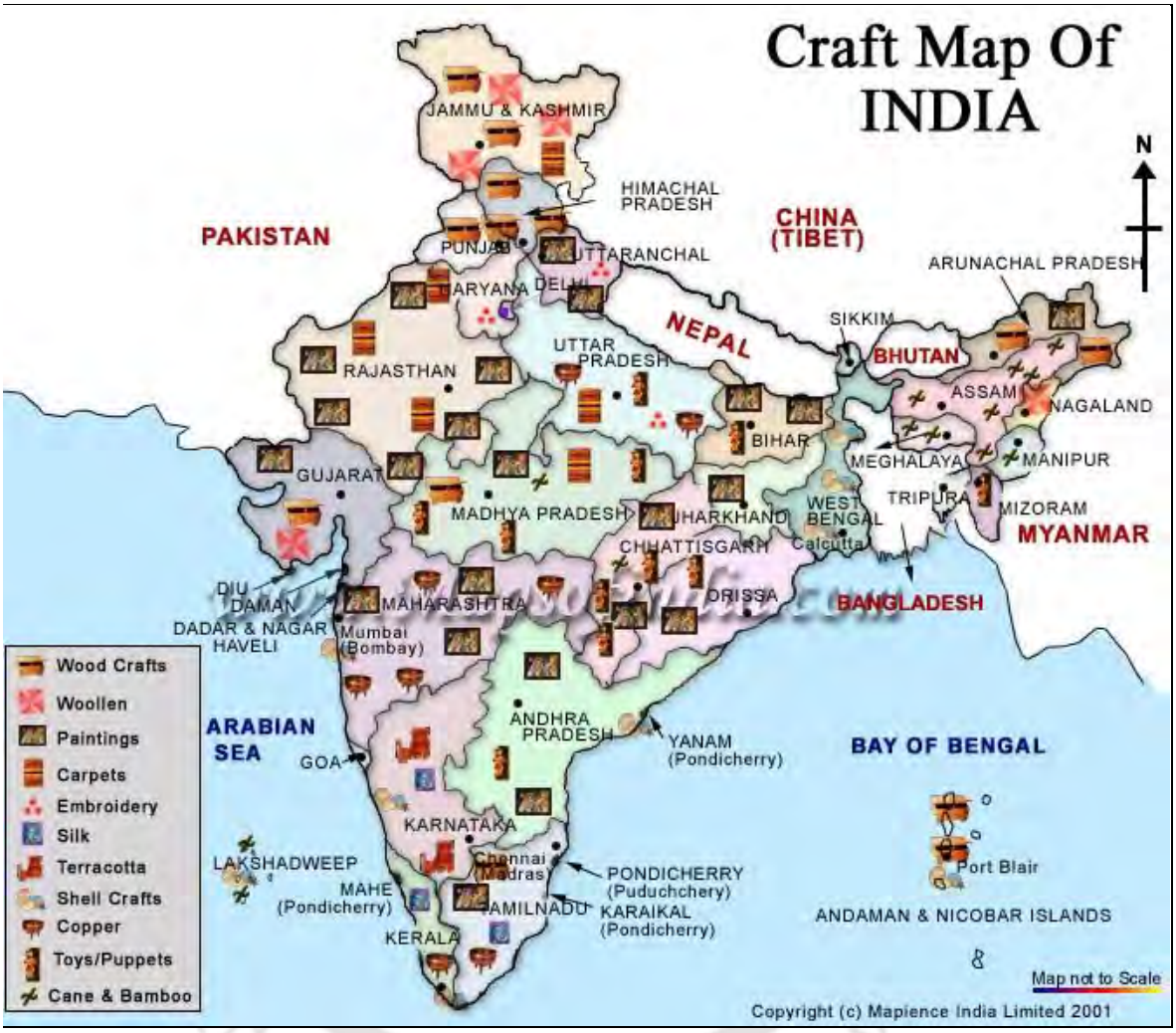


Fig. 1.3: Approximate map showing different crafts in various parts of India (Source: www.mapsofindia.com)

A lot of literature briefly describes the importance of crafts in the development of skills in the artisans. India has nearly 3,000 unique Arts & Crafts, many of which are as old as the Indian civilization itself, and are an embodiment of India's intellectual and aesthetic properties. They have the potential to be revived quite quickly, leveraging, and adapting existing skills to suit both traditional and modern markets.

India is one of the major exporters of the craft items to the other parts of the world. This handicraft industry is mostly labor-intensive and spreads across rural and urban India. This sector is considered

as the second largest unorganized employment sector (retrieved from http://www.india-exports.com/, 2018) after agriculture in India. Some of the craft practices have become a full-fledge source of living for the weaker section of the society. According to the Directorate General of Commercial Intelligence and Statistics, Kolkata, Indian Handicraft industry has a turnover of 1.9 billion US$ in the last decade. Though there was a considerable grown in the handicraft sector in the previous decade, it had declined to 5% in 2017-2018. The Table-1.1 shows India's exports of Handicrafts to different countries.

Table-1.1: Top ten destinations of India's Export for Handicrafts (Source: DGCI&S, Kolkata, India)

Sl. No.	Country	2000-2001(in million US$)	2001-2002(in million US$)	2002-2003(in million US$)
1	USA	294.8517	219.176	324.6047
2	UK	61.6174	56.1987	79.1673
3	Germany	37.554	30.4357	47.2585
4	France	31.013	29.4103	37.5341
5	Netherlands	29.243	25.8394	37.3164
6	Spain	21.8287	19.0162	30.4608
7	Italy	27.9376	19.89	24.0536
8	U A E	14.6376	12.205	20.9196
9	Canada	15.2344	12.8124	17.6554
10	Belgium-Luxembourg	9.0019	9.5755	14.5125

The Export Council for Handicraft, India has also shown that the USA is the major importer of the Indian Handicraft products. Fig.1.4 shows the different countries which import the Handicraft from India.

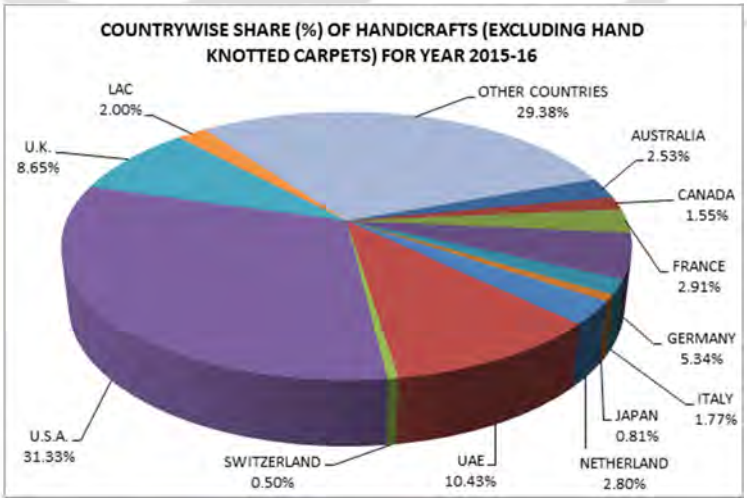


Fig. 1.4: Major importers of Indian Handicraft products (2015-16) (Source: Export Promotion Council for Handicrafts)

The items, which account for a significant share of export turnover, include - art metalware, woodware, hand-printed textiles, hand-knotted and embroidered textiles, leather goods, stoneware, paintings and sculpture, jewelry and antique & collectibles. The items, which account for a significant share of export turnover, include - art metalware, woodware, hand-printed textiles, hand-knotted and embroidered textiles, leather goods, stoneware, paintings and sculpture, jewelry and antique & collectibles.

The industrial revolution and the increasing productivity had slowed down the growth and the quality of arts and crafts, but for some decades now, the scenario has changed, and machine-made products no longer attract the people. Presently handicrafts are being considered as vocational media, and it has also opted for style statement and the leisure pursuit. Today, the crafts and craftspeople have a vital role to play in modern India – not just as part of its culture and tradition, but as part of its economic future. Modern-day products are made up of plastics and other materials, which are replacing the crafts made by natural materials like bamboo and clay. This kind of replacement not only is influencing the environment in the long term but also the lives of the craftsman involved in the making of the crafts items. Technological improvements may create new business areas, and the companies will try to adopt these any come up with the latest products. So, because of the upcoming technologies, the past craft knowledge also has to be updated and preserved to make it available for the companies, artisans, and future generations.

The present research tries to see how can this diminishing knowledge of the craftsman due to modernization be conserved by technology in the upcoming years. The craftsmanship in the present world has merely become a part-time work and people see their work mere as a fashion or aesthetic material. To make craftsmanship as the main steam source of livelihood, a major intervention is required from the government as well as the common man. Also, a design intervention is needed to tackle this problem of vanishing crafts.

Traditional arts, crafts, and designs have always been a fascination for humans. Conservation of this Arts and craft is essential for many reasons.

- It helps to preserve culture or heritage, which might get lost in time.
- It helps the craftsman to get engaged and earn his livelihood.
- It helps to showcase one’s history and past.
- It helps to learn and cultivate the knowledge embedded with them.
- It helps the persons to get to know various designs followed by the craftsman.

The people in the Craft sector are diminishing day by day, so it is important to trap the knowledge of older generations before it is eliminated. One of the reasons why people are diminishing in this sector is the difficulty in achieving the skills. The required skills for the mastery of this crafts take a lot of time and involves the practitioner to be an apprentice with the 'master craftsman.' The master craftsmen are the people who are the experts in the field on the crafts. They have gained these skills from their master and ancestors who had been practicing crafts. The crafts produced by these craftsmen are very high in the quality and retain a signature mark in it. The products which are produced by master craftsman are high in the cost due to their originality.

The final products have less perfection and lesser market value if novice designers produce them. Once the designer gets experience then there is a high demand for his products. This requires a large amount of time and dedication from the designers, which is not possible in this fast-moving world. Therefore, the designers have shown less interest in the hand created items and move to easier way of producing the crafts by machines. This has an impact on the older crafts. The inherited essence from the centuries in the designs is getting lost. Therefore, there is a need to redefine the way in which we conserve the traditional arts and crafts. This can be possible by mixing the modern-day technologies and the past knowledge of the craftsman.

Capturing the past knowledge of the craftsman can help us to understand them better. Research has suggested that understanding the user has resulted in better solving the wicked problems in design. Literature (Polanyi, 1962; Wigg, 1994) has classified knowledge into two broad categories: implicit and explicit. The documentation of explicit knowledge is easy. It is easily found in books, magazines, journals, etc. Whereas the implicit knowledge is very difficult to capture as in remains in the minds of the people. Implicit knowledge is also known as 'Tacit knowledge'. The term Tacit knowledge was coined by Micheal Polanyi in 1962. Literature (Polanyi, 1962) shows that tacit knowledge can be achieved by repeated practice of a craft or training in a certain task. Some of the examples of gaining tacit knowledge are learning bicycle, learning to swim etc. The focus of this thesis is to capture the tacit knowledge of the craftsman. This knowledge is studied by understanding the mental blocks of the craftsman when they are engaged in craft production.

The present research is based on the posit that if the mental block of the craftsman is studied, understood and captured then it can be conserved for the future generations. The present thesis tries to bridge this gap between traditional crafts and the modern-day technologies. The study tries to validate these posit by the help of a few case studies. In these case studies, the tacit and the explicit component of the whole process of the craft making is studied and distinguish.

1.3 Scope of the research

The thesis is limited to tackling the tacit knowledge component involved in the crafts sector. Particularly the crafts sectors like pottery, bamboo crafts and idol making as practiced in selected parts of India. The upliftment of the craft sector in comparison to other sector is also the point of interest of this thesis. Since the craft industry tries to depend upon the skill of the craftsman and other traditional practices, programs, workshops, and methods from master craftsman should be organized to enhance these skills among them. Also, there should be some form of digital incorporation in this sector. The present usage of software like Photoshop, Illustrator, and CAD (Computer-Aided Design) for designing, pattern making and enhancing creativity to the craftsman should also be considered during their making of the crafts as these have become modern tools replacing traditional hand tools. This, in turn, increases the curiosity and the enthusiasm among the learners as well as the practitioners involved in the craft making.

1.4 Definition of the terms used in the thesis

Traditional Culture and Craft

There are many definitions of traditional culture and crafts in the literature but the one, which is followed in this thesis, is as follows: *'The practices followed in different communities of India carried by them from their ancestors'* (UNESCO, 2004)

Crafts according to Oxford Dictionary is *'a calling requiring special skill and knowledge, especially manual art.'*

Handicrafts

Handicraft is the processing of the materials by hand with hand tools. Handicraft is deeply frozen in society and contributes to preserving and sending traditions.

(retrieved from http://www.handicrafts.nic.in, 2017)

Craftsman

Craftsman is termed as a 'person who is skilled in a particular craft'

(retrieved from Cambridge Dictionary,2018)

Artist

Artist is a person who creates things with great skill and imagination.

(retrieved from Cambridge Dictionary,2018)

Skills

Skill is an ability to do an activity or job well, especially because you have practiced it. Skills also refer to the ability to apply knowledge to specific situations. Skills are developed through practice, through a combination of sensory input and output

(retrieved from Cambridge Dictionary,2018)

Knowledge

A set of organised statements of facts or ideas, presenting a reasoned judgment or an experimental result, which is transmitted to others through some communication medium in some systematic form (Bell D ,1976). Knowledge is also defined as 'the fact or condition of knowing something with a considerable degree of familiarity gained through experience of or contact or association with the individual or thing so known [experience]'. Knowledge is understanding of or information about a subject that you get by experience or study, either known by one person or by people. (retrieved from Cambridge Dictionary, 2018). Knowledge can be broadly divided into two categories as in Fig. 1.5.

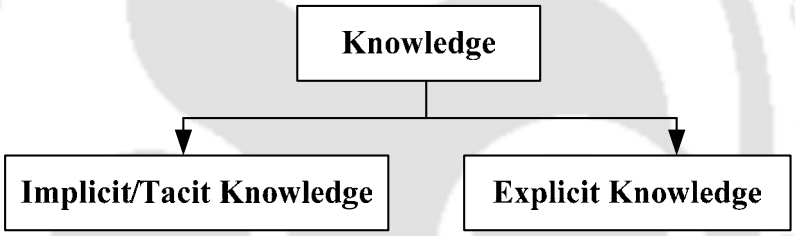


Fig. 1.5: Knowledge classification (Author generated).

Implicit/Tacit knowledge

It is the knowledge which is obtained by a person by repeated practice of a skill and remains in his minds

Explicit Knowledge

The knowledge that can be coded and can be found in the different formats like books, magazines, journals and other materials

Expert systems

Expert systems are the programs that draw upon the organized expertise of more than one human experts. (Lopez F., 1987)

Ethnography

Ethnography is the art and science of describing a group and culture. Ethnography is a research process in which the researcher closely observes, records, and engages in the daily lives for an extended period of time, watching what happens and listen to what is said in the community to throw light on the issues that focusses on the research (Bryman, A., 2001)

Human-Computer Interaction (HCI): It is a branch of Computer Science which deals with the interaction between the user and the machine (Jacko A., 2012).

1.5 Background of this Research

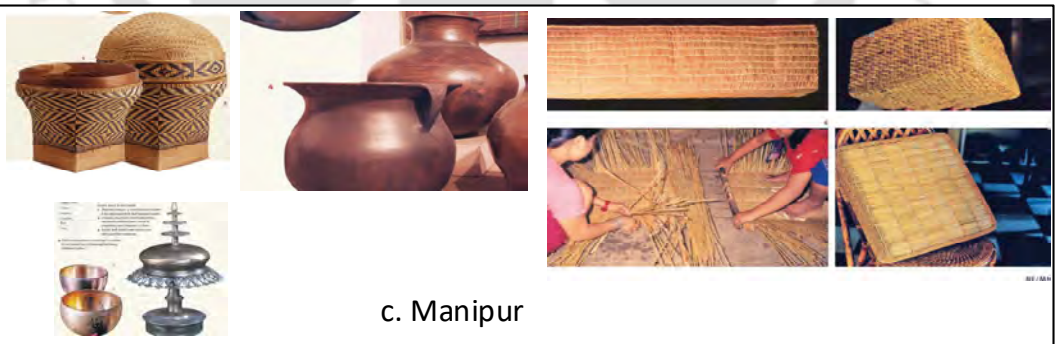
The background of the research revolves around the craftsman, skills and the design knowledge behind these skills. Design is one of the fundamental activities of the human that has contributed significantly towards the escalation of mass production, and mass consumption (Kumar V., 2015). In this process, it has neglected the traditional craft products. Various steps like museums, libraries, etc. are built by the government towards this conservation but a holistic approach is still needed for their conservation.

The north-eastern part of India is very rich in the crafts industry. The traditional tribes of the northeastern part of India are masters in certain bamboo crafts (retrieved from http://www.dsource.in/gallery/bamboo-weaving-patterns, 2017). This part of India has rich natural vegetation and have ample opportunity for natural resources to be used in the crafts industry. Fig. 1.6 shows different crafts practiced in the various states of North-East India. Though the crafts are practiced long from ancient civilization but the methods of transfer of technical knowledge and skills is still in the rudimentary state. This mainly depends on the manual skills and the apprenticeship with the masters.

Some of the crafts shown in Fig. 1.6 are bamboo craft, brassware, cane furniture, sheetalpatti grass mat, eri silk spinning, pottery, apa-tani bamboo products, carpet weaving, wood carving, textile handloom, flattened bamboo containers, bead craft, cane haversacks, coiled cone hats, bell metal work, reed mats, knup-bamboo rain shields, gourd craft, kophi cane baskets, ku-buddhist figurines, choktse-tables, bamboo furniture katlamara, pressed clay work of melaghar, bamboo fences, and tripuri textiles.

a. Assam

b. Arunachal Pradesh



c. Manipur

d. Meghalaya

e. Mizoram

f. Nagaland

g. Sikkim

Fig. 1.6: Some craft practiced in the different states in North-eastern India (a. Assam, b. Arunachal Pradesh, c. Manipur, d. Meghalaya, e. Mizoram, f. Nagaland, g. Sikkim, h. Tripura) (Sources: http://www.mospi.gov.in, 2019)

Due to the mass-produced commercial plastic goods most of the crafts items go unnoticed. The final price of the crafts items also could not compete with the commercialized goods. The craftsmen have to reduce the price of their items in order to sustain in the market. The tribes live in the remote parts, so there also is a communication gap between them and the market to sell the crafts. So, they make the crafts only for local use and so the knowledge of the craft remains confined only to that region.

The present state of the crafts items is trending more towards the commercial side and losing the traditional aesthetic look in them. The human touch is also lacking in the present commercial products. Rigorous training is required to cultivate the human touch in the crafts. Practicing the crafts helps to gain implicit as well as the explicit knowledge in it.

Tacit knowledge is the knowledge which is acquired by repeated practice, experience or teaching certain skills to the learner (Polanyi, 1962). This can be observed in various industries like craft, jewelry, etc. where skills of the labor matter. Acquiring this knowledge has always been an important factor in the industries. For example, a new employee is trained under the hands of an older experienced employee. Shifts in the transfer of know-how have been observed from traditional manual methods to modern-day technological advance computer systems. In this shift, traditional knowledge of the practitioner is getting lost. This can be observed in a variety of industries such as craft etc. (Sarkar.S,1998) People engaged in these industries are seeking alternative ways of working with computers for utilizing knowledge which was traditionally transmitted from master to apprentice. Capturing this tacit knowledge especially has been one of interest to several researchers.

The ancient crafts and trade industry have a major impact on the population of today for modernization. With the advent of the modern machine and mass-produced goods, the ancient crafts

industry has suffered a lot. The local craftsmen who are engaged in this industry have faced challenges and were forced to sell their products at a lower price. To help the local craftsmen many programs are begin held by the local government. In 1967 the World Craft Council was set up with the motive to support and strength the local craftsmanship. There are numerous programs, which are begin organized by the council in this regard. The council is registered in Belgium as an international organization. The 17th General Assembly meeting was held in 2012 at Chennai, India. Though the world has been aware of the importance of the local and cultural crafts but very less development is been done to promote it among the youth of today.

1.6 Motivation

The traditional crafts and arts have been conserved in the museums and art houses. In this practice, the visual perspective of the craft is saved. The documentation of these helps to learn the history of the crafts. But the real-time practice and the knowledge of the craftsman involved in the activity is still not conserved. The real essence of the making of the crafts items is also not seen by this conservation. Certain methods of storage like the video making help to see the difference in the preservation of the art and crafts. But here too the overall activity is captured but the human touch or the feel while doing the craft is lacking. So the practice of the conservation of this traditional crafts needs to be redefined and a design intervention is needed. For this, an interdisciplinary approach is required, which involves knowledge from different disciplines like Design, Human-Computer Interaction, Psychology, and Craft to address these gaps and issues. Fig.1.7 shows an overview of the research area involved in this study.

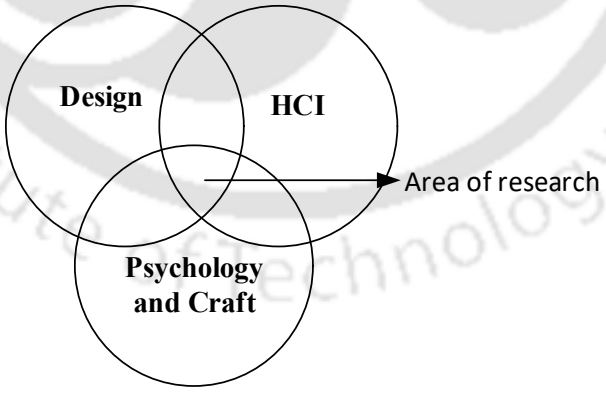


Fig. 1.7: An overview of the research areas involved in this research (Author generated)

1.7 Raising Unanswered Research Questions

The knowledge involved during the crafts making varies widely. This can be divided into two types – one is implicit knowledge and the other part is the explicit knowledge. The implicit part is the very much available through the literature, videos, and pictures. But the explicit part remains with the

craftsman. It is generally acquired by practicing the craft for a much longer period of time. So, if there is a way to capture and preserve as well as transfer tacit knowledge of the craftsmen into some form of reusable documentation it is possible to replicate and preserve such knowledge and use it in the future. If some part of the 'Tacit knowledge' can be captured into digital form it can be helpful in understating crafts in a more intuitive manner.

Such a tacit knowledge repository is expected to help in wide-ranging knowledge engineering activities ranging from conservation to heritage mapping including anthropology as well as engineering and manufacture domains.

Two specific problems arose during this research.

1) How to capture 'Tacit knowledge'?

2) How to transfer tacit knowledge from human knowledge domain to machine knowledge domain?

The thesis focuses to answer these research questions by combining the present methods of photography and videography along with the other modern digital techniques available.

1.8 Research Questions

Research Problems

- There is no bridge to join the gap between modern technologies and traditional crafts.
- There are fewer research studies to capture the tacit knowledge of craftsmen

Research Questions

RQ1: How do we identify different components of knowledge (especially tacit knowledge) from live crafts and artifacts?

RQ2: How to Isolate and transfer tacit component from artifacts?

RQ3: How to program/digitize tacit knowledge component such that

- it can be utilized by a design researcher wanting to continue tacit knowledge and traditional crafts for the purpose of training a new generation of craftsman
- A common user can use it
- It is used by a heritage museum for identifying craft artifacts, categorizations, and classification of crafts

1.9 Working posits of the research

- P1: If there is a way to capture and preserve the tacit knowledge part through a transference method, same knowledge could be used by future users to relearn.

- P2: Tacit knowledge when captured and documented in a digital form can become a database for training new generations of craftsman who may or may not have a connection with traditions.
- P3: Tacit knowledge when digitized can bridge the gap between traditional handicrafts and current engineering practices of mass production.

1.10 Research Methodology and Framework of the study

The research focuses on the study of the skills of the craftsman and the process of acquiring them. The skills are both the combination of tacit as well as the explicit knowledge in it. The overall data collected are qualitative in nature which require to study specific craftsman. The contextual inquiry of the craftsman was carried out and also an ethnographic study of different craftsmen was performed. The methodology of study to achieve the research objective is mentioned in sections 1.8 is given below:

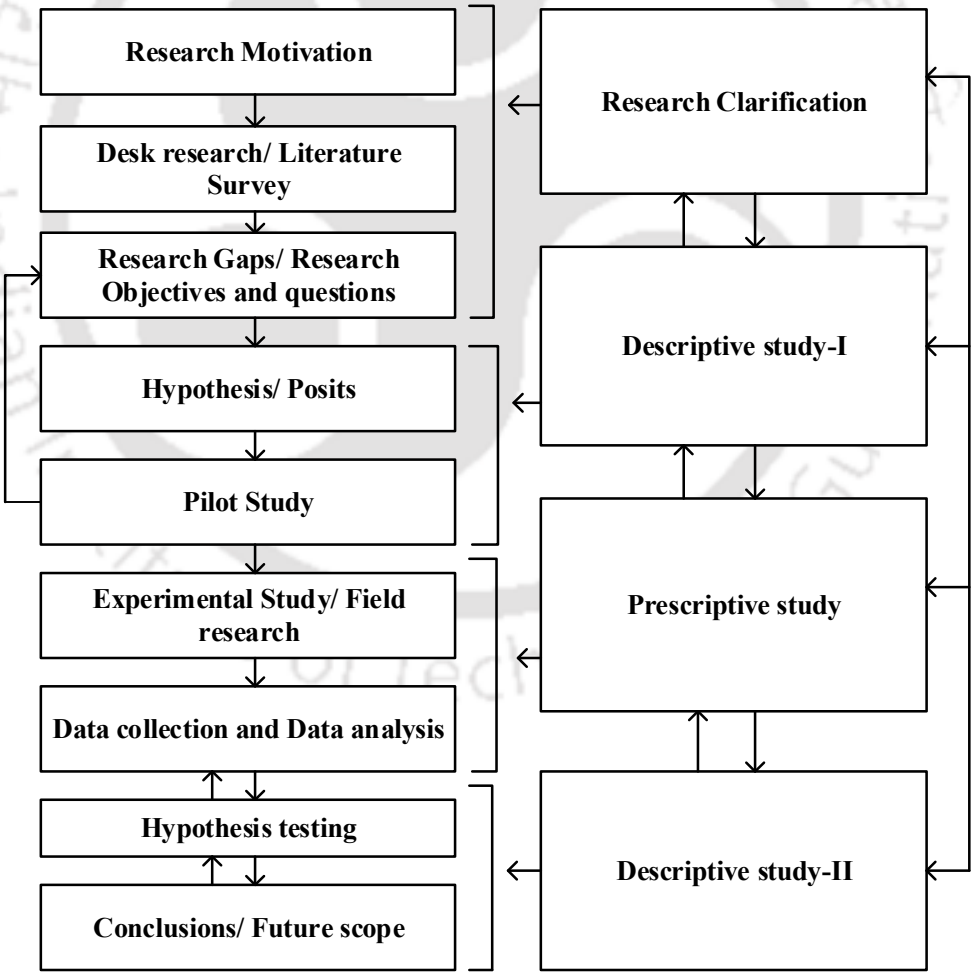


Fig. 1.8: Research methodology adjusted from (Blessing et al., 2009)

A detailed description of the methodology followed and its relation to the present study is explained in the sections 2.5 and 3.3.

The Design Research Methodology (DRM) shown in the Fig. 1.9 provides a path for the methodological framework which was used in this research. DRM has four different stages- Research clarification, Descriptive study-I, Prescriptive study, Descriptive study-II. In the research clarification stage through evidence is found out from literature to support the research goal set for the researcher. A brief review of literature for the present study is presented in chapter-2. The summary of the literature suggests the potential of the research problem chosen, the research questions asked and the research objective framed for thesis.

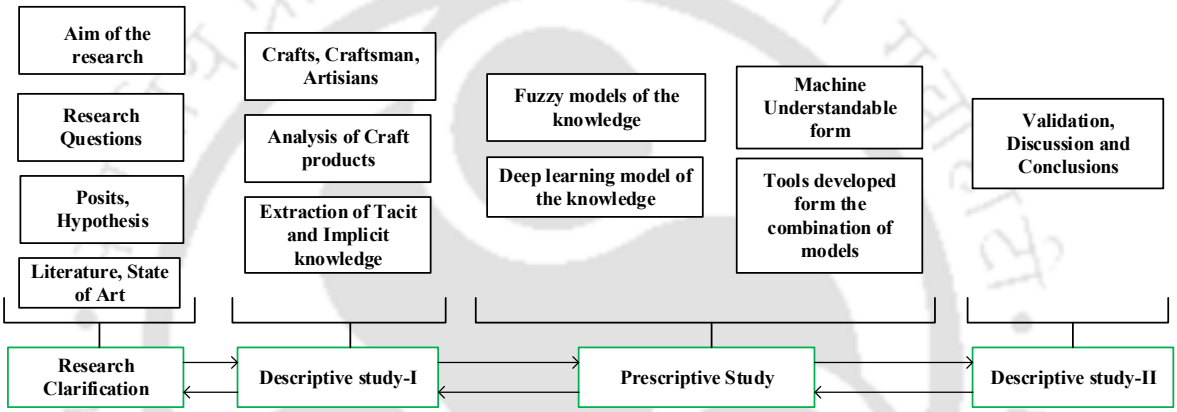


Fig. 1.9: DRM Methodology applied to the structure followed in this research

All the stages of the DRM are iterative in nature and get modified during the research. In the Descriptive study-I stage the researchers is clear with the goal of the research and supports it with more literature, and detailed study. Once the above stage is carried out by the researcher the next stage is procured. In the Prescriptive study stage the researcher uses their increased understanding of the research to elaborate the research's aim and description. More factors influencing the research are analyzed and a detailed study is carried out in the research. The Descriptive study-II stage is where the researcher investigates the impact of the support which was created/study during the previous stages. For further research the researcher has to revisit DS-1.

1.11 Knowledge transfer channels

The literature shows that many tools are developed to measure the knowledge of the subjects in different scenario.

User personas are a great tool for sharing empathy (Semertzaki E.,2011). Stories are the way we share empathy in our culture. Storyboarding is a method to tell experience of a user in a particular situation.

Knowledge transfer channels can be informal or formal, personal or impersonal (Semertzaki E.,2011). Informal mechanisms (such as informal seminars or coffee break conversations) refer to socialization and are more effective in small organizations. However, such mechanisms may involve certain amounts of knowledge loss due to the lack of a formal coding of the knowledge. Formal transfer mechanisms (such as training sessions) may ensure greater distribution of knowledge but may inhibit creativity. Face-to-face interactions and communications are the optimal ways to externalize tacit knowledge (Semertzaki E.,2011)

Personal channels (such as apprenticeships) may be more effective for distributing highly contextual knowledge whereas impersonal channels (such as knowledge repositories), may be most effective for knowledge that can be readily codified and generalized to other contexts. Information Technologies can support all four forms of knowledge transfer channels. Some tools and technologies associated with the knowledge management in the organization are shown in Table: 1.2.

Table: 1.2 – Tools and technologies associated with Knowledge management cycle (Source: Jashapara A., 2005)

Knowledge cycle	Organization cycle	Capturing knowledge	Evaluating knowledge	Sharing knowledge	Storing knowledge
Explicit knowledge	Taxonomy tools	Information retrieval tools	Online analytical tools	Internet	Data warehouses
		Search engines	Knowledge discovery in the database tools	Intranet	
		Agent technology	Machine-based learning	Extranet	
				Groupware tools	
				Expertise yellow pages	
				E-learning	
Tacit knowledge	Ontology tools	Cognitive mapping tools	Case-Based reasoning	E-mail	Visualization techniques
				Text-based conferencing	
				Video conference	

Some of the tools used widely for the knowledge flow are described below.

Hierarchies. It is one of the oldest tools to represent knowledge. Human mind had the natural tendencies to categorize the things in a hierarchical manner. Whenever there is hierarchy then it becomes easy and natural to understand things. One example of hierarchy can be seen in Fig.1.10 below

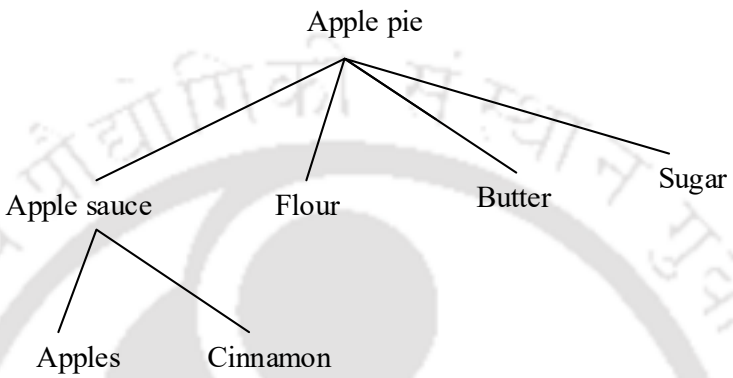


Fig.1.10: An example of hierarchy representation of knowledge (Semertzaki E., 2011)

Though many types of links are possible in a hierarchy, some links generally used in object-oriented programming are shown in Fig. 1.11.

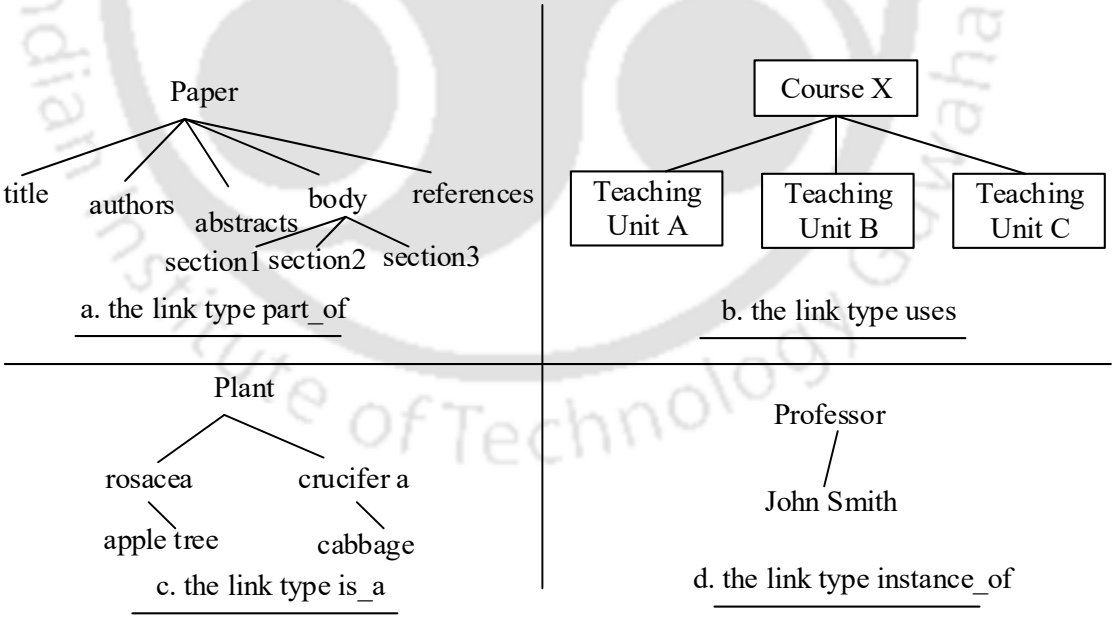


Fig.1.11 Different link types in a hierarchy (Semertzaki E., 2011)

Mind maps: Mind maps are a concept representing technique. It is an informal way of recalling the ones thoughts to put forward in a map. Mind map was first introduced by Buzan in 1974 (Semertzaki E.,2011). One example of the mind map can be illustrated in Fig. 1.12.

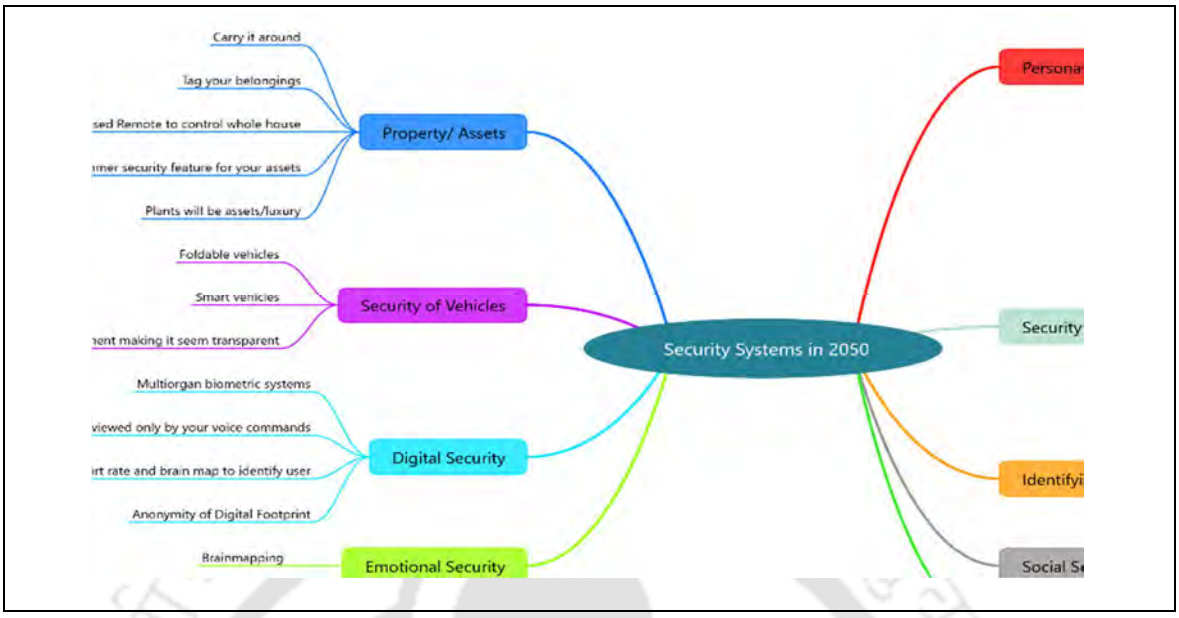


Fig. 1.12 Example of a Mind map

Concept Maps: A concept map is a set of nodes corresponding to concepts and are connected by arcs to each other. It was first developed by Novak in 1992 for understanding the way students represent concept in their time. One example of the concept map is shown in Fig. 1.13

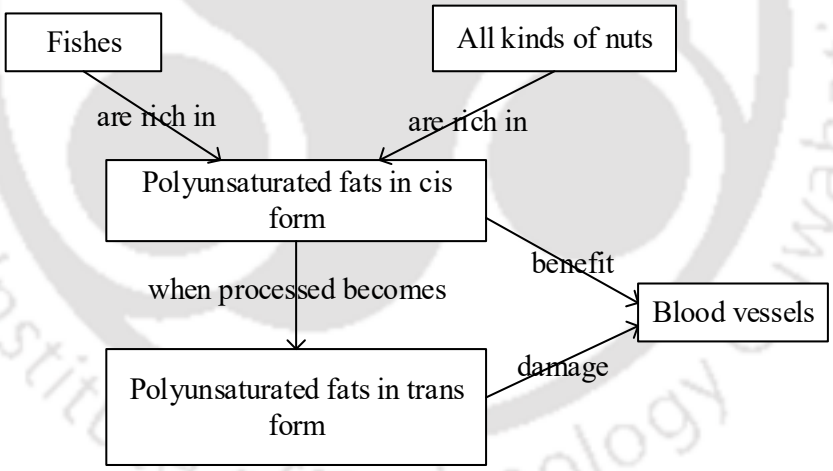


Fig. 1.13 Example of a Concept map (Semertzaki E.,2011)

Entity relationship diagrams (E-R diagram): It is a graphical tool to support the conceptual architecture of database system. It was first introduced by Chen in 1976. An E-R diagram is a graph which contains three types of nodes: entities, relationships and attributes. Fig. 1.14 shows an example of E-R diagram.

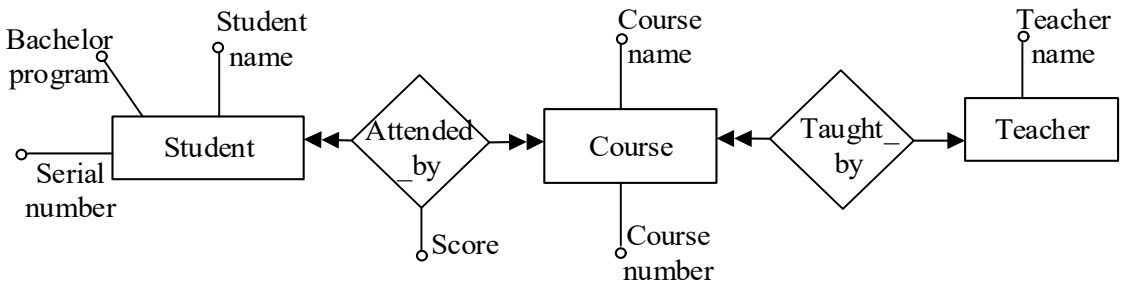


Fig. 1.14: Example of an E-R Diagram (Semertzaki E.,2011)

Entities (students, course, teachers) are represented by rectangle boxes and attributes are represented as small circles. Each entity must have atleast one attribute. In Fig. 1.15 student entity has three attributes, the entity course has two attribute and entity teacher has one attribute. The diamond shaped boxes are the relationship between entities. The double arrow represents the 'many' relationship and the single arrow represent single relationship. The relation taught_by is of the type one to many. This reflects the hypothesis that a teacher may teach many courses but a course must be taught by a single teacher.

Petri Nets:

Petri Nets were originally invented by Carl Adam Petri in 1939 for the purpose of describing chemical processes. Petri Nets provide a graphical notation for modelling stepwise processes, but have also an underpinning rigorous mathematical definition which makes them a fully computable type of representation. An example of the Petri Net is shown in Fig. 1.15. It is a graph which can contain only nodes of two types: places (represented by a circle) and transitions (represented by a segment).

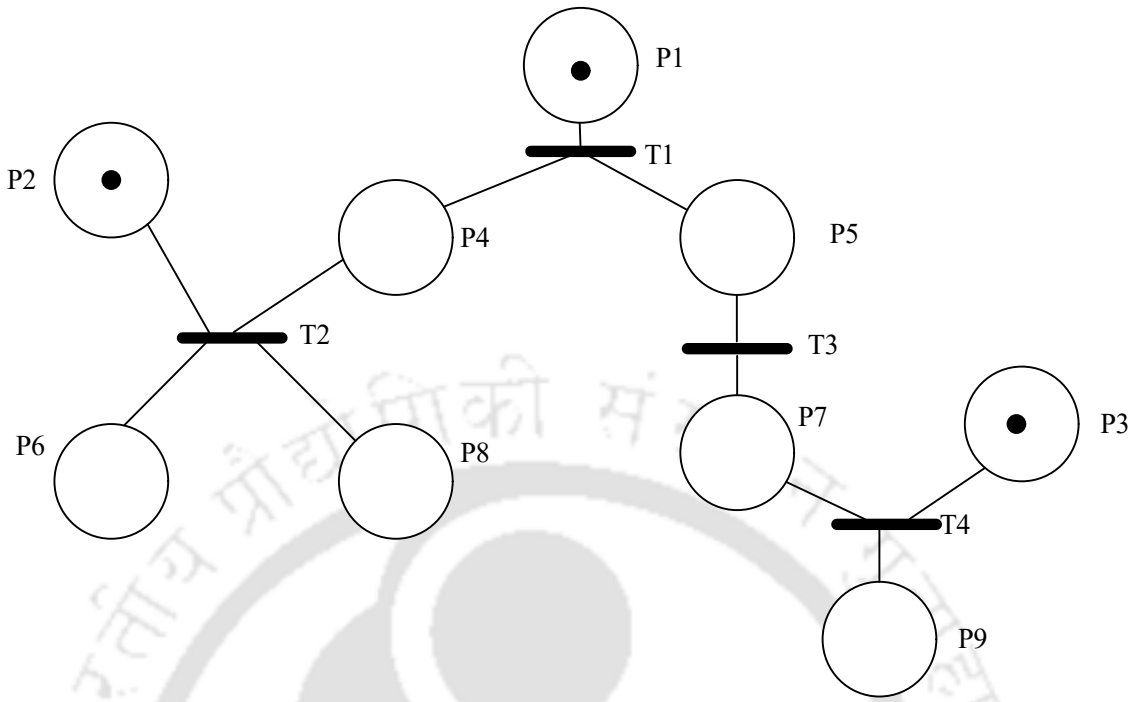


Fig. 1.15: Example of a Petri Net (Semertzaki E.,2011)

T1, T2, T3, T4 are the transitions and P1 to P9 are the nodes. Petri Nets make the representation of knowledge easy to understand and make it possible to implement it to the machine level. The Table 1.3 summaries the above-mentioned tools in which can represent the knowledge types.

Table 1.3 Representational approaches versus knowledge types and representation purposes (Semertzaki E.,2011)

	Knowledge type	Purposes
Hierarchies	• Hierarchical knowledge • Specific points of view • Also, for complex knowledge	• Integrating personal knowledge • Expressing specific points of view • Communication
Mind Maps	• Hierarchical organization • Individual concepts description • Single point of view • Also, for complex knowledge	• Ease of use • Brainstorming • Recollection • Collaboration • Communication
Concept Maps	• Hierarchical and reticular knowledge • Relations among individual entities • Integration of multiple points of view	• Ease of use • Brainstorming • Collaboration • Communication (knowledge of limited complexity)

E–R diagrams	• Relations among collections (classes) of entities (static knowledge) • Entities qualified by attributes • Relations qualified by attributes • Different types of relations (1:1, 1: N, N: N)	• Highly focused representations • Communication (knowledge of limited complexity) • Repositories of static knowledge • Strong automatic support
Petri Nets	• Interacting processes, activities or events (dynamic knowledge) • Resources flow among processes • Rules of precedence	• Highly focused representations • Collaboration • Communication (knowledge of limited complexity) • Repositories of procedural knowledge • Strong automatic support
Petri Net hierarchies	• Complex networks of processes, activities or events (dynamic knowledge) • Hierarchical organization • Resources flow among processes • Rules of precedence	• Highly focused representations • Communication (complex knowledge) • Repositories of procedural knowledge • Strong automatic support

A brief overview of the methods, though not comprehensive, was mentioned by Ylihärsilä (Ylihärsilä, 2007) for the transfer of tacit knowledge.

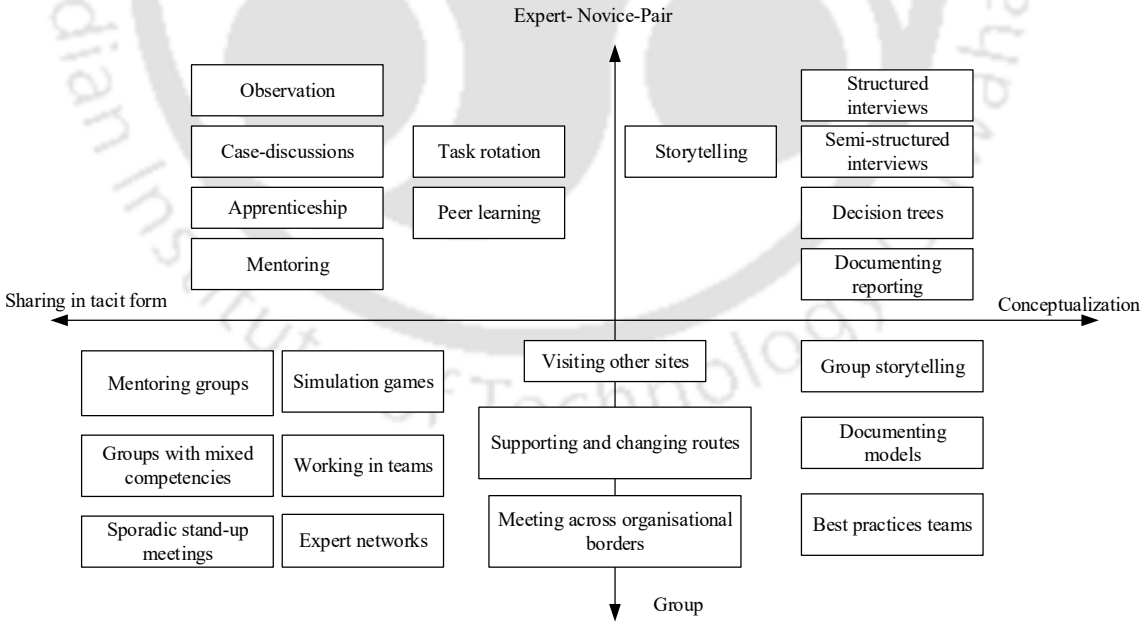


Fig. 1.16: Methods to transfer tacit knowledge (Ylihärsilä, 2007)

For this thesis some of the methods were combined and applied in the capturing of tacit knowledge of the craftsman.

1.12 Contribution by the thesis

The thesis is an attempt to demonstrate the idea of capturing the tacit component of knowledge and converting it to explicit knowledge. As such may literatures are available in this area, most are inclined to the organization level of capture (Nonaka, 1962) and less are towards the crafts domain. This research focuses into the individual aspect of knowledge mainly on the craftsman and the skills possessed by them.

1.13 Summary of the chapters

A diagrammatic representation of the chapter is shown in Fig. 1.17.

The thesis is structured into the following chapters:

Chapter-1 Introduction

The chapter introduces the research works containing research motivation, research background, research gaps, aim and objectives, methodological framework, positioning of research, thesis structure.

Chapter-2 Related Literature Review

This chapter is focused on bringing relevant literature and related work on the craft sector, knowledge management and design impact on the craft sector. It starts with literature on the practice of craft design, then studies the historical evolution of intangible and tangible cultural heritage concepts in craft, understanding of tacit and implicit knowledge as a whole, existing approaches, etc. the chapter concludes with the research gaps addressed in this thesis with aim and objectives of the study.

Chapter-3 Exploring Crafts and Craftsman through pilot studies, methodology and experiments

This chapter discusses the proposed framework followed during the research. The different pilot study was conducted and then the main experiment was conducted for the different craft items chosen and was proceeded for the FIS model is explained in the next chapter.

Chapter-4 Development of a digital tool for tacit knowledge embedded in craft objects

The Fuzzy Inference System was developed form the inputs of the tacit knowledge captured in the chapter- 3. This chapter gives a detailed explanation of how the FIS system was developed and implemented

Chapter-5 Adaptation of machine learning to craft domain

This chapter explains the application of transfer learning to the craft domain for capturing the detail knowledge embedded in the craft objects.

Chapter-6 Validation of the model

The chapter gives a brief validated of the FIS system developed in the chapter-4.

Chapter-7 Discussions and Conclusions

This chapter summarizes the main findings and limitations of this research. It discusses its major contributions, general implications in the field and indicates potential paths for future research

Chapter-8 Contributions of the research

The important contributions and limitations of the research are explained in this chapter.

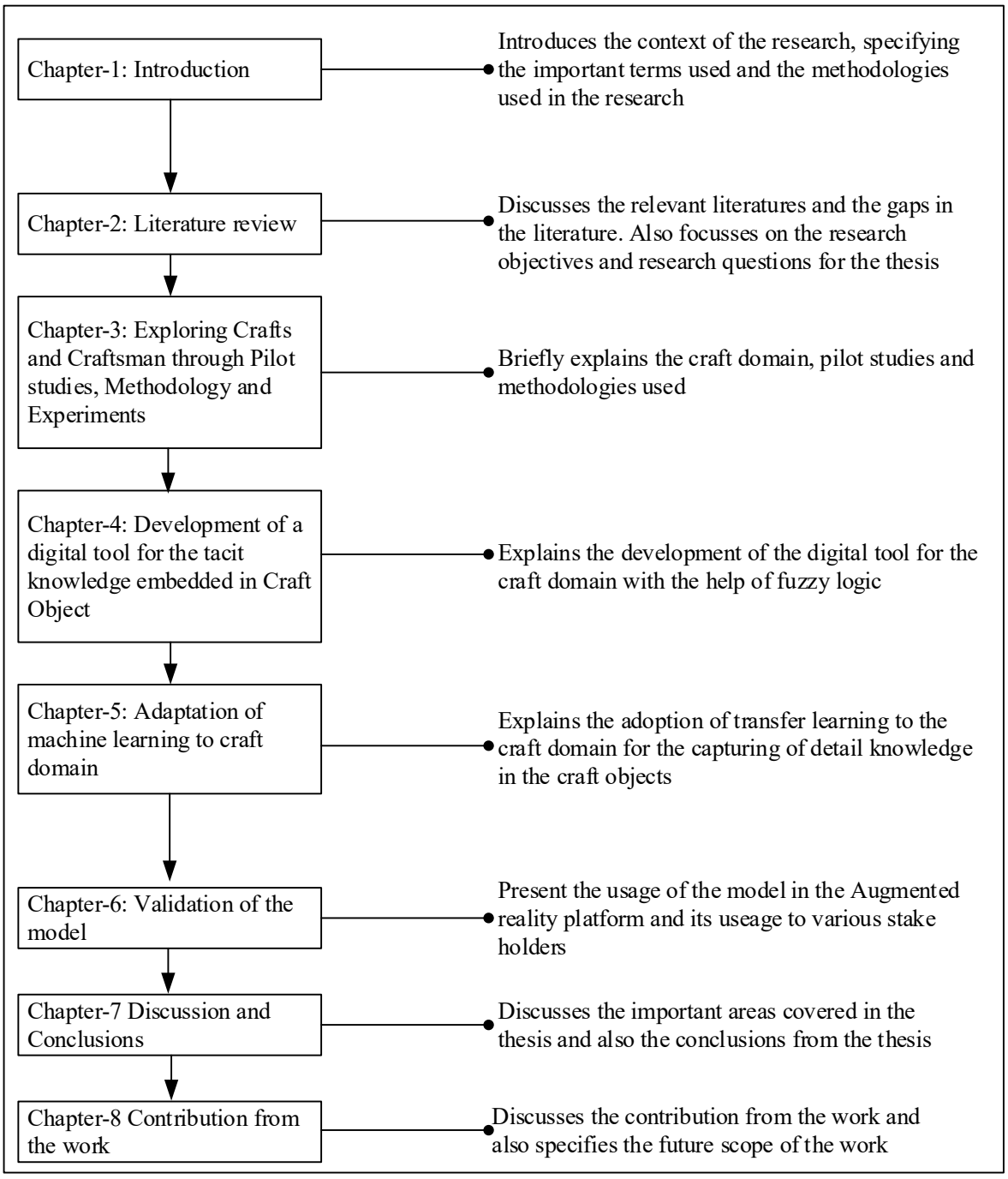


Fig. 1.17: Diagrammatic representation of the chapters

Chapter-2 Literature Review

***Abstract**: This chapter covers a brief literature review on the topic. Based upon the nature of the problem the literature review varies in the four categories: craft and cultural heritage, knowledge management, design studies and digital cultural heritage. The research gaps were identified from the literature survey and possible area of research was identified.*

2.1 Introduction

The research area chosen in this research consists of variety of fields. To understand the tacit knowledge of the craftsman, we need to understand the psychology of the craftsman, the crafts produce by them and the surrounding in which they are work. This category of research falls into an inter-disciplinary area of crafts, cultural heritage, knowledge management and design studies. Also, the impact of technology in the crafts sector needs to be understood and its application into these areas into another sector also is to be studied. Overall 662 articles (includes books, Journal papers, magazines, thesis etc.) were studied to really understand the topic of research and pointing out the gap in them. The main areas of interest in this research are craft and cultural heritage, knowledge management, design science and digital crafts and cultural heritage. Fig. 2.1 shows the relation between the different research areas for this study. Researchers have done a vast amount of study in documenting the traditional Arts and Crafts. This can be seen in the works from both Indian as well as foreign research origins.

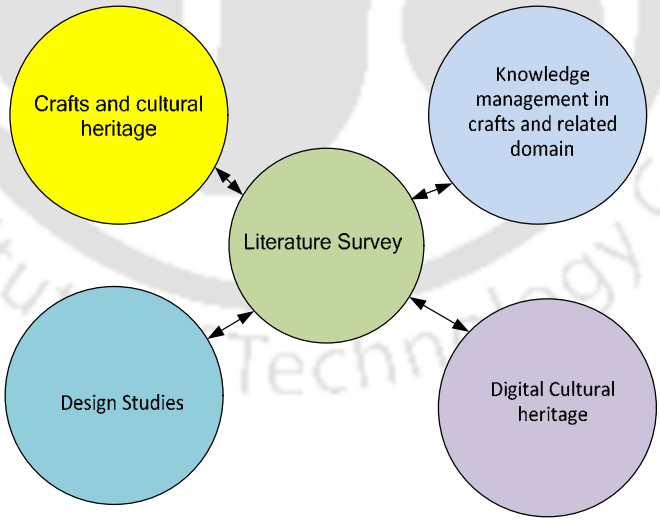


Fig. 2.1: Relation between different research areas for this study (Author generated)

2.2 Understanding the knowledge and its management process in craft domain

Knowledge can be understood by understanding the components by which is it composed of. Ancori, (Ancori et al, 2000) states that absolute truth can be obtained by linear thinking in which the data is

turned into knowledge and then the knowledge is confronted with wisdom as shown in Fig.2.2 below.

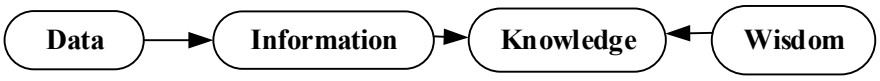


Fig.2.2: Linear process of knowledge formation (Ancori et al.,2000)

Ancori has describes that there are basic four steps in which the knowledge is structured: crude knowledge; how to use this crude knowledge; exchanges of the knowledge formed in the previous step; how to manage this knowledge. Generally, the term knowledge is used in different context. Fred Nickols gives the three usages of knowledge (Nickols, 2012). First, it refers to a state of knowing, by which we also mean to be acquainted or familiar with, to be aware of, to recognize or apprehend facts, methods, principles, techniques and so on. This common usage corresponds to what is often referred to as "know about." Second, use of the word "knowledge" refer to "the capacity for action," an understanding or grasp of facts, methods, principles and techniques sufficient to apply them in the course of making things happen. This corresponds to "know how." Third, usage of the term "knowledge" refers to codified, captured and accumulated facts, methods, principles, techniques and so on. This way, we are referring to a body of knowledge that has been articulated and captured in the form of books, papers, formulas, procedure manuals, computer code and so on. So, we can term the knowledge into two different categories. One that is reflected in the person's internal state that comes into his actions and the other one that can be articulated and frequently recorder. This can be seen in the iceberg diagram shown in the Fig. 2.3 below. It can be seen that most of the reality issues are presents in the minds of the individuals which is termed as implicit or the tacit components of the knowledge. The implicit or the tacit components are sometimes sub-conscious in nature. The other part of the knowledge is the explicit component. This is found as procedure documents, standards, records etc. This can be easily documented and read or followed when it is needed.

Thus, knowledge can be categorized into different forms. One of the ways of classification is explicit knowledge, tacit knowledge, declarative knowledge and procedural knowledge. (Nickols,2000). The Fig.2.4 shows the basic difference between the tacit, implicit and the explicit form of knowledge. There can be two ways in which knowledge can be articulated. If the answer is yes, then it will fall into the category of explicit and if it is no the it comes into the category of tacit.

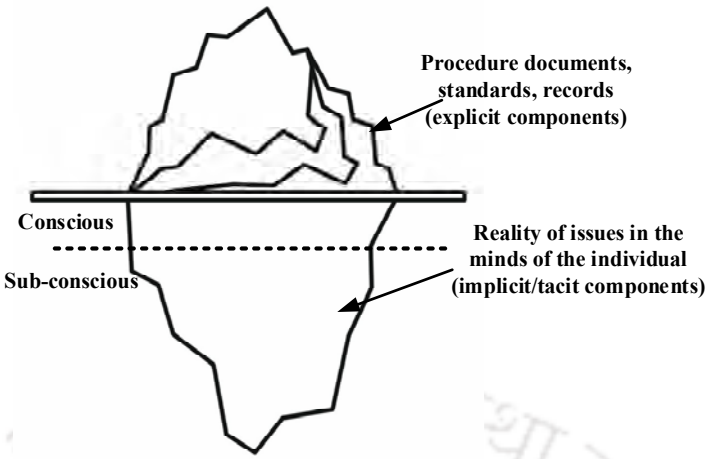


Fig.2.3: Iceberg diagram showing the two categories of knowledge (Loewen D, 2017)

Similarly, the declarative knowledge is a kind of explicit knowledge in which the description of facts, things, methods and procedure is present. Whereas the procedural knowledge is something which manifests itself in the doing of something for example motor skills and the mental skills of a person in recognizing somebody's face, riding a bicycle, playing a piano, making a craft etc. The Fig. 2.5 shows the framework by Nickols (Nickols F., 2000) which shows the relationship between the four kinds of knowledge described above.

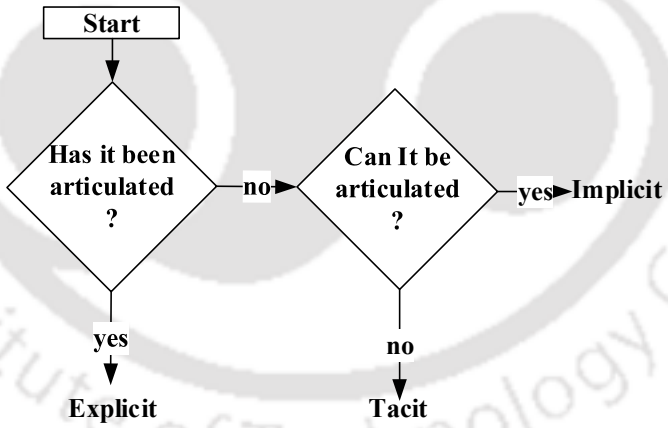


Fig.2.4: The basic difference in tacit, implicit and explicit knowledge (Nickols F.,2000)

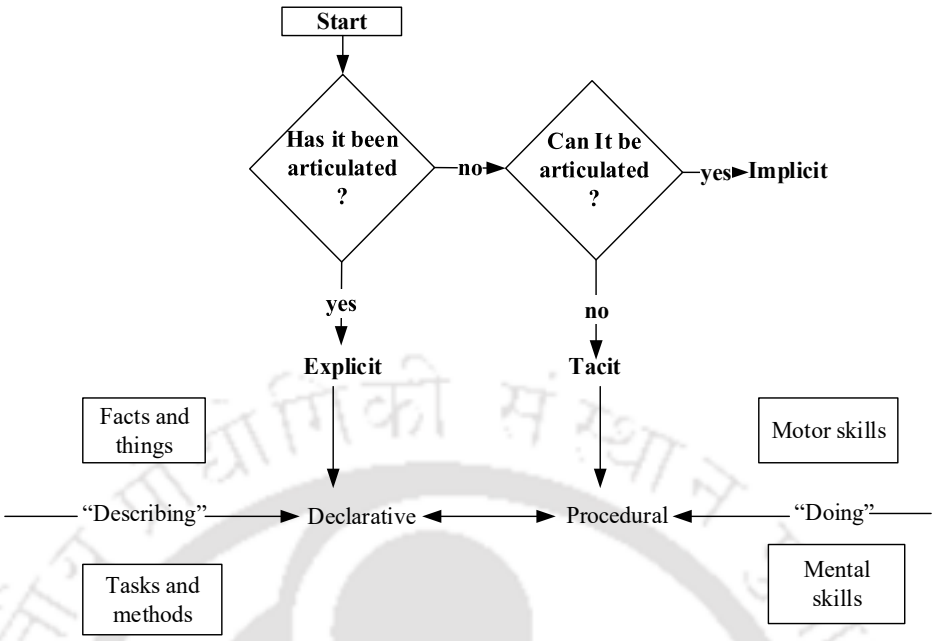


Fig.2.5: Relationship between the four types of knowledge (Nickols F.,2000)

The distinction between the explicit and tacit knowledge was introduced by Polanyi and Nonaka (Polanyi, 1962; Nonaka, 1991). Likewise, Molander (Molander, 1992) discusses that knowledge can be of two types one is scientific and the other is practical. This former is based on the theories and descriptions. The latter is gained through practice and apprenticeship. Ancori also aims to shed some light on the complex relationships between codified and tacit knowledge. The main transformation investigated by economists is the transformation of knowledge into information, i.e. the codification of knowledge. The process of transformation of knowledge into a commodity, which can be called the 'commodification' of knowledge Driving schools offer two kinds of 'knowledge products': they make sure that drivers will 'know the codes' (the pure codified form) and they train them through practice and experience acquisition (in a purely tacit form). Generally, tacit knowledge is referred to the hidden knowledge. The ability of an individual to interpret something in terms of his knowledge and try to correlate it to the existing knowledge is significant. The area of 'semantic' relates the significance of an object to an action or another object.

Dalkir (Dalkir, 2013) has also distinguished the differences between data, information and knowledge. According to Dalkir "data" is the directly observable fact like numbers. "Information" is the analyzed data for example numbers can be used in showing the time like 7.00 pm. "Knowledge" is the meaningful arrangement of the data and information for example I will check my timings to make sure to attend the conference seminar at 7.00 pm. Wiig (Wiig, 1994) had classified the knowledge into a hierarchy structure. Fig. 2.6 shows the hierarchical form of the knowledge represented by Wiig.

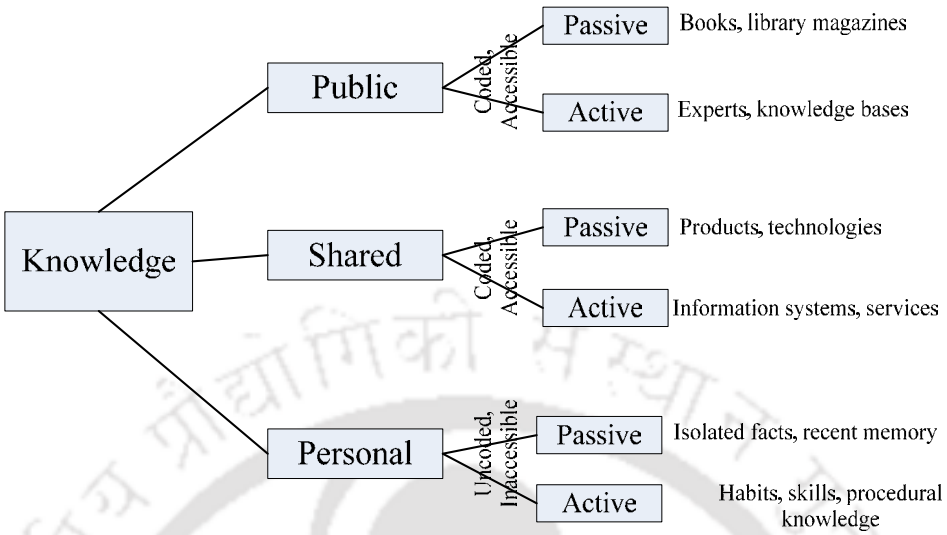


Fig.2.6: Wiig's hierarchy of knowledge forms (Wiigs, 1994)

Wiigs research shows that the tacit knowledge is personal and it is very difficult to code it, since it is inaccessible. Differences in the definition of tacit knowledge tend to be due to the differences in interpretation of the concept itself (Haldin-Herrgard, 2003). Table.2.1 shows the some of the prototypes of the tacit knowledge.

Table-2.1: Some prototypes/epitomes of Tacit Knowledge (Haldin- Herrgard T, 2003)

	From Abstract to Concrete		
Collective	• common sense • common beliefs • shared norms • organizational memories • shared meaning	• culture • collective know-how • common in experience • collective ability • shared values • social institutions • shared code	• best practice
Individual /team	• cognitive schemes • unconscious norms • mental models • attitudes • opinions • a group senses • inexplicable mental processes • understanding	• non-analytical behavior • automatic knowledge • experience • knowledge base • values • perspective • judgment • non-canonical practice	• life-examples • creativity • skills • bodily • communication • coordination • management • negotiation • operational • patterns of experience

		• rule-of-thumb • knowledge base • predictions • routinized knowledge • values • opinion	• improvisation • tricks • estimation • routines • techniques • genres
Individual	• intuition • feeling for • beliefs • hunch • gut-feeling • emotional knowing • flashes of inspiration • percepts • know in one's body • feels as… • looks as… • thoughts • sounds as….	• skills • bodily • cognitive • inductive • people • intuitive knowledge • flash of insight • percept • care-why • know-how • insight • second nature • talent • practical intelligence • unarticulated preferences • inner competence • personal competence • oneness of body and mind • people knowledge • sense-making	• sense making • instinctive reaction • artistic vision • ability • skills • physical • social • crafts • taste • after the fact awareness • master's sureness of action • skillful • sense-making

The first step to classify different knowledge in a conversation is to see which knowledge is general knowledge and which is not normal. There are very few literatures which adresses this classification of knowledge. Balconi (Balconi et al.,2007) rightly pointed out that if the classification is done, then also the classifiers ignore the personal knowledge of subjects. The author speaks about the non-existing codebook for the tacit part of the knowledge. The literature also states that this kind of codebook generally exist in the minds of the people. Generating them seems to be a tough task for the people.

According to Balconi (Balconi et al.,2007) knowledge can be represented in three main categories:

a. Knowledge as competence;
b. Knowledge as acquaintance;

c. Knowledge as recognition of information.

The author refers the Knowledge of competence as the ability of an individual to perform certain activities from simple physical exercise as suggested by Polanyi (Polanyi, 1962). The author states that the linguist knowledge cannot be transmitted with the codified rules. So, if the linguistic is a form of tacit knowledge it can be learnt by personal practice.

2.2.1 Why is tacit knowledge important in craft domain?

The main benefit of the tacit knowledge is working with the real objects. The craft domain requires skills and projects which are live and real in nature. Explicit knowledge (or information) can be considered to be the procedures and rules in controlling the action as opposed to tacit knowledge which is a core part of the experienced operator's skill in her craft or profession and is built on learning via actual experience and action such as learning from a master over a passage of time on how to run the plant to optimum capacity. Hands-on training could thus be considered a method of transferring tacit knowledge. Not all knowledge is created equally. We think of knowledge as something that can be recorded in words, visualized and taught. However, this isn't always the case. Tacit knowledge is a class of knowledge that's difficult to communicate. Firms would like to prevent knowledge loss due to employee turnover. However, tacit knowledge always remains with the employee. Some examples are business critical knowledge that are difficult to write down, visualize and teach., how to speak a language, innovation, leadership, aesthetic sense, sales, body language, intuition, humor, snowboarding, emotional Intelligence. With tacit knowledge, people are not often aware of the knowledge they possess or how it can be valuable to others. Effective transfer of tacit knowledge generally requires extensive personal contact, regular interaction and trust. This kind of knowledge can only be revealed through practice in a particular context and transmitted through social networks. It can be seen in the model proposed by Gill (Gill J H., 2000) in which he states that explicit and tacit knowledge are linked through human experience via cognitive, linking awareness and activity. Fig. 2.7 shows Gill's model.

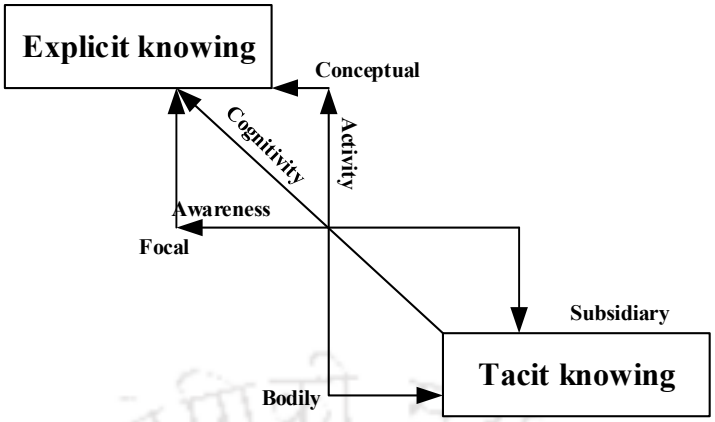


Fig.2.7: Gills model of cognitive experience (Gill J H., 2000)

Nonaka and Takeuchi (Nonaka I et al., 1995) had proposed a four mode of knowledge conversion known as SECI (Socialization Externalization Combination and Internalization) model. Fig. 2.8 shows the proposed model by Nonaka and Takeuchi.

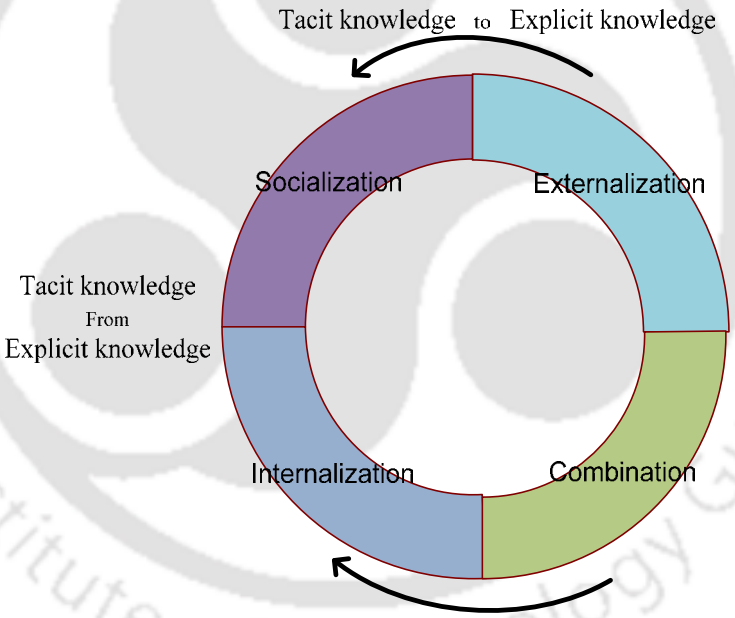


Fig.2.8: Knowledge conversion model by (Nonaka and Takeuchi, 1995)

According to Nonaka, tacit knowledge can be converted to explicit knowledge. This could be achieved through socialization, Internalization, externalization or the combination of the above three. It can be seen from the above that it is very difficult to capture the tacit knowledge since there are various factors involved in it. The SECI model can be explained to the craft domain as illustrated in Fig. 2.9. The model shows the tacit to tacit conversion of skills of craftsman by apprenticeship or discussion or practice, then the skills are transferred into a report and then the report is transferred

through e-mail and finally other users can learn it and improve their tacit knowledge.

The importance of the tacit knowledge is explained here in the form of Storytelling. Schilcher (Schilcher, 2007) explained that tacit knowledge is as important as the theoretical knowledge available in the companies. Since it is gained by practical and concrete working process in the company. They have insisted on the facts that tacit knowledge does not exist primarily in a formalized or accurately recordable mode and therefore it is not to be understood as a thing, an object or a tangible good. For the above reason it occurs unconsciously by skilled persons.

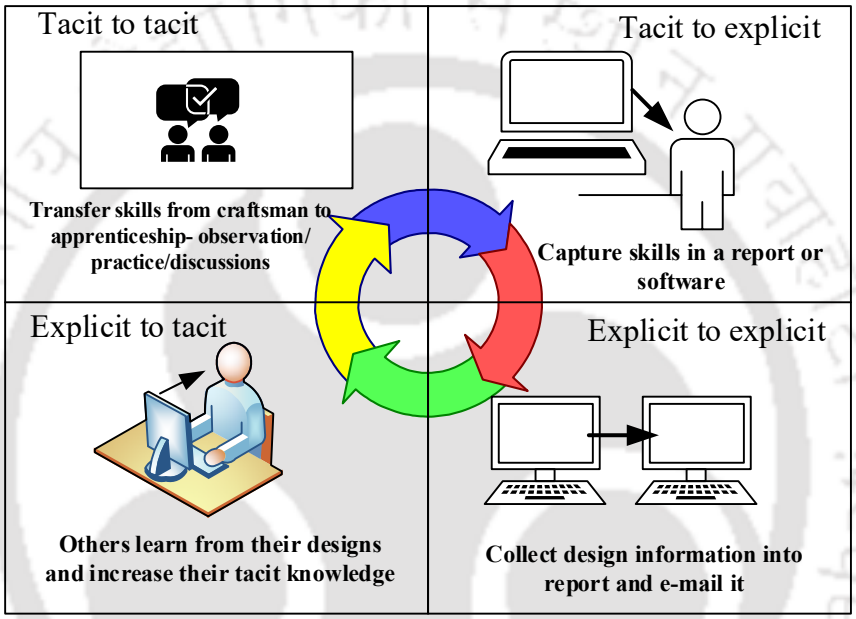


Fig.2.9: Modified knowledge conversion model for the craft domain (Nonaka and Takeuchi ,1995)

Schilcher, describes *'Story telling' as a method in which the employee is encouraged to tell his experience, memories and attitude in an interview like situation*.

Then the interviewer (together with the interviewed person) tries to create a story out of the interview, event or a project and presents it to other employees, so that they get benefitted from the story. The experience can be documented by the photos, movies or computerized based simulations.

Schilcher concludes that the written documentation or databases are very difficult to deal with the tacit component of the knowledge. Therefore, storytelling can be an approach in documenting and distributing the tacit knowledge. Story telling provides a platform to capture tacit knowledge. Story telling along with other tools and ideas can enhance the depth of tacit knowledge in an organization. However, the story build may be fuzzy in nature but it provides necessary initiation towards the goal of propagating the tacit knowledge in an organization.

Researchers have used the Delphi technique to extract the knowledge in the organization level knowledge management (Ganesh, 2014). Vincent Hoogerheide (Hoogerheide, 2014) has stressed that 'example learning' is effective in the students with low prior knowledge and has been used in the online based learning. Vincent has compared different results with and without example among different group of students to find that examples have a least effect on the learning curve of the students. But to gain the tacit knowledge of the master the student has to study and have effective communication with him. There is lot of work which concentrates on the representation of Knowledgebase in different domains like medical, cognitive sciences, organizational sciences, information and library sciences, technical writing and journalism, anthropology and sociology, storytelling and communication studies (Dalkir,2013).

According to Parsaye (Parsave, 1988), there are three major approaches to the capture of tacit knowledge from groups and individuals. They are as follows:

- Interviewing experts.
- Learning by being told.
- Learning by observation. and observing the process used to solve it.

Svinicki & Dixon (Svinicki et al, 1987) studied the Kolb's model of learning and modified it for the classroom activities. The Fig.2.10 shows the representation of the modified Kolb's model used by the authors. It gives a brief idea of imparting the lessons and their learning experience based upon the experiments and observation. This shows that implicit knowledge takes time and constant practice to be grasp by the students.

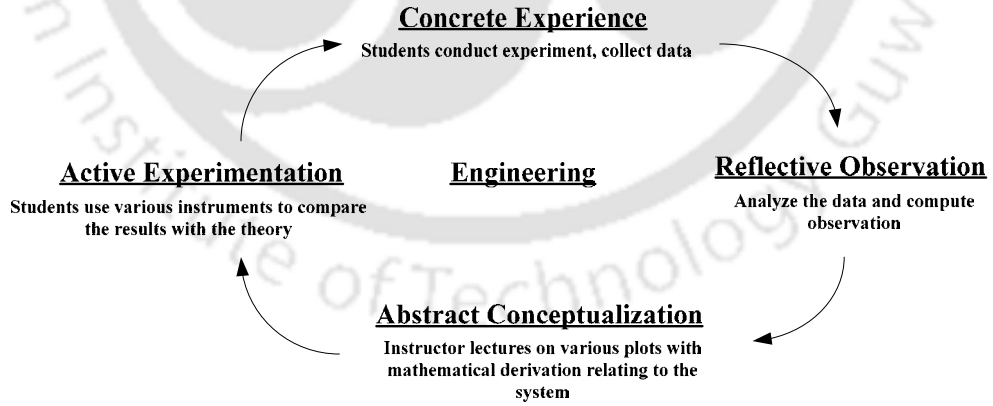


Fig. 2.10: Sample Experimental Learning Sequence for engineering discipline (Svinicki,1987)

There are various tools available to capture the knowledge and convert it into implicit form. One of the ways to capture the knowledge is by the use of Ontology. Ontology as defined by Gruber (Gruber T., 2008) gives a relation to the representation of a model of any domain knowledge. Ontologies represent static domain knowledge and PSMs will be used inside Semantic Web Services that model

reasoning processes and deal with that domain knowledge. In Ontology, we can distinguish between essence and existence. The essence of something is what this something is (Gambra, 1999). However, an existence is to be present among things in the real world. For instance, a centaur is half a man and half a horse, so it has essence though it does not exist.

Definition of Ontology:

- An ontology defines the basic terms and relations comprising the vocabulary of a topic area as well as the rules for combining terms and relations to define extensions to the vocabulary. (Neches, 1991)
- An ontology is an explicit specification of a conceptualization. (Gruber T., 2008)
- An ontology is a formal, explicit specification of a shared conceptualization. Conceptualization refers to an abstract model of some phenomenon in the world by having identified the relevant concepts of that phenomenon. Explicit means that the type of concepts used, and the constraints on their use are explicitly defined. Formal refers to the fact that the ontology should be machine-readable. Shared reflects the notion that an ontology captures consensual knowledge, that is, it is not private of some individual, but accepted by a group. (Studer, 1998).

The definition of Ontology was also beautifully explained by Mizoguchi (Mizoguchi, 2003) by giving an example of the table with three blocks. The systematic arrangement of the three blocks with respect to table on which they have been kept was represented using ontology. If the blocks and their arrangement are represented hierarchically then it was easily arranged. And if they are not represented properly then they are difficult to arrange.

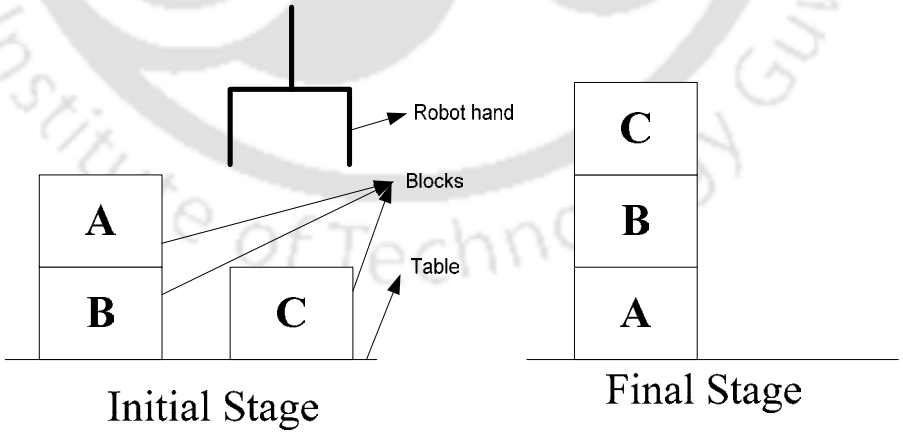


Fig.2.11: Block arrangement problem, (Mizoguchi, 2003)

Mizoguchi explains that ontology is about conceptualization of the knowledge based upon the relations and concepts. Ontology was used in the development of a device, CHARM (Convincing Human Action Rationalized Model) for training the novice nurses with the implicit knowledge from

experienced nurses (Sasajima, 2013). Several authors have used ontology to represent different knowledge forms but none of the researchers have used it to represent the craft domain.

The above types of knowledge involve verbal communication between the master and the apprenticeship. K.S. Johannessen pointed out that the formation and implement of language follows certain rules and theories in it. The author said that language has a vocabulary which consists of logical constants and empirical variables. These constants and variable along with the rules make a user to make complete sentences to communicate with another user using the particular language. To completely master the language, one has to master the rules and the vocabulary. This mastery is possible by practicing the language and using it appropriately at different situation (Johannessen, 1990).

This was studies by Saaristo (Saaristo, 2012). His work focusses on the knowledge sharing and management of knowledge among the employees in Ziliot International limited, a multinational company. The strength and the weakness of the knowledge sharing was studies in his work. Semi structured interviews were conducted between different personnel working in the company. The results of the interviews point out that the challenges in the knowledge sharing and the knowledge management are caused by the multicultural environment of the case company leading to difficulties in communication, and also by the structure of case company's management. This was due to the trust issues between the employees of the company which was multicultural in nature. According to the author cultural background played an important role in the spreading of the tacit and explicit knowledge. The study raises three research questions and tries to answer them. The research questions are:

- What are the weaknesses in the knowledge management and the knowledge sharing in Ziliot?
- What are the best practices in Ziliot regarding the knowledge management and the knowledge sharing?
- How can the knowledge sharing be improved in Ziliot?

The research searches the answer for the above-mentioned research questions. The research also points out the importance of communication in the transfer of the tacit knowledge.

Similarly, inferences were found by Pondy (Pondy, 1979), according to him language is a kind of technology that helps in processing data. They identified four different roles which language play in an organizational behavior: control of perception, attribution of meaning, facilitation of communication, provision of a channel of social influence. Wittgenstein (Wittgenstein, 1991) in his studies has pointed out that to understand a particular sentence one has to understand the language. Unless a communicator has through knowledge of the language he will not be able to express to a situation effectively in that language. The author also remarks that language is like a way of living.

He uses the examples of recognition of human faces, the art of pointing the fingers are a kind of understanding of a person.

I.Josefson studied the nurses in Britain and England. The author argued that a great deal of nursing is passed from a senior nurse to a newly joined nurse through apprenticeship (I.Josefson , 2012). D. Smith states that apprenticeship is one of the excellent methods to transfer knowledge and common sense to the learner (Smith. 2002).

While designing a cross-disciplinary project in Computer-Aided manufacturing (Rosenbrock, H. H. et.al.,2012) suggested that skills of the operators should be kept in the mind of designer. Operators should have the freedom to shift strategies without losing software support. The tacit knowledge and skill of the operator are used to avert or correct error. Grant (Grant RM., 1996) studied the transfer of the knowledge in the firms. He suggested four mechanism of transfer of knowledge with in the firm. They are the rules and directives, sequencing, routines, group problem solving and decision making. He has also suggested that common language is an enhancer of knowledge integration. Lack of the common language is sometimes a significant barrier in the knowledge transfer.

D. Smith also studied the Dhokra artisans of West Bengal, India. The tribe worked on the decorated brassware products created by the cire perdue or lost wax process which is now getting lost. He has suggested that the theory of artificial as proposed by Massimo Negrotti (Negrotti, 1999) can be a path way in archiving the lost knowledge of the craftsman. Their project was involved in creating a mu1ltimedia archive of the tacit knowledge of the artisan.

Fig.2.12: Dhokra Art (Source: Internet, 2016)

Cliff Bowman reports that tacit knowledge is a kind of resource for individuals. The author has again categorized knowledge into two categories: one that is cod able and the other which is possessed by the individuals (Bowman, 2001). The author has discussed different characteristics of tacit knowledge one is that it is difficult to write down (Nonaka, 1991). Other characteristics of the tacit knowledge is that it is personal, practical (can be described by a process), context specific.

The authors have given several methodologies to extract or study the tacit knowledge:

Cognitive maps: They are the maps in which the individual thinks casually about a problem upon his own views. There are several cognitive maps like casual maps (graphical representation consisting

of nodes and arrows linking each other),

Self-Q: This is a technique which was developed by Bugon in 1983 in which the participants interviews themselves. So, there is no interference from other members and the participants formulate their questions based upon their own knowledge.

Semi-Structured interviews: It is a kind of an interview in which the purpose is pre-determined like if we want to hear causes of success from a participant then we can ask them to tell stories about their success.

Metaphors: They are the means in which a participant can communicate an ambiguous situation by relating it to a metaphor.

Several other researchers (Koskinen, 2003) have also given different techniques of acquisition of knowledge like: Action learning and Informal interaction between people involved in the innovation process Most of the researchers have tried to study the different crafts in various parts of India and other parts of the world. Marshall McLuhan, in 1966 (McLuhan, H. M. ,1966) had pointed out that the importance of the craftsman in the future in 'global village' concept. In his concept he has mentioned that with the increase in the technology and cultural globalization the world will become a mixed market place and thus the craftsman will be playing a major role in promoting their culture and also the business. There is also a program launched by the Taiwanese government in the Small and Medium Scale industries which helped to promote a particular product in a particular town called as 'One Town One Product'. In this program the government is trying to influence a common trend in a town (McLuhan, H. M. ,1966) that can popularize a craft in that locality. Personalization of the items for the consumers is now becoming common trend in the major multinational companies. Consumers are viewed as the individual entities. The product which belongs to one consumer varies from the product owned by the other customer (Tung, 2012; Lash,1993). Researchers have also shown that the local crafts can influence by the material chosen for the crafts (Nimkulrat, 2012).

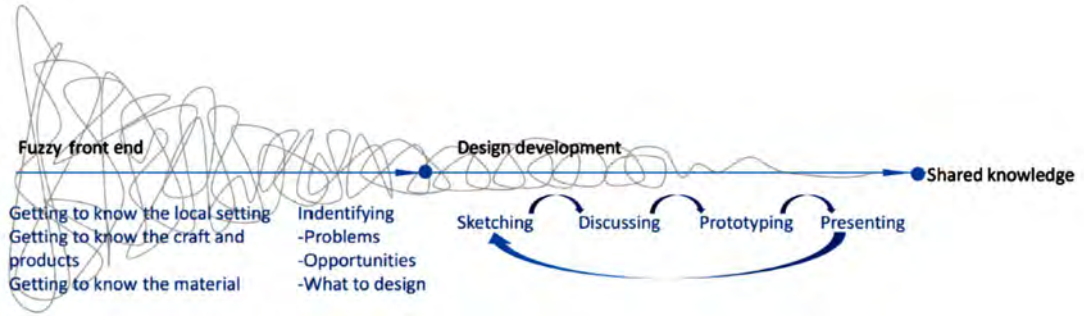


Fig.2.13: Tung's Crafts-design collaboration (2012)

Fig.2.13 shows the collaboration between the artisans and the designers in the building of a physical prototype.

Fig.2.14: Combination of modern-day materials with the traditional crafts item (Tung, 2012)

Researchers have also studied the combination of the modern-day equipment with the traditional crafts items to give a classy look to the products (Tung, 2012). Companies like Asus, Bamboo and Samsung have also implemented traditional crafts materials like bamboo and wood to their products. Improving the work environment of the craftsmen will help their future generations to stay in and around the crafts industry. The high demand of the crafted items with the human touch has a wide scope among the population. Technology can be used to renovate the work place of the craftsmen by providing with tools which can retain their knowledge. This knowledge can be extracted when in need by the craftsmen and help them to make their life easy. In the absence of the master craftsmen the younger generation craftsmen can learn by themselves in the work environment and thus show interest in the craft product making.

In the book, Traditional Korean Designs (Madeleine Orban-Szontagh, 1991) the pictorial notation of the various traditional Korean designs are illustrated. It states that at one point of the history the Koreans were the tutors to Japanese transmitting Buddhism and its related arts beginning in the sixth century AD. This resulted in the Japanese factories in the seventh century. Though the book revealed some of the designs of the earlier century but it lacked the experience of the past culture of Koreans. Some of the designs can be seen below:

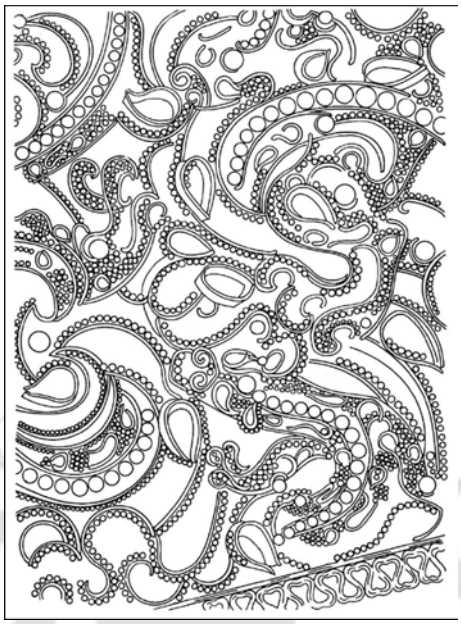


Fig.2.15: Enlarged detail of the golden buckle, 1st and 2nd century (Madeleine, 1991)

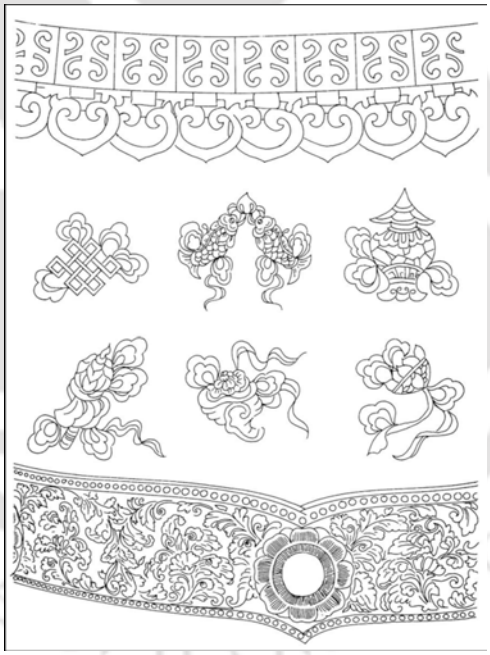


Fig.2.16: Metal belt, Old Silla, 5-6th century, embroidered Buddhist symbols (Madeleine, 1991)

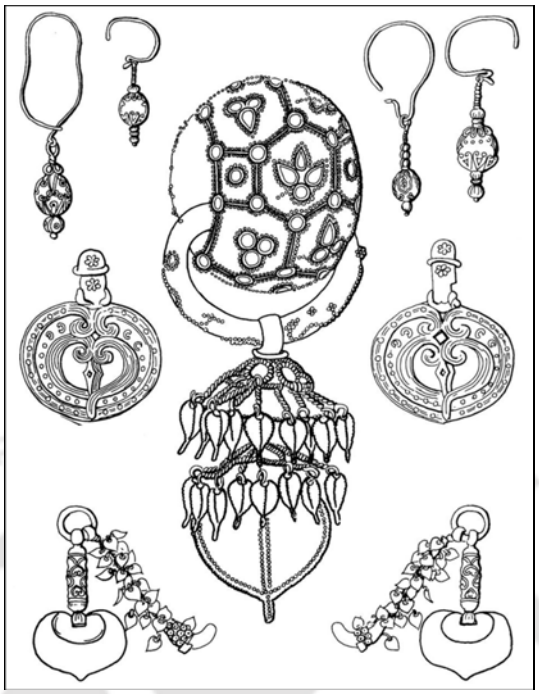


Fig.2.17: Earrings, Old Silla (Madeleine,1991)

Hacker illustrates the practice of Indian craftsman by Jaidev Baghel. Baghel had won the India's National Craftsman Award in 1977 (Hacker, 2016). Some of the works of the artists are shown in Fig. 2.18

Fig.2.18: Art works of Jaidev Baghel (Katherine, H, 2016)

Similarly, Triharini's research tried to explain the definition of craft and steps taken by the government of Japan to preserve the traditional crafts in Japan (Triharini, 2014). The research covers some history of the traditional craft practices in Japan. Kogei (the Japanese term for craft) is a process

to make a craft from the traditional items using superior technology and skills. Similarly Mingei is another Japanese term used which consists of two terms: minshuu (people), and the word, kogei (craft), and means the people's craft. There are two case study , one of Yamanaka Lacquerware from Japan and the other of bamboo weaving craft from West Java, Indonesia considered in this research. The conclusion of the thesis is a frame map to help the local NGOs and government to take steps in the conservation of the traditional craft as illustrated in Fig.2.19.

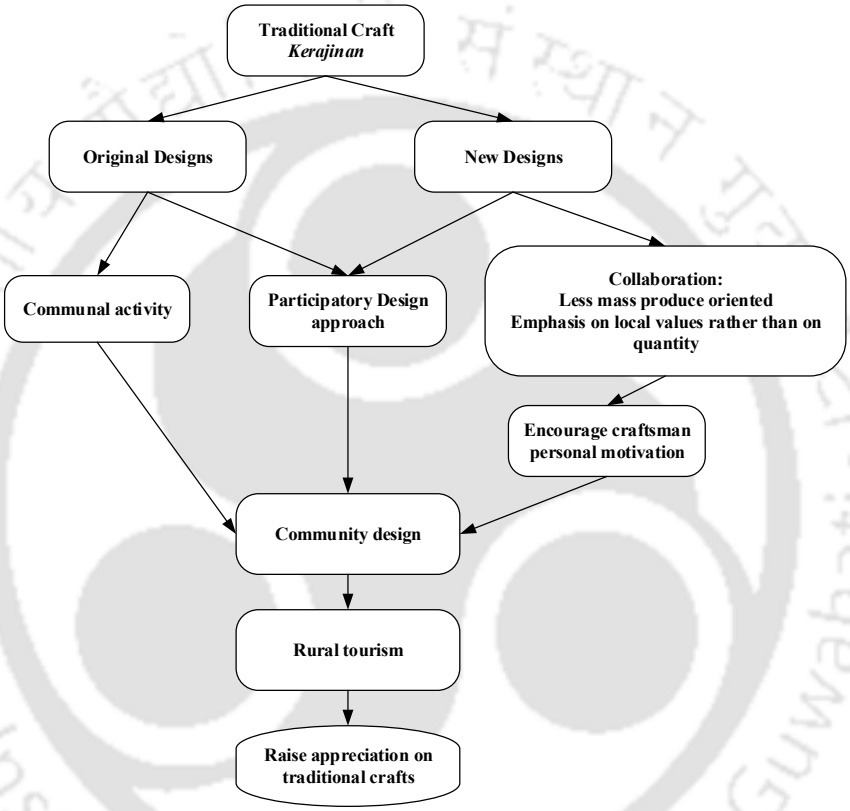


Fig.2.19: Chart of Integrated Design Approach for developing traditional craft design (Triharini M., 2014)

2.2.2 Fuzziness in the craft knowledge

The knowledge involved in producing the crafts includes the skill of the craftsman and the embedded knowledge in the crafts products. It's a combination of both tacit as well as the explicit component of knowledge. To study the tacit knowledge of the crafts man we need to study the fuzziness in the craft items.

The decisions taken by the craftsman during craft making are intuitive in nature and the thumb rule base which he/she had learnt during his apprenticeship from masters or mentors.

In fuzzy based approach the variables adopted are expressed in the form of simple linguistic words which can be easily understood. The topic of fuzzy logic was first introduced by Lofti A. Zadeh (Zadeh ,1983; 1996) in his paper as fuzzy sets. According to him fuzzy set is defined as follows :'if X be a space of points, with a generic element of X as x, then

*A fuzzy set **A** in **X** is characterized by a membership function **fA(x)**which associates with each point in **X** a real number in the interval **[0,1]**, with the values of **fA(x)** at **x** representing the "grade of membership" of **x** in **A**.'*

Generally, in mathematics the categorization is discrete in nature i.e., either a feature belongs to a particular set or does not belong to it. This is not the ideal case in the real-life scenario, in which the data is in the combined state of both discrete and continuous (quantitative and qualitative). However, to have a continuous nature of categorization we need continuous function to represent them. For example, we want to measure the weight of a person and specify who is fat and who is not fat. Suppose we say that the person who is above 80 kg is considered fat. The sharp edge membership function describes this and indicates that whether somebody falls under this category or not. It is very difficult for this type of the membership function to describe a real-life scenario.

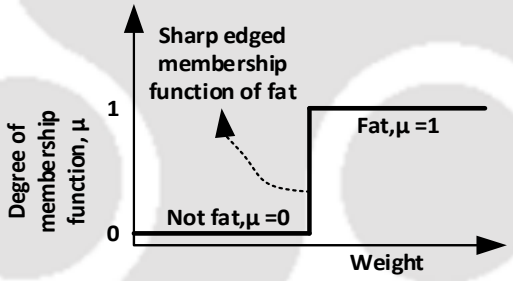


Fig.2.20: Sharp edged membership function representing the weight of a person; μ= degree of membership function (Author generated)

The continuous membership function helps to tackle this scenario and can describe it. For example, a person of 79 kg can be more towards fat and less towards thin person. Fig.2.21 shows a continuous membership function describing the categorization of the fatness problem.

So when there are large number of real time variables in a problem, then categorization of the elements become easy when we use fuzzy based approach (Zadeh, 1996).

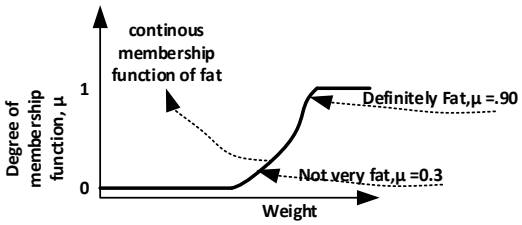


Fig.2.21: Continuous membership function representing the weight of a person (Author generated)

In the paper, Prof. Zadeh points out that fuzzy can help in solving the problems which have uncertainty. Management of uncertainty is an intrinsically important issue in the design of expert systems because much of the information in the knowledge base of a typical expert system is imprecise, incomplete or not totally reliable.

The knowledge base of an expert system is a repository of human knowledge. As, much of human knowledge is implicit in nature, the knowledge base of an expert system is a collection of rules and facts which are neither totally certain nor totally consistent.

Researchers have tried to include the human knowledge in to the database of the expert systems. For instance, Norman WC, and Clive Dilnot (Norman et al, 2001) explored the extracts of the CAD designs and the traditional designs in a jewellery industry in Hong Kong. They insist on more and more interaction with the goldsmiths to extract the knowledge which they have, so that it can be included in the CAD database. This database can be further used for more innovative design which had the tacit knowledge of the craftsman as well as modern approach of CAD in it.

Molnárka (Molnárka, 2009) used fuzzy system to diagnose the buildings as a case study. In the case study, the paper, sketches out the facts of uncertainties of the visual examination procedure in building diagnostics, then describes the architecture and components of the fuzzy expert system. Thereafter, the operation of this method is illustrated through three building diagnostics case studies.

Hassan (Hassan, 2017) implements the fuzzy logic to measure the heart condition of the patients. The inputs variable for the study were blood pressure, cholesterol, maximum heart rate, blood sugar, old peak and age. The fuzzy expert system thus developed could accurately suggest different prescription to the patients.

2.3 Artificial Intelligence and its relation to Knowledge Management in Craft domain

Artificial Intelligence (AI) comes under the umbrella of Human Computer Interaction (HCI). The phrase AI, which was coined by John McCarthy three decades ago, evades a concise and formal definition to date (Bender,1996). AI is the science to create the intelligence of machines such as

computers (Konar, 1999). It is mostly known as “the study and design of intelligent agents”, where an intelligent is a system that perceives its environment and takes actions in response to its environment. Knowledge management is an emerging area which is gaining interest by both industry and government. As we move toward building knowledge organizations, knowledge management will play a fundamental role towards the success of transforming individual knowledge into organizational knowledge. One of the key building blocks for developing and advancing this field of knowledge management is artificial intelligence, which many knowledge management practitioners and theorists are overlooking.

Modern day manufacturing systems are trying to mimic the human and the different capabilities possessed by them of adjusting into different scenarios. The differences in the size, shape and orientation of the parts are easily handled by the human operator. The modern manufacturing systems are now capable of handling what a human operator was able to do. Computational Intelligence has been applied to number of manufacturing settings. It helps in allowing the robots to mimic the human operator and helping them in performing the repetitive tasks. The different senses of the human like vision, language processing etc. are been successfully implement into robots. Some of them are: Knowledge-based systems, Planning testing and diagnostic systems, Augmented reality systems.

Knowledge- based systems: Knowledge based engineering (KBE) is a technology based on the use of dedicated software tools called KBE systems, which are able to capture and systematically reuse product and process engineering knowledge, with the final goal of reducing time and costs of product development by means of the following: Automation of repetitive and non-creative design tasks, Support of multidisciplinary design optimization in all the phases of the design process (Rocca, 2012)

A knowledge-based system is a computer program that contains the expertise required for solving a problem. Knowledge-based systems derive their power of knowledge stored in the knowledge base (Kusiak, 2000). The typical architecture of a knowledge-based system is shown in Fig.2.22.

Planning, testing and diagnostic systems: The planning, testing and diagnostics is carried by the simulating the developed algorithm. The simulation of the algorithms developed is tested in real time environment.

Augmented reality systems: Augmented Reality (AR) is a variation of Virtual Environments (VE), or Virtual Reality as it is more commonly called. VE technologies completely immerse a user inside a synthetic environment (Rocca, 2012). When the user is immersed he/she cannot see the real world around her/him. In contrast, in AR the user can see the real world around him with virtual objects overlaying in it.

The application of AR can be found in several research, for instance, Mohammed-Amin (2015) describes museum as the places of edutainment where storytelling plays an important role. His research illustrates the use of new technology mobile augmented reality (AR) in museums. The research empirically investigates the application of mobile AR for enhancing visits to museums and historic sites.

Different devices which are used in the AR are head mounted devices, haptic devices like cyber hand, cyber glove etc. AR is used in the modern assembly techniques to the feasibility of the assembly in the real world. Smart Assembly will try to use most of the principles of AR to make the assembly operation a reality of future.

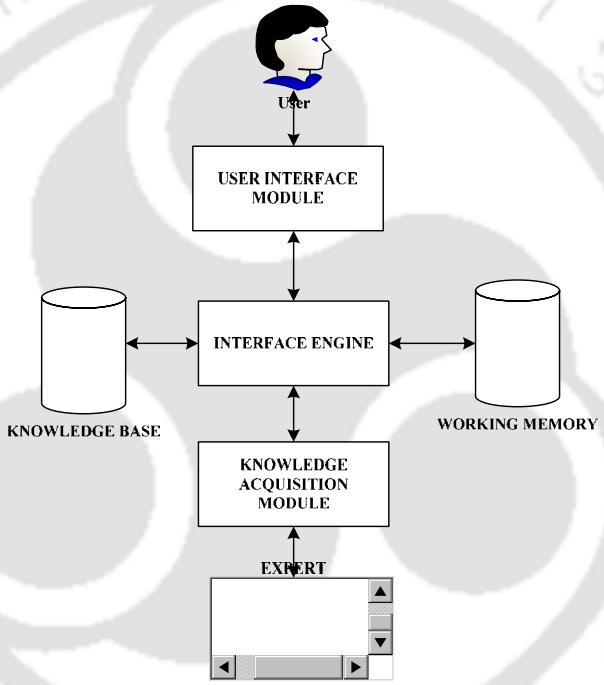


Fig.2.22: Architecture of Knowledge-based System (Kusiak, 2000)

2.3.1 Acquisition of Knowledge

AI has played a significant role in the acquisition of knowledge in the modern devices. Knowledge-based systems (KBS) solve problems that are normally solved by human 'experts'. More precisely a KBS can be defined as "an intelligent computer program that uses knowledge and inference procedures to solve problems that are difficult enough to require significant human expertise for their solution". KBS consists of some representation of expertise, some representation of a problem to be solved, and some mechanisms to apply the expertise to a problem. Although expertise may be

captured and represented in various forms, one common representation for expertise is in the form of rules.

Knowledge-based Systems are based upon an explicit model of knowledge required to solve a problem, using a formal model that enables system to reason using first principles. However, despite the undoubted success of Knowledge-based Systems in many sectors developers of these systems have come across several problems. Knowledge-based Systems are typically structured in a set of rules extracted from the experts. However, knowledge engineering found it hard to uncover the hundreds of rules that the expert used to solve problems - because the expert does not reveal everything what he/she knows, or he or she does not want to surrender the knowledge, or mainly because the expert often had hard time trying to articulate his or her problem-solving skill in the form of IF-THEN rules. This last problem became known as the knowledge acquisition bottleneck. In addition, while rules seemed like nice compact representations to collect, it is often the case that rules have many exceptions making the knowledge acquisition problem that much harder. To complicate matters even further, it was necessary to trace the interactions between rules to ensure that they could chain together properly, and that contradictions were eliminated. Researchers have already tried to use the knowledge of the experts in the classical AI. Generally, an expert system is designed to assist the human in an intelligent way. These expert systems have the knowledge of the real experts in that domain and the can provide required solutions in that area like a real expert does (Giarratano, 1981).

Gingerich (Gingerich, 1990) details the steps, which are involved in the development of an expert system. The first step is to 'Select a suitable problem'. After selecting the suitable problem, which can be worked upon the next step is to acquire the knowledge required for the building of the expert system. The next step is the selection of the tool for the building of the expert systems. Then develop a prototype and the complete systems and then evaluate the system. The last and the final step is to integrate it into the work environment. Turing's (Turing, 2009) paper revolves under this scenario in which the author tries to ask the basic question: 'Can Machines Think?'. The author then clarifies that the answer which is given by the computer is a database of the solution which is already fed into it.

The emergence of the World Wide Web has played a key role in facilitating knowledge management. Hare's (Hare, 2015) work deals with the omnipresence of the computers in our daily life. His research states that computers are now used to design things which was very difficult to design in the past. His thesis deals with the physical presence of humans in the computer embedded products. Physicality is loosely defined as '*the physical aspects or qualities of both an object and its interaction*; *this includes our physical bodies in relation to that object*.' The work tries to uncover

one of the important topics in HCI which is: the role of physicality in the building of the low-Fi prototypes. The major challenge is to develop knowledge management tools in an effective and user-friendly way. Some of the tools and technologies employed by construction organizations to manage knowledge are shown in the Table.2.2 Some of these techniques can be applied to the craft industry to understand the behavior of craftsman.

Table-2.2: Different technologies to manage knowledge in Construction organization (Egbu, 2003)

Technologies & Techniques	
Telephone	IT based database
Internet/Intranet	Knowledge based Expert systems
Documents and reports	Video conferencing
Face-to-face meetings	Groupware
Interaction with supply chain	Storytelling
Formal on-the-job training	Knowledge maps
Formal education and training	Brainstorming sessions
IT-based database	Project Summaries
Work manuals	Coaching and mentoring
Informal networks	Bulletin boards
Cross-functional teamwork	Job rotation

Virtual Reality (VR) is another technology that provide an immersive environment for users to obtain experience that is difficult to have in reality. VR can enhance the analysis and validation of digital products. VR is an integration of different technologies which includes simulation, computer graphics, human-machine interface technology, multimedia technology, sensor technology and network technology. VR has also been used to make products more humanized. (Song, 2016). For instance, (Forgy. 1979) developed an algorithm which can reduce the production systems time of pattern matching. The research follows an algorithm written in LISP programming language to evaluate the pattern in the system. The thesis introduces the RETE Match algorithm to compare the features of the production system. The production system generally contains statements which have Left hand sides and right-hand side. The algorithm developed in this thesis tries to compare the right-hand side statements to see the accuracy of the inputs. Then it gives a result which is optimal in nature by trying to save memory by deleting the previous comparisons statements.

Similarly, (Lopez, 1987) discussed an idea to create an expert system in a single or multiprocessor architecture. The system he developed tried to use the module from the expert objects. This production system has two levels one is at the expert object level and the other is at the rule set level. The systems help a user by allowing them to draw a conceivable type of blackboard structure or graph. The graph can be easily specifying the structure in the parallel production system. Expert

systems are the computer-based programs that are organized by the expertise of human experts. Human experts explain the problem and solve them by the help of heuristics (rule of thumbs).

These rules are of the form*: if <something is true> then <perform some action>,* these are called as productions. Fig. 2.23 illustrates the system, it shows the engine where the production rules are conserved and when there is a conflict the rules are fired. It continues till the conflict set empty.

Table 2.3: Two kinds of approach to build an expert system (Whitley, Edgar A, 1991)

	Formal domains	Semi-formal domains
Approach used	Functionalist	Socio-technical
Relationship between expert systems and domain	Expert system models the domain	Expert systems are integral part of the system
View of reality	Single, measurable reality	Many public versions of the reality
Conceptual view of system	Design as a machine Machine centered approach	Design as a tool
Form of the knowledge	Knowledge is available in discrete chucks	Knowledge is socially constructed
Problems arise because	Users don't know enough	Users don't have an appropriate understanding
Communication involves	Simple transfer of knowledge	Users add to communication
Involvement of users	Little consideration given	Much consideration given

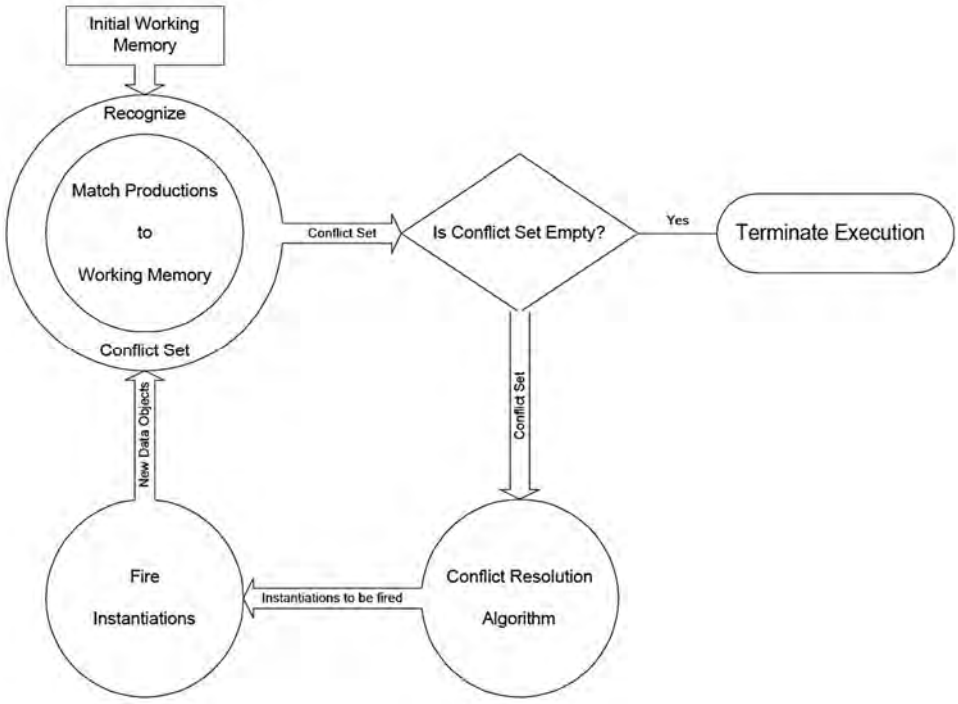


Fig.2.23: Production system recognizing act (Lopez, 1987)

Whitley (Whitley, 1991) provides certain guideline in which an expert system can be build. Whitley's work discusses two approaches to build an expert system. This is illustrated in Table 2.3.

Tough the expert systems gave solution by the rules framed by the programmer, it was sometimes difficult to guess the accuracy of the system. For example in the paper (Barker et al , 1989) a case study of an expert system called XCON is described. This expert system was built for the digital support to the companies which dealt with huge production unit. Sometime critical issues require human intervention as the expert system was unable to conclude which was relevant in that situation. The paper covers the benefit and advantages of the expert system. Dym, Clive also (Clive, 1985) presented an overview of an expert system. IN the explanation, Clive states that expert systems gives an advice to the user based upon the knowledge of the human expert database.

According to Clive, *an expert system is a computer program that performs a task normally done by an expert or a consultant, and in so doing it uses captured, heuristic knowledge*. The paper shows the basic structure of the expert system adapted from Feigenbaum and McCorduck. Fig 2.24 illustrates the structure, it consists of the knowledge engineer who is a bridge between the experts, and the system. There is expert knowledge which is present in the Knowledge base. The system also consists of an inference engine which is a gateway to the user wo require the expert advice.

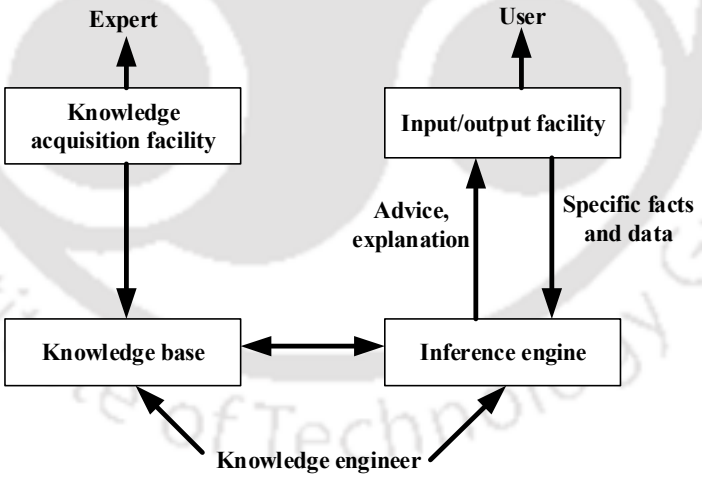


Fig.2.24: Basic Structure of the expert system (Dym, Clive L, 1985 adapted from Feigenbaum and McCorduck)

Likewise, Capelo (Capelo, 2017) developed a computer vision system which was embedded into the robot CASPER. CASPER was built for helping children suffering with Autism Spectrum Disorder to learn social skills. Different algorithms were tested for the face recognition, body motion recognition of the children. The best of the algorithm was used for the robot.

To study the users and the different stakeholders in different scenarios, researchers have tried to categorize the different personal data for the users. The increase in the number of users of smart phone has also increased the security of their personal data.

In recent years, data science is gaining more and more interests. This has become possible by the diffusion of embedded intelligence in smart devices that possess increasing computational capabilities and are becoming more and more intertwined with our lives. The smartphone users are also at a steady rise, Fig. 2.25 and Table-2.4.

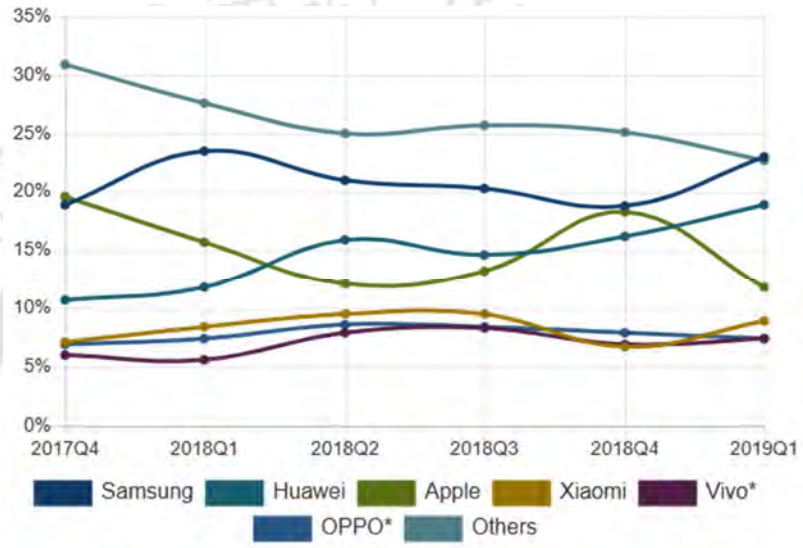


Fig. 2.25: Smartphone market share worldwide (Source: International Data Corporation, 2019)

Table- 2.4: Quarter shipments of smartphone from different top smartphone company (Source: International Data Corporation, 2019)

Quarter	2017Q4	2018Q1	2018Q2	2018Q3	2018Q4	2019Q1
Samsung	18.9%	23.5%	21.0%	20.3%	18.8%	23.0%
Huawei	10.7%	11.8%	15.9%	14.6%	16.2%	18.9%
Apple	19.6%	15.7%	12.1%	13.2%	18.3%	11.8%
Xiaomi	7.1%	8.4%	9.5%	9.5%	6.7%	8.9%
Vivo	6.0%	5.6%	7.9%	8.3%	6.9%	7.4%
OPPO	6.9%	7.4%	8.6%	8.4%	7.9%	7.4%
Others	30.9%	27.6%	25.0%	25.7%	25.1%	22.7%
TOTAL	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**
Quarter	**2017Q4**	**2018Q1**	**2018Q2**	**2018Q3**	**2018Q4**	**2019Q1**

The smartphone; its impact and relevance can be properly evaluated by two measures. The first one is the Smartphone Penetration Rate, which is the measure of the number of users that own and use at least one smartphone. There are yearly conducted surveys that show an amazing 30,9% of worldwide smartphone adoption in 2017, that corresponds to 2.5 Billion people.

The second one is the Smartphone Usage Statistics, which is the amount of time spent using smartphone in specific situations. A person uses the smartphone for an average of 3 hours per day; if we ignore the sleeping time, it corresponds to almost 19% of the time available during the day. In addition to the time spent using the phone, there are other interesting dimensions that should be considered. For example, 52% of UK owners look at the device within 15 minutes after wake up in the morning, which increases to 86%3 within one hour. Similar values can be found considering the time interval between when the user looks at the phone and when he goes to sleep, with a 43% within 15 minutes that raise up to 77% within one hour. (Bignotti, 2018).

The above literature suggests the growing importance of digital technologies in our lives. It cannot be ignored that in the future the digital world will be growing and becoming a part and parcel of human needs.

2.4 Research into digital craft and craft heritage

Cultural heritage as defined by UNESCO (UNESCO, 2017) are the ways of living by a community which are passed from present generation to the future generations. These may include the customs, practices, places, objects and artistic expressions. According to UNESCO, there are two kinds of Cultural heritage: Tangible and Intangible (ICOMOS, 2002).

Tangible cultural heritage consists of the building, monuments, landscapes and artefacts. The intangible cultural heritage includes oral traditions, performing arts, social practices, rituals, festive events, knowledge and practices concerning nature and the universe or the knowledge and skills to produce traditional crafts.

During the International Conference on the Safeguarding of Tangible and Intangible Cultural Heritage: Towards an Integrated Approach in 2004, Nara Japan (UNESCO, 2017) the importance of intangible cultural heritage in terms of knowledge transfer from one generation to the next was discussed as an important topic. Conserving this and developing ways of preserving this heritage is a subject of research in various streams of humanities, art and science and technology. The heritage diagram by Simon Thruley in Fig.2.26 explains how we can promote the cultural heritage and make the most of our history for a fruitful future (Thurley S., 2005).

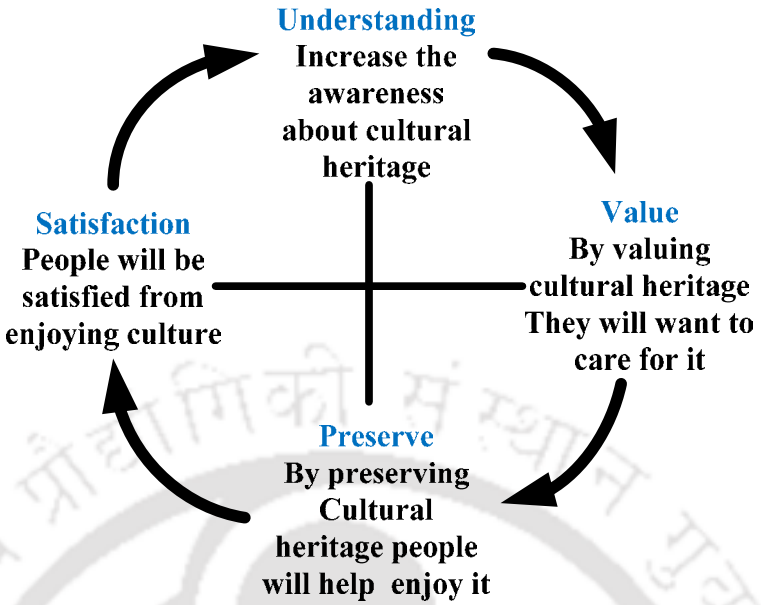


Fig.2.26: Heritage Diagram (Thurley S., 2005)

The heritage diagram gives an overview of the benefits from the conservation of the cultural heritage but it lacks to provide us the philosophy behind the cultural heritage conservation. There are many important steps taken towards conservation of tangible cultural heritage. But very few steps are being carried out for the conservation of the intangible cultural heritage.

The conservation work of intangible crafts can be seen in parts of India too. The crafts domain has been an exciting area of work for the designers and researchers in India since independence. The Indian Craft museum in New Delhi is an excellent example of conservation of art from various parts of India. Sethi et al. (Sethi,2013; Greenough,1995) has studied the Dilli craft village in India and has mapped the craft there to the contemporary India. A major role was played by Pupul Jayakar in the traditional crafts tourism Post-Independence from British rule in India. (Sahay, 1994; Venkatesan, 2006).

Elsewhere in the world too researchers have been making attempts to preserve and transmit traditional knowledge. In the review of the book, 'Nigeria's traditional Crafts' the author (Hodge,1982) has mentioned about the varied description of Crafts ranging from wood carvings, decorated gourds, mat work and basketry, woven textiles, died textiles, leather working, pottery, beads and bead works, Bida glass, wall decoration, and finally cicatrisation, body decoration, and hairdressing in Nigeria. The author has also mentioned about the lack of the importance to the crafts sector in Nigeria. For example, some of the primitive's methods of pot making in Nigeria like Gwari pot making and techniques used by the Yoruba potters are neglected and may be lost if not conserved in due course of time.

Industries are attempting to capture the experience of retiring employees by assigning them new trainees for apprenticeship learning. Knowledge and practice time gaps and disconnect between traditional practices (say in different pockets of bamboo basket weaving communities) starts reflecting in such training too. The present generation of youth in the North eastern part of India is migrating to the cities in search of the other more lucrative occupations. To continue preserving skills and to retain new generations into the crafts-trade new design ideas but within the traditional boundary become necessary (Sahay, 1994).

Designers and researchers are attempting this problem in different manners. Some of them are encouraging the practicing of ancient arts and painting among youth. Some are trying to generate the awareness of the positive benefits which the art and craft practice can do. Cultivating the crafts and art helps once to develop his creativeness, helps to nourish the artist in them, helps to develop self-confidence which in turns does wonders in their lives.

Fig.2.27: Gwari pot (Source: Internet,2016)

In a blog article Athavankar (Athavankar,2017) raises some important question, 'Is sketching as a representation tool an indispensable part of design problem solving?' Athavankar argues that if sketching is necessary then it should be considered as an essential skill in the design and architectural careers. He conducted an experiment in which the designer is given a design problem to solve and is blindfolded and thus prevented from sketching. The designer builds a mental map of the solution to solve the problem. It was difficult for the designer to solving the problem as mental images are fragile and are difficult to work with. As a result, Athavankar modifies his previously raised question

'What design thinking needs is an ability to represent an object in some form that act as a relatively stable display, but allows you to manipulate it quickly and effortlessly. Such a definition no doubt fits sketching, but is inclusive enough to legitimately accommodate other forms of representations like mental imagery. Even if designer develops competence in handling one of them, he should be able to make a reasonable headway in design career.'

The above paragraph suggests that to cultivate the metal model of an idea some form of flexible tangible interface is required. Likewise, the human brain tries to process things in a systematic or categorical manner. In the book, *The Discipline of Organizing*, (Glushko,2013) Annechino, and

Hemerly have term categorization as the process of grouping things, people, processes, abstractions –anything, really – into categories. This can be seen while we encounter daily objects. The authors give an example of a door knob and its various classification as compared to a window door knob and a main entrance door's door knob. In the example the categorization of the door knob helps a person to obviously recognize when he is in front of a main door or he is about to close a window. This experience of categorization helps a user to see things/objects in a systematic manner. According to Annechino, and Hemerly, categories are sometimes called as equivalence classes because all the members of a category are similar in nature. Category judgements are not only used to classify what is included in the class but also to classify what is excluded in the it.

The different mode of categorization according to Annechino, and Hemerly, are classical and modern.

In the classical point of view, the members of a class are defined by the necessary and sufficient condition. Example a cupcake is defined by certain characteristic shape, texture, and taste.

The categories can be implemented in an organization by various technological tools. *Schemas* are one of the methods which are used to represent categories. For example, an extremely simple data schema might describe a system for organizing a pair of shoes on a spreadsheet. The data schema specifies that the spreadsheet contains information about pairs of shoes (the "pairs of shoes" entity), and has four columns, or data elements. One column contains the row number, which is automatically generated by our spreadsheet program. The row number is an attribute of the shoes entity that uniquely identifies each pair of shoes. In addition, our data schema might specify that there are three additional columns that we have labelled "Size," "M/F," and "Heel Height". The labelled columns are also attributes of the shoes entity, but they need not be unique for each shoe. Further, the schema might specify that the "Size" column must contain a number on the standard US shoe size chart; the "M/F" column must contain either the letter "M" to indicate that the pair is sized for men, or an "F" to indicate that the pair is sized for women; and the "Heel Height" column must contain heel height in inches, with 0 representing no heel. Every item on the spreadsheet must have a unique row number, a US shoe size, an "M" or "F" indication, and a heel height in inches. Schemas are one of the important tools to collect the data in a categorical manner.

Likewise, another researcher, Connell (Connell, 2000) also focuses on the concept of categorization or sorting. Connell argue that categorization is due to the conceptual processing. It means that human brain tries to categorize the things based on the certain concepts which it has earlier processes for

example the categories of table or categories of chairs etc. There were two experiments carried out for the choosing the category.

In the first experiment consisted of choosing an example of category based upon the context. For example: "The girl played the guitar while the others sang around the campfire". The subjects were to rate how good an example guitar is on a 7-point scale. A score of 1 (one) means that you feel guitar is a very good example of the category (musical instruments) in this context. A score of 7 (seven) mean that subjects feel that guitar its very poorly with their idea or image of an appropriate instrument in the context of a campfire. A score of 4 (four) means that the subject feel guitar fits moderately well, and so on. Subjects were told to use the other numbers of the 7-point scale to indicate intermediate judgements.

In the second experiment the subjects were asked to judge how good an example of a category an item is. The subjects may see a pair like this: "animal dog". The subjects were asked to rate how good an example of animal that dog is on a 7-point scale. A score of 1 (one) means that they feel dog is a very good example of the category animal. A score of 7 (seven) mean that they feel that dog fits very poorly with your idea or image of what a good example of Animal is. A score of 4 (four) means that they feel dog fits moderately well, and so on. Subjects were told to use the other numbers of the 7-point scale indicate intermediate judgements. After the experiments the different objects were given a single score rating and ranked accordingly in terms of the context.

Cornell concluded that categorization in terms of the context was helpful in users to rate the things properly and so it forms an important element in categorization or sorting of things. The ability of the brain to recognize and detect different objects in some seconds is remarkable in nature. To make it out in the computer systems is a really difficult task. The field of visual categorization is an active area of research. (Mohan K, 2013).

The idea of digitalization in Craft sector utilizing the above methods and ways discussed above can help revolutionize it among different stake holders. This in turn would help the creative, emotional as well hands on practice on craft to cultivate.

2.5 Implementation of designs research into craft and cultural heritage

Design plays an important role in solving various wicked problems in the daily life. There are various definitions of design available in the literature. Design is an activity to change the current situation into a preferred situation. (Simon, 1996). Design is an activity that has an effect on nearly every sphere of human life (Pahl and Beitz, 2013). With more and more advancement in the science and technology, the field of product design is proceeding towards innovative and more creative path.

Slowly the world is witnessing thousands of immerging new products in the market. Some of the products sustain in the market and some of them take into new form after some modification. Design is an essential part of the products life cycle.

During the craft production the craftsman have an impact on the design and so the products were economical in nature. The mass production of the product was on the specific designs which can be repetitive in nature. Slowly when the mass production started the manufacturer's design were used to make the final product and sold to the customers. In the mass customization the manufacturer provided a variety of designs to the customers to choose from. In the recent developments in the manufacturing, customers want to get the desired product which are personalized in nature. The personal attachment comes into the design when the customers as well as the artisans become the part of the design. Pahl and Beitz (Pahl, 2007) explain different stages of the product during its life cycle. Design is important stage in the lifecycle. The product lifecycle showing the different stages of the product is shown in Fig.2.28. It starts with the market need or the problem. The next stage of the lifecycle is the product planning or task setting stage. Then comes the design and development stage, this stage contains many sub stages like the concepts of the designs to be formed, the analysis of the concept, whether the concept is feasible or not etc. The design stage is followed by the production stage. This is followed by the marketing stage where decisions are taken for the marketing strategies of the product. The last three stages are the use or consumption or maintenance stage; Energy recovery and recycling stage; the disposal stage.

The different phases of the lifecycle can also be applied to the craft sector. But the main disadvantage in applying these stages is each and every craft sector had a different method in its production. So, to see if the craft sector can be normalized and put into a single life cycle we looked in to the design morphology.

A project in design goes through a number of time phases. Morphology of design refers to the collection of these time phases. The morphology of design as given by M. Asimow (Asimow,1962) is illustrated in Fig.2.29. It consists of seven phases. The first three stages of the design morphology given by Asimow are the primary design stages. The rest of the stages are the production-consumption phases. In the first three stages the rough idea of the problem is discussed and whether it is possible in the resources of the design are discussed. It starts with ideas and then the detail design is illustrated in theses stages. The next stage of the morphology is planning for the manufacturing which helps a designer and the production manage about the feasibility of the manufacturing of the detail design. The planning for the distribution, use and retirement of the product are discussed in the rest stages of the morphology. Asimov morphology helps to understand the design in detail. The

various steps help in clearly getting the picture of the products from the nascent stage till the disposal stage.

Craft and cultural heritage are followed from various centuries and are dated back to many decades. These were the practices followed by humans from their ancestors and forefathers. To understand and study these practices a lot of in-depth research is needed. Specifying the design aspects in these crafts is also a challenging task. If we carefully study the lifecycle as well as the design morphology, then we can get to know how much research years have been spent in the formulation of these theories.

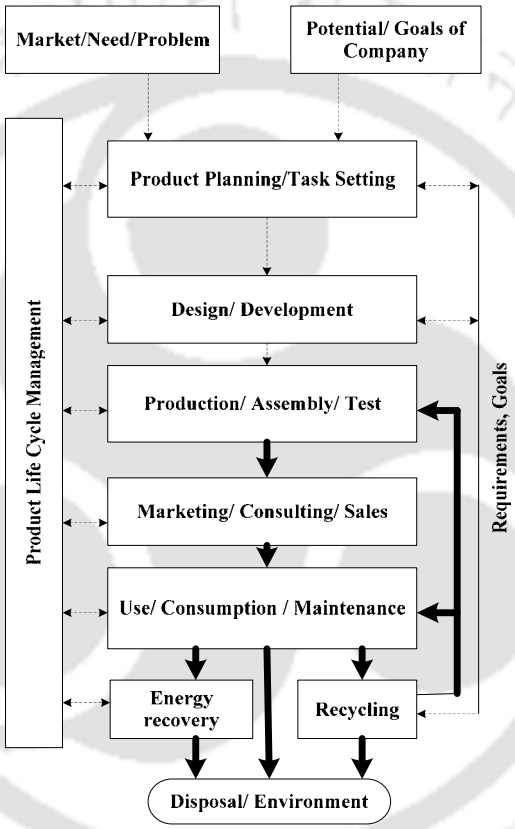


Fig.2.28: Life cycle of a product (Pahl, 2007)

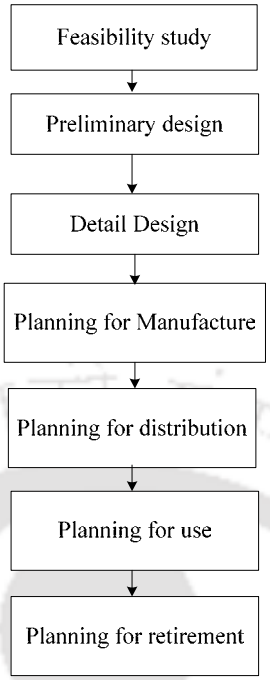


Fig.2.29: Morphology of design (Asimow,1962)

To find the design link of the crafts products various research articles are written by many researchers. Kersey et. al (Kersey et al,1985) have given a brief review about the state of Indian crafts during the World War I scenario. During this period there was a high demand of traditional crafts goods which resulted in the imitation of the original craft goods. This led to some companies to export some low-cost goods from the foreign market. So, the demand for the original craft goods was diluted. Research has shown that formal education is a facilitator of the progress. A study by A. Collins (Collins, 1989) about the formal form of education started that the development of nation is based on the quality and quantity of people educated in that nation. This is seen in the industrialized nation where the importance of apprenticeship training before industrialization played a major role in the development of the country. The value of thinking and problem solving practically in the presence of masters brings large amount of confidence to the students/learners.

Design is a complex, multifaceted phenomenon, involving: people, a developing product, a process involving a multitude of activities and procedures; a wide variety of knowledge, tools and methods; an organization; as well as a micro-economic and macro-economic context. (Blessing et al., 2009). Design research can be considered to have passed through three overlapping phases: The Experiential, Intellectual, and Experimental (Wallace et al., 2000). The design research as per Blessing and Chakrabati: is the development of understanding and the development of the support

for design. Fig.2.30 illustrates the overall aim and objectives followed during a typical design research project.

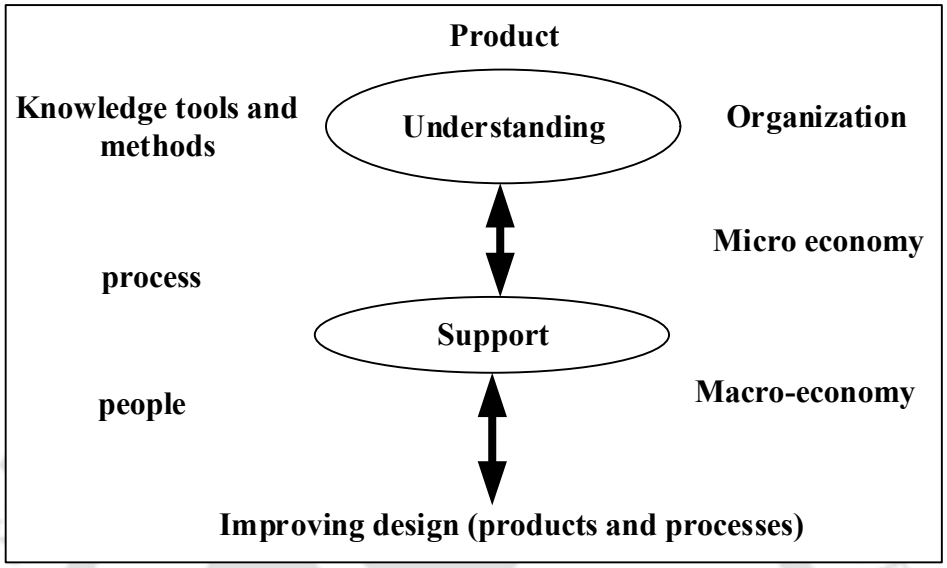


Fig.2.30: Design research: aim, objectives and facets of design (Blessing et al., 2009)

The Design Research Methodology (DRM) proposed by Blessing and Chakrabati is an approach and a set of supporting methods and guidelines for doing design research. The DRM and its relation to design and design research is illustrated in the Fig. 2.31. DRM provides a understanding and support to go to the next stage i.e., design research. Likewise, after reaching the design research phase the practice of the research is expressed in design practice and design education stage.

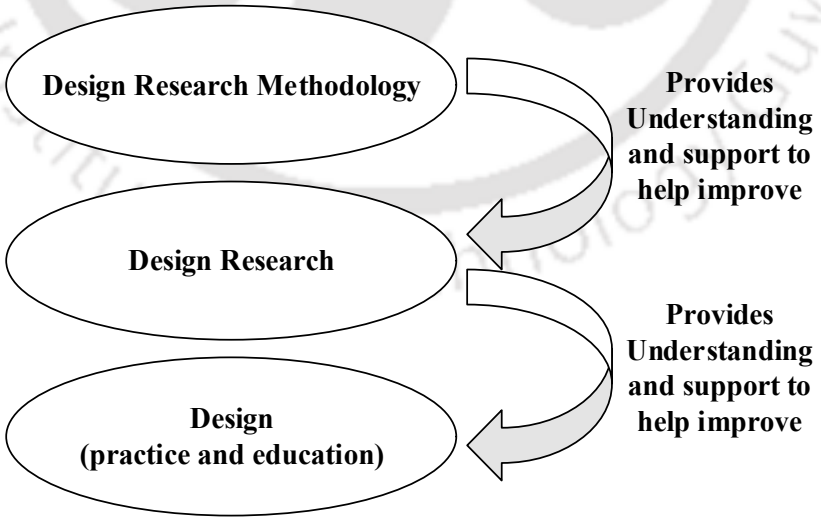


Fig.2.31: Relationship between DRM, Design and Design research (Blessing et al., 2009)

The DRM framework developed by Blessing and Chakrabarti (Blessing et al., 2009) is illustrated in the Fig. 2.32 and described as follows. The DRM consist of four stages: Research Clarification, Descriptive Study I, Prescriptive Study (PS) and Descriptive Study II. In the Research clarification stage the researcher tries to find some indicators that support the assumptions made for the research goal to achieve. In the Descriptive study I the researcher is having a clear idea of the goal and the area, if it is not clear then they have to again research the literature survey and have clear variables affecting their research.

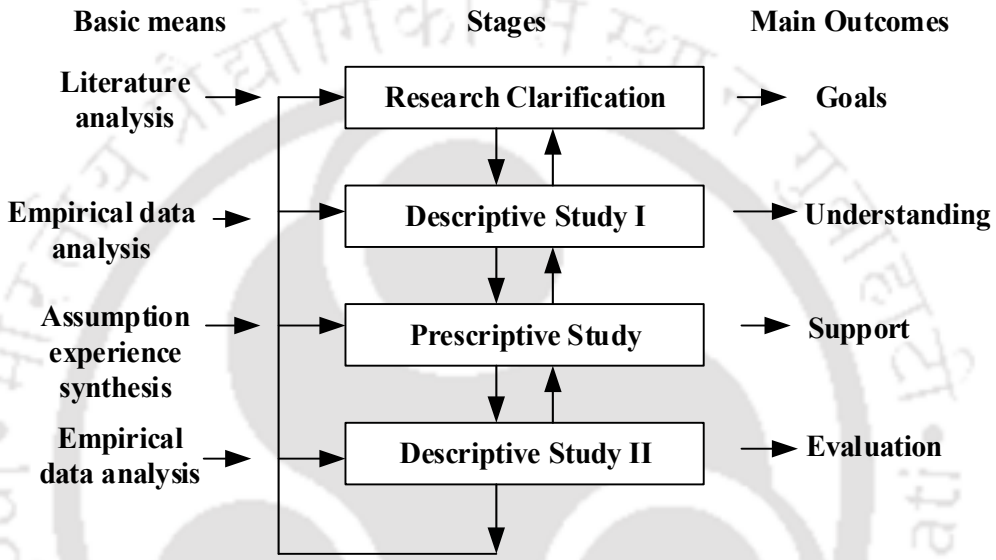


Fig. 2.32: DRM framework (Blessing et al., 2009)

The third stage of the research is prescriptive study in which the researcher uses their increased understanding of the existing situation to correct and elaborate on their initial description of the desired situation. This description represents their vision on how addressing one or more factors in the existing situation would lead to the realization of the desired, improved situation. In the Descriptive Study II the researcher investigates the impact of the study so far and tries to see it is matching with the desired situation. The above four stages are iterative in nature and often carried out to see whether they fulfill the desired outcomes at each stage. To avoid the unexpected iterations, the researcher in design has to plan for each stage. Based on the DRM framework the authors seven types of the research projects and their main focus. Fig.2.33 shows the types of the research projects according to DRM.

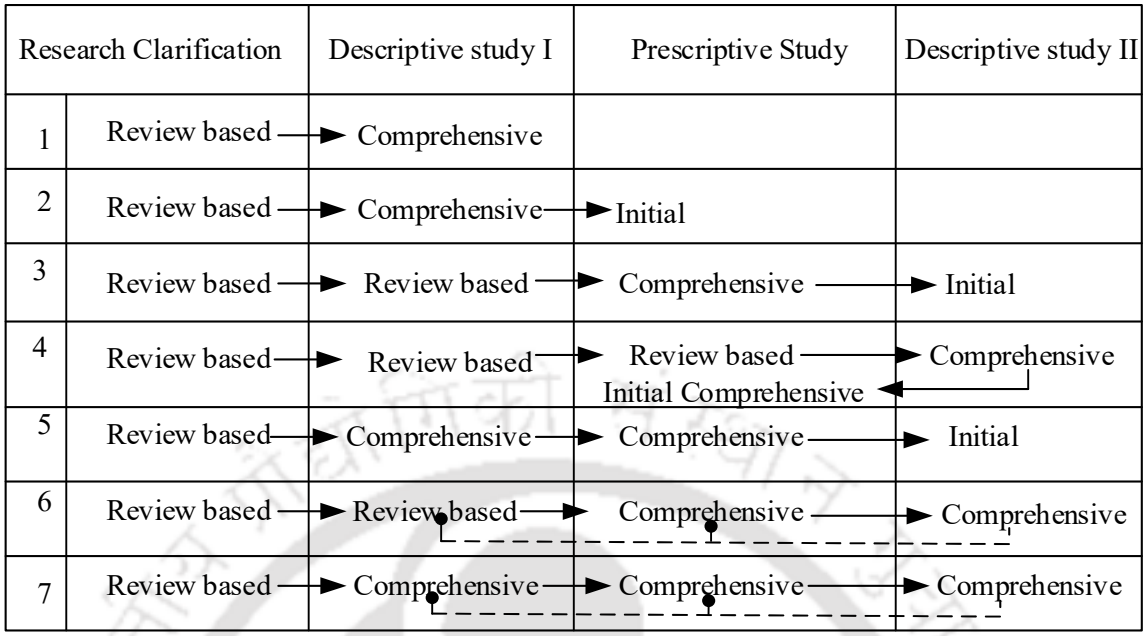


Fig.2.33: Types of design research projects according to DRM (Blessing and Chakrabarti, 2009)

Type1 type of study is undertaken when there is a comprehensive study. The result of this type can be used in understanding the success of the research and which metrics can be used.

Type 2 type of study is undertaken when there is comprehensive study along with the solution is some existing solution is present. It is used to better understand the existing solution and then this is used for the improvement.

Type 3 type of study is undertaken when there is a clear understanding of the literature survey. This type of research helps in the development of the support system. The DS II is undertaken for its evaluation.

Type 4 type of research is taken when the support is already present and the evaluation part is necessary. A Comprehensive DS-II is followed by suggestions for improvement.

Type 5 study is carried out when there seems to be a combination of type 2 and type 3 kind of research. In this the researcher aims at developing a support system with little understanding of the existing situation.

Type 6 project combines the type 3and type 4 kind of research. The level of understanding of the research is obtained from literature review (Review-based DS-I) is sufficient to develop the support (Comprehensive PS), and the project resources allow formal evaluation of the support (Comprehensive DS-II). Depending on the results of the evaluation and the available resources, this is followed by a revisit of the PS or DS-I stage, either as an Initial study or a Comprehensive study.

The last kind of research, type 7 is very comprehensive in nature and involve a detail understanding of the present situation. This make the research to revisit DS-I, PS and DS-II when required.

The topic of research chosen in this thesis can be related to **type 5** kind of research. The main aim is to develop a support system for understanding the craft sectors based upon the tacit knowledge of the craftsman and the embedded knowledge in the craft objects. So to achieve this the design elements present in the craft are studied first, so that the crafts can be categories into different types.

2.5.1 Research methods

The work required a detailed understanding of knowledge developed during craft making process. To answer the research questions, the various data collection methods to be used in the similar studies are reviewed, from the point of view of their ability to help observe and capture the knowledge generated, captured and reused by the observed set of designers in different projects and design stages in which they are involved. The data collection methods are chosen considering the most appropriate ways of answering the research questions, and with least intrusion and disturbance to the subjects. In the literature most of the results are obtained from questionnaire surveys that are retrospective in nature, and does not need to consider the permissible limits and constraints typically imposed by the conditions. In this research, methods had to be identified and framed together taking the environmental and working constraints into account, while still allowing to obtain the rich and realistic data from the craftsman. Some of the real time data collection methods are shown in the Table.2.5.

Table.2.5: Real time data collection methods (Blessing et al., 2009)

Observation (no involvement of the researcher); • **taking field notes;** • **recording activities against time;** • **counting occurrences and contents of particular events;** • **measuring values and occurrences;**
Participant observation (the researcher as participant); • **several of the other techniques have been used to collect the data;**
Simultaneous verbalization (audio or video taped); • **thinking aloud;** • **introspection (commenting on one's own mental activity);** • **interviewing during the actual process;** • **talking aloud/recording team discussions;**
Diary keeping (designer as observer, or observing participant); • **keeping a diary of the type instructed by a researcher;** • **keeping a diary as designer/researcher;**

Recording the evolution of documents through snapshots;

- **photographing sketches, drawings at regular intervals;**
- **videoing the evolution process of a document;**
- **keeping computer logs;**

Computer simulation;

- **spatial visualization tasks**
- **computer games to obtain information about specific behavior.**

The common data collection methods used in the studies related to cultural behavior are questionnaires, unstructured interviews, voice recordings, video recordings, ethnography and protocol analysis. The rest of this section elaborates the purposes and usage of these methods.

Questionnaires: They are the initial phase of the research where the researcher asks initial questions to the subjects to get the data from them. This information provides an adequate background with which to understand the subject and the projects in which (s)he is currently involved, and helps understand the behavior of the subject during the observational period.

Unstructured interviews: Unstructured interviews are conducted with the subjects observed whenever problems have been faced in understanding subjects' activities that occurred during an observation. Generally, the problems are written down in the data sheets during the observation, and unstructured interviews are conducted at the end of the working hours. This helps to clarify the doubts and reduce the uncertainty of the information recorded in the data sheets.

Voice recordings: Voice recorders are employed whenever there has been an interaction between the subject under observation and any other person, so as to capture the conversations between them. These conversations are later transcribed and analyzed using protocol analysis.

Video recordings: Video recorders are used to capture information during the complex interactions that involved two or more people with documents or other information sources. The video recordings added more value to the captured information by providing details about gestures and postures assumed by the subjects .

Ethnography: Ethnography is used by the researcher to study the subject in their natural environment. This research is used to obtain data which are very specific and qualitative in nature.

Protocol analysis: Protocol analysis is a research method which is frequently used in design research to understand activities involved in designing. However, the use of this method in knowledge acquisition has been limited, due to various industrial constraints. In this analysis, the voice and video recordings have been transcribed, and the transcribed protocols have been coded suitably to answer

the research questions. A transcription represents the utterances made by the subject, which are typed into a text format. The transcription contains the text, time and subjects' identification mark for each utterance. Even though various tools have been proposed in the literature to assist in the transcription activity, it still consumes around four to five hours to transcribe one hour of voice/video recording (Sarkar et al., 2007).

2.6 Summary of review

The literature survey focused on several aspects of research on the tacit knowledge of the crafts objects and the craftsman. Based on the literature survey in the previous section three major gaps were identified in developing the heuristics for the tacit knowledge capturing in the crafts domain

2.6.1 Lack of comprehensive method of conservation of the intangible cultural heritage

Literature suggests that there are methods available for the conservation of the tangible cultural heritage but very few methods are available towards the conservation of the intangible cultural heritage. With the passage of time, some of the intangible cultural heritage have already been perished. Therefore, steps have to be taken to conserve these heritages. This gap gives the opportunity to the researchers to generate various innovative solutions for the above problem. The thesis tries to solve this research gap by suggesting an innovative heuristic for conserving the in tangible cultural heritage.

2.6.2 Lack of proper model to study the mental model of the craftsman

The traditional morphology of design by Asimov suggest the various phases of the design followed during the product design stage. Likewise, (Kolb,1984; Peter Honey, and Alan Mumfords,1992) suggests various model of learning. The above models give a brief description of the design phase but have given any model to study the traditional craft processes. This gap is being addressed in the thesis. The thesis proposes a model to study the mental model of the craftsman while they are involved in the craft making process.

2.6.3 Lack of comprehensive heuristic for capturing the tacit knowledge of the craftsman

There is a lack of comprehensive heuristics for capturing the tacit knowledge of the craftsman. The traditional morphology, which are used for training novice designers, are not sufficient for teaching them traditional craft. Learning of craft involves apprenticeship and long hours of practice by the learner with the master craftsman. Therefore, in the absence of the master craftsman it becomes

difficult for a novice designer to grasp the concepts of the craftsmanship. Therefore, there is need of a proper heuristics or guideline to learn a particular craft. This issue is being addressed in the thesis.

- Products can become more sustainable if they embed in them the tacit knowledge along with the changing technology knowledge.
- There is a possibility to understand the tacit knowledge that goes into the making and production of product.
- The techniques developed in this research hold promise to be developed further into a research tool& method to capture tacit knowledge in Design.
- The present research tries to bridge the above gap, ie., modern technologies and past crafts by capturing the tacit knowledge of the craftsmen working in the bamboo and crafts industries.

Emerging markets for the crafts products.

The lifestyle of the modern consumers is increasing towards individual signature items and products. This will also be an opportunity for the craftsman to make an influence in the customized product market.

Based on the above conclusions the aims and objective of the research was formulated.

2.7 Aims and Objective of Research

The aims and objective of the research are as follows:

Aim of this research

This research aims on developing, creating by experimentation, a digital tool to capture the implicit knowledge on the traditional culture and crafts in different crafts of India.

Objectives

OB1: To identify the intangible cultural heritage in the craft domain.

OB2: Re training the craftsman who wish to learn during the absence of the master.

OB3: Identification of the archaeology and to conserve the heritage.

OB4: To develop a tool which will help these crafts to remain safe for longer time.

2.7.1 Research Problems and Research Questions

Research Problems

- There is no bridge to join the gap between the modern technologies and traditional crafts.
- There is less research studies to capture the tacit knowledge of craftsmen

Research Questions

RQ1: How do we identify different components of knowledge (especially tacit knowledge) from live crafts and artefacts?

RQ2: How to Isolate and transfer tacit component from artefacts?

RQ3: How to program/digitize tacit knowledge component such that

- It can be utilized by a design researcher wanting to continue tacit knowledge and traditional crafts for the purpose of training a new generation of craftsman
- Common user can use it
- It is used by a heritage museum for identifying craft artefacts, categorizations and classification of crafts

2.7.2 Working posits of the research

P1: If there is a way to capture and preserve the tacit knowledge part through a transference method, same knowledge could be used by future users to relearn.

P2: Tacit knowledge when captured and documented in a digital form can become a database for training new generations of craftsman who may or may not have connection with traditions.

P3: Tacit knowledge when digitized can bridge the gap between traditional handicrafts and current engineering practices of mass production.

2.8 Summary of chapter

The chapter covers the literature review of the topics related to the present research. The gaps in the research were identified and the main aims and objectives of the research was formulated. The overall research questions arising out of the literature survey were raised in section 2.7. Some of the posits was laid for the next phase of the research which will be discussed in the subsequent chapters.

Chapter-3 Exploring Crafts and Craftsman through Pilot studies, Methodology and Experiments

Abstract: *After the formulation of the research gaps and broad area of research in the previous chapter the research questions and objectives of the research were discussed in this chapter. A section discusses the research methodology adopted for this thesis. The initial pilot study carried out for understanding this research. The chapter progresses with the experiments conducted after the pilot study and. the summary of the chapter.*

3.1 Introduction

Based on the literature survey and gaps found from it the research aims and objective were formulated and are revisited in this chapter. As discussed in the literature, to study the craftsman and their tacit knowledge of the crafts, a detail observation of them working in their natural environment is required. A holistic approach towards the problem is required. The research problem is studied through the design perspective point of view. The aim of the thesis as formulated in the previous chapter was *to develop a digital tool to capture the implicit knowledge of the traditional crafts in India*. The topic is a collaboration of the field of HCI and design methodology. The main stakeholders in this research are the designers and the craftsman involved in the craft sector. So, a detailed observation of the various activities of the craftsman is required in this research. The study involves a user-centric approach which is mainly focused in the usability engineering under the umbrella of HCI. The user centric approach follows an iterative methodology as discussed in the literature. The Fig. 3.1 shows the user centric approach (adapted from ISO 9241-210:2010).

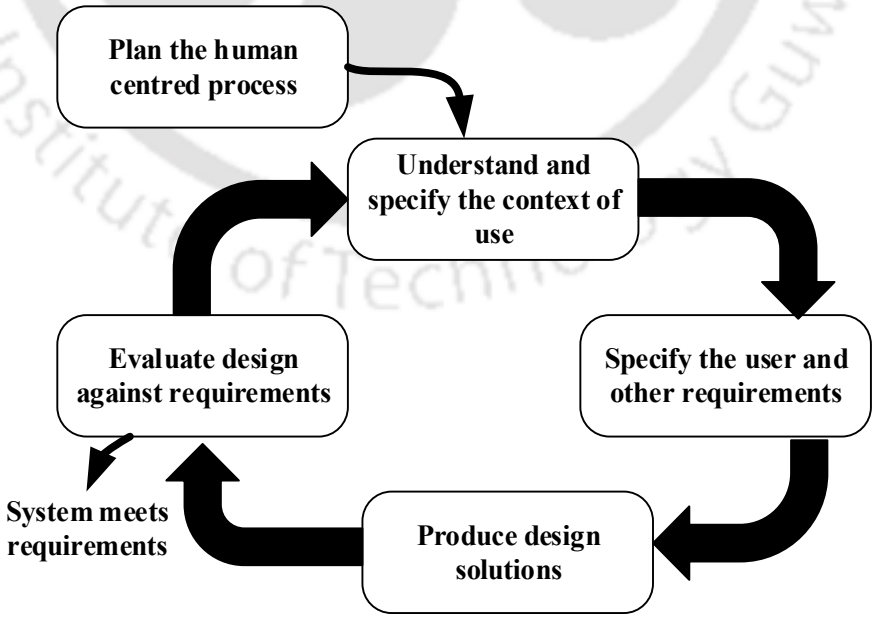


Fig..3.1: User Centric Design Process (ISO 9241-210:2010)

User-centric approach involves a series of steps. The first step is to plan the study and formulate the problem and then understand the context of use of the given problem. What are the user needs and requirements? After finding the users' needs and requirements, design solutions are proposed. The final steps are to evaluate the design requirements with the design solutions previously proposed. Else repeat the above steps again to find a better solution for the problem. User-centric approach has many benefits if it is implemented in a systematic manner.

For example, a few researchers tried to study the individuals living in the community and those migrated away from the community. For this they (Normile, 2018) studied the behavior of the customers coming to Starbucks and predicted whether they belong to the rice growing ancestors or wheat growing ancestors. The study was mainly based on the hypothesis that the Western culture allows the individual to thrive alone whereas most of the Asian cultured people depend on the group responsibilities. And because rice take twice as much as the work load to grow than the wheat cultivation, so the rice community famers depend on the group cultivation. This was evident from the experiment carried on by Thomas Talhelm (Normile, 2018), in Starbucks, in Chinese cities, where the researcher found out that the wheat region persons were drinking their lattes alone whereas the rice growing population was trying to sit together and drink. In a similar manner the cultural background of communities in the India was seen together settling at one place in a village. This was also found in other professions where the communities were divided according to the job which they performed.

This scenario helped in the development of the craft such as pottery, bamboo items, textiles, wood crafts, painting, metal works, etc. where skill of the craftsman is important. The skills can be taught by apprenticing the students to work under the master. In a closed community this was easier and was also helped in the flourishment of a particular trade. But due to technological advancement and economics demands of the families the grand children of the craft communities were not willing to take up their ancestor job. So, the knowledge, of the particular trade is getting depleted with due course of time.

To know the reason of this depletion and to get answer for the research questions

RQ1: How do we identify different components of knowledge (especially tacit knowledge) from live crafts and artefacts?

RQ2: How to Isolate and transfer tacit component from artefacts?

more we did initial pilot studies for the research.

3.2 Pilot studies (Understanding the craftsman)

In order to find out how knowledge is generated and how it is transferred we did some pilot study.

Pilot study-I

The pilot study was carried for understanding the craft making process of the craftsman. One product: the bamboo basket, were selected for the pilot study.

As discussed in the Section 2.5 of chapter 2 this type of research falls into the type5 category (Blessing and Chakrabarti, 2009). The prominent research methodologies followed in this kind of research are unstructured interviews, ethnography and protocol analysis.

Unstructured interview and field study: According to (Randall et.al., 2007) the purpose of the field work is to:

- To be able to articulate the unarticulated and tacit knowledge used in that work
- To make low-level details that have become invisible and habitual into visible materials that can be considered in design decision making
- To get to the work structure

According to Beyer and Holzblatt, field study is a 'language of description' (Randall et.al., 2007). Watching, occasionally listening, making notes, and so forth are not sufficient, to do good fieldwork. In their work they state that 'language' is necessary so that the actions under observation can be coherently and systematically structured. According to them language, combines textual descriptions and diagrammatic representations along five different dimensions. They are

- The flow of work
- The sequencing of work
- The role of artefacts in the work
- The nature of culture in the workplace
- The physical space in which work occurs

These have selected these dimensions, on the basis of their experience over years of field work and designs.

Ethnography: According to the book 'Ethnography for Designers' (Cranz G, 2016) ethnography is defined as: 'how to actively listen to the knowledge people have their own culture'. This is done by listening to the vocabulary terms underlying structure of thought that people use to describe accepts

of their culture. Also, by responding to the underlying cognitive structure or pattern the designer can respond to the user and interpret the results creatively.

According to Crabtree (Crabtree,2014) there are certain first principles which are necessary for an ethno methodological approach.

- *Work*:

  Ethnomethodology focuses very specifically on the 'work' that a setting's members engage in to accomplish the naturally occurring activities they are involved in. The notion of 'work' employed in ethno methodological studies derives from Harvey Sacks' reflections. On Doing 'Being Ordinary' (1984) where he introduces us to the idea that no matter how mundane and familiar our activities might be, it takes practical effort on our behalf, and on that of the others involved too, to make them happen.
- *Natural accountability*:

  Natural accountability is also a factor to lookout in ethnography. This means that the members of a setting can see the work that is going on around them and know what it is that they and the other parties to the work are doing. Furthermore, and unproblematically, members can offer an account of what they can see and what they are doing that others will recognize too: a natural account of action seen and done in the doing of the ordinary work of a setting: of walking, running, riding; of driving, and all of the rest of the mundane things that make up the work of the particular settings you might encounter in everyday life.
- *Reflexivity*:

  The notion of reflexivity is common currency in the social sciences. It is used to remind us that ethnography is not only about going and looking at what people do but that it is also and in significant respects about 'writing culture' too. Consequently, we are urged to be cautious, to exercise reflexivity in our studies. It might be thought that this means we need to reflect on our own conduct when doing fieldwork and writing accounts of what we have seen.
- *Studying Work*: the data collected during ethnography study the documentation and presentation of the data is essential to show the real experience by the community on whim the ethnography study was conducted.
- *Practical action and practical reasoning*: During ethnography study researchers sometimes stay with the family of the community, to experience the cultural aspect of the community understudy.

When we speak of naturally accountable activities, what is it that we are speaking of? The social sciences offer a plethora of definitions of 'activity' and its correlates 'action' and 'agency'.

Ethnography is an approach to social research that is of increasing interest to the designers of collaborative computing systems (Crabtree 2003). The purpose of sensitizing designers to the sociality of work is not necessarily one of addressing design issues directly but rather of identifying broader issues upon which effective design turns - issues to do with what to automate and what to leave to human skill and judgement, for example? To meet the needs of the designer ethnography is termed into quick and dirty ethnography, concurrent ethnography, evaluative ethnography, and re-examination of studies.

- Quick and Dirty Ethnography: It is an ethnography type where the designer spent less time on the work site and get a quick picture of the site. This can be seen in the Fig. 3.2.

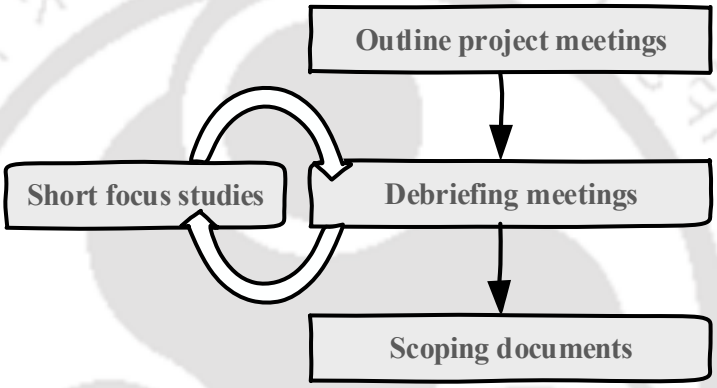
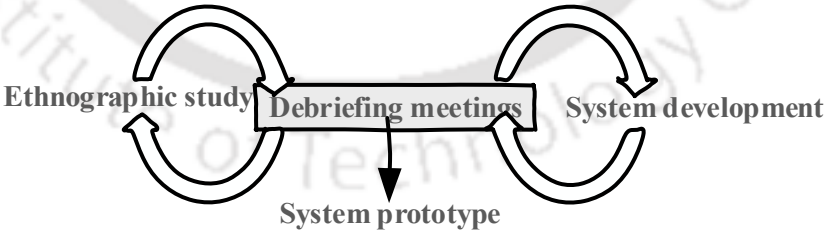


Fig.3.2: Quick and dirty ethnography (Crabtree 2003)

- Concurrent ethnography: In this type of ethnography the investigation of the work and the system design proceeds in a parallel manner. It is iterative process in which the design gets modified as the investigation proceeds. This can be seen in the Fig.3.3.



Fig,3.3: Concurrent ethnography (Crabtree 2003)

- Evaluative ethnography: Evaluative ethnography is a more focused version of quick and dirty ethnography; which is to say that it does not require a prolonged period of fieldwork. The purpose of evaluative ethnography is to provide a 'sanity check' of design proposals or of an existing prototype, where analytic emphasis is placed on establishing the 'workability' of the

proposed design solution – i.e., to assess the proposed solution's efficacy in relation to the actual performance of work. Fig 3.4 illustrates the evaluative ethnography.

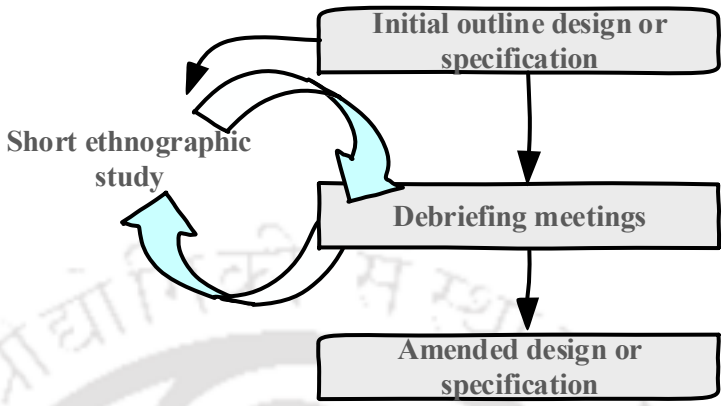


Fig.3.4: Evaluative ethnography (Crabtree 2003)

- Re-examination of Studies: The purpose of this ethnography study is to assemble a corpus of studies that may be drawn upon to identify common issues across a variety of domains. Such findings may be used to sensitize designers to common arrangements of cooperation in various workplaces and to issues that may therefore be of relevance in particular kinds of design undertaking.

Crabtree (2014) also suggested some steps to note before going for ethnography study. They are discussed as follows:

1. Immerse yourself in the setting
2. Focus on what is happening in front of your eyes
3. Develop your competence in the setting's work
    a. Attend to practical action and practical reasoning
    b. Scrutinize interactional work
    c. Identify work practice
4. Verify your findings with those who do the work

The requirement of the problem motivated us to go for the ethnography study in this research. To study the tacit knowledge of the craftsman the natural environment where the craftsman is working was needed. Ethnography approach was best suited method for the practicality of the research problem chosen. Ethnography was construed of as method that may help systems developers analyze the work of the design space and produce an answer to the question by formulating specific design solutions.

Contextual Inquiry

Contextual Inquiry is a qualitative data gathering and data analysis methodology which involves talking with users in their workplaces as they do real work. The inquiry is focused on clearly defined set of concerns. It provides a concrete observational data based on in-the-moment experience that is different from the data given in questionnaires (Raven & Flanders, 1996). This methodology helped us in the field work with the craftsman.

The above methodologies were followed during the pilot study.

3.2.1 Pilot study I: Bamboo basket making process

North Eastern part of India is abundant in craft and bamboo industries (Fig.3.5). In an article Prof. A G Rao (1994) speaks about the bamboo craft industry in India. The author states 'a well-crafted bamboo product stands out as an example of human ingenuity'. The author describes about his experience of bamboo crafts and its influence as a craft in many parts of India especially North eastern part of India. The author raises several questions in this article one of which is 'Can we integrate knowledge, skills and attributes of bamboo craft in our education?' The author describes the influence of bamboo in education, bamboo in craft industry and bamboo as a resource material. The influence of craft into Japanese culture can be seen in their education where origami paper craft is imparted as a training to students. Prof. Rao presents a career map (Fig.3.6) for imparting bamboo craft in education in India. This can be inculcated to other craft products to provide various creative idea among the youths. Since bamboo craft is a sustainable product, so making it part of the education and incorporating it a secondary profession would help in uplifting certain sectors of people in a society. The main aim of this research was to study the skills involved in the crafts making. So to achieve this feat a number of craft products were to be studied and the stakeholders involved in them also has to be observed. The pilot study is an attempt to study the log lasting tradition of bamboo crafts in the craft sector.

The study was carried out in the Student Activity Center of Indian Institute of Technology Guwahati, India where a workshop for the bamboo craft was organized by SPIC MACAY, which is a non-political nationwide voluntary movement in India that organizes programs of classical music and dance, folk arts, crafts, yoga, classic cinema screenings, heritage walks, etc. inside school and college campuses throughout the world to make students more aware about Indian and world heritage (retrieved from http://www.spicmacay.com/, 2018).

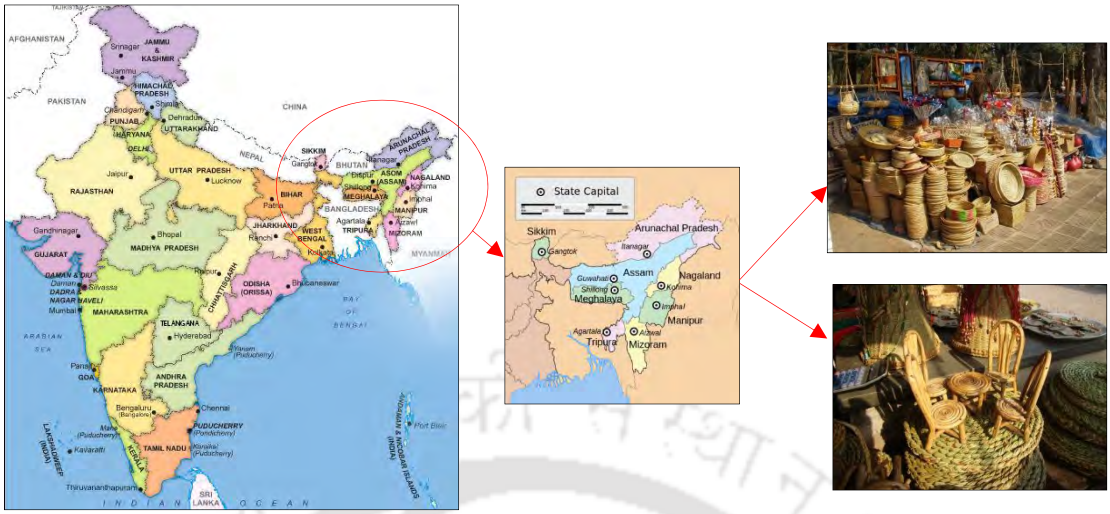


Fig.3.5: Influence of crafts in North-Eastern part of India (Source: Internet)

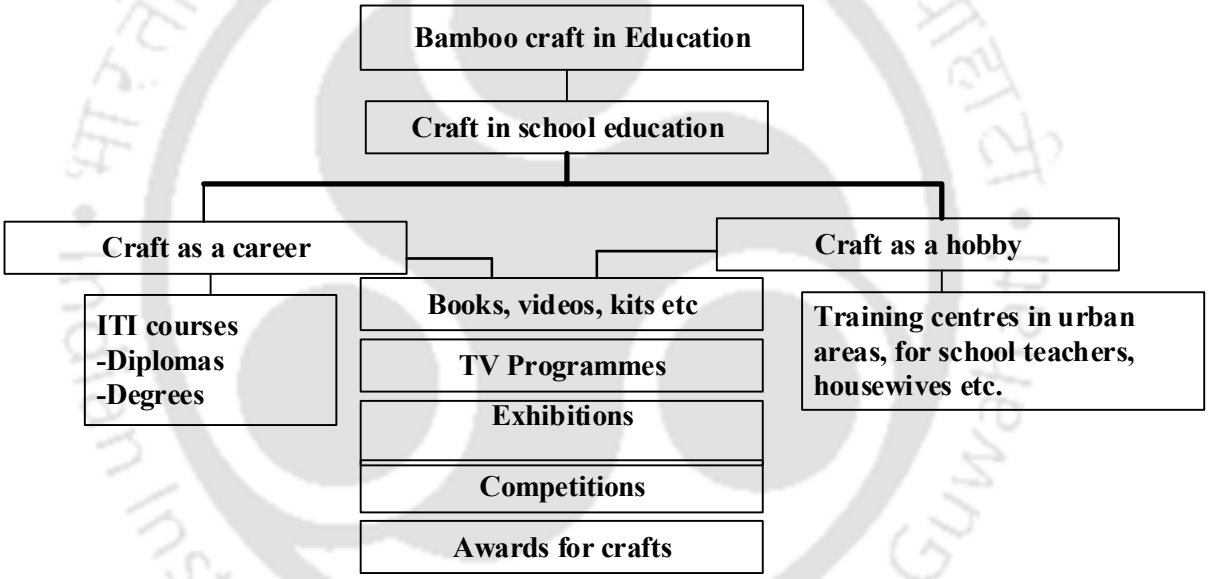
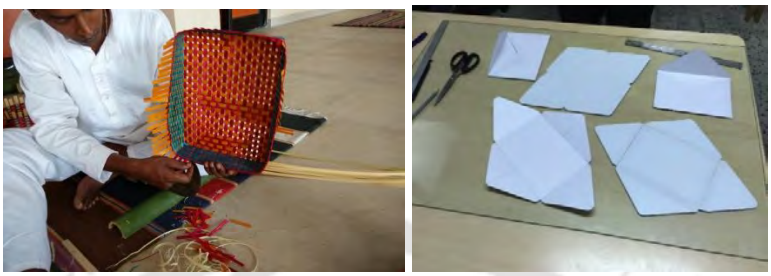


Fig.3.6: Bamboo craft in education (Rao. A.G, 1994)

To extract the tacit knowledge of the craftsmen few experiments involving four craftsmen were performed when they were working with bamboo. One of the craftsmen is expert in the bamboo basket making and the others were learner. The expert craftsmen were able to do around 30 baskets working 4 hours in a day. The expert craftsman involved in the making of the bamboo basket had a variety of baskets designs in his mind. The simplest of the basket was the basket tray which was flat in nature and was direct combinations of different strips of the basket in a flat arrangement. The only difference in the pattern occurred when the walls of the basket was made. This require to turn the bamboo strip in a certain direction which made the wall perpendicular the flat surface previously.

The pilot study involved observation of the craftsman when he is making the craft. Certain unstructured questions were also asked by the researcher during the study.

Fig.3.7 a show a craftsman working with the bamboo to make a basket. The master craftsmen use bamboo strips which are having a certain thickness suitable for the particular basket.



a. b.

Fig.3.7: a. Bamboo basket making process b. Paper envelop making process (Author generated)

To start a bamboo basket, the master craftsmen followed a series of steps:

1. Choose the particular thickness of the bamboo.
2. Dip the bamboo in the water. Here water acts as a coolant to soften the bamboo for easy folding.
3. Fold the bamboo into different steps so that the final outcome is strong enough to hold different objects.

The strips were cut into a certain thickness required for making the basket. The length of the strips was also maintained. The strips were colored into different colors for an aesthetic look to the basket. Natural colors were used for the coloring. Traditional tools like sickle was used in the cutting of the bamboo. The different leaners, here four numbers, tried to learn from the master. The miniature bending of the bamboo at certain edges were little difficult for the learners to grasp. But with the practice they were also able to perform it.

Understanding the craftsman (Unstructured Interview with the craftsman and learners):

The study was carried out in an environment which was not the usual one for the craftsman. But the master craftsman was comfortable in the environment. The materials needed for the craft was bamboo, a sickle for cutting the bamboo.

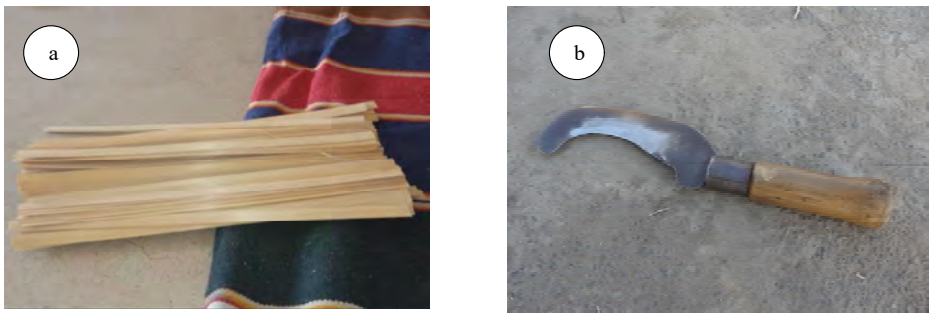


Fig. 3.8 a. Bamboo strips and b. sickle (Author generated)

It was observed that the craftsman was doing the craft and by seeing him the other learners were able to perform the step. The difficulties faced by the learners was address by the physical action of performing and doing the crafts by the master craftsman. The bamboo strips were dissected into a certain thickness was the master craftsman was able to perform easily. When asked why he answered the difficulties by performing the craft. The craftsman said:

'By observing, the learner can easily grasp the idea, which I have learned from by forefathers. I wanted the learners to give a first-hand experience with the crafts, that is the reason I want them to make the and practice the craft by themselves with their own hand.'

It was also observed that the learners behaved like apprenticeship under the master craftsman to learn the craft. One of the learners said:

'It became easy for me to get learn the craft first-hand. I was very excited to get my first craft of my own hands'

This was a significant observation regarding the research question raised earlier in the chapter. To find the possible opportunities to capture the embedded tacit knowledge we moved to second case study.

Some of the inference was drawn based upon the observation. Table.3.1 shows some knowledge which was extracted from the bamboo model.

Table.3.1: Some application of the tacit knowledge observed in the pilot study

Sl No.	Operation	Tacit knowledge used			Tacit knowledge captured in knowledge system
		Lessons learnt	*Learning by doing*	*Unique property*	
1	Craftsman starting with 'Jati' bamboo	Knowledge of physical and material	Choosing the accurate bamboo	Touch and feel of bamboo	Material property

		behaviour of bamboo			
2	Cutting bamboo to approximate sizes	Understanding of different sizes of bamboo	Cutting to accurate size	Size and thickness of cut pieces	Size of the bamboo
3	Builds up the form of the basket by stitching the primary and secondary strips	Understand and mold the preferred shape	Moulding accurately by hand	Stitching exactly like craft	Stitching shape or curve and gap between the strips
4	Unconsciously makes error in the craft which gives a unique shape of the basket	Accounts the human error and tolerances	Minimize the error	Unique shape of basket	Shape of the basket

Based on the skills of the craftsman a variety of baskets and craft items are classified. The classification was done according to the different features found in each of the craft products. In this classification very less, tacit knowledge was captured. Based upon the extracted data the ontology of the crafts domain was developed. There were various tools available for the development of the ontology. Here Protégé (2014) is used to develop the ontology model. Protégé is a free, open source ontology editor and knowledge-based framework software hoisted by Stanford University. Fig. 3.9 shows the ontological model developed for the craft domain.

The pilot study was a brief understanding of the bamboo craft practice. This understanding motivated to go for full experimental understanding of the craftsman and the tacit knowledge they possess to do the craft practice. Since the craft practice is very old and primitive in nature, so covering all the aspect is very difficult and out of the scope for this research. So, our focus is on very limited craft practices, which can help to understand the knowledge embedded in them.

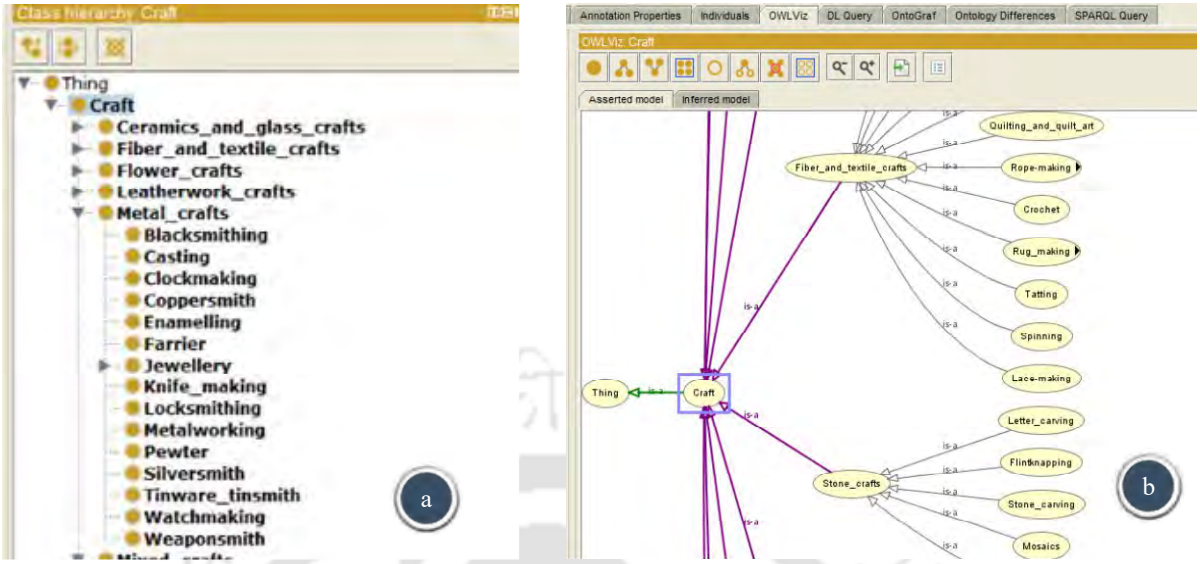


Fig.3.9 a. Ontology of Craft domain in the Protégé software b. the asserted model representation of the ontology model developed

3.2.2 Pilot study-2: Paper envelop making process for mentally disabled persons

The second pilot study was paper making envelop process for the mentally disabled persons (Fig. 3.10b). This pilot study was conducted to see the complications which are found while capturing the tacit knowledge in a different condition other than the craft sector. The paper envelops and other products are a kind of Do It Yourself (DIY) crafts. According to Camburn and Wood (Camburn, et.al, 2018) DIY is the practice where the end user creates a product for personal use and not for commercial use. They have stated five important principles that can be used in the in DIY. They are

- Repurpose : to integrated and repurpose commercial consumer product.
- Satisfice : adaptive quality to match the approach to skill set of a designer.
- Stencil :to test at each stage of assembly, use sequence of assembly to guide interface detailing
- Layer : to start with rough dimensioning of the outer shape and then filling and completing the whole product.
- Standardize : use repetitive manufacturing process to save effort and machine costs.

In the paper-envelop making process some of the above principles are used to get a fine paper envelop. The pilot study was to develop a die for the paper making envelop for mentally disabled persons. This experiment was carried out again to capture the tacit knowledge transfer during the making of dies for the envelop making for mentally disabled persons.

In this pilot study the emphasis was laid on the mentally disable person. According to Collins dictionary (2017) *mental disability is a condition that limits a person's intellectual capacity, resulting directly or indirectly from injury to the brain or from abnormal neurological development.* This reduces the capacity of a person to perform effectively even the daily chores.

The observations were carried on in a nearby Regional Institute of Mental Health. There were patients who were either admitted to the hospital by their family members or by some of their relatives. The patients were from a lower income background of family, so some of them had to go for making same craft items to earn their livelihood. The different problems faced by the mental patients was studied.

Problems:

There were various problems faced by the patients admitted in the hospital. The patients were either isolated by the family members and had no one to look after them. They had little understanding of the everyday things which they do. The mental conditions of the patients were such that they require somebody to support them every time they approach to do an activity. In this case they had to perform a vocational activity which will help them to engage and spent their time. The activity like paper envelops, paper bags, paper files and embroidery items were taken up the mental institute for the patients. In this case they faced the below mentioned difficulties:

1. The paper products which were manufacture were not up to the standards of the market.
2. **The paper products involved certain level of skills which was very difficult for the patients to capture**.
3. It was difficult for the instructors to teach each and every patient every time they go for a product.
4. The handling of sharp tools in the cutting is also a risk for the patients as they can harm themselves while handling them.
5. The time taken to make the products was also more as compared to the commercially available methods.

Design & making

Some of the old designs produced by the patients can be seen in Fig.3.10. The older designs of the paper bag and envelop took more time and were difficult to produce for the patients.

a b

Fig.3.10: Old designs of paper bags (a) and envelops (b) made by hand using normal tools like scissors and rulers (author generated)

The tools involved in the making of the products were sharp and may harm the patients during the work. So, a design intervention was much needed to provide them a product, which would assist them during the making of paper bags and envelops.

Design approach to the problem

The mentally disabled persons had to mainly depend up on their 'tacit knowledge' for making this envelops. Here three cases of the design methods to develop the die for the patients.

Case-1: Brainstorming session

Brain storming was the term used by Osborn in 1953. It is a method which a group of people gather to generate new ideas and solutions to a problem in a specific domain (Osborn, 1953). The general flow diagram of a brainstorming is illustrated in Fig. 3.11.

SCAMPER was first introduced by Bob Eberle (1996) to address targeted questions that help solve problems or ignite creativity during brainstorming meetings. The name SCAMPER is acronym for seven techniques; (S) substitute, (C) combine, (A) adapt, (M) modify, (P) put to another use, (E) eliminate and (R) reverse. These keywords represent the necessary questions.

- Substitute comes up with another topic that is equivalent to the present topic.
- Combine adds information to the original topic.
- Adjust identifies ways to construct the topic in a more flexible and adjusted material.
- Modify creatively changes the topic.
- Put to other uses identifies the possible scenarios and situations where this topic can be used.
- Eliminate removes ideas or elements from the topic that are not valuable.

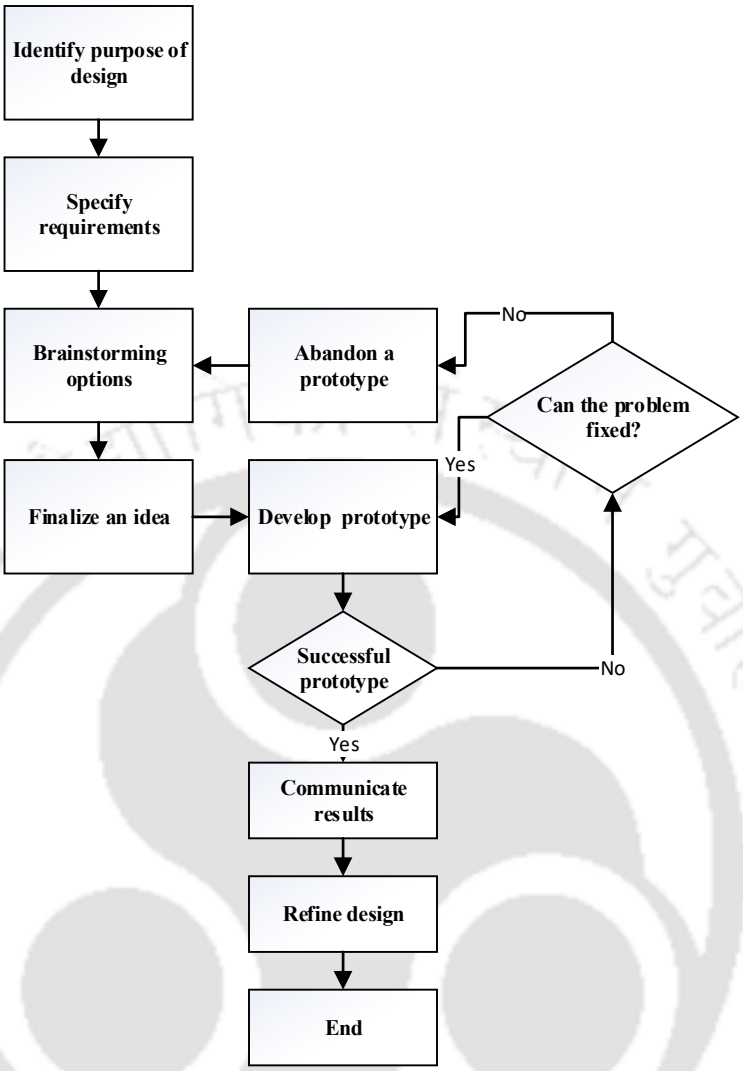


Fig.3.11: A Simple Brain storming flowchart (Source: www.umnnaba.com, 2018)

Case-2 Use of SCAMPER (Substitute, Combine, Adjust, Modify, put to use, Eliminate, Reverse)

- Reverse, rearrange evolves a new concept from the original concept.

The two design methods discussed were used to find few solutions for the paper envelop making problem for the Mentally disable persons. Fig.3.12 shows the three design solutions obtained for the paper envelop problem. After the combination of the design solutions which were obtained an improved version of the solution was worked out as shown in Fig. 3.13.

Though the final outcome of the problem was a die, but it gave a through understaning of the design thinking process involved during the solving of the problem. The proposed solution tried to address the problems of the patients as mentioned earlier. In understanding the problem the tacit knowedge of the patients were considered. This outcome of which helped in the simple solution.

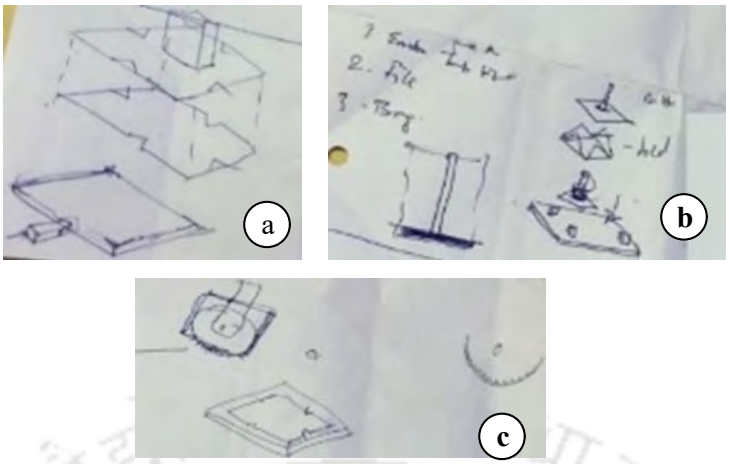


Fig.3.12 a. Design-1, b. Design-2, c.Design-3

Fig.3.13: Proposed die solution for the mentally disable persons

Outcomes from the pilot case studies

Pilot study-1

- The 1st pilot study suggested the importance of the apprenticeship learning under the master craftsman.
- It also suggested the difference in the experience of learning from implicit sources and tacit knowledge of the craftsman.

Pilot study-2

- The 2nd pilot study suggested the importance of skills in the accomplishment of the task in the mentally challenged persons.
- The skills which is tacit for the patients plays an important role in their daily activities.

Owing to the outcomes of the pilot studies a methodology was proposed to carry on the thesis further. The subsequent section will cover the methodology in detail.

3.3 Methodology followed during the research

Based on the pilot study and the methodologies discussed in the chapter 2, a methodology was proposed to be followed in the research. To fulfil the aims and objectives and to answer the research question raised before certain other methods were adopted for the research. As mentioned earlier the ethnography study was used in the pilot study. Along with the ethnography study protocol analysis was also carried out to know the tacit knowledge of the craftsman and the craft products used. The research is qualitative in nature and the data which is collected in rich and raw data from the craftsman. So, the methods used in this research followed a similar fashion as mentioned in the 'grounded theory'.

Grounded theory (GT) was founded by Glaser and Strauss (Glaser et al., 1967). It is a method to generative new theory which is grounded in data that has been systematically collected and analyzed. This theory was developed in the area of social science but can be used in other applications too (Lawrence and Tar, 2013). Some of the features of the GT are suitable for the study in this research. They are as follows: Data collections and analysis are done simultaneously in GT. Categories and analytical codes are developed from the data and pre-existing conceptualizations are not used. Theoretical samplings are used to refine the categories. Social process are discovered in the data. Analytical memos are used between coding and writings. Categories are integrated into a theoretical framework. The GT is illustrated in the Fig.3.14 below.

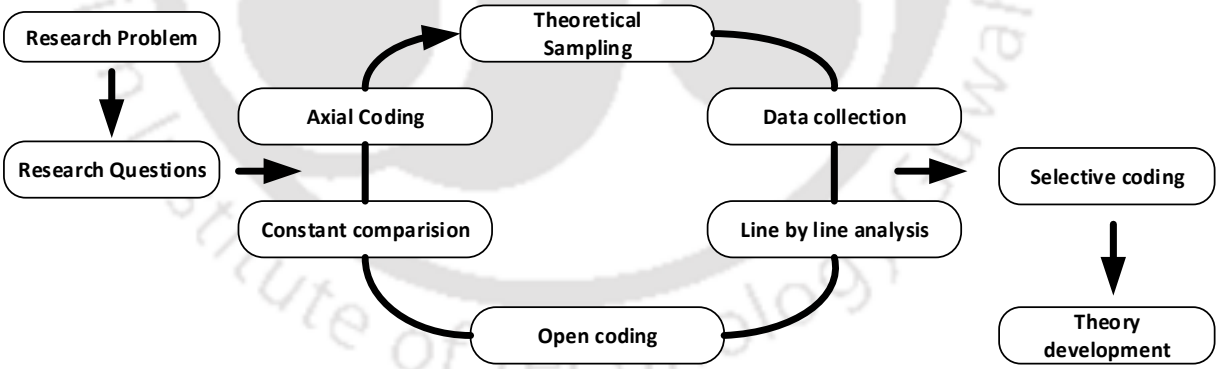


Fig.3.14: Grounded theory as described by Glaser and Strauss (adapted from Choi et.al, 2018)

In the GT after the research problem is formulated and the research questions are raised, the theoretical sampling is collected. The data collection is a crucial step in the GT. Once the data is collected it is analyzed either line by line, sentence by sentence, paragraph by paragraph. The next step in the GT is the coding of the analyzed data. According to the research which the researcher is working, the coding of the data is carried out. The open coding is the initial level of coding where there is generation of largely descriptive data. This type of the coding gives rise to low level type of

categories. Generally, a coding paradigm is used to sensitize the data to have link between one category to another. This kind of categorization is sometimes called as the axial coding. These process which involves the theoretical sampling, data collection, analysis and coding is cyclic in nature and result usually give rise to the next stage of the GT, i.e. selective coding. After this stage the new theory development stage is reached. In our research a similar kind methodology is proposed and adopted inspired by GT and other methodologies described in chapter 2.

The methodology adopted in this research is as follows. The data is generally collected by using the ethnography studies of the various craft process. This research follows the following proposed methodology (Fig.3.15) for achieving the objectives discussed in the section 2.7.

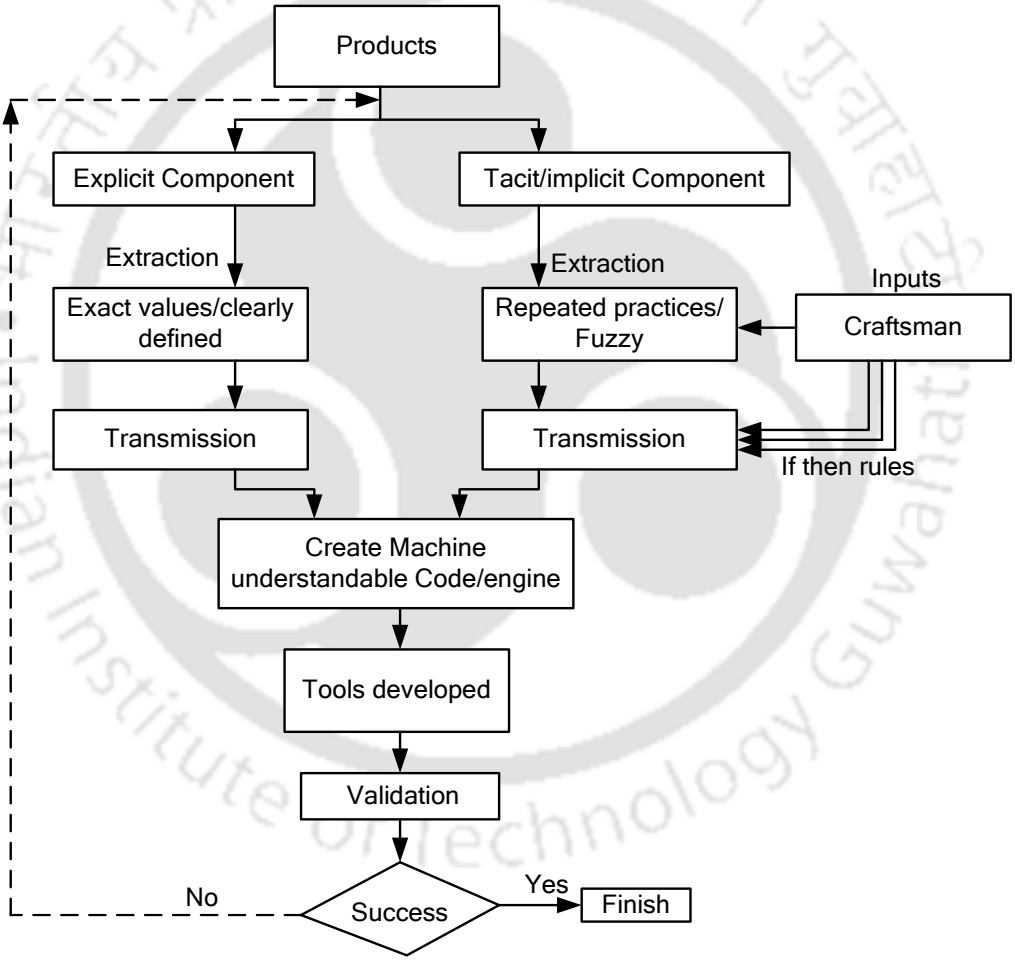


Fig.3.15: Methodology followed during the research (Source: author generated)

The first step followed in the methodology is to choose the products in the craft domain for the experiment study. Since the research is to study the tacit knowledge of craftsman involved during the craft making process, so it was necessary to select suitable craft objects for the study. During the manufacturing of the craft objects some of the tacit knowledge gets embedded into them and this

makes them distinguishable from one another. By studying different craft objects in a similar category, we can see the difference of tacit knowledge which is present in them. So, it becomes important to choose different craft objects and study them minutely during this research.

The next step in the methodology is to extract the tacit and explicit knowledge from the craftsman and the products prototypes. This is an important step in the methodology. As described in chapter 1, section 1.3 'tacit knowledge' is *the knowledge which is obtained by the person by repeated practice and remains in his minds, it difficult to capture it and extract*. So, during this phase of the methodology the detailed observation of the craft practice and the craft object reveals certain traces of the embedded tacit knowledge in them. This may be present as a combination of both tacit as well as explicit knowledge. So this step is a crucial and significant step in the proposed methodology to distinguish between both the tacit and the explicit knowledge of craftsman embedded in the craft products.

The next phase of the methodology is the conversion of the tacit knowledge into the explicit knowledge. Evident from the literature suggests that researcher and great leaders have made attempts to transform their tacit knowledge into explicit knowledge. This explicit knowledge can be used for different applications, for example it can be used for repeated usage by inputting it into the computer understandable form. Similar benefits are mentioned if a knowledge-based tool is developed for the designers (Potter, 2000). Some among them are:

- Once built, a computerized designer would not be prone to human error or forgetfulness, and so, would be able to produce designs of consistently high quality.
- Design expertise would no longer be lost to the organization when human designers retire or move to other companies.
- Computer files and memory can be duplicated with ease: this would allow the design expertise to be distributed throughout the organization, and internet facilities could enable it to be transferred rapidly to the remote location at which it is needed.

Craftsman use their tacit knowledge to produce crafts which are good and have their signature mark in it and this knowledge and the craft can be considered as their implicit knowledge in their final product. Since this knowledge is involved in the craft making process from the initial conceptual stage till the final stage of the product, it becomes necessary to study the tacit knowledge of the craftsman. Craftsman are highly trained in their profession who use their skills to transform the knowledge in to useful products. To convert this translation of the process into design-oriented

solution a specific logic is required. Researcher (Potter,2000) have studied three main logics which used in this kind of problem definition and solutions namely: deduction, induction and abduction.

Deduction: In deduction the conclusion is drawn based upon the set of premises which is logically valid (Potter, 2000). For example:

IF an artefact is made up of aluminum

THEN the artifact will not rust *rule*

Artefact x is made of aluminum *proposition*

_____

Artefact x will not rust *conclusion*

The deduction process tries to prove the facts that are present as implicit knowledge in the premises. The modern-day computation systems may be viewed as deductive systems which analyses the data received from various sources.

Induction: Induction is a process in which the inference is made from the particulars of the event to come to a generalize conclusion (Potter, 2000) for example:

Artefact 1 is made up of aluminum AND artifact 1 does not rust

Artefact 2 is made up of aluminum AND artifact 2 does not rust

….

Artefact n is made up of aluminum AND artifact n does not rust *premises*

_____

IF artefact x is made up of aluminum

THEN artefact x will not rust *rule*

In the induction method the experiences of the craftsman are taken and then a conclusion is drawn out of them. In induction learning generally happens and it can be used in the similar instance of events in the future. If in any case the next aluminum happens to be rusted then the original rule is termed as false, in spite of the truth of the earlier observations.

Potter (Potter, 2000) also described the problems which generally occur when induction method is used. Some of them are as follows:

- How many examples are sufficient to needed to draw a useful conclusion?
- The observations made can have greater number of inductions, like

  IF artefact x does not rust THEN artifact x is made up of Aluminum

So, the mere association of A with B does not seem to be a sufficient condition for making an induction.

- The principle of induction seems to be circular in nature. The future of an incident depends on the past incident.

In spite of these difficulties' induction is one of the powerful principles when we are considering the experiences of the designers and the craftsman. The induction method of learning is used in the machine learning applications to automate different models.

Abduction: The last logic which is used in this research is the principle of abduction. It is a form of inference that describes the data into a hypothesis which best explains itself (Potter, 2000). For example:

IF the artefact is made up of Aluminum

THEN the artefact does not rust *rule*

Artefact x does not rust *proposition*

_____

Artefact x is made up of Aluminum *conclusion*

The principle of abduction was introduced by Charles Sanders Peirce (Buchler, 2014). He had recognized abduction as a distinct form of reasoning. In the above example though the conclusion is true but it can also be inferenced that the artefact is made of some non-corrosive material other than aluminium. This principle can also be explained in terms of the data available and a particular hypothesis explaining the data which cannot be explained from any other sources. So, we can consider that the hypothesis is the best possible solution available at that particular time (Josephson and Josephson, 1994). It is a powerful everyday reasoning process, one which allows useful inferences to be made in situations where only partial or uncertain information is available.

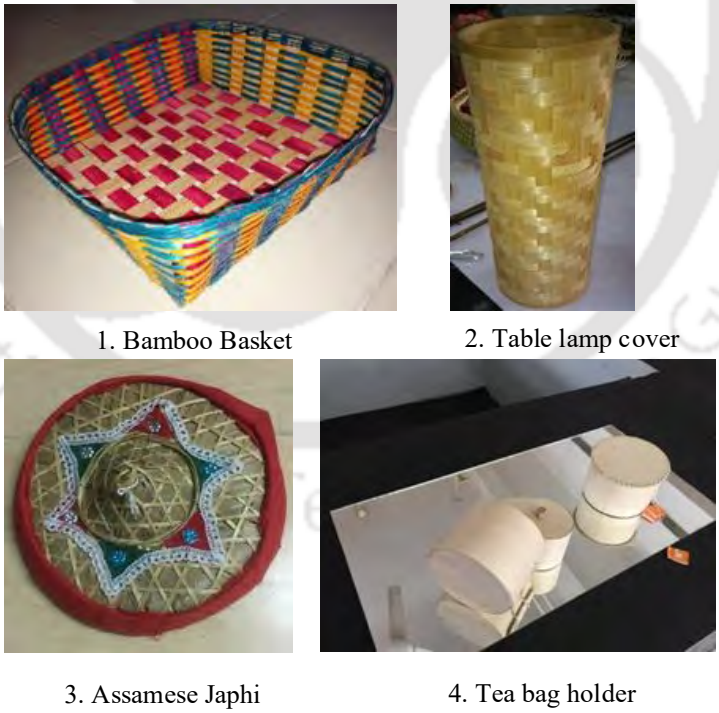
Literature (Zadeh, 1996) also suggests that fuzzy expert systems can be used for solving the problems which has inputs which are fuzzy in nature. This can be seen in daily application in some appliances like air conditioners, washing machines etc. Sometimes when the user is also not sure of the decisions

to be taken like judging the weather as colder, less hot, or mild weather when there is less clouds in the sky, fuzzy logic helps in giving a possible solution. Fuzzy systems can help to solve the problem by providing the interconnection between the various conditions taken during the problem formation. Therefore, Fuzzy systems can be chosen for the development of a machine cod able engine. To test the robustness of the system different fuzzy systems developed were combined to give a full system. The tool developed was then validated with an application developed using this engine. The next few sections of this chapter will describe the experiments which were carried out in this thesis.

3.4 Experiments

An analysis of the pilot study was carried out and the significance of the tacit knowledge of the craftsman during the making of the craft was observed. An understanding of the pilot study was prepared to see the tacit knowledge during the processes. Then few of the craft artefacts from Assam, Odisha and West Bengal were selected for the final experimental product case studies.

Ethnography study as well as contextual enquiry was used in case of the all the case studies selected. Then a through protocol analysis was carries for each of the case studies taken. The case studies are explained below:



1. Bamboo Basket 2. Table lamp cover

3. Assamese Japhi 4. Tea bag holder

Fig.3.16a: Craft items chosen for the case study; 1. Bamboo basket; 2. Table lamp cover made up of bamboo; 3. Assamese Japhi; 4. Tea bag holder made up of bamboo. (Source: Author generated)

5. Curtain stand

6. Craft ornaments

7. Diya

8. Shiv Idol

Fig.3.16b: Craft items chosen for the case study; 5. Curtain stand; 6. Craft ornament made up of bamboo; 7. Diya or earthen lamp; Shiv idol made up of clay (Source: Author generated)

The craft chosen for the case studies are shown in the Fig.16a and Fig.16b. The reason for choosing the case studies in Fig.16a and Fig.16b are as follows:

- The craftsman who are involved in the making of these bamboo crafts are trained traditionally and possess skills which are tacit in nature passed from their forefathers to them.
- The craft artefacts are made up of bamboo which is a sustainable material and has less effect on the environment.
- There are certain elements of culture which is present in the craft products chosen for example the 'Japhi' is a traditional hat made up of bamboo specially worn by the people in Assam, India and regarded as a symbol of Assamese culture.
- The Diya or the earthen lamp are used by the people of India to lighten the houses during the festivals and special occasions.
- The idols are also used to represent different forms or gods and goddesses in the different cultures in India.
- Both the Diya and idols are made up of mud and clay which creates less impact in their end of life phase to the environment.

- All the above craft items require skills and tacit knowledge of the craftsman which is important in the final shaping of the products.

Case studies:

1. Bamboo basket making process

The Bamboo basket making process was revisited to see the process involved in its making.

Fig.3.17: Bamboo craft making process (Source: Author generated)

The bamboo basket making process was again studied to see in detail the tacit knowledge and other forms of knowledge in its making. As discussed in the section 3.2.1 during the bamboo making process the tacit as well as the explicit knowledge of the craftsman is required.

A detailed description of the field extract of the bamboo craftsman is mentioned in the Appendix-A. As such there is no description of the whole bamboo craft process in the previous literatures. A few researchers have articulated the whole process. It is due to practice and the apprenticeship with the master craftsman, the new learners pick up the craft. As described in the initial pilot study a similar approach was used to study the bamboo craftsman. The process of the bamboo basket is illustrated in the Fig.3.18 below. As we can see that the bamboo strips are cut into uniform shape having a definite length, width and thickness. This knowledge of cutting the bamboo into strips is obtained by repeated practice by the craftsman.

Fig.3.18: Process of bamboo basket making (Source: Author generated)

The Fig.3.18c describes the craftsman making alternative folds in the bamboo strips. The details in the folds is obtained due to the uniform spacing of the bamboo strips. A uniform mesh is formed after the total process is fulfilled. Unless the craftsman is an expert in this process it is difficult to obtained a uniform basket.

2. Curtain stand using bamboo-craft process

The second craft object picked for the study was the curtain stand made up of bamboo. The curtain stand is also sustainable in nature and it contains circular pieces of bamboo which are held together by the thin thread attached. The Fig.3.19 shows the curtain stand used in this study.

Fig.3.19: Curtain stand made up of bamboo. (Source: Author generated)

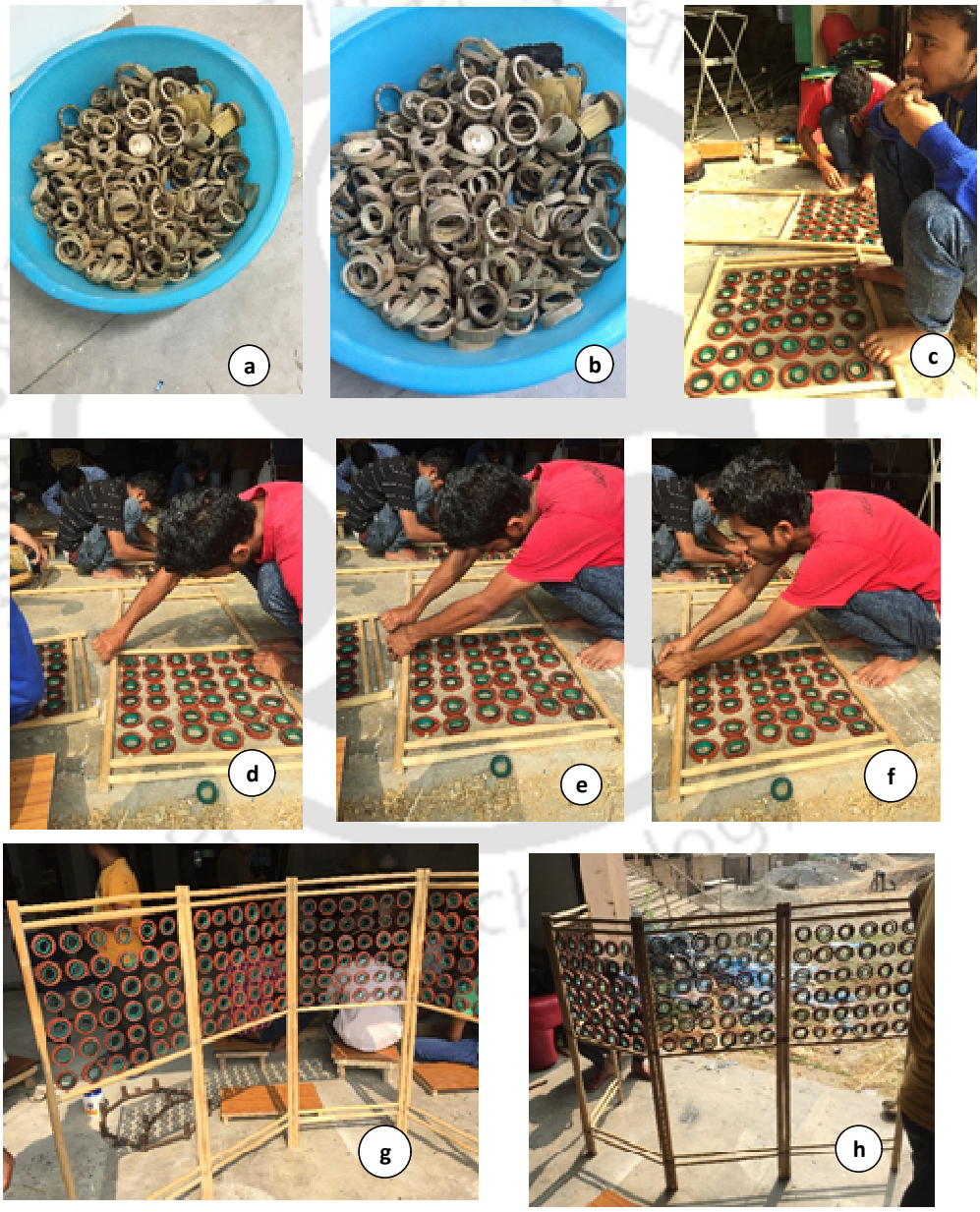


Fig.3.20: Curtain stand using bamboo-craft process (Source: Author generated)

The process flow in the making of the curtain stand is illustrated in the Fig.3.20. In the initial stage of the process the bamboo sticks were chipped into circular shape as shown in the Fig.3.20a. The circular shape bamboo is colored according to the need. The smaller and the larger circular pieces of the bamboo are grouped together and tied with the thread. A contextual inquiry of the craftsman is shown in the Appendix-A. The final bamboo curtain stand had four stand each having 36 bamboo chips in it. The initial placing of the circular chips required certain skill of the craftsman and it also played a major role in the pattern formed after the final product was developed. The curtain stands thus developed could be easily folded and used in a limited space if needed.

3. Bamboo Tea-bag process

The third craft item chosen was the bamboo tea bag as shown in the Fig. 3.21. It is made by removing the thin slice of bamboo and then sewn together to form the upper and the lower covers.

Fig.3.21: Teabag holder made up of bamboo (Source: Author generated)

The craftsman involved in the making of this tea bag was highly skilled in nature. The process of making the tea bag is illustrated in the Fig.3.22. The first step in the making of the tea bag was getting the slice of the bamboo required in the tea bag. The minimum thickness of the slice was 2mm and the maximum was 4mm. The craftsman was careful enough to see that the slice is not torn apart while the product was under construction. To make the product aesthetically look good a similar color or the thread was used as the slice of the bamboo. The craft product was fixed together with the adhesive and the treads by the craftsman as can be seen in the Fig.3.22c. Different shaped of the tea bag were developed by the craftsman.

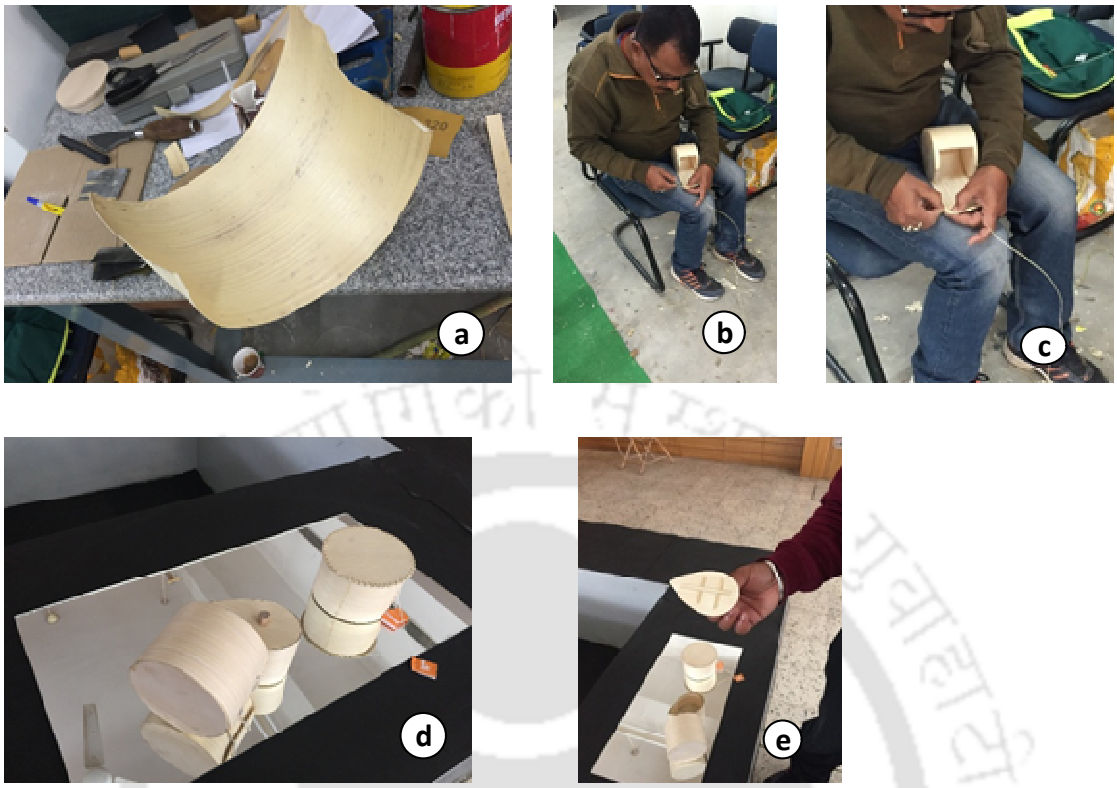


Fig.3.22: Bamboo tea-bag making process (Source: Author generated)

4. Idol making process

The fourth craft process chosen for the study is idol making which is carried out in different parts of India. Different craftsman uses different methods in the making of the idol. One of the process of Idol making is covered in this thesis as shown in Fig.3.23.

Fig.3.23: Idol Craft making process (Source: Author generated)

The steps involved in the idol making is illustrated in the Fig.3.23. The first step in the idol making process is the core making. In this step mud and clay is mixed together to get the perfect shape of the idol's hand, bracelets etc (Fig 3.23a, 3.23b).in the form of the core so that it can be reproduced again. The next step is the making of the body of the idol (Fig 3.23e), in this step the craftsman uses his skills to give a perfect shape to the idol. The painting of the idol is the subsequent step in which the different color combination is used to paint the idol. The color is chosen based upon the mythological character and it carries a significant meaning in a culture specially in India for example the color green represent prosperous nature of the mother nature or environment. The demand in the idol making increases during the festival season in India. There is also demand in the idols in other parts of India, where people believe in God and worship them.

Therefore, the demand in the skill craftsman in this sector is more. If the craftsman is able to transfer the knowledge of culture to the product and helps to get a good idol out of it, then he is in high demand. To master this skill, it requires a lot of practice and apprenticeship under the master.

5. Diya making process

The fifth craft product which was chosen for the study in this thesis is Diya or earthen lamp. This craft item falls in the category of pottery industry. The pottery is a traditional craft practice followed by human civilizations from the past. Tough it is a practice which has long history as mentioned in chapter 1 of this thesis there is a slow degradation in this craft practice due to modernization.Fig.3.24 illustrates the pottery craft practice which was used for the production of Diya. The main point of focus in this thesis is the skills which are required in the production of Diya by the craftsman who is involved in this industry. The subject who was studied in this case study has practiced this profession from last 15 years. After a contextual inquiry (Appendix A) into the Diya making process it was inferred that he had learned this practice from his forefathers who also got this knowledge of pottery from their ancestors. But due to modernization slowly the pottery industry is losing is charm among the youths to take up this practice.

Fig.3.24: Diya craft making process (Source: Author generated)

After the case studies were selected and their processes were studied by doing an ethnographic as well as contextual enquiry into the process, a protocol analysis was carried for each of the data collected from the studies. The case studies were thoroughly examined and the next step of protocol analysis was carried out to separate the tacit and then implicit part in the process of making the craft.

3.5 Details description of the Diya making process

In this section we take the example of Diya making process. To study the mental model of the craftsman the whole process of the Diya making was observed when the craftsman was working on the making of the Diya. The ethnographic study involved the authors to be present at the site when the craftsman was working on the model. The process map of the Diya making is shown in the Fig.3.25 below.

Process map of the Diya

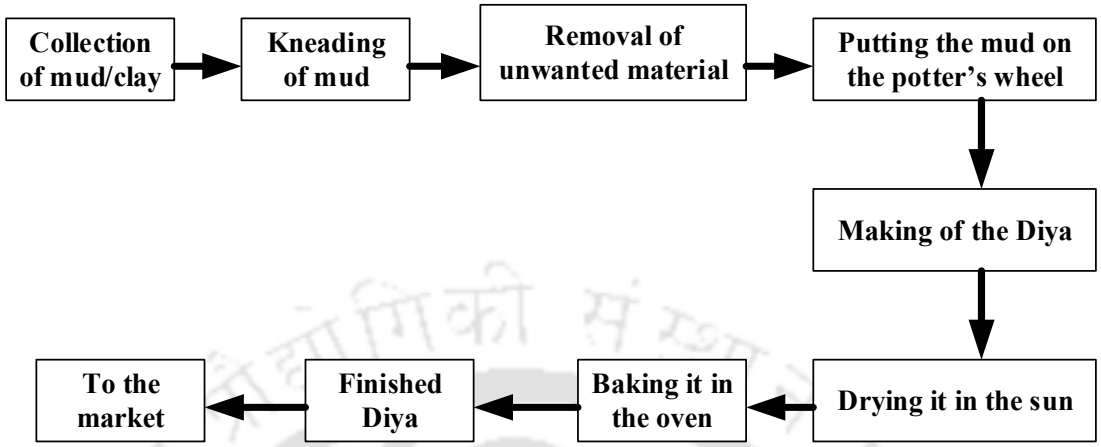


Fig.3.25: Process map of Diya making process (Source: Author generated)

The process of Diya making starts with the selection of the mud/clay, which is suitable for the Diya making. This is done by the craftsman along with checking the quality of the mud in the region nearby. The next step involves in the kneading the mud which is done to smoothen it. Then unwanted materials like grass, straws and stones etc. from the mud is separated. This is done by using a metal string to slide into the lump of the mud initially taken for making diyas. The potter then starts to make the diyas by using his hands to give a shape it and then carefully separates it from the wheel and keeps it for drying. After the drying of the diyas in the sun, they are then baked in the oven to strength it. The final diyas are then obtained. The protocol analysis of the process was done to separate the tacit and the implicit component of craftsman thinking model. This is shown in the Table-3.2 below.

Table.3.2: Extraction of tacit knowledge from the Diya making process

Steps	Processes	Photos/videos	Task/protocols carried by the craftsman	Knowledge type	
				Explicit knowledge	**Implicit knowledge**
1	Obtaining the clay		'We have to see the quality and the grain size of the mud/clay'	Chemical composition of the mud should be known	The experience of choosing the mud for a time period has made the craftsman to correctly select the mud quality just by seeing it (color).
2	Kneading the mud/clay		'We need to knead the mud to soften it'	The mud should be soft enough to get a proper shape	The softness of the mud is known

					by just touching it with hand
3	Removal of unwanted material		'we need to remove the grass and stones present in the mud'	Removal of unwanted materials is necessary for the smooth product free from cracks	~
4	Making of the Diya		'The Diya has to be round in shape'	Roundness here can be termed into Dimensions Form	The implicit part here is the extent to which it can be made round depends on the craftsman (variation in the geometrical variations)
5	Drying the Diyas in the sun		'We need to dry it to make it strong'	The solidness of the Diyas are measured by how dried it is.	The craftsman can see the color and feel to judge the dryness of the Diyas
6	Baking the Diyas		'The Diyas are baked'	It gives enough strength and resistant to resist oil during its usage	The color and temperature is set with the experience of baking it for years.

After the tacit and the implicit components of the Diya making process was developed the next step was to generate the tacit markers from the protocol analysis. This was used for the digitization of the whole Diya making process. Fig.3.26 shows the generation of the markers. We call these marker as *tacit markers*. These markers are the indicators of the patterns which are followed by the craftsman in their process in different domain. In case of the Diya making process some of the tacit markers are illustrated in the Fig.3.26.

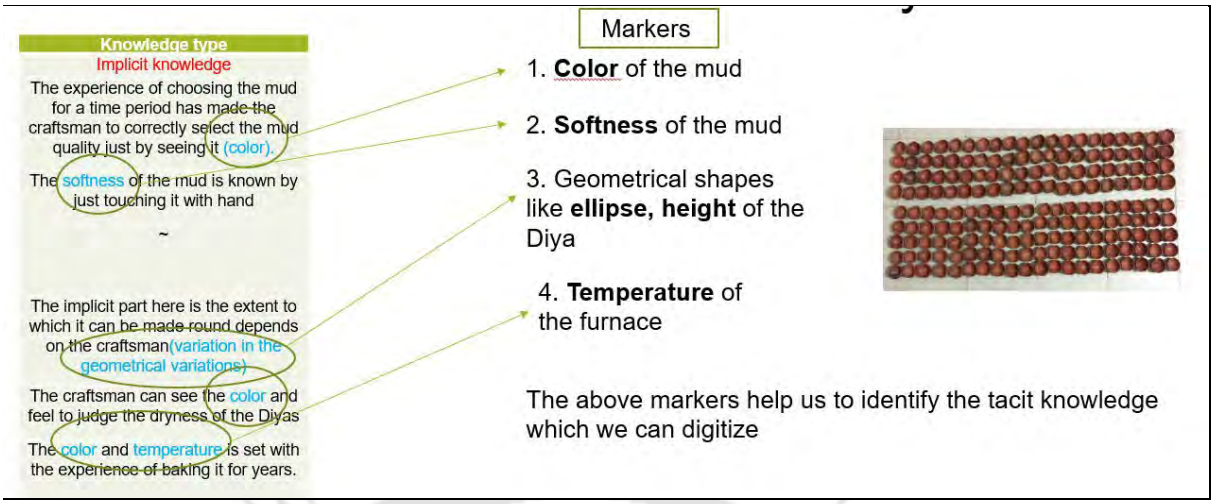


Fig.3.26: Generation of the tacit makers in the Diya making process (Source: Author generated)

Once the tacit markers are generated the different groups of the diyas are compared based up several factors. Given below is a comparison between different groups of Diya based up their forms.

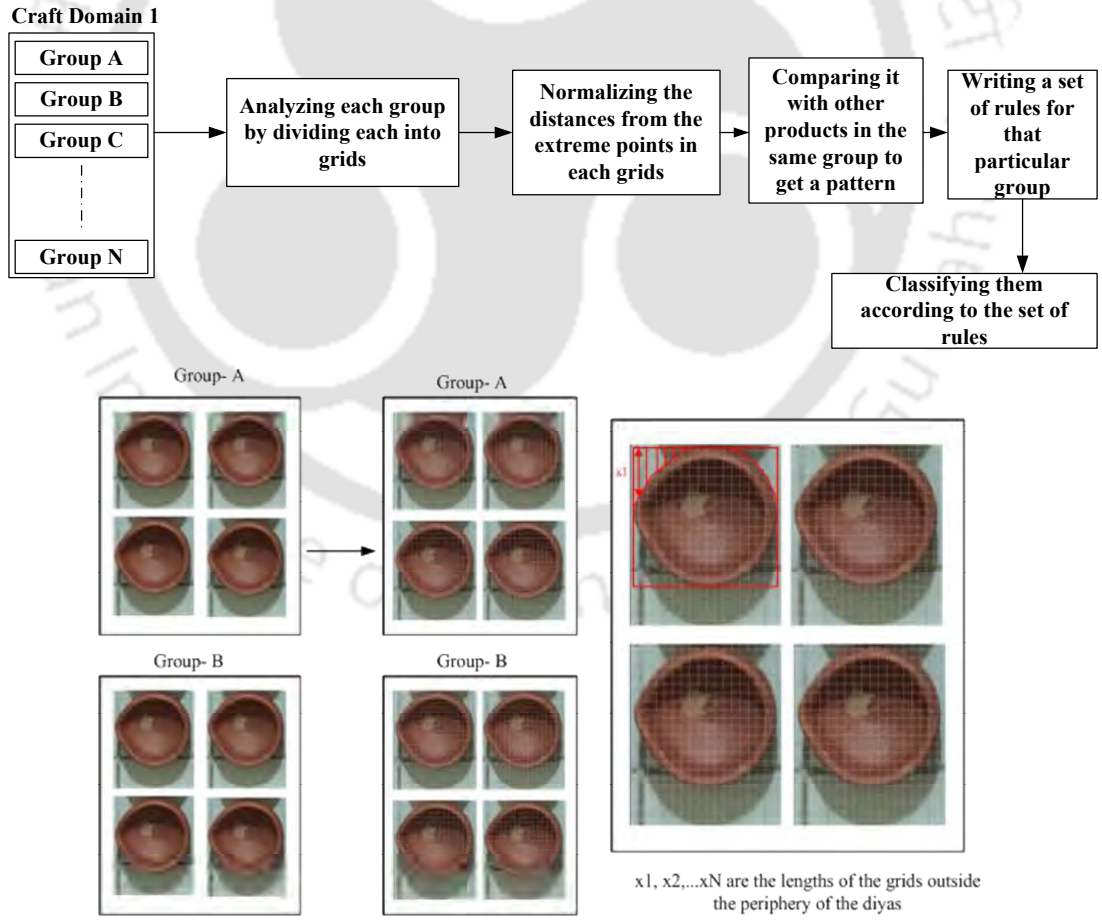


Fig.3.27: Proposed steps to compare the different groups of Diya (Source: Author generated)

The different groups of the diyas were physical measured. The different features, which were measure for a Diya, were Upper diameter, Lower diameter, height, nose radius, thickness, depth and inner diameter. These features can be seen in the Fig.3.28 below.

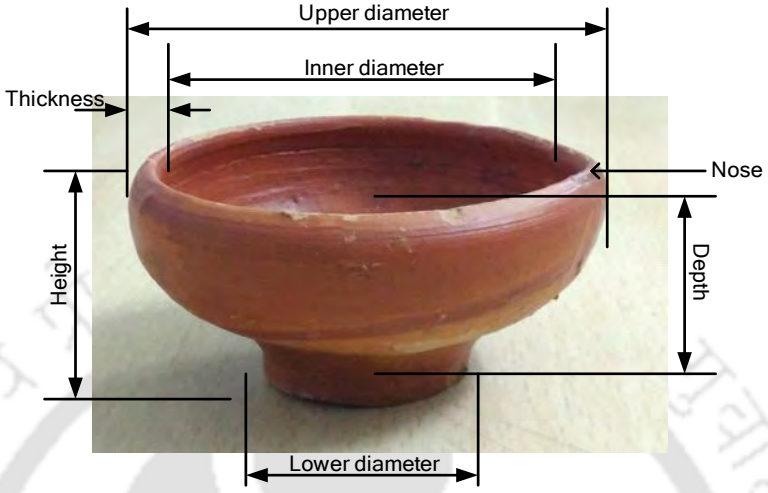


Fig.3.28: Different nomenclature of the Diya (Source: Author generated)

The Fig.3.29 shows the measurements taken for two craftsmen from two different regions of India.

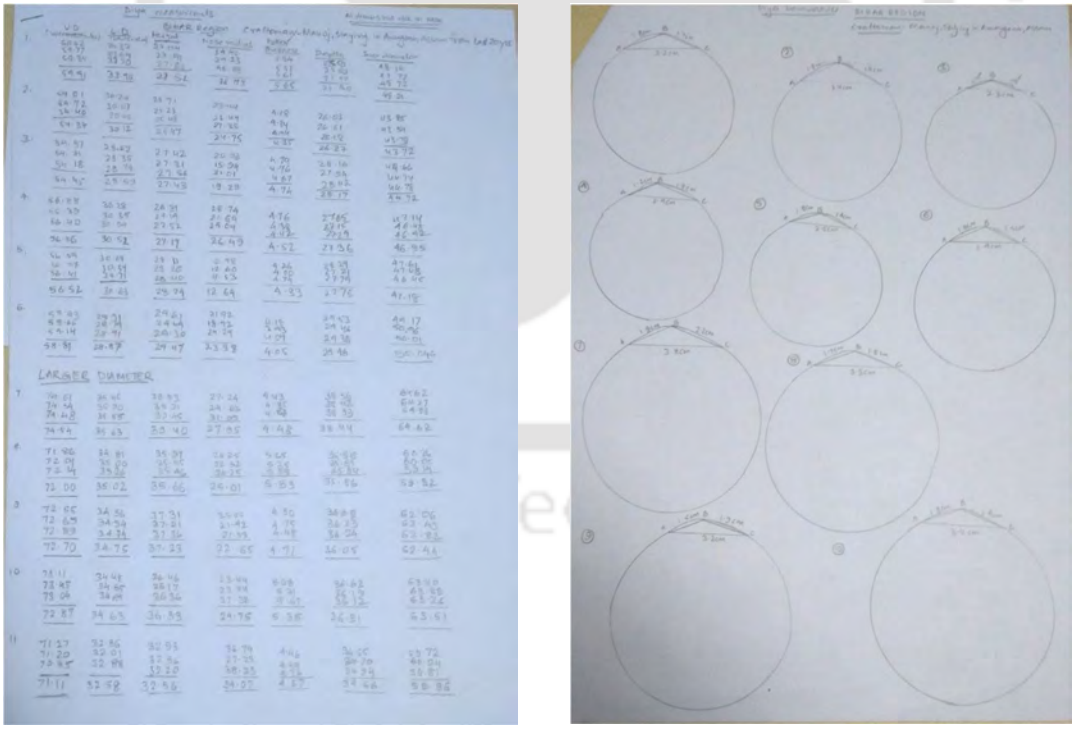


Fig.3.29: Measurement of different parameters based on the shape of the Diya from two craftsmen. (Source: Author generated)

Since any craft item is 3Dimensional so we required the 3D thumbprint to compare it with other similar craft of the family e.g.-Diya of same group. So, Microsoft Kinect V2 along with Kscan 3D1.2 and Skanect was used for the scanning and getting a 3D file of the Diya. Microsoft Kinect V2 is a device which has three sensors in scanning an object. The two sensors take the image of the object and the infrared sensor which is the third sensor tries to calculate the depth of the object scanned. Skanect is a software which helps to read the scanned image and convert it into 3 Dimensional cloud points or any other meshing format which can be read in the system. With the help of device and the software the image of the Diya was scanned to get the 3D file that contains most of the physical features related to curves and the color of the Diya.

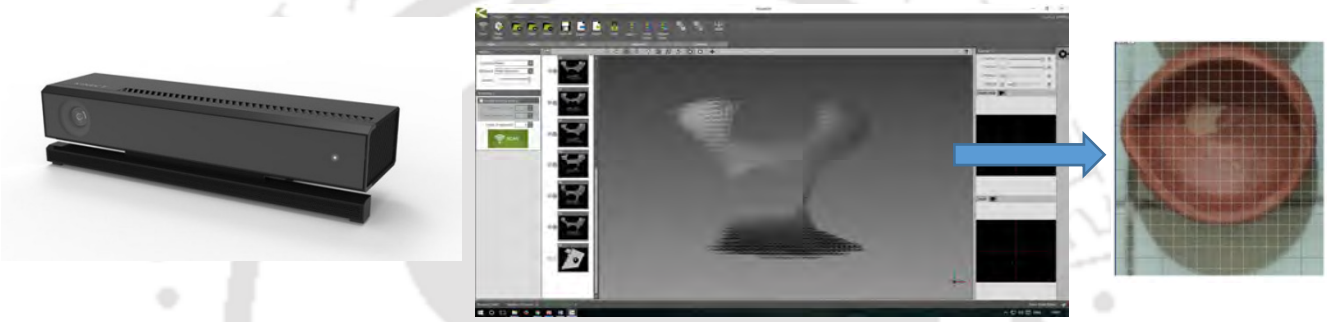


Fig.3.30: Kinect V2 and KScan 3D file of the Diya (Image source: Internet and Author generated, 2017)

With the help of 3D file of the Diya the comparison between the different Diya from different craftsman was easier. The next Chapter deals with the analysis of the data collected from the various case studies mentioned in this chapter. For each of the case studies the different tacit as well as the explicit component of the knowledge was calculated.

3.6 Details description of the Idol making process

The idol making process is seasonal in many parts of India. This happens when there is a festival in India. Some of the festivals which are famous in India are Ganesh Chaturthi, Druga puja, Sarasvati puja etc. During these festivals the idols of Gods and Goddesses are built by the artisans and craftsman who are specialized in making them. In this section we are wanted to study the idol making process in the Eastern part of India. An ethnographic study was carried out studying the idol making process in Amingoan, Assam, India. The process map of the idol making is shown in the Fig. 3.31.

Process map of the Idol making

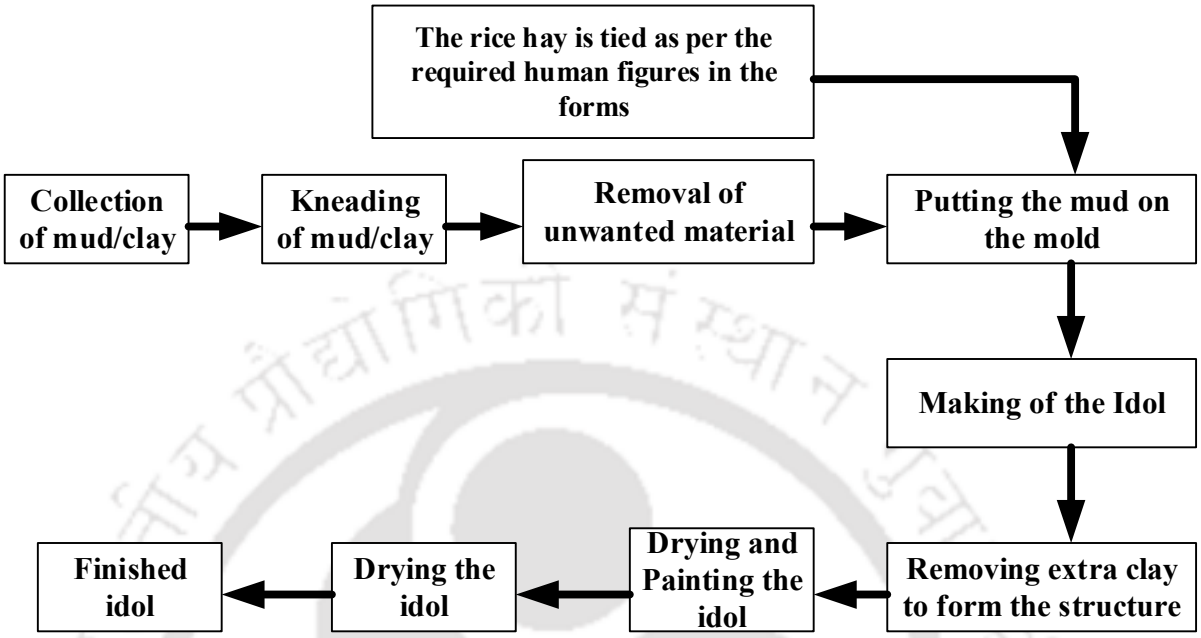
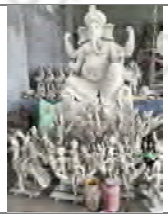


Fig.3.31: Process map of Idol making process (Source: Author generated)

The process of idol making starts with the selection of the mud/clay, which is suitable for the idol making. This is done by the craftsman along with checking the quality of the mud in the region nearby. The next step involves in the kneading the mud which is done to smoothen it. Then unwanted materials like grass, straws and stones etc. from the mud is separated. Before using the mud/clay the rice hay is used to make the idol figure. Then the mud is applied to the hay figure built. Once the model is ready the clay is put into the mold to make the jeweler and other accessory of the idol. A cotton cloth is warped around the idol model to avoid the cracks on it. Then a small amount of clay is applied to the idol. The idol is left for drying After the idol is dried up, it is spray painted with the help of water colors. The craftsman then paints the intricate details of the model like the eyes, eyebrows, the nails, the lips and other details which are unique to the idol. After the painting is done the model is decorated with the cloth or other jewelry which was intended for it. After the observation of the idol making process, some of the tacit knowledge involved in its making was extracted. This is shown in the Table-3.3 below.

Table.3.3: Extraction of tacit knowledge from the Idol making process

Steps	Processes	Photos/videos	Task/protocols carried by the craftsman	Knowledge type	
				Explicit knowledge	**Implicit knowledge**

1	Obtaining the clay		'We have to see the quality and the grain size of the mud/clay'	Chemical composition of the mud should be known	The experience of choosing the mud for a time period has made the craftsman to correctly select the mud quality just by seeing it (color).
2	Kneading the mud/clay		'We need to knead the mud to soften it'	The mud should be soft enough to get a proper shape	The softness of the mud is known by just touching it with hand
3	Removal of unwanted material		'we need to remove the grass and stones present in the mud'	Removal of unwanted materials is necessary for the smooth product free from cracks	~
4	The rice hay is tied as per the required figure in the forms		'we need to accurately make the idol figures'	accurate dimensions of the idol is made	The craftsman can accurately tie the rice hay to how much big the idol has to the made up of. (shape)
5	Putting the mud on the mold and rice hay structure		'we tried to give it a compact look'	Accurate structure of the idol is made	The craftsman is making the body of the idol similar to mythology
6	Removing extra clay to form the structure		'we look into the details of the idol'	The facial structure, sitting posture, and other details are craved into the idol	The details of mythological character is built into the model(comparison)
7	Drying the idol		'wanted to see that water colour and cotton cloth are equally dried'	The required quantity of drying is done	The craftsman just checks the strength of the idol by drying it

8	Finishing the idol		'we see any other details which are required to make the idol perfect'	Other accessories like jewellery etc. are put to the idol	The craftsman see that it has come to the desired shape and size as compared to the mythological character(comparison)

After the tacit and the implicit components of the idol making process was developed the next step was to generate the tacit markers from the protocol analysis. This was used for the digitization of the whole idol making process. Fig.3.32 shows the generation of the *tacit markers*. These markers are the indicators of the patterns which are followed by the craftsman in their process in different domain. In case of the idol making process some of the tacit markers are illustrated in the Fig.3.32.

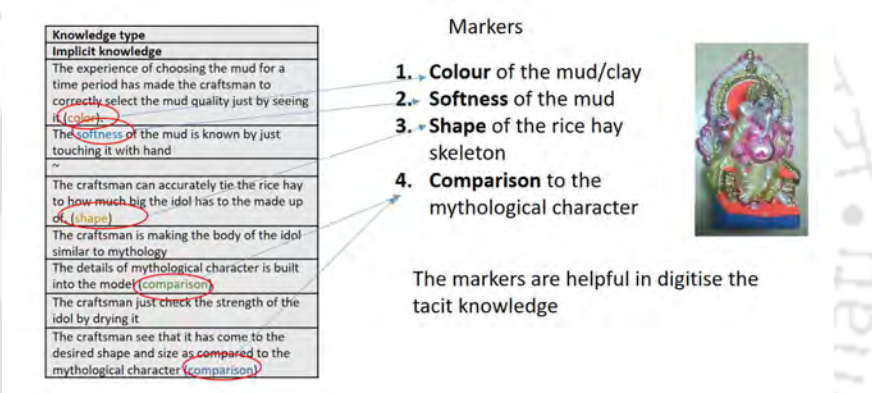


Fig.3.32: Generation of the tacit makers in the Idol making process (Source: Author generated)

The features like color, shape of the idol was considered for the classification of the idols from two different regions. Shown below in the Fig. 3.33 is a classification of the idols based upon the shape of the idol.

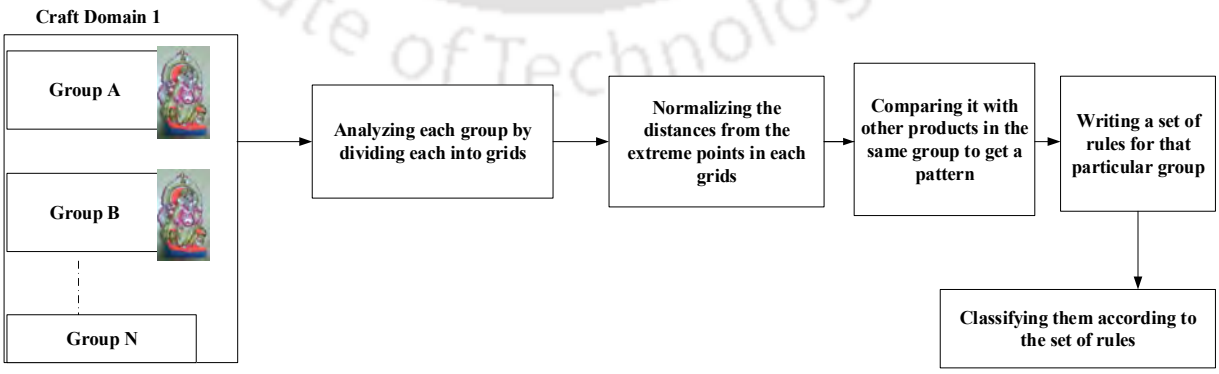


Fig.3.33: Classification of the idols based upon the shape of the idols

3.7 Details description of bamboo tea-bag process

Bamboo tea-bag is a particular type of crafts product which is available in the North-Eastern part of India. It has anesthetic look in itself and is made up of sustainable material, bamboo. The making of bamboo tea-bag holder required a very thick stem of bamboo which is having a larger width. A contextual study was carried out to study the process of bamboo tea bag making process. North eastern part of India especially Assam, state in this part, is famous for its tea production. The commercial production of tea in India started long back during the British conquest in India. Since then tea is one of the major beverages in India. Although the history of drinking tea dates back to many centuries in many Asian countries like China, Mongolia etc. Storing of the tea to prevent it from getting contacted with moisture is always being a major concern.

Bamboo tea bag is used to store and easily access the tea bags when making tea. The process map for making the bamboo tea bag holder is shown in Fig.3.34.

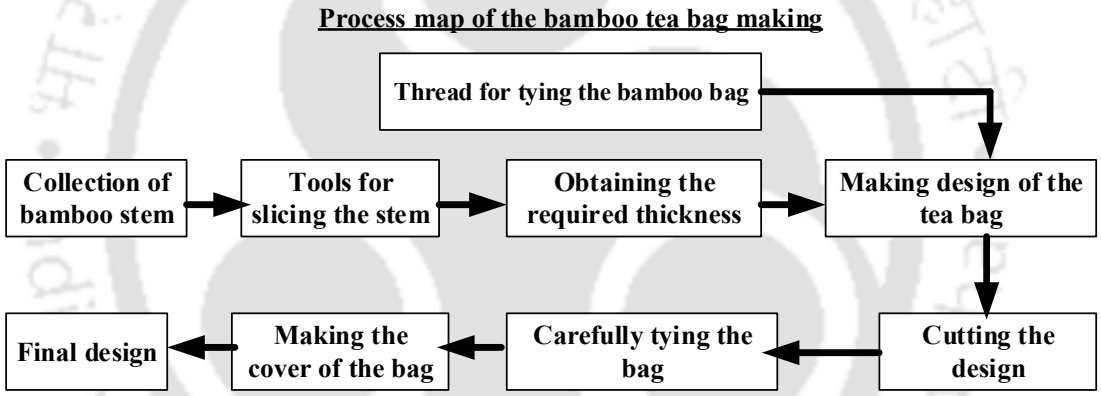
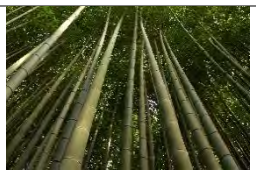
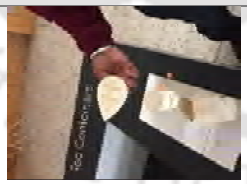


Fig.3.34: Process map of bamboo tea bag making (Source: Author generated)

The process of bag making starts with the selection of collection of the bamboo stem, which is suitable for the teabag making. The collected bamboo stem is dressed and sliced to obtain raw material which can be suitably made into the holder for tea bags. The thickness of the slice of the raw material is very less and has to be carefully done not to spoil the bamboo stem as a whole. The next phase of the process is making the design of the tea bag holder which can hold enough tea bags in it. The designs are cut from the raw material and then are tied to the other parts by the bamboo thread. After the observation of the bamboo tea bag making process, some of the tacit knowledge involved in its making was extracted. This is shown in the Table-3.4 below.

Table.3.4: Extraction of tacit knowledge from the bamboo tea bag making process

Steps	Processes	Photos/videos	Task/protocols carried by the craftsman	Knowledge type	
				Explicit knowledge	**Implicit knowledge**

1	Collection of bamboo stem		'We collect bamboo stems which can be suitably cut into the tea bags'	The thick of the bamboo stem is important in the making of the bamboo tea holder	The craftsman can judge the bamboo by seeing its thickness
2	Tools for slicing the stem		'commonly used tools like hacksaw, machete etc. are used in the cutting of bamboo'	Careful observations are taken to slice the bamboo stem	The craftsman has the experience of cutting the bamboo stem
3	Obtaining the required thickness		'The bamboo slice are not too thick'	The thickness in which the bamboo are sliced should be flexible enough	The approximate thickness of the bamboo material
4	Making the design of the tea bag		'We tried circular shape, elliptical shape and others '	Shapes which can accommodate the tea bags was made	An approximate shape according to craftsman was designed
5	Cutting the design		'The bamboo material was cut into the design'	The bamboo was cut according to the design decided	The cutting was done keeping design in mind by the craftsman
6	Carefully tying the bag		'The bamboo material for the bag were tied together with thread'	The different parts of the bamboo bag was tied to each other	The experience of craftsman helped to tie the bag nicely
7	Making the cover of the bag		'Cover of the tea bag was also made up of bamboo'	The material of the cover was also bamboo	Material of the cover
8	Final design		'The final design was aesthetic to look and was having enough space for storing tea bags'	The final design of the bamboo bag was aesthetic	Final design was unique and aesthetic.

After the tacit and the implicit components of the bamboo tea bag making process was developed the next step was to generate the tacit markers from the protocol analysis. This was used for the digitization of the bamboo bag making process. Fig.3.35 shows the generation of the *tacit markers*. These markers are the indicators of the patterns which are followed by the craftsman in their process in different domain. In case of the idol making process some of the tacit markers are illustrated in the Fig.3.35.

Fig.3.35: Generation of the tacit makers in the bamboo tea bag making process (Source: Author generated)

The features like thickness, shape, volume of the tea bag was considered for the classification of the bag from two different regions. Shown below in the Fig. 3.36 is a classification of the tea bags based upon the shape of the bag.

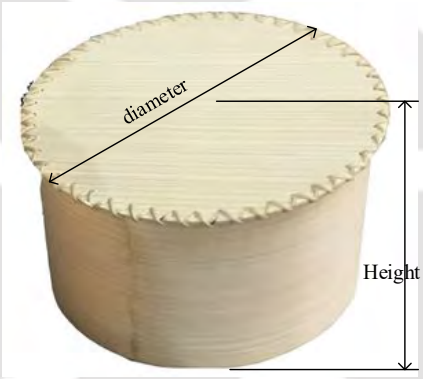


Fig.3.36: Classification of the bamboo tea bag holder based upon the shape of the bag

3.8 Details description of curtain stand using bamboo-craft process

Bamboo craft is practiced in many parts of the world. In India the north eastern part is reach in the bamboo plants, so it is a common among people to practice bamboo craft. Bamboo curtain stand is one of these crafts which can be seen in different parts of northeastern India. It depends on the craft community which practices these craft and so the curtain stand varies from one region to another. One of the curtain stands is being studied here in this thesis. The bamboo curtain stands servers as a partition in the long room. The process map of the bamboo curtain stand is shown in the Fig. 3.37.

Process map of bamboo curtain stand

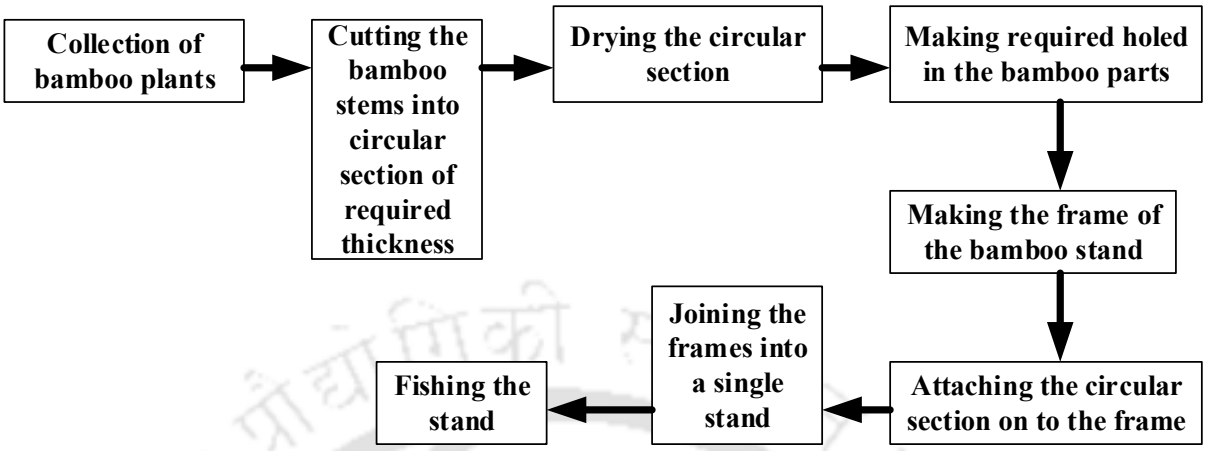
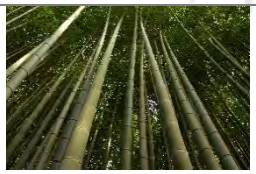
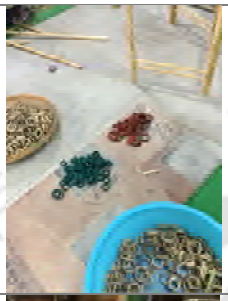


Fig.3.37: Process map of bamboo curtain stand (Source: Author generated)

The process of bamboo curtain stand starts with the specification needed for the stand. The stand needed to be on the floor, so it suitable enough to serve its purpose. The next step is the making is the collection of suitable bamboo stems. The stems are then cut into circular portion which can be used in the stand. The circular parts are colored and dried in the sun. The next step involves making holes in the bamboo parts. The frame of the stand is made by joining it together either with bamboo of the hinges available in the common market. After the frame is ready the circular parts are fixed into the frame using the threads. Once the parts are fixed the other frame is also made ready. The different frames are then joined together to make a complete structure. During this making process the researchers did a contextual enquiry on the craftsman who were building the curtain structure. During the conversation some of the tacit and implicit component of the knowledge was extracted from them as well as the object they produce. This is shown in the Table-3.5 below.

Table.3.5: Extraction of tacit knowledge from the bamboo curtain stand making process

Steps	Processes	Photos/videos	Task/protocols carried by the craftsman	Knowledge type	
				Explicit knowledge	**Implicit knowledge**
1	Collection of bamboo plants		'The bamboo stems were little raw and green when we collected them'	The moisture content in the stem helps to identify the stem for raw material	The experience of craftsman helps him to choose the bamboo.

2	Cutting the bamboo into circular section of required thickness		'We cut the bamboo stem into required thickness'	The circular sections of the bamboo is cut from the stem	The parts are of equal circular shape
3	Drying the coloured circular parts		'The colouring of the circular section is done with water colour, so that it retains in the parts'	The circular parts are dried to a certain amount of time under the sun.	The colour and the drying temperature are decided by the craftsman
4	Making required hole in the bamboo parts		'The holes were carefully made into the circular parts'	The dimensions of the holes made were such that it did not crack the raw material.	The craftsman were able to make the hole precisely.
5	Making the frame of the bamboo stand		'frames were made as per the specification of the design'	'Design height and placement of the stand determine the height of the frame'	The frames were built strongly as per the designs
6	Attaching the circular sections on to the frame		The circular sections which were coloured were attached on to the frame	'Required distance between the circular parts was observed before it was attached into the frame'	The craftsman knows how many circular sections, as well as the distance which needs to be left and then attached it the frame.

7	Joining the frames into a single frame		'Joining can be done with the help of bamboo provided'	To make the product natural as well as sustainable the frames were joined with bamboo straps.	'Straps were of flexible in nature to join it into the frame'
8	Final design of the stand		'The final design may consist of three to five frames'	The number of designs for the frame was chosen as per the design of the room	~

After the tacit and the implicit components of the curtain stand making process was developed the next step was to generate the tacit markers from the protocol analysis. Fig.3.38 shows the generation of the *tacit markers*. These markers are the indicators of the patterns which are followed by the craftsman in their process in different domain. In case of the curtain stand some of the tacit markers are illustrated in the Fig.3.38.

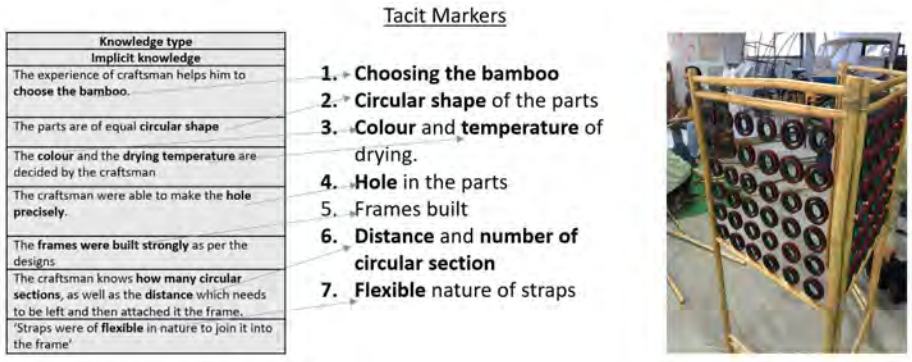


Fig.3.38: Generation of the tacit makers in the bamboo curtain stand (Source: Author generated)

The features like color, shape, height of the curtain stand was considered for the classification of the stands from two different regions. Shown below in the Fig. 3.39 is a classification of the stand based upon the geometrical details of the curtain stand.

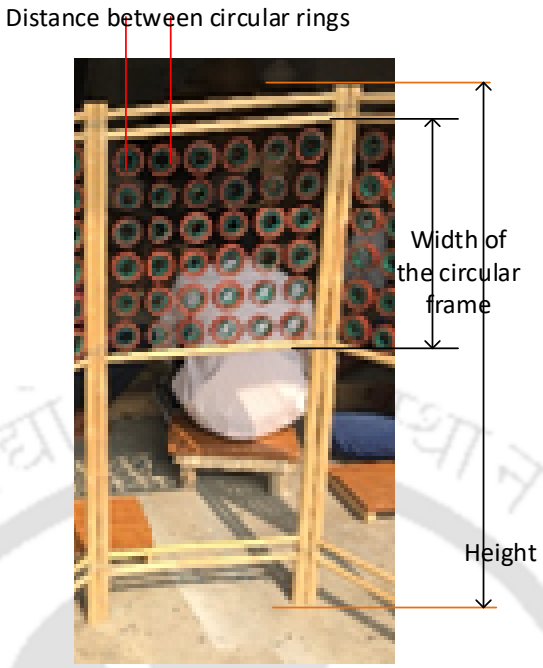


Fig.3.39: Curtain stand based upon the geometrical detail

The stand varies upon the distance between the circular rings. Even the circular rings are replaced by the bamboo straps.

3.9 Details description of bamboo basket making process

Bamboo basket are one of the useful crafts practiced in the North-eastern part of India. It was used by the antient people to make basket for storing fruits, vegetables and other basic household materials. Bamboo basket are made up bamboo which is natural fiber and biodegradable. So, it is a good product in and is sustainable in nature. Bamboo baskets are made by bamboo craftsman. It requires both the skills and hard labor to practice and make bamboo baskets. There are various methods to make a bamboo basket. The bamboo baskets are coming in varieties of shapes and sizes. Bamboo baskets are made by weaving the bamboo strips in variety of patterns. If someone wants to weave bamboo baskets, he/she will have to learn how to make basic weaving patterns. To make patterns we need bamboo strips. If bamboo is not available we can use paper strips to make these patterns. Some of the patterns are shown in the Fig. 3.40 and Fig. 3.41.

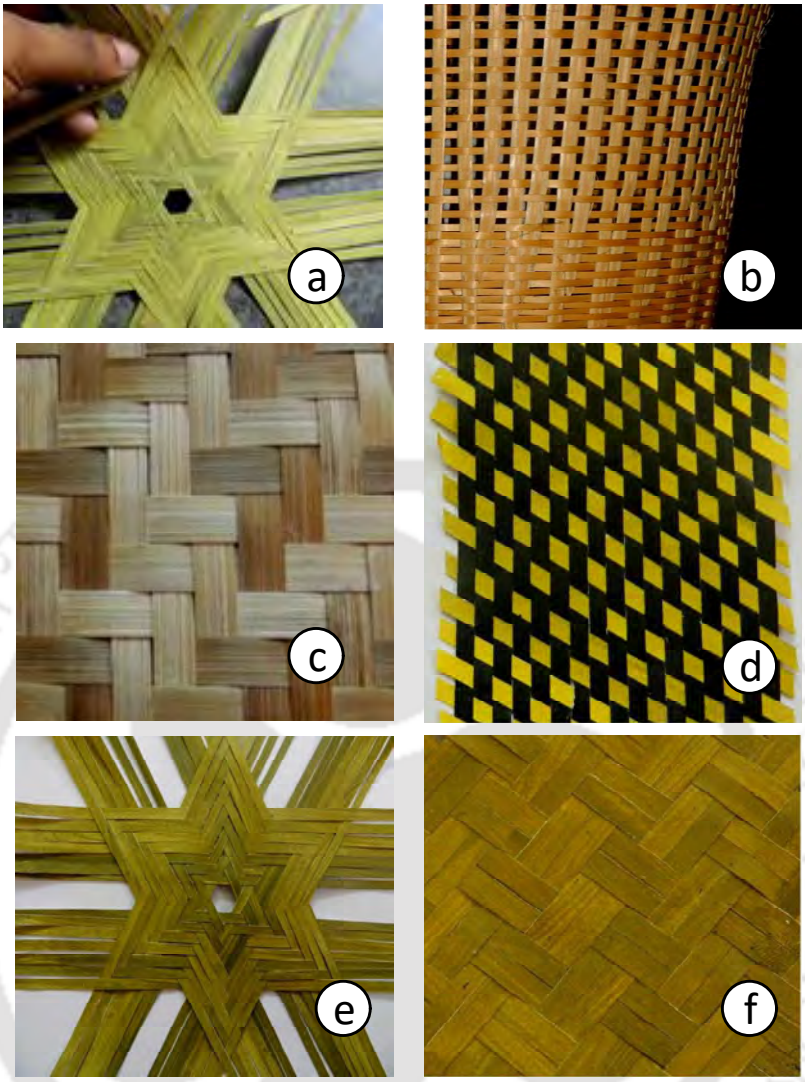


Fig.3.40: Bamboo weaving patterns (a,e. star pattern, b,c. netting pattern, d. diagonal pattern, e. double diagonal pattern) (Source: D'Source, India)

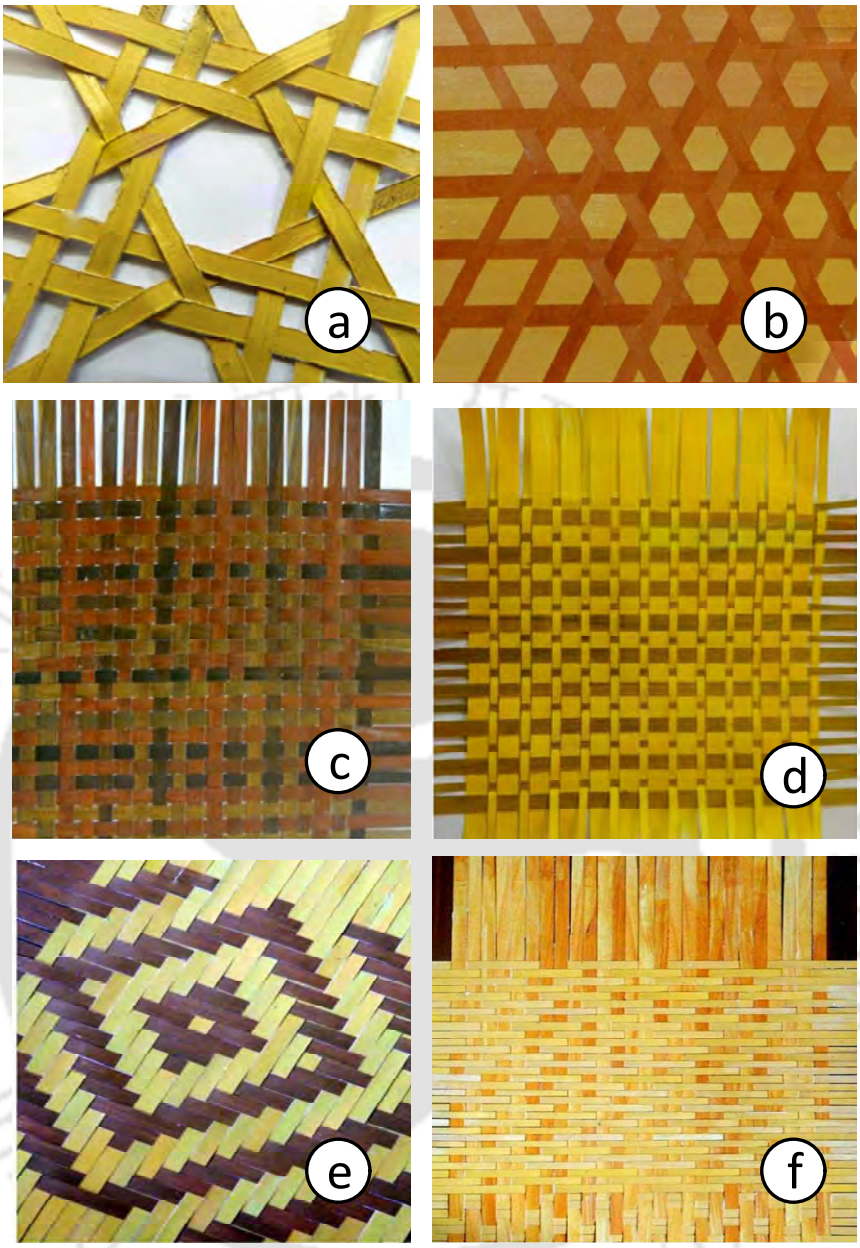


Fig.3.41: Bamboo weaving patterns (a,b. star pattern, c,d,f. cross netting pattern, e. continuous square netting) (Source: D'Source, India)

The above patterns are used by the master craftsman to make different types of baskets. In our study we have considered one of the simplest patterns for making the basket. There were novice users and the master craftsman involved in the making of the bamboo basket. The process map of making the bamboo basket is illustrated in the Fig. 3.42.

Process map of bamboo basket making

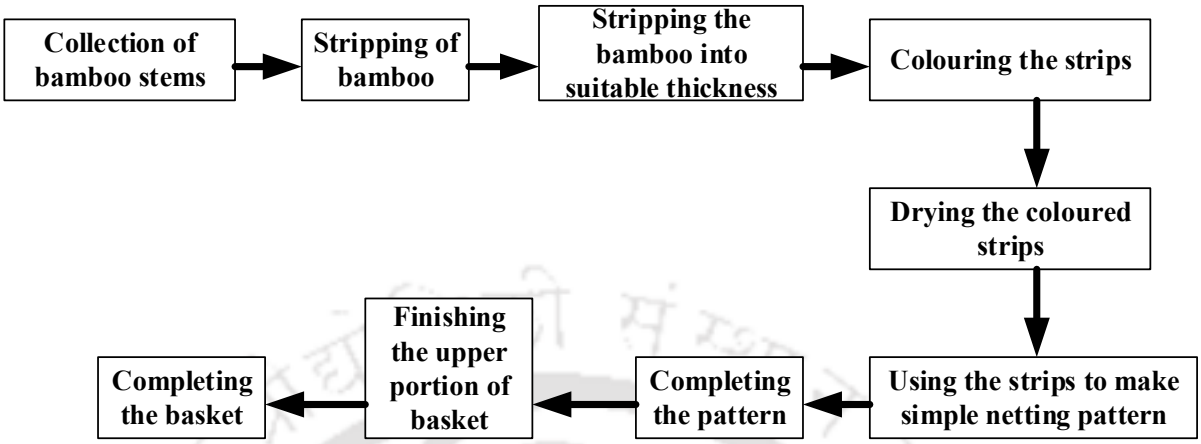
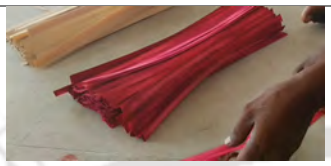
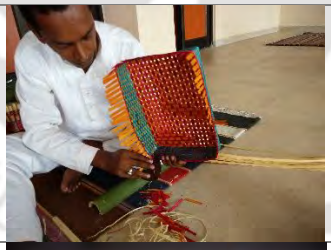
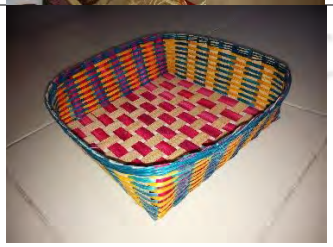


Fig.3.42: Process map of bamboo basket making process (Source: Author generated)

The process of bamboo basket making starts with the collection of good quality of bamboo for the baskets. The collected bamboo is then stripped into required thickness which can be used in the bamboo basket making process. The strips are then colored and dried for making the baskets. Then after they are dried they are used in the making of the basket. The basket making begins with the simple patter, in this study we have taken few simple patterns like netting pattern, continuous pattern, start pattern. Once the pattern making begins the basket takes the shape as desired by the craftsman. The final touch up is given at the top portion of the basket carefully by the craftsman After the observation of the bamboo basket process, some of the tacit knowledge involved in its making was extracted. This is shown in the Table-3.6 below.

Table.3.6: Extraction of tacit knowledge from bamboo basket making process

Steps	Processes	Photos/videos	Task/protocols carried by the craftsman	Knowledge type	
				Explicit knowledge	**Implicit knowledge**
1	Collection of bamboo stems		'We collect bamboo stems which can be easily cut and made into fibres'	The moisture content in the bamboo stems helps them to turns into fibres	The craftsman knows exactly which bamboo stem to select
2	Stripping of the bamboo stems		'We are able to work on the bamboo to strip them into fibres'	The selection of bamboo stems helps them to easily work on the bamboo	The experience of working on the bamboo stem helps in the stripping it

3	Stripping of large pieces into smaller suitable thickness		'The large strips of bamboo are cut into medium ones'	The requirement leads to uniform length of smaller strips	The craftsman knows what is the required size of strip which can be made to a basket without wasting the bamboo
4	Colouring of the strips		'Sometimes natural colours are used in the colouring'	The colours give an aesthetic look to the final design of basket	Choosing colour
5	Drying of the coloured strips		'After colouring we dry them'	~	The required amount of time and temperature for drying
6	Using the dry strips to make netting pattern		'We sometimes use water during the pattern making of the basket'	The water gives required flexibility to the bamboo strip	The craftsman knows how much is the flexibility required during working on the pattern of the bamboo basket
7	Completing the pattern to get a shape of the basket		'we repeat the pattern to get the final shape of the basket'	The craftsman knows the exact radius to get the pattern	Radius of turning the strips to get the required basket shape
8	Finishing the upper portion and thus the basket.		'final basket is made by closing the opening of the basket'	The final design is prepared	Final design contains certain craftsman errors which gives an unique look to the basket

After the tacit and the implicit components of the bamboo basket making process was developed the next step was to generate the tacit markers from the protocol analysis. This was used for the

digitization of the whole basket making process. Fig.3.42 shows the generation of the *tacit markers*. These markers are the indicators of the patterns which are followed by the craftsman in their process in different domain. In case of the bamboo basket making process some of the tacit markers are illustrated in the Fig.3.43.

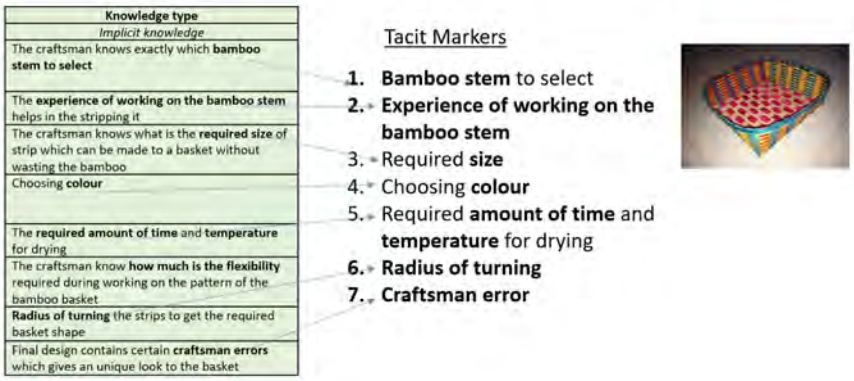


Fig.3.43: Generation of the tacit makers in the Idol making process (Source: Author generated)

The features like color, shape of the basket was considered for the classification of the basket from two different regions. Shown below in the Fig. 3.44 is a geometrical representation of the basket based upon the shape of the basket.

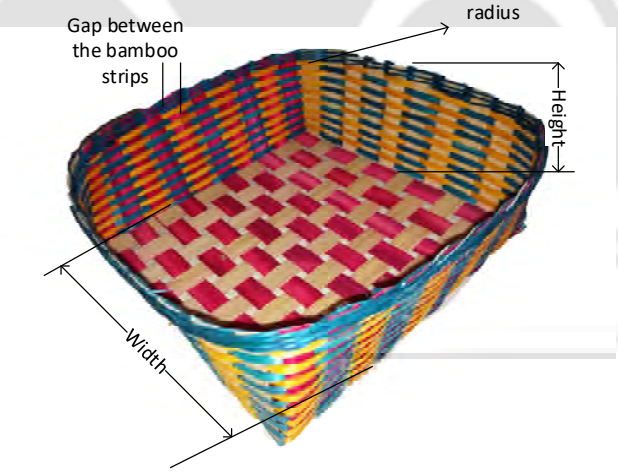


Fig.3.44: Geometrical representation of the basket based upon its shape

The next Chapter deals with the analysis of the data collected from the various case studies mentioned in this chapter. For each of the case studies the different tacit as well as the explicit component of the knowledge was analyzed.

3.10 Summary of the chapter

This chapter started with framing of the research questions and the pilot studies conducted for the thesis. The proposed methodology which is followed in this thesis is also discussed in this chapter. Different crafts which are considered in this thesis is also discussed in this chapter. The classification of the tacit and the explicit component is illustrated with different case studies. This would be used for the analysis in the subsequent chapter.

Chapter-4 Development of a digital tool for the tacit knowledge embedded in Craft Object

Abstract: *This chapter describes the tools used in the capturing and representing the tacit knowledge captured in the various craft objects describes in chapter-3. The chapter tries to show with the case studies the implementation of the digital tool in the craft domain.*

4.1 Introduction

We had seen in chapter-2 the difficulties faced by the researchers in transferring the tacit knowledge into digital form. There are several instances in which the tacit knowledge transfer is discussed in the office or corporate scenario when a skilled employee leaves the organization. The knowledge management division of an organization helps in the transfer of the knowledge from the experienced employee to a new joined employee. This is done as a part of apprenticeship training of new joined employee with the experienced employee. The present research tries to see if tacit knowledge which is transferred from the craftsman to their apprentices, can be converted digitally. The next section of this chapter deals with the development of the fuzzy model for the tacit knowledge captures as discussed in the chapter-3 earlier for the Diya making process.

A Diya is the Indian name of the mud-lamp (earthen lamp) with oil and wick immersed in it. It is as illustrated in Fig. 3.28 and Fig. 4.1 below.

Fig. 4.1 A typical Indian mud lamp (Diya)

The design of the Diya is simple in nature as it is made by pottery. Some of the designs contains patterns at the edge of the lamp or may also contain motifs on it. The structure of a lamp is simple enough to carry a required amount of oil which can be used for light during the nights in villages of India where electricity is not present. This lamp is easily made by pottery which requires certain skills in giving a shape and volume to it. It is also cheaply available in many parts of the rural as well as the modern India. Though it us simple design but there is some minute difference from one part of the country to another.

4.2 Development of the fuzzy model for Diya making process

The mental model of the craftsman during the process of making the Diya was studied and was needed to be captured. Some of the steps which were followed by the craftsman during the making of the Diya was very difficult for them to explain. During the process of Diya making there were certain steps which the craftsman was not able to explain and agreed that it was due to the practice of the profession that this had come naturally to him. There were lack of words or sometime they could not give particular explanation as why they had taken that particular step. The different shapes of the Diya were obtained by different craftsman. Though the craftsman had made different diyas there were similarities in diyas produced by each of the craftsman. Sometime by their experiences they were able to remove the Diya when it was at a particular shape on the potter's wheel automatically without any prior indication to the step. So, in this thesis we tried to model the experience of the craftsman. We wanted to mimic the craftsman and try to accurately model the Diya as it was done by him. As discussed in the section 3.3 the abductive reasoning and fuzzy systems can help in modelling the system since it is done purely based upon the experience of the craftsman or the tacit knowledge of the craftsman. The different features which can be considered during the modelling of the fuzzy system of a Diya are:

a. Shape of the Diya
b. Size of the Diya
c. Color of the Diya

Here we show the fuzzy inference engine (FIS) for the shape and size of the Diya. Different features as shown in Fig 4.2 are taken after analyzing 50 diyas from two different craftsman. The Diya considered in this thesis are available in common among different parts of India. We have not considered the other models of the earthen lamps available. The reason for choosing this model of Diya was to see the uniformity while the comparisons is made between two regions and the craftsman making Diya of the same variety. The different features of the Diya were considered for the study. We narrowed down into the seven features of the Diya. The seven different features identified as follows:

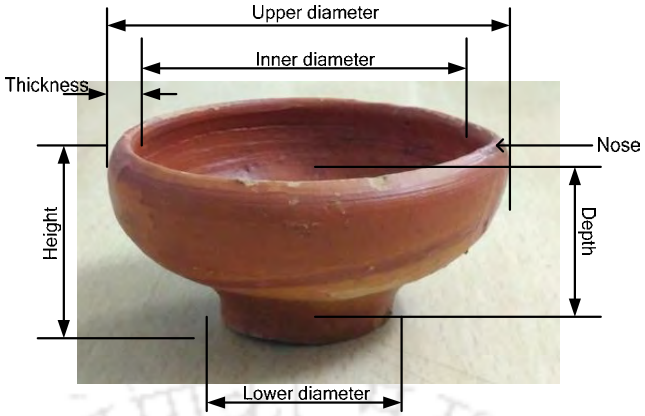


Fig.4.2: Different parameters of a typical Diya (Source: Author generated)

Upper diameter

Lower diameter

Height

Nose radius

Thickness

Depth and inner diameter

The tacit knowledge of the craftsman helps him to decides the upper diameter, lower diameter, height, nose radius, thickness, depth and inner diameter of the Diya. So, during the process of making the Diya the craftsman automatically removes the Diya when it is at that particular stage. Based on these factors and the actual measurement of the dimensions of the Diya a fuzzy inference engine is being developed.

MATLAB® was used in the building of the FIS engine. Mamdani fuzzy engine was used in the development of the FIS system. For the de-fuzzification centroid method used for the FIS system. This is shown in the block diagram below:

Fig. 4.3: Block diagram followed for the FIS system

Based on the inputs from the two different craftsman the ranges of the different features were decided. They were physically measured for the diyas from the two craftsmen. The physical measurement unknowingly depicted similarities in features from each of the craftsman. The FIS engine for the

shape of the Diya had seven inputs features as mentioned above and the once output classifier. The geometrical variables were weighted into the semantic weighing scale as illustrated in Fig.4.4

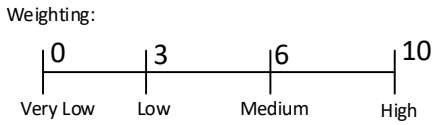


Fig.4.4: Semantic weighing scale (Source: author generated)

The Upper diameter input feature have a range from 0 to 75. The membership function for the upper diameter feature have three values: low, medium and high. Here low corresponds to the lowest possible range of diameter (here 47 to 54) of Diya found from the knowledge of the craftsman. The defuzzification analysis is carried by converting the triangular fuzzy numbers into exact values.

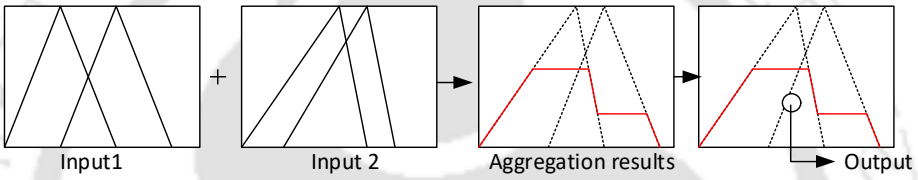


Fig. 4.5: Defuzzification results of two input functions. (Source: Author generated)

The membership function for different variables were developed using MATLAB® and are described below. For different inputs like Lower diameter, height, nose radius etc. the membership functions (MFs) were developed. This section shows the different membership functions. Similarly, the membership functions of all the input parameter have the different ranges of low, medium and high value. These ranges were also fixed after getting the fuzzy inputs from the craftsman and cross checking with the physical prototypes of the diyas from that craftsman. Out of the various inputs available in the MATLAB, the triangular type of the inputs was considered for the low, medium and high ranges of the functions. The division of the different inputs helped the researchers to form the rules which can be unique and can help to predict the output easily. The output of the Fuzzy Inference System (FIS) engine leads to a categorization of the based on the inputs. The membership function of the output of the FIS is shown in the Fig.4.6 below. After the development of the membership functions the fuzzy rules were framed for the Diya model

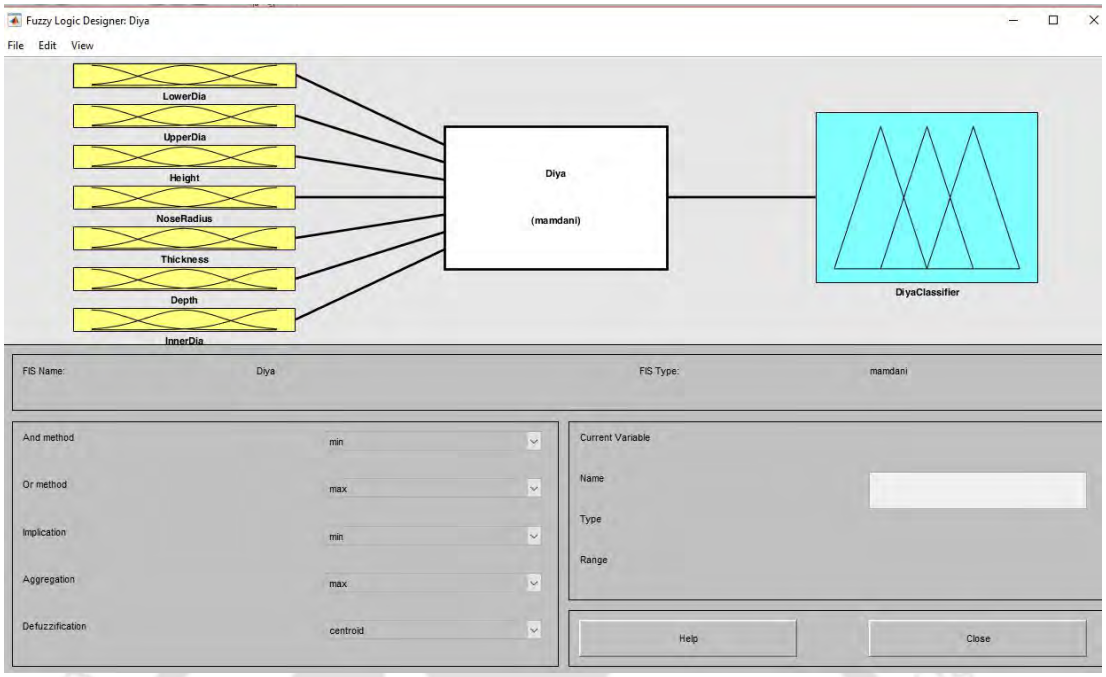


Fig. 4.6: Inputs and output of the shape FIS of a Diya.

The seven inputs along with their membership functions are described below. Since, the Upper diameter input feature have a range from 0 to 75. The membership function for the upper diameter feature have three values: low, medium and high. Here low corresponds to the lowest possible range of diameter (here 47 to 54) of Diya found from the tacit knowledge of the craftsman. s

Table- 4.1: The truth table of a Diya from a craftsman (T=true, F= False)

Features Values in mm	Upper diameter	Lower Diameter	Height	Nose Radius	Thickness	Depth	Inner Diameter
0-5	F	F	F	F	T	T	F
6-10	F	F	F	T	F	T	F
11-15	F	F	T	T	F	T	F
16-20	F	F	T	F	F	T	F
21-25	F	F	F	F	F	T	F
26-30	F	F	F	F	F	F	F
31-35	F	F	F	F	F	F	T
36-40	F	F	F	F	F	F	T
41-50	T	T	F	F	F	F	F
51-55	T	T	F	F	F	F	F
56-60	F	F	F	F	F	F	F
61-65	F	F	F	F	F	F	F

66-70	F	F	F	F	F	F	F
71-75	F	F	F	F	F	F	F
76-80	F	F	F	F	F	F	F

Fig.4.7: Membership function for Upper diameter input parameter

For the different inputs like Lower diameter, height, nose radius etc. the membership functions were developed.

Similarly, the membership functions of all the input parameter have the different ranges of low, medium and high value. These ranges were also fixed after getting the fuzzy inputs from the craftsman and cross checking with the physical prototypes of the diyas from that craftsman. The triangular type of the inputs was considered for the low, medium and high ranges of the functions.

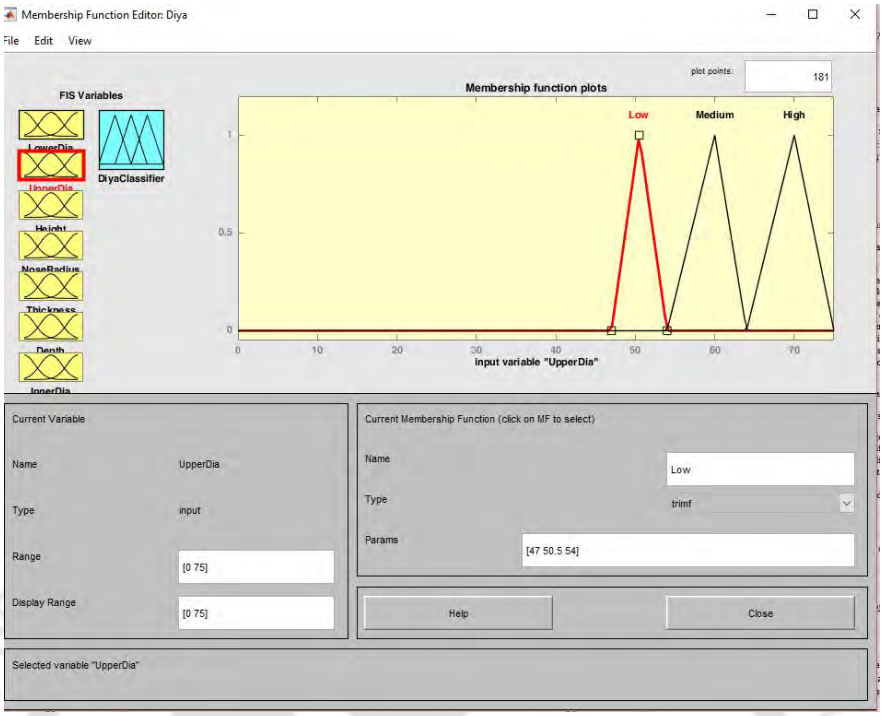


Fig.4.8: Membership function for Inner diameter input parameter

Fig.4.9: Membership function for height input parameter

Fig 4.10: Membership function for Nose radius input parameter

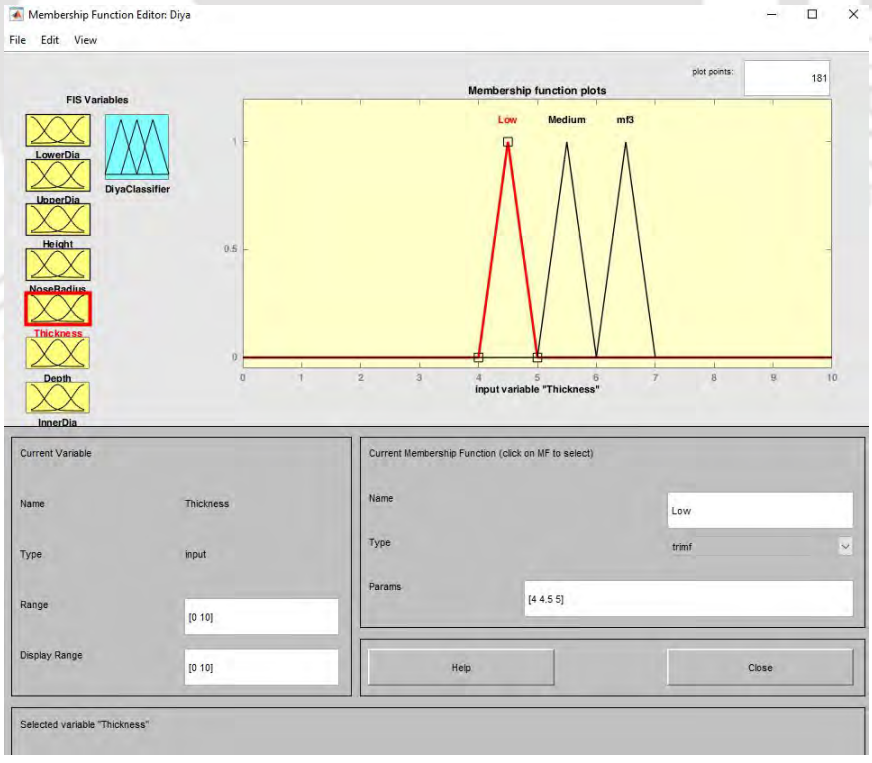


Fig.4.11: Membership function for thickness input parameter

Fig 4.12: Membership function for Depth input parameter

Fig 4.13: Membership function for inner thickness input parameter

The output of the FIS engine leads to a categorization of the based on the inputs. The membership function of the output of the FIS is shown in the Fig.4.14 below.

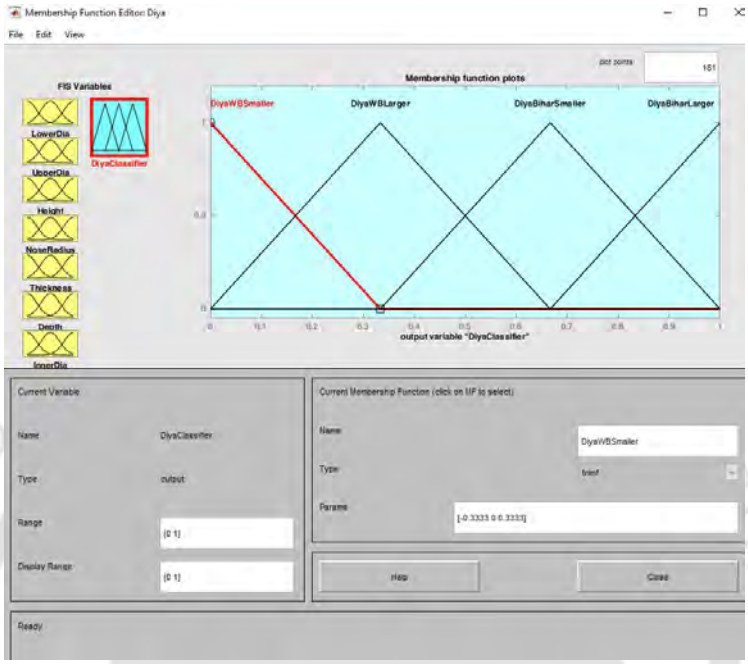


Fig 4.14: Output membership function of the diya.fis system

Initial phase of the FIS system consisted of four rules as shown in the Fig 4.15 below. Gradually the rules of the fuzzy system were increased. This was from the tacit knowledge gained from the craftsman of the particular Diya.

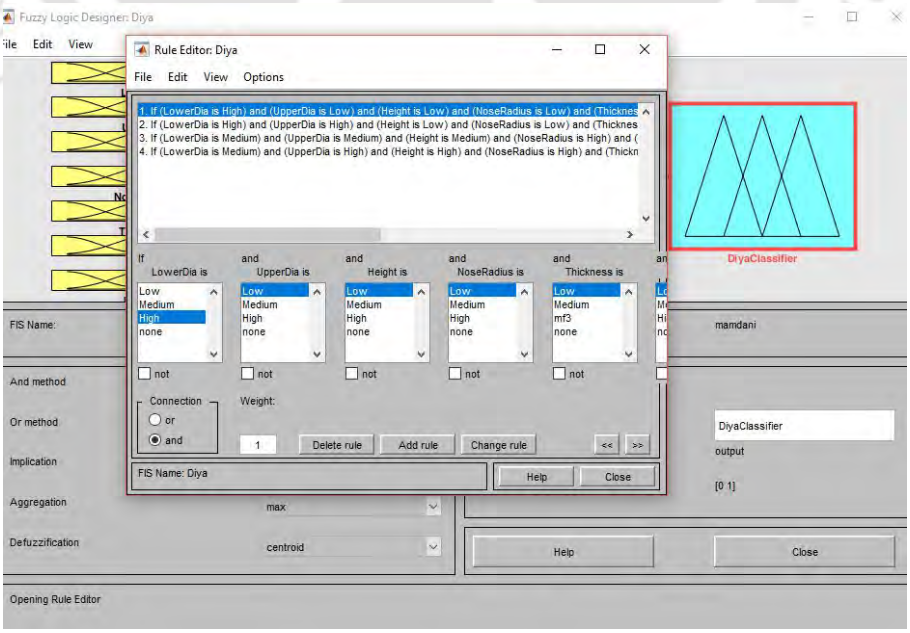


Fig 4.15: Rules to classify the Diya based on the shape of the Diya.

The Fig. 4.16 shows the rules involved in the shape FIS engine

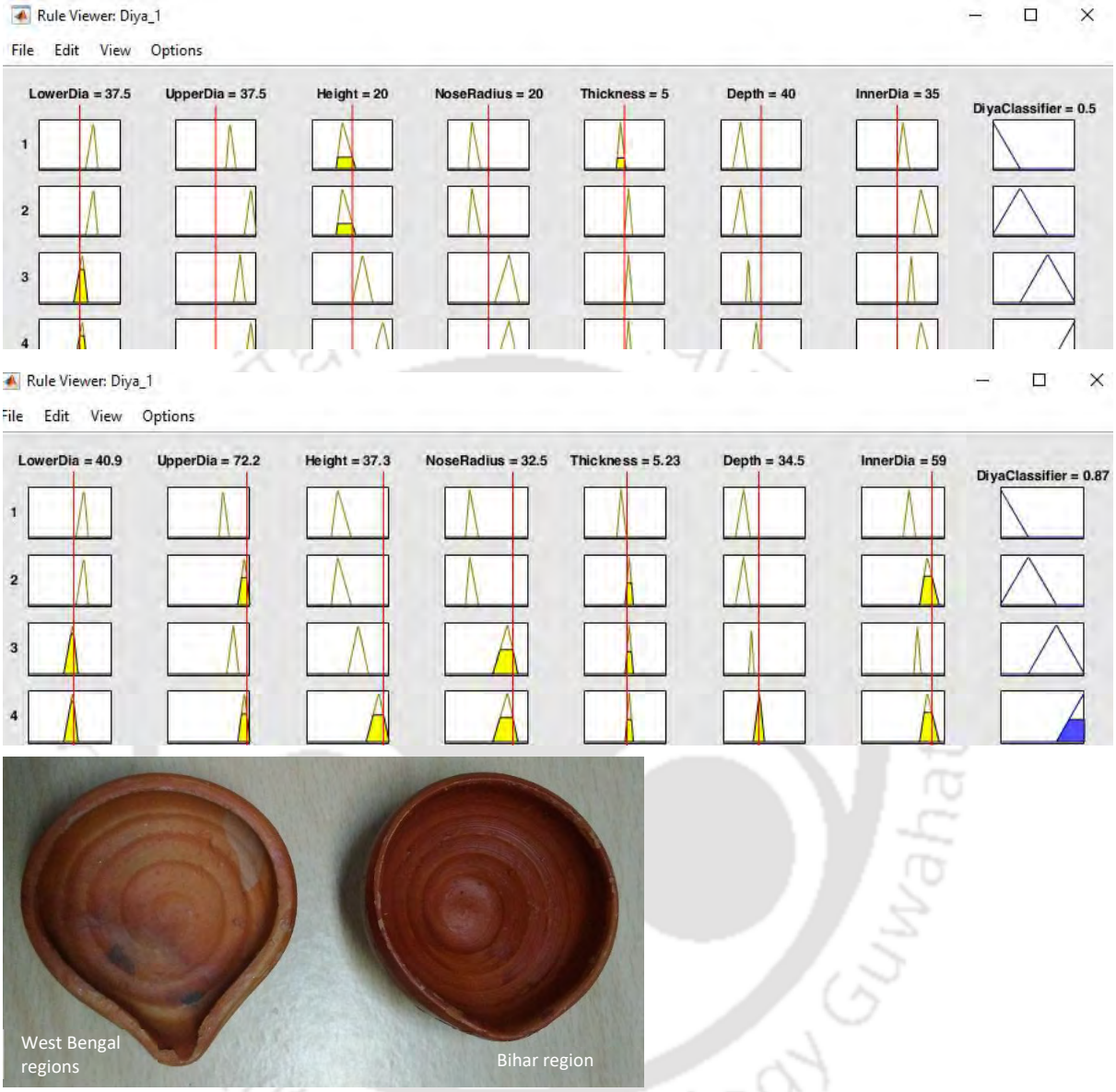


Fig. 4.16: Rule implementation of the Diya FIS system

Similarly, the FIS system was developed for the other feature pointed out in the previous section for Diya and then combined together and were implemented into the machine engine.

4.3 Development of fuzzy model for other case studies

Idol making process: The process of making idol was discussed in section 3.6 previously. It contained many steps which was illustrated in Fig. 3.31. The finished idol embeds in it several features as well as artists skillful acts. The beauty, aesthetic look and feel in the idol make it a unique creation of a craftsman. It also embeds some of the features which can be specific for an artist for example, some

the facial features if the idol is a Hindu mythological Gods character. Fig 4.17 shows an idol from a craftsman residing in Amingoan, Assam.

Fig. 4.17: Ganesh idol (Source: Author generated)

The features identified in the Fig. 4.17 and Fig.3.32 varies from one craftsman to another craftsman and according to the region and skills sets possessed by the craftsman in a particular geographical area. The detection of these features helps us to identify the craftsman's tacit knowledge and to which geographical area they belong to. This will help the artisans who wanted to see the unique features in a particular idol from a craftsman in that particular area. This helps them to see the new feature and they can compare different idols of same category from different regions.

The fuzzy inference system of the idol entails to match a set of inputs to the output using the fuzzy logic. As discussed earlier, fuzzy logic is a multivalued logic that allows an intermediate value to be defined between 0 and 1 which contracts to the earlier Boolean logic where only two values (0 or 1) are considered.

The architecture of FIS system involves four steps as shown in the Fig. 4.18. Fuzzification, knowledgebase, inference engine and defuzzification. In the fuzzification step the crisp inputs are converted to linguistic variables by using the membership functions which are stored in the knowledge base. The membership function can be of different types, the Triangular function, Trapezoidal function or the Gaussian function.

In the inference engine, the IF_THEN rules stored in the knowledge base are used to compute the fuzzy output from the fuzzy input. In the defuzzification step, the fuzzy output is converted to crisp

value by using the same membership function used in the fuzzification step. Different defuzzification methods can be used to obtain the crisp value, such as the Centroid of Area, Bisector of Area, Mean of Max, Smallest of Max, and Largest of Max (Iman et.al., 2019).

There are several fuzzy inference systems which are used by different researchers. Out of them the commonly used ones are Mamdani fuzzy system and the other one is Sugeno fuzzy system. The difference between these types comes from the consequents, of their fuzzy rules which make the procedures of their aggregation and defuzzification different as well.

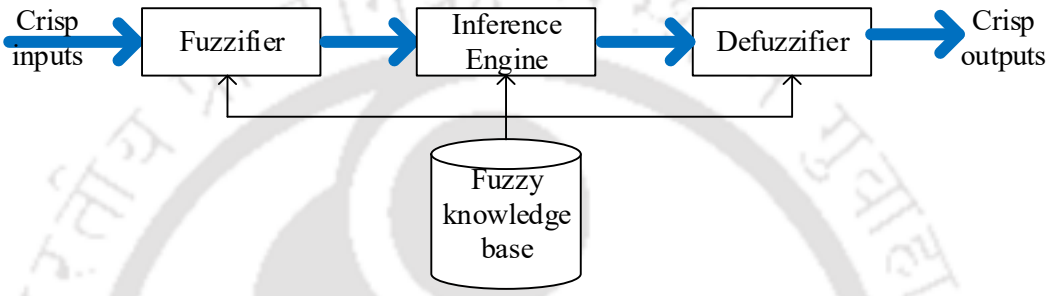
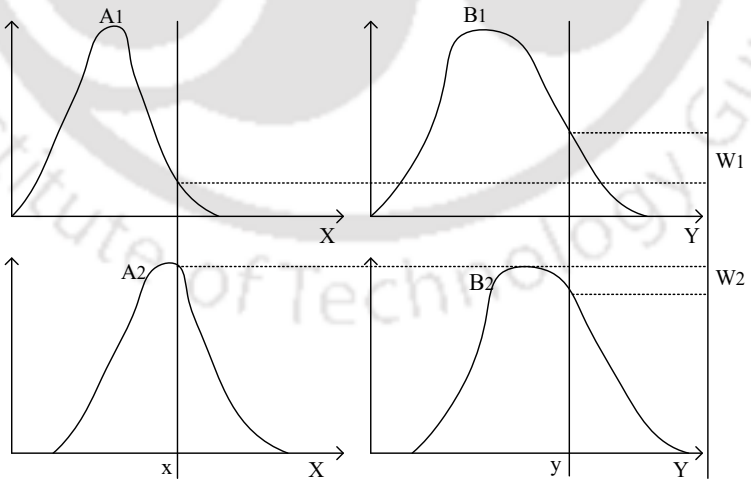
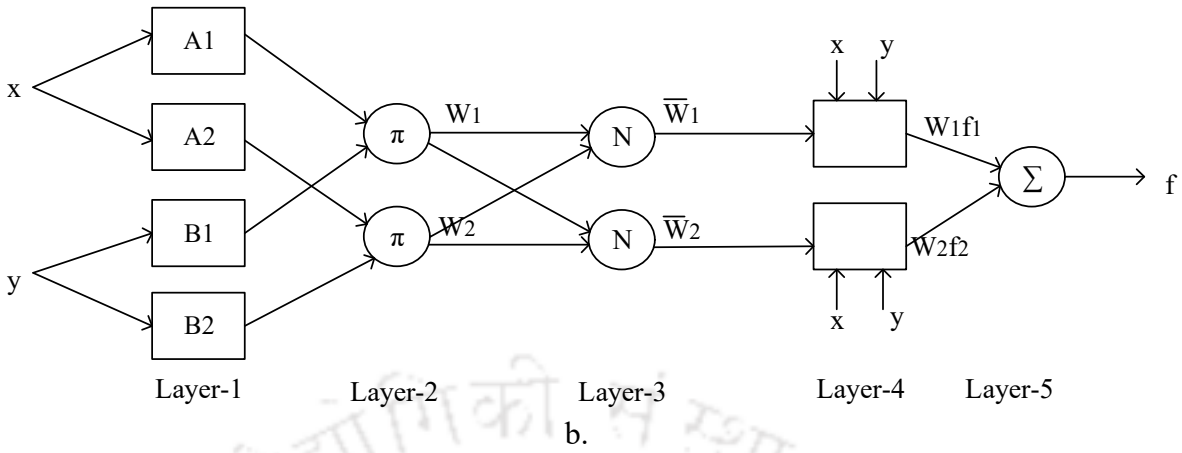


Fig. 4.18: FIS architecture

ANFIS is a combination of the Artificial Neural Network and Fuzzy Inference system. This was first introduced by Jyh-Shing Roger Jang in 1992 (Iman et.al., 2019). It works in Sugeno fuzzy inference system and its structure is similar to the multilayer feedforward neural network structure, except that the links in ANFIS indicate the signals' flow direction and there are no associated weights with the links. A typical ANFIS system is illustrated in the Fig. 4.19 below.



a.



b.

Fig.4.19 a: Sugeno fuzzy model, b: The ANFIS architecture

Considering the above model and two simple inputs x and y and output as f, the rules can be defined as follows:

Rule1: if x is A_1 and y is B_1, then $f= p_1x+q_1y+r_1$ (4.1)

Rule2: if x is A_2 and y is B_2, then $f= p_2x+q_2y+r_2$ (4.2)

Where A_1, B_1, A_2 and B_2 are the membership function and p_1, q_1, r_1, p_2, q_2, r_1 and r_2 are the design parameters which are determined by training.

The ANFIS system in Fig.4.19 consists of five layers. The first and fourth layers contain an adaptive node. The other layers contain nonadoptive nodes (fixed node).

Layer-1 consists of nodes which are adjusted to a functional parameter. The output of each node is the value of membership function of the next layer.

$$O_{1i} = \mu_{Ai}(x), i = 1,2 \quad (4.3)$$

$$O_{1,i} = \mu_{Bi-2}(x), i = 3,4 \quad (4.4)$$

where μ_{Ai} and μ_{Bi-2} are the degree of the membership functions for the fuzzy sets A_i and B_i.

Layer-2 consists of nodes which are fixed in nature and provide firing for the next rule. The output of this layer is multiplied with the signals coming from the successor nodes in the previous layer.

$$O_{2i} = w_i = \mu_{Ai}(x) + \mu_{Bi}(x), i = 1,2 \quad (4.5)$$

where w_i represent the firing strength of each rule.

Layer-3 also consists of nodes which are fixed in nature. The output of every node is the normalized strength which is the ratio between the i^{th} rules' firing to the total sum of the rules firings strength.

$$O_{3i} = \overline{w_i} = \frac{w_i}{\sum_i w_i} \quad (4.6)$$

Layer-4 consists of nodes which are the adaptive nodes to and output. The node function is defined by:

$$O_{4,i} = w_i(f_i) = w_i(p_i x + q_i y + r_i) \quad (4.7)$$

where w_i is the firing strength from the previous layer and $p_i x + q_i y + r_i$ are the parameters in the node.

Layer-5: in this layer there is only a single node which is fixed and calculates the total summation of all the arriving signals from the previous node to find the final output

$$O_{5,i} = \sum_i \overline{w_i} f_i = \frac{\sum_i w_i f_i}{\sum_i w_i} \quad (4.8)$$

The flow diagram for the ANFIS model is adopted from (Iman et.al., 2019). This is illustrated in the Fig. 4.20. The 1st step in the ANFIS model is similar to the FIS model used for the Diya case study and requires collection of the data set.

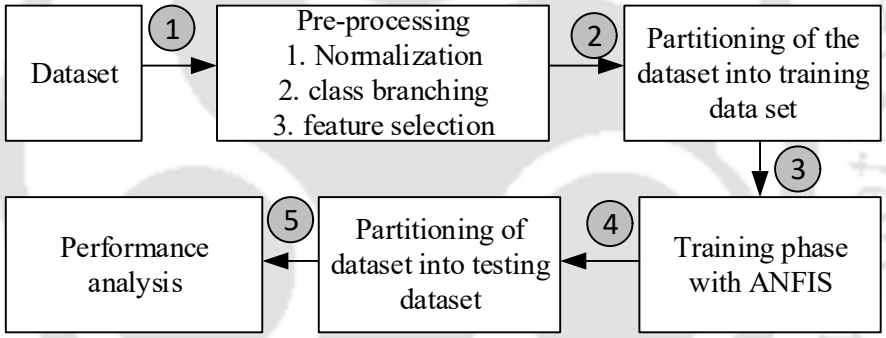


Fig.4.20: Flow of the steps for the ANFIS model (Adapted: Iman et.al., 2019)

The dataset used for this case study was mainly idols of Lord Ganesh from Amingoan, Assam region of two craftsman and other idols collected from other parts of India. The idols were basically in sitting position as shown in Fig.4.17. The similar idols were also from different artists from other geographical regions of India. The overall idol craftsman idols collected were 35 in numbers which are divided into four regions of India namely North, South, East and West parts.

Table.4.2: Feature of the idol making process

Feature ID	Feature Name	Description
F1	Duration(years)	Duration of practice of craft by craftsman
F2	Age (years)	Age of the craftsman

F3	Shape (0,1)	Shape of the idol (Uniform=0, Non-uniform=1)
F4	C1	Color of the body (R=255, G=192, B=203)
F5	C2	Color of the seats (R=255, G=215, B=0)
F6	Position of pet (0,1)	The position of pet (0= right corner,1= left corner)
T(target)	Location (0,1,2,3)	0=North, 1=South, 2=East, 3= West

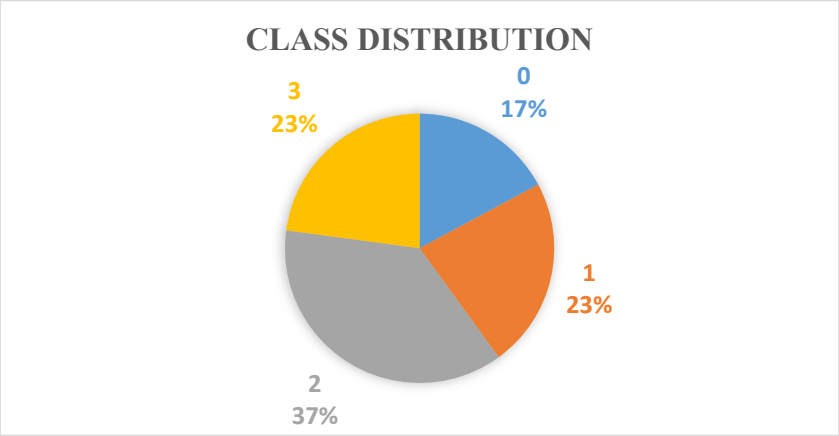


Fig. 4.21: Class distribution of the idols

Table 4.2 contains the features considered for the idol making process and the class of distribution of the idol considered from the dataset.

Table 4.3 shows the statistical analysis of the features considered in the idol making process. It shows the mean, median and stand deviation of different features. Table 4.4 shows the correlation of the features considered along with the target.

Table 4.3: Analysis of the idol dataset

	Mean	**Median**	**Standard deviation**	**Maximum**	**Minimum**
F1	13.38	13.5	6.94	25	0
F2	39.75	38.5	12.29	65	20
F3	0.58	1	0.5	1	0
F4	226.11	225.5	17.22	255	192
F5	132.16	145.5	71.80	255	0
F6	0.56	1	0.50	1	0
T	1.67	2	1.01	3	0

Table. 4.4: Correlation between each attribute and the target attribute

Attribute pairs	**Correlation coefficient**

F1 and T	0.12
F2 and T	0.29
F3 and T	-0.05
F4 and T	-0.07
F5 and T	0.12
F6 and T	0.26

Using MATLAB and ANFIS classifier the idol dataset was analyzed. The initial step was to normalize the dataset features to an interval of 0 to 1. Then the dataset was divided into testing and training data set.

The structure of ANFIS used in this case study consisted of five inputs and a single output. The number of epochs used was 3 with and error tolerance of 0.00001. The first and the fifth input functions were assigned three member each and also the other three outputs are assigned three membership functions. The total number of rules generated was 729.

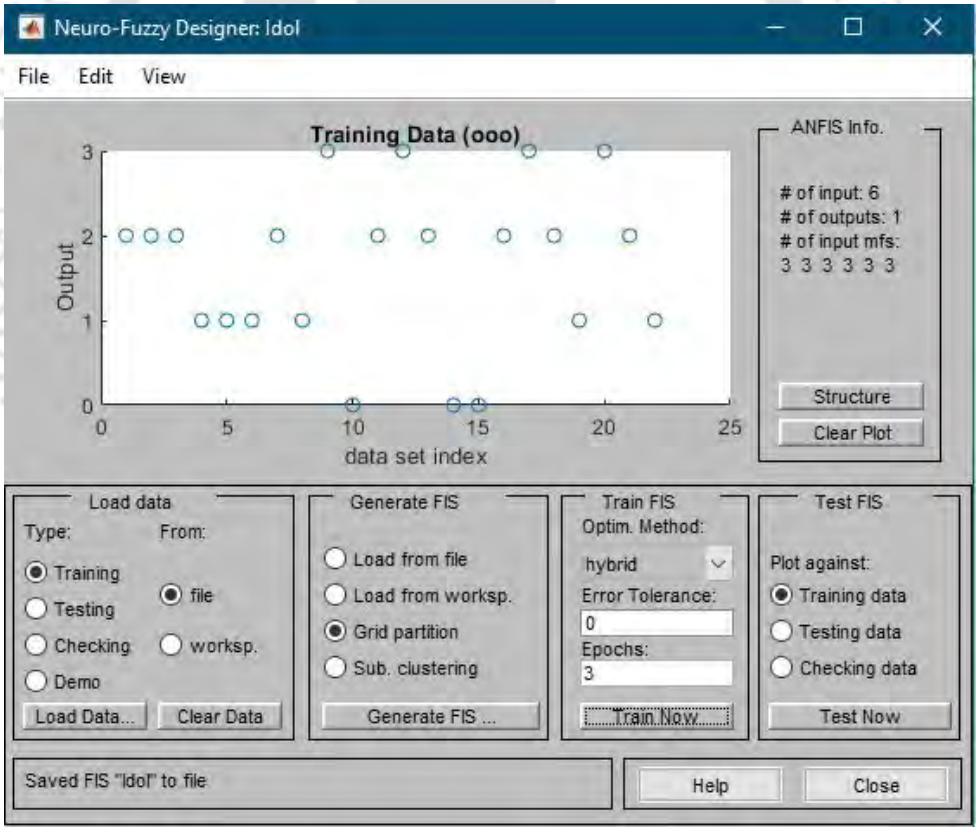


Fig.4.22: Training the dataset

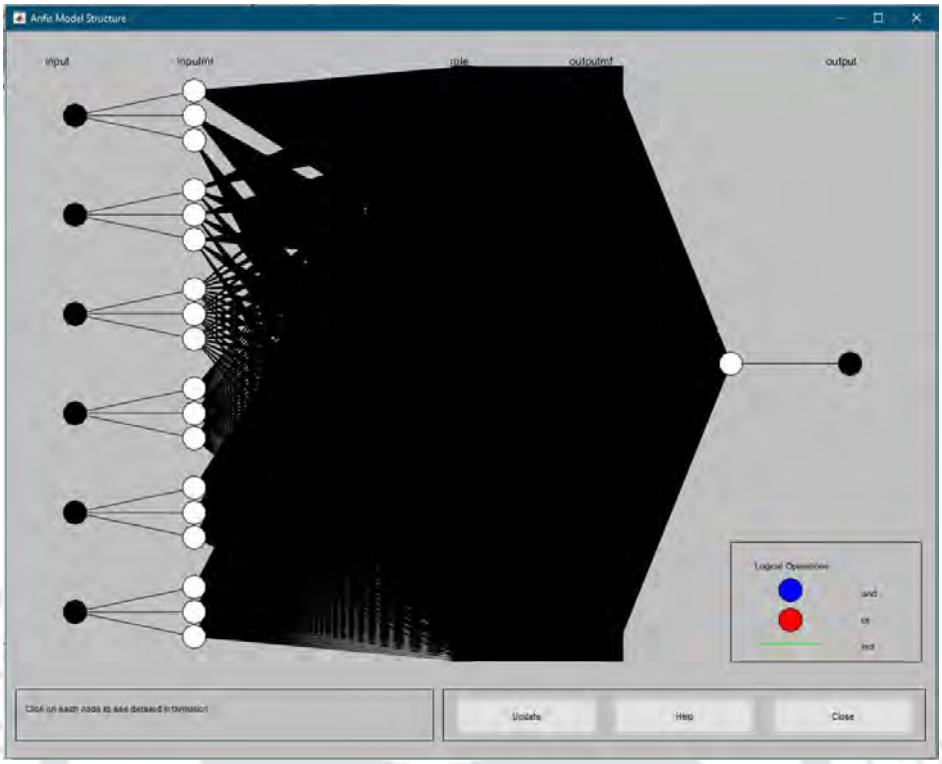


Fig. 4.23: ANFIS Structure for Idol

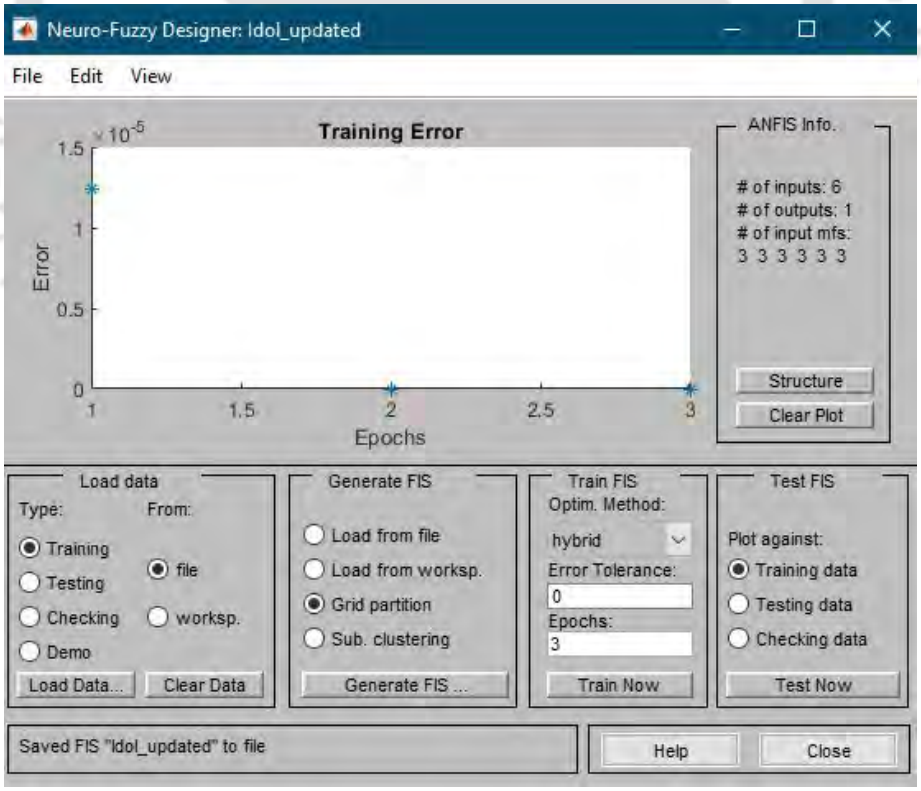


Fig.4.24: Generation of the FIS system

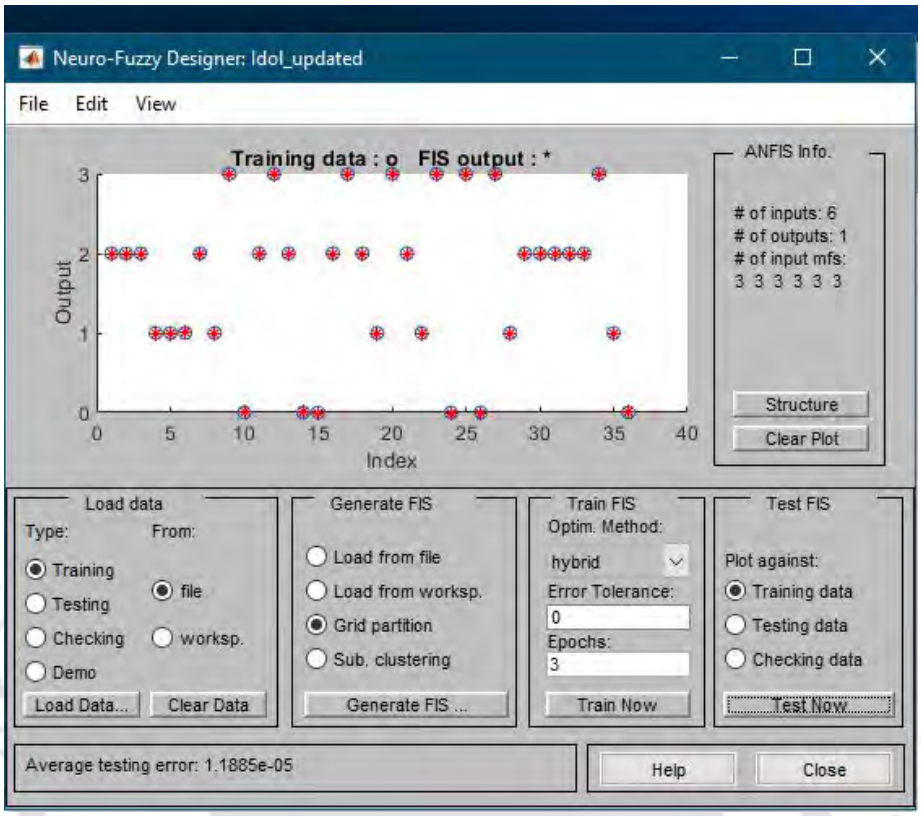


Fig. 4.25 Training vs FIS output

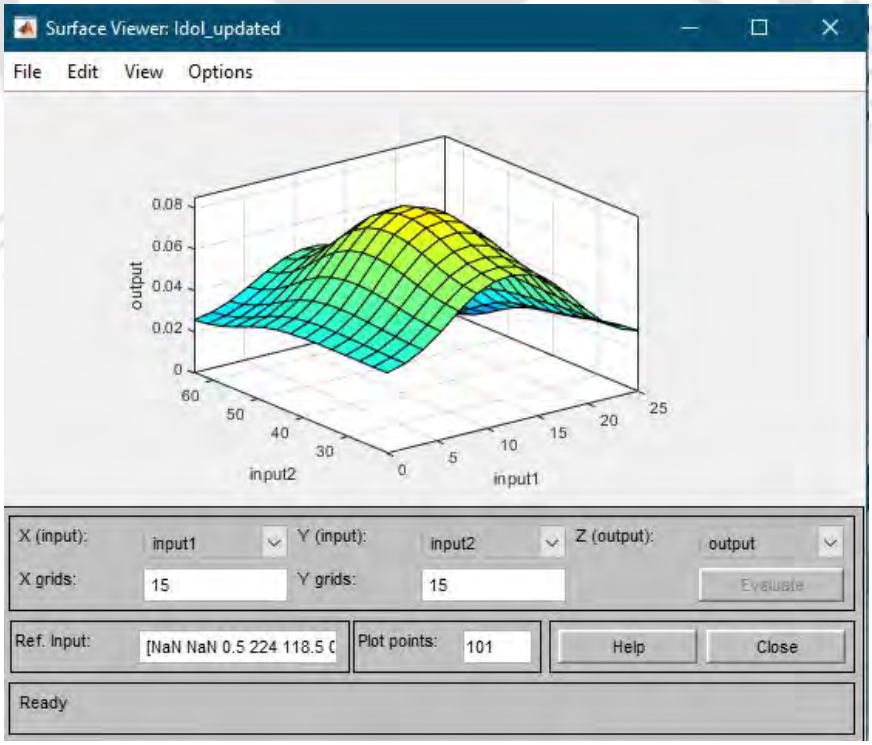


Fig. 4.26: Surface map of the idol making process

```
ANFIS info:
    Number of nodes: 1503
    Number of linear parameters: 729
    Number of nonlinear parameters: 36
    Total number of parameters: 765
    Number of training data pairs: 36
    Number of checking data pairs: 0
    Number of fuzzy rules: 729

Warning: number of data is smaller than number of modifiable parameters

Start training ANFIS ...

   1     1.23589e-05
   2     1.18845e-05

Designated epoch number reached --> ANFIS training completed at epoch 2.

Minimal training RMSE = 0.000012
>>
```

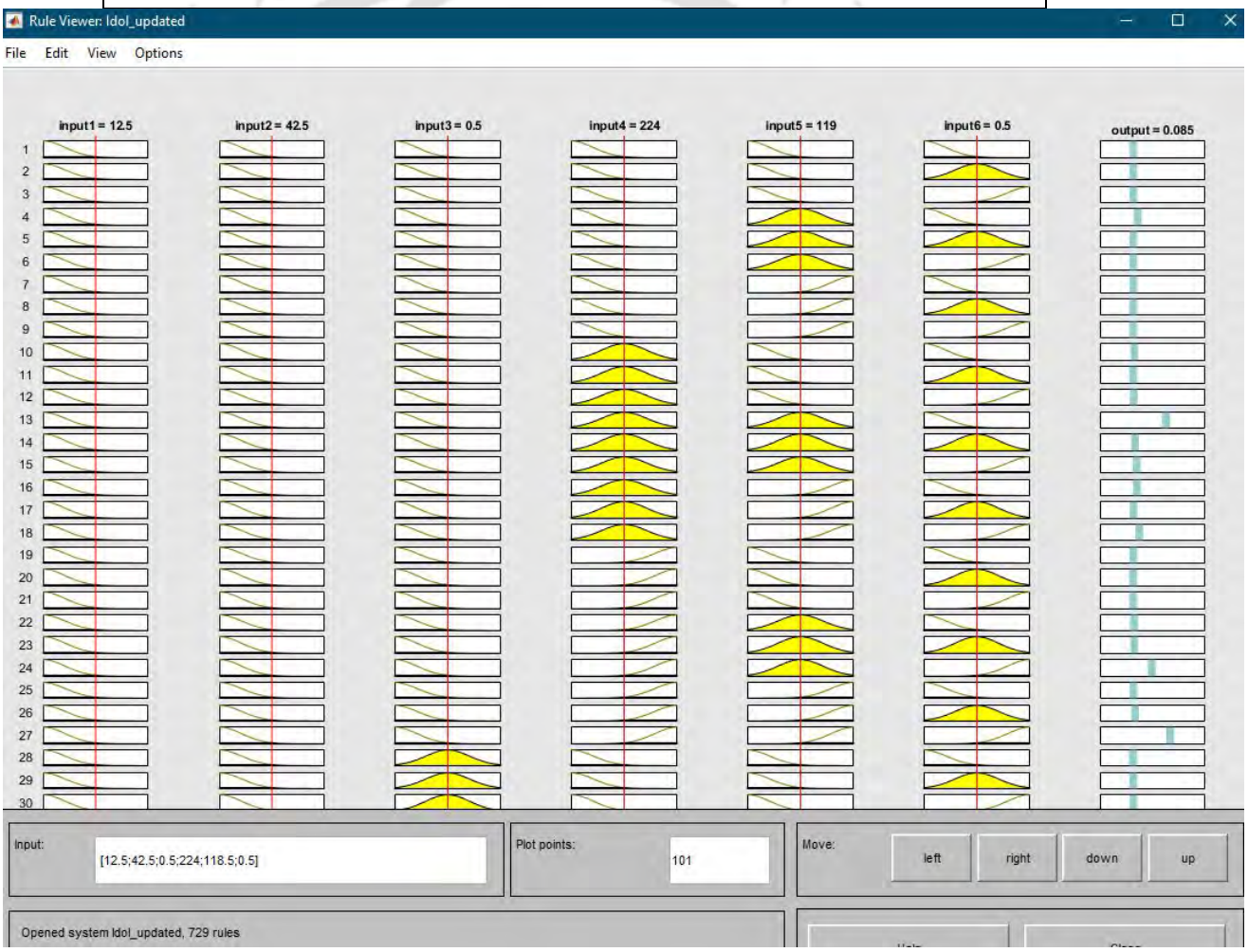


Fig.4.27: Rules for the FIS system for idol making process

Several evaluation metrics were used to compare the performance of the classifiers above. Fig 4.27 shows the Root Mean Square Error (RMSE) of the classifier. RMSE is a performance measure

method that is used to measure the dis-similarity between the results predicted by the classifier and the target value. RMSE value is calculated as below

$$RMSE = \sqrt{\frac{\sum_{i=1}^{n}(y_i - \hat{y}_i)^2}{n}}$$

where y_i represents the target value, $\hat{y}_i$ represents the predicted value by the classifier and n represents the number of the data sample. For the 'idol ANFIS' the minimal training RMSE was found to be 0.000012.

Bamboo-tea bag process: In the chapter-3 the bamboo tea bag making process is discussed. Since the tea bag is used as a commonly used storage container in the Eastern part of India, so the dataset of the tea bag was to mainly concern to this geographical region. As discussed in the section 3.7 tacit markers were generated from the protocol analysis of the ethnographic study. The features like thickness of the bamboo, shape of the design, material of the cover was considered for the analysis of the cases study.

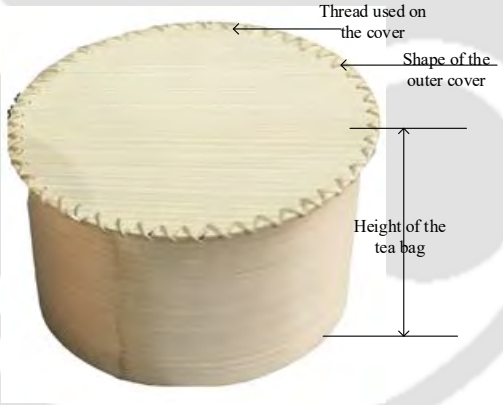


Fig. 4.28: Bamboo tea bag (Source: Author generated)

Table.4.5: Features of the bamboo-tea bag process

Feature ID	Feature Name	Description
F1	Shape (0,1)	Shape of the bamboo tea bag (Uniform=0, Non-uniform=1)
F2	H1	Height of the bag (10 to 15)
F3	T1	Thickness of the strip (1 to 3)
F4	Material of the cover (0,1)	The material of the cover used (0= bamboo,1= plastic)
T(target)	Location (0,1,2,3)	0=North, 1=South, 2=East, 3= West

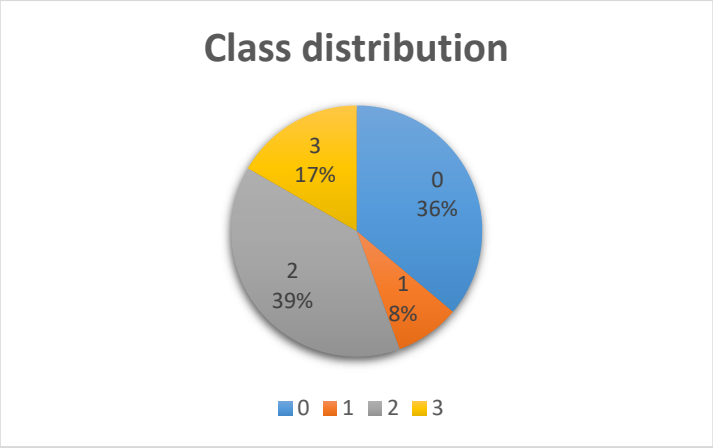


Fig. 4.29: Class distribution of the bamboo-tea bag process

Table. 4.6: Analysis of the bamboo-tea bag process

	Mean	Median	Standard deviation	Maximum	Minimum
F1	0.5	0.5	0.51	1	0
F2	12.58	13	1.52	15	10
F3	1.67	1	0.79	3	1
F4	0.56	1	0.50	1	0
T	1.36	2	1.15	3	0

Table.4.7: Correlation between each attribute and the target attribute

Attribute pairs	Correlation coefficient
F1 and T	0.12
F2 and T	0.15
F3 and T	0.04
F4 and T	0.23

Using MATLAB and ANFIS classifier the tea-bag dataset was analyzed. The initial step was to normalize the dataset features to an interval of 0 to 1. Then the dataset was divided into testing and training data set.

The structure of ANFIS used in this case study consisted of four inputs and a single output. The number of epochs used was 3 with and error tolerance of 0.012. The first and the fifth input functions were assigned three member each and also the other three outputs are assigned three membership functions. The total number of rules generated was 81.

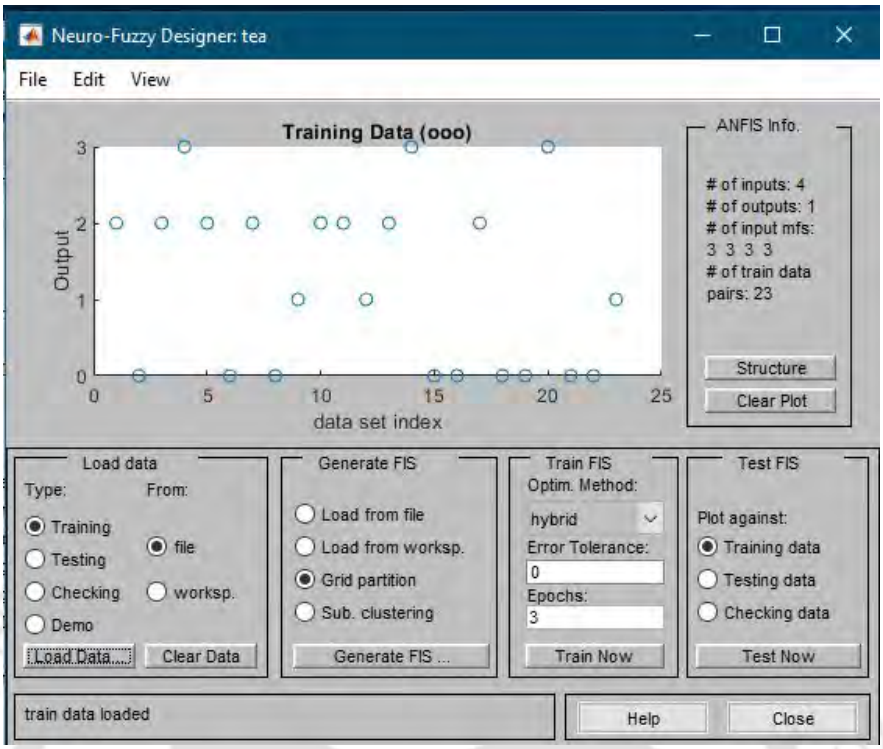


Fig.4.30: Training data for bamboo tea bag

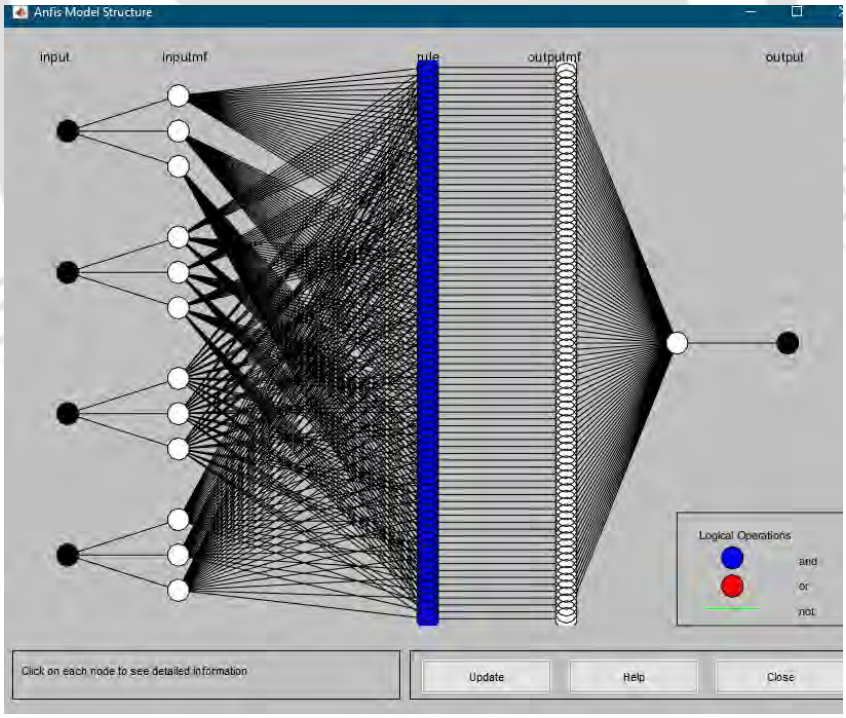


Fig. 4.31: ANFIS structure for the tea bag

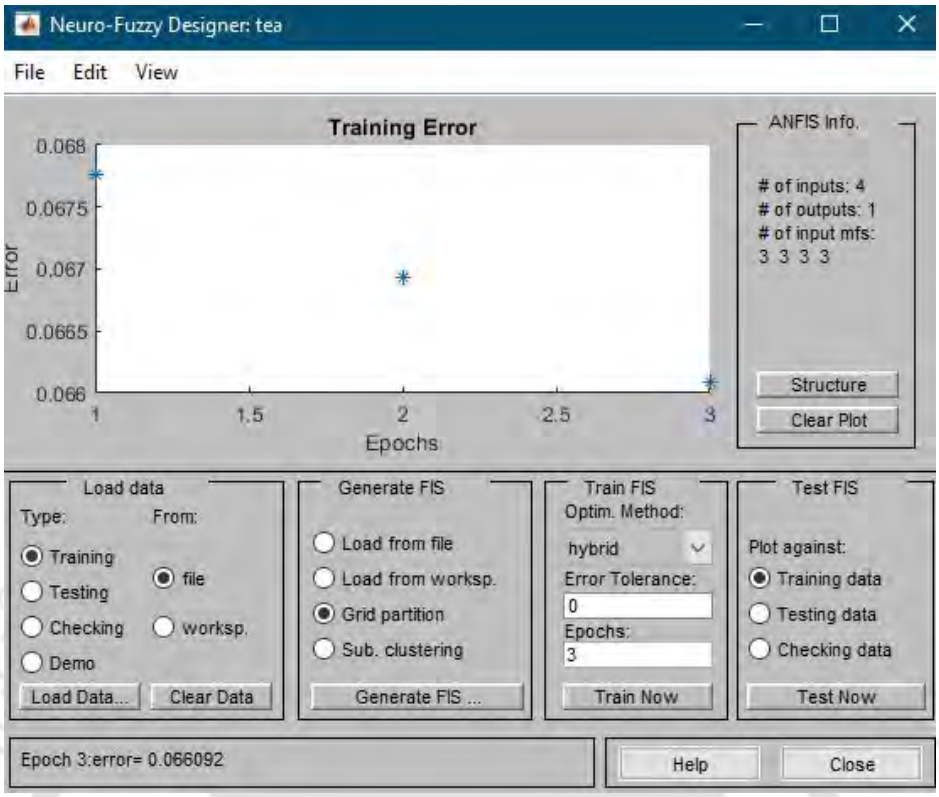


Fig. 4.32: Training error in ANFIS system for tea bag

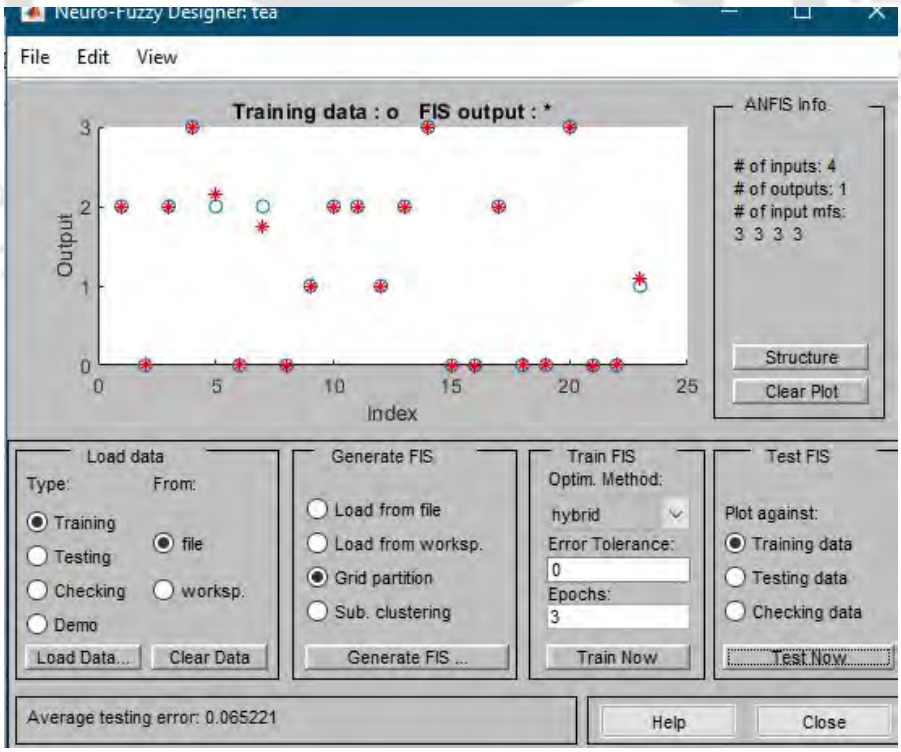


Fig. 4.33: Training vs FIS output for Tea bag

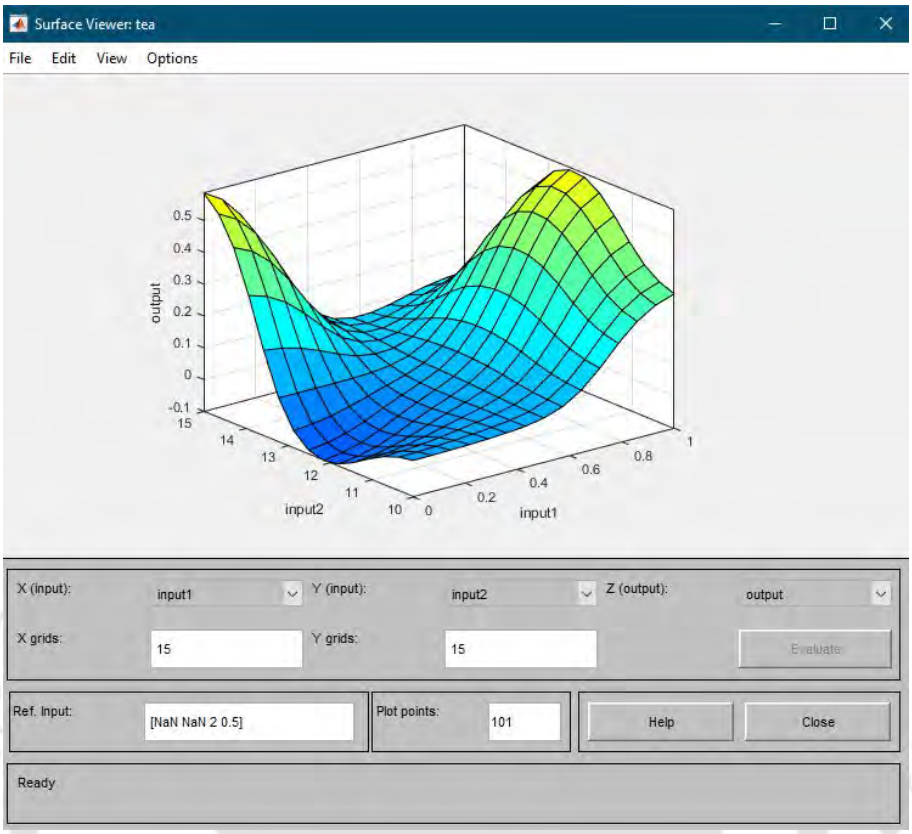


Fig. 4.34: Surface map for tea bag making process

```
   2     0.0669378

Designated epoch number reached --> ANFIS training completed at epoch 2.

Minimal training RMSE = 0.066938

ANFIS info:
    Number of nodes: 193
    Number of linear parameters: 81
    Number of nonlinear parameters: 24
    Total number of parameters: 105
    Number of training data pairs: 23
    Number of checking data pairs: 0
    Number of fuzzy rules: 81

Warning: number of data is smaller than number of modifiable parameters

Start training ANFIS ...

   1     0.0669378
   2     0.0660916

Designated epoch number reached --> ANFIS training completed at epoch 2.

Minimal training RMSE = 0.066092

ANFIS info:
    Number of nodes: 193
    Number of linear parameters: 81
    Number of nonlinear parameters: 24
    Total number of parameters: 105
    Number of training data pairs: 23
    Number of checking data pairs: 0
    Number of fuzzy rules: 81

Warning: number of data is smaller than number of modifiable parameters

Start training ANFIS ...

   1     0.0660916
   2     0.0652213

Designated epoch number reached --> ANFIS training completed at epoch 2.

Minimal training RMSE = 0.065221
>>
```

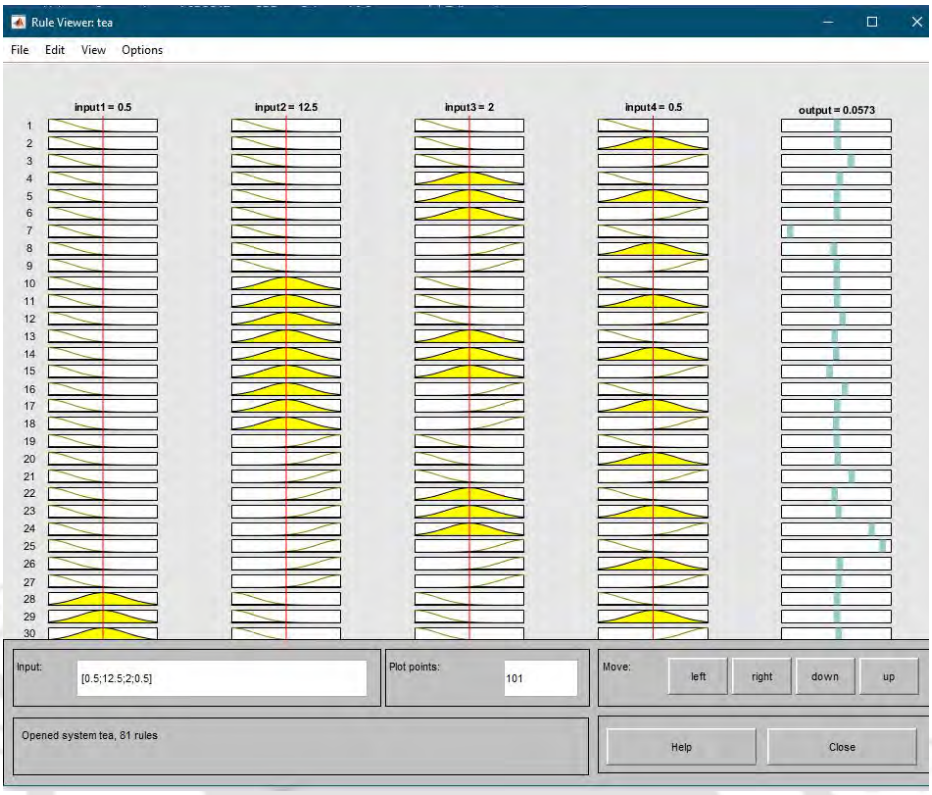


Fig.4.35: Rules for the ANFIS tea bag process

Bamboo curtain making process: The next case study which was considered in this research was the bamboo curtain making process. The bamboo curtain making process also is common to the regions where the bamboo craft is practiced and people usually

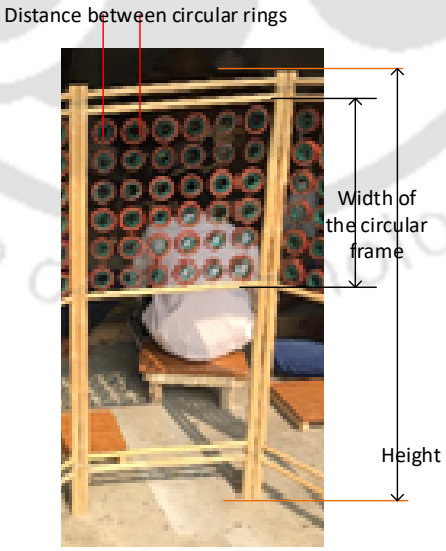


Fig.4.36: Bamboo Curtain stand

Table 4.8: Features of the bamboo curtain process

Feature ID	Feature Name	Description
F1	H1	Height of the stand (152 to 170)
F2	W1	Width of the circular frame (91 to 170)
F3	D1	Distance between the circular rings (10 to 15)
F4	D2	Distance between the frames (40 to 60)
F5	N1	Number of frames (1 to 5)
T(target)	Location (0,1,2,3)	0=North, 1=South, 2=East, 3= West

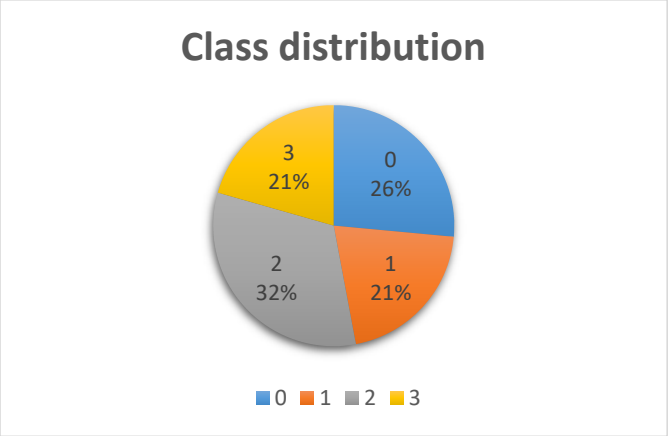


Fig. 4.37: Class distribution of the bamboo-curtain process

Table 4.9: Analysis of the bamboo-tea bag process

	Mean	**Median**	**Standard deviation**	**Maximum**	**Minimum**
F1	162.53	164	5.26	170	152
F2	129.14	124	25.79	170	91
F3	12.64	13	1.58	15	10
F4	50.81	51.5	5.40	60	40
F5	3.06	3	1.47	5	1
T	1.56	2	1.13	3	0

Table 4.10: Correlation between each attribute and the target attribute

Attribute pairs	**Correlation coefficient**
F1 and T	-0.18
F2 and T	0.08
F3 and T	-0.14
F4 and T	0.15
F5 and T	-0,26

Using MATLAB and ANFIS classifier the bamboo curtain stand dataset was analyzed. The initial step was to normalize the dataset features to an interval of 0 to 1. Then the dataset was divided into testing and training data set.

The structure of ANFIS used in this case study consisted of four inputs and a single output. The number of epochs used was 3 with and error tolerance of 0.00001. The first and the fifth input functions were assigned three member each and also the other three outputs are assigned three membership functions. The total number of rules generated was 243.

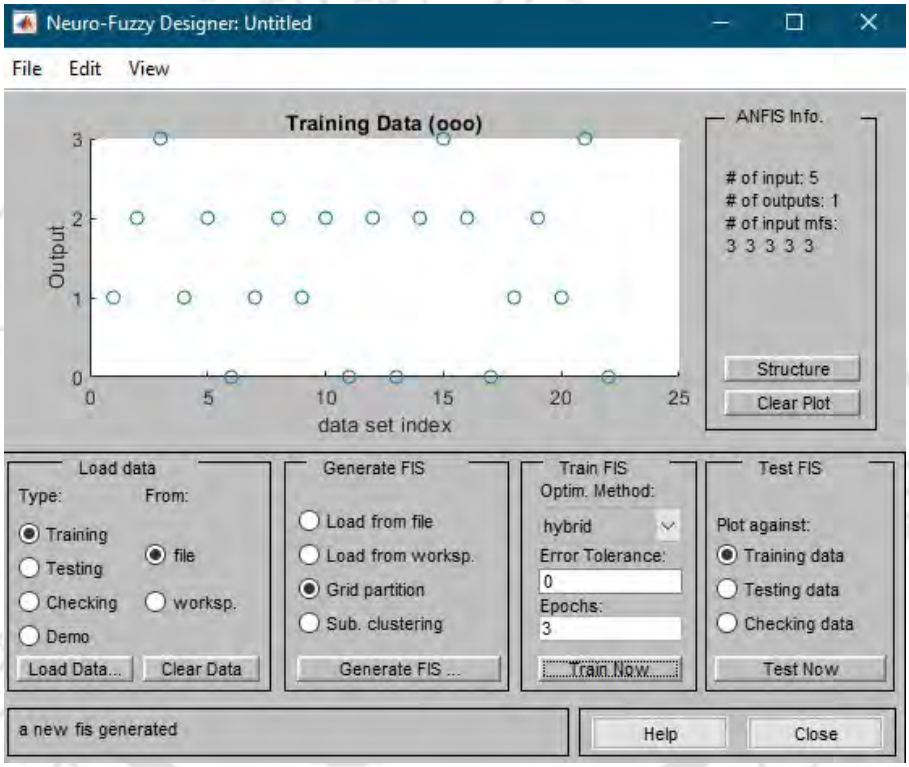


Fig. 4.38: Training data for bamboo curtain stand

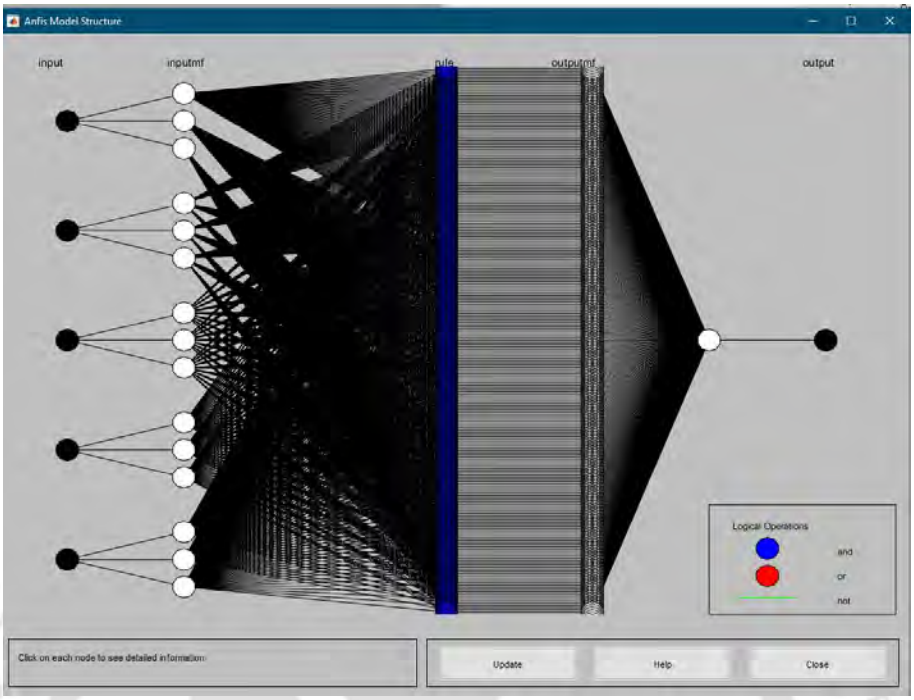


Fig. 4.39: ANFIS structure for the bamboo curtain stand

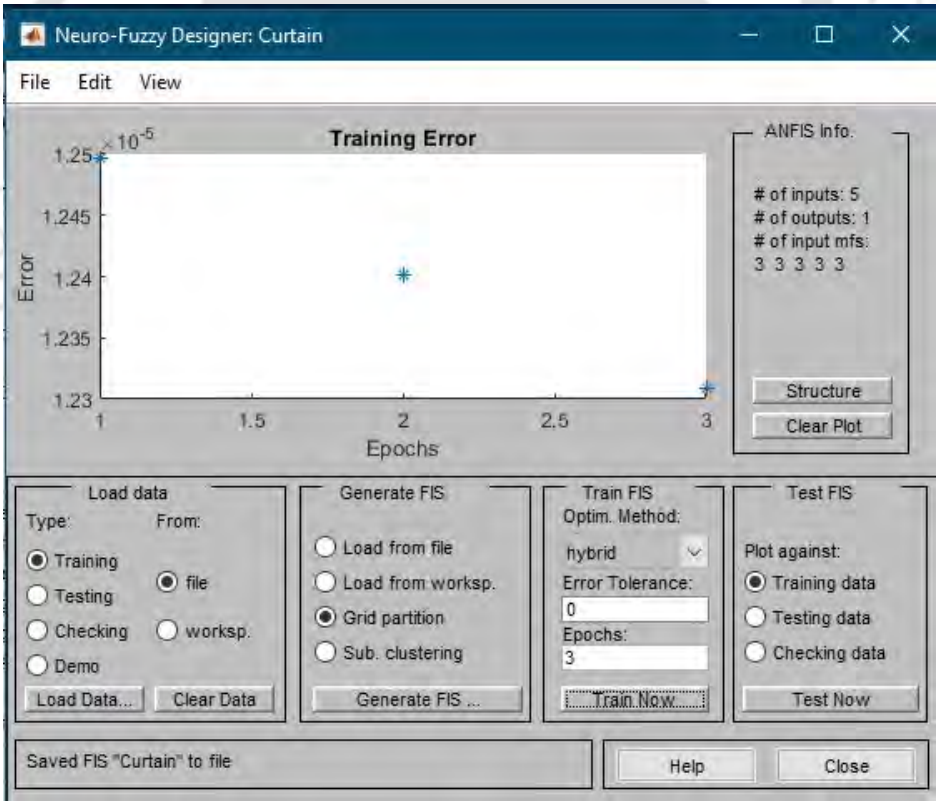


Fig. 4.40: Training error in ANFIS system for Bamboo curtain stand

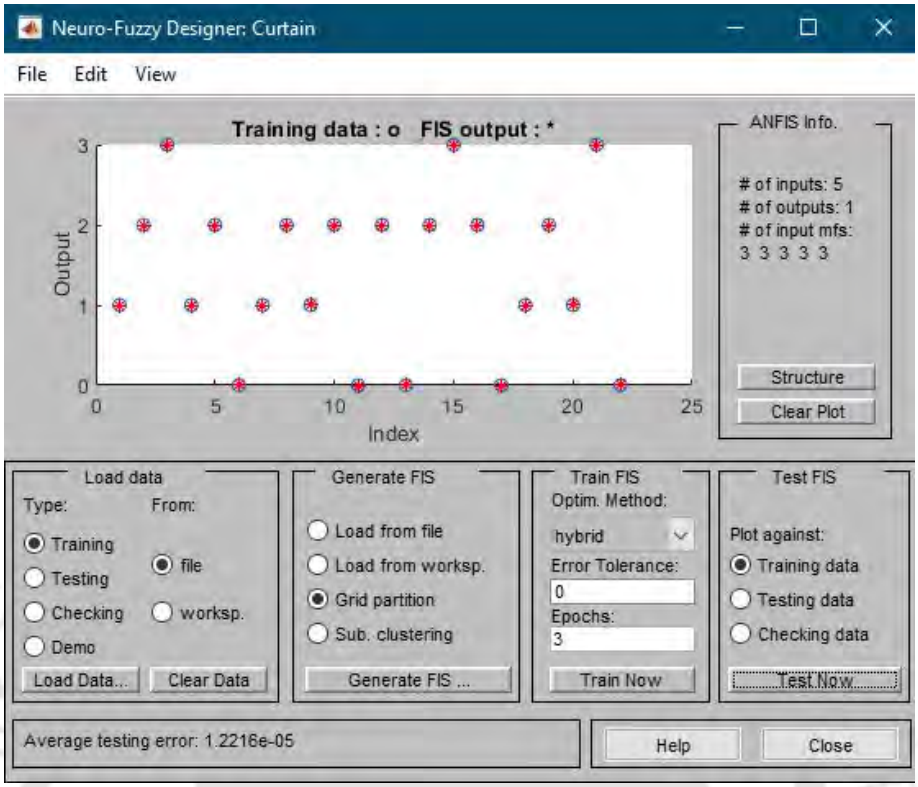
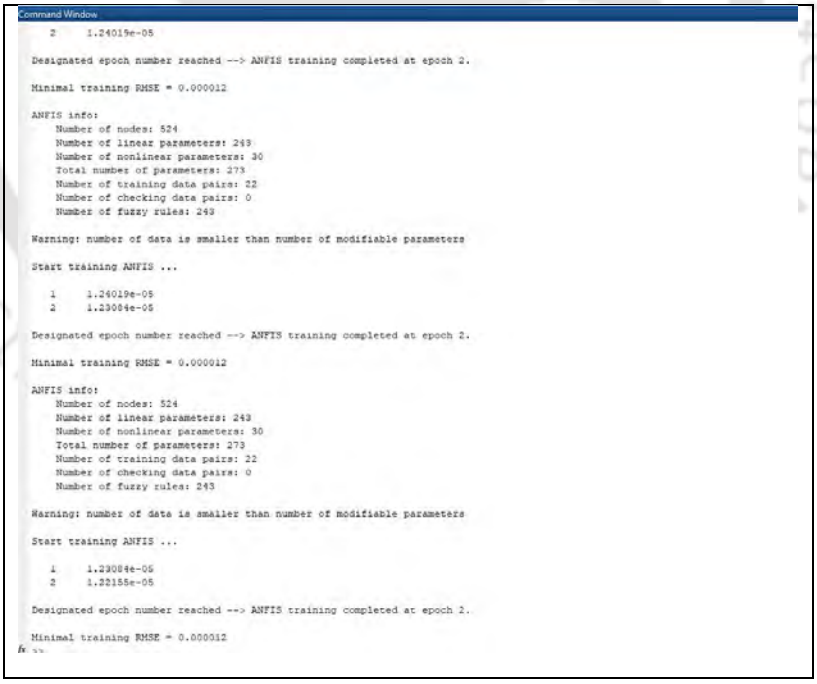


Fig. 4.41: Training vs FIS output for bamboo curtain stand



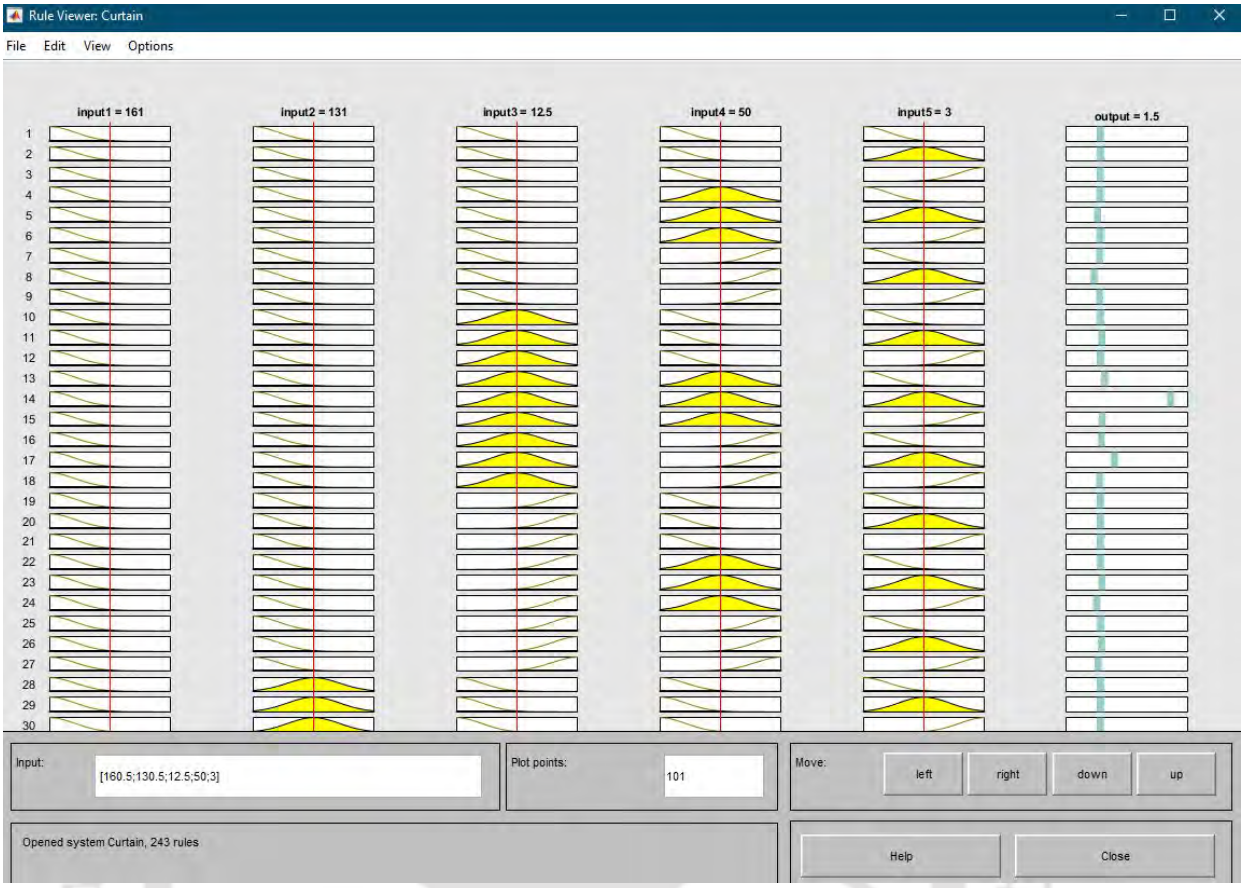


Fig. 4.42: Rules generated for the ANFIS system of bamboo curtain stand

Bamboo basket making process: The ANFIS model was also develop for the bamboo basket making process. The basket making process involves many designs, only simple netting pattern was used in this study.

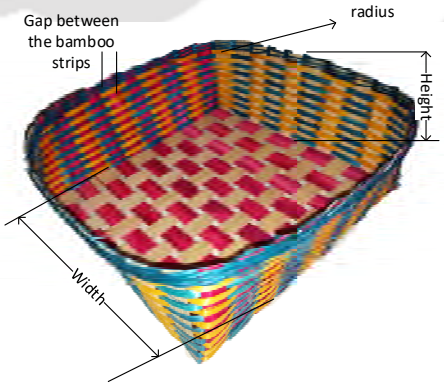


Fig. 4.43: Bamboo basket

Table 4.11: Features of the bamboo basket process

Feature ID	Feature Name	Description
F1	H1	Height of the basket (10 to 50)

F2	W1	Width of the basket (10 to 50)
F3	D1	Gap between the bamboo strips (1 to 3)
F4	R1	Radius of the corners (3 to 10)
F5	N1	Number of colors used (1 to 5)
T(target)	Location (0,1,2,3)	0=North, 1=South, 2=East, 3= West

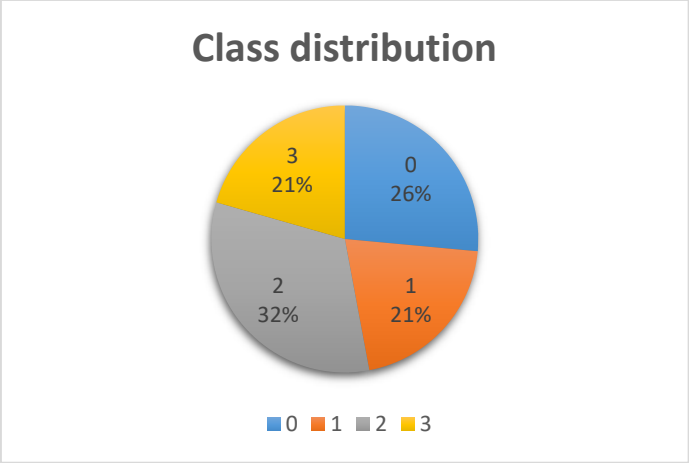


Fig. 4.44: Class distribution of the bamboo-basket process

The class distribution is as illustrated in the Fig. 4.44. As the target group is divided into four regions of the country so the craft was also chosen from the craftsman from the four different parts of the country.

Table. 4.12: Analysis of the bamboo-tea bag process

	Mean	**Median**	**Standard deviation**	**Maximum**	**Minimum**
F1	32.08	33	13.15	50	10
F2	28.53	26	11.25	50	10
F3	1.94	2	0.79	3	1
F4	6.89	7	2.50	10	3
F5	2.94	3	1.43	5	1
T	1.22	1	0.98	3	0

Table 4.13: Correlation between each attribute and the target attribute

Attribute pairs	**Correlation coefficient**
F1 and T	-0.02
F2 and T	0.14
F3 and T	-0.35
F4 and T	-0.33
F5 and T	-0.12

Using MATLAB and ANFIS classifier the bamboo basket dataset was analyzed. The initial step was to normalize the dataset features to an interval of 0 to 1. Then the dataset was divided into testing and training data set.

The structure of ANFIS used in this case study consisted of four inputs and a single output. The number of epochs used was 3 with and error tolerance of 0.00001. The first and the fifth input functions were assigned three member each and also the other three outputs are assigned three membership functions. The total number of rules generated was 243.

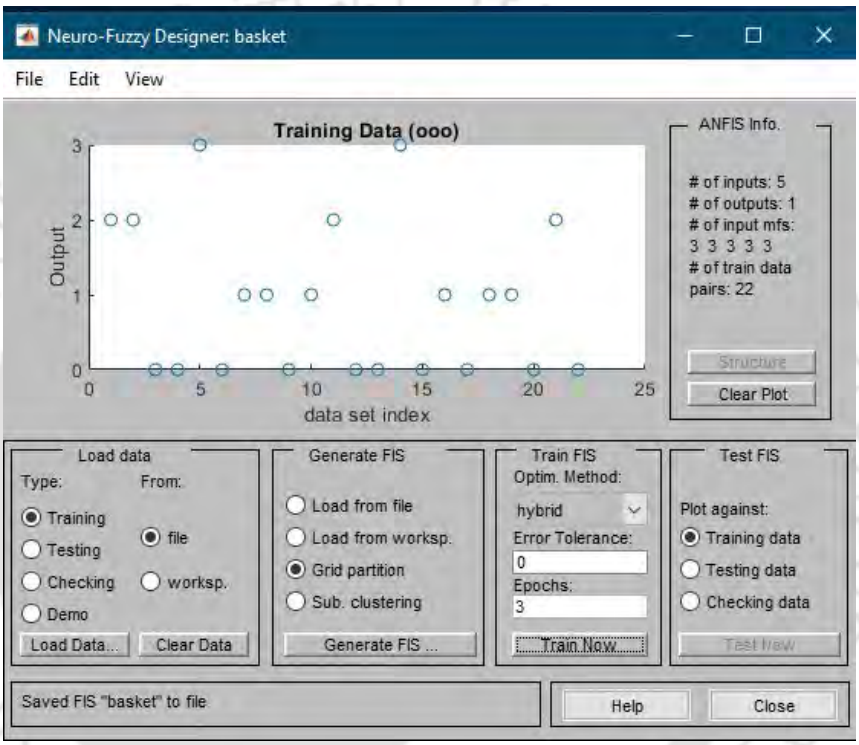


Fig.4.45: Training data loaded for bamboo basket process

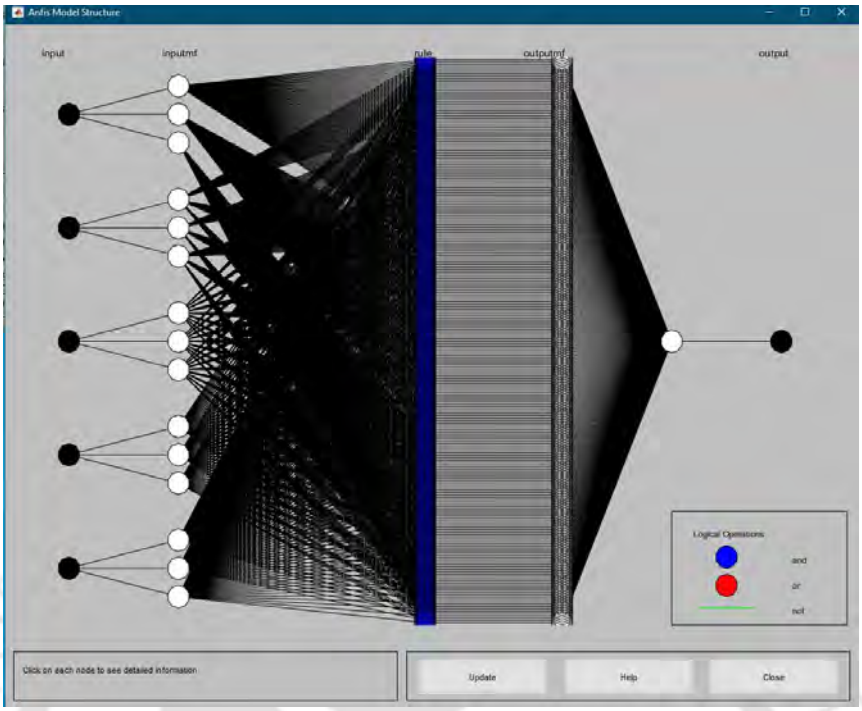


Fig. 4.46: ANFIS structure for the bamboo basket

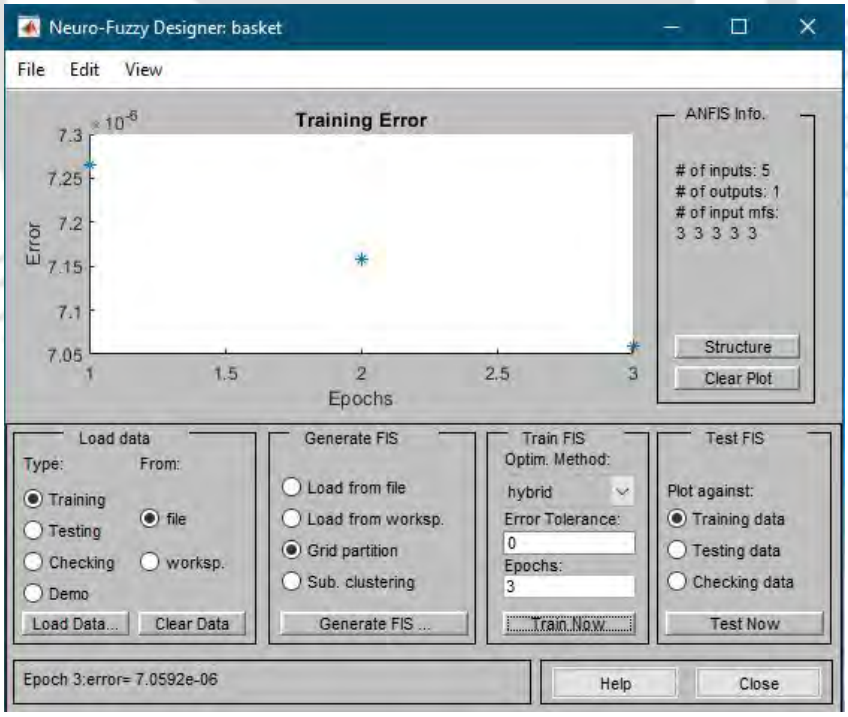


Fig. 4.47: Training error for Bamboo basket data

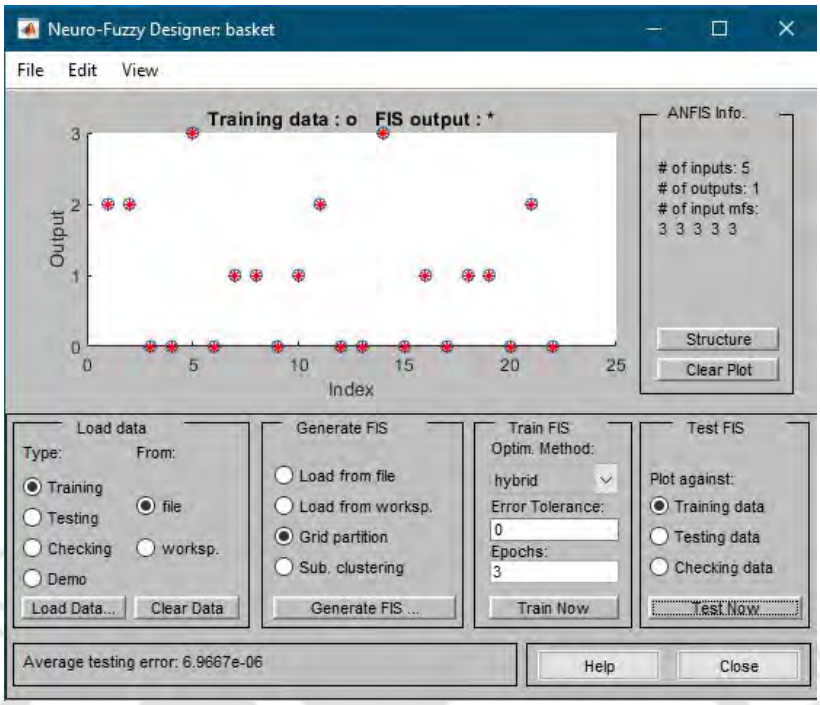


Fig. 4.48: Training Vs FIS Output data for bamboo basket process

```
    2     7.15882e-06

Designated epoch number reached --> ANFIS training completed at epoch 2.

Minimal training RMSE = 0.000007

ANFIS info:
    Number of nodes: 524
    Number of linear parameters: 243
    Number of nonlinear parameters: 30
    Total number of parameters: 273
    Number of training data pairs: 22
    Number of checking data pairs: 0
    Number of fuzzy rules: 243

Warning: number of data is smaller than number of modifiable parameters

Start training ANFIS ...

   1     7.15882e-06
   2     7.05924e-06

Designated epoch number reached --> ANFIS training completed at epoch 2.

Minimal training RMSE = 0.000007

ANFIS info:
    Number of nodes: 524
    Number of linear parameters: 243
    Number of nonlinear parameters: 30
    Total number of parameters: 273
    Number of training data pairs: 22
    Number of checking data pairs: 0
    Number of fuzzy rules: 243

Warning: number of data is smaller than number of modifiable parameters

Start training ANFIS ...

   1     7.05924e-06
   2     6.96668e-06

Designated epoch number reached --> ANFIS training completed at epoch 2.

Minimal training RMSE = 0.000007
fx >>
```

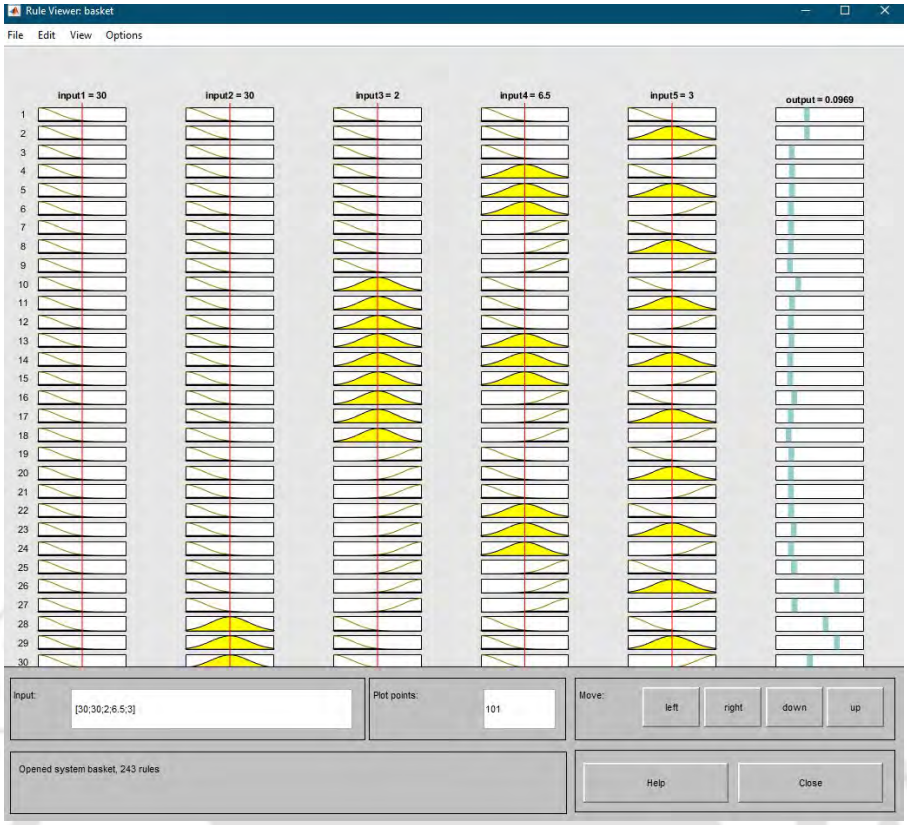


Fig. 4.49: Rules generated for the ANFIS system for bamboo basket process.

4.4 FIS system for all the craft studies:

The FIS system for the next 4 experimental case products was also build in a similar way as described above. The methodology proposed was followed and research questions RQ1 and RQ2 were satisfied so far in this chapter. This is illustrated in the Fig. 4.50 below:

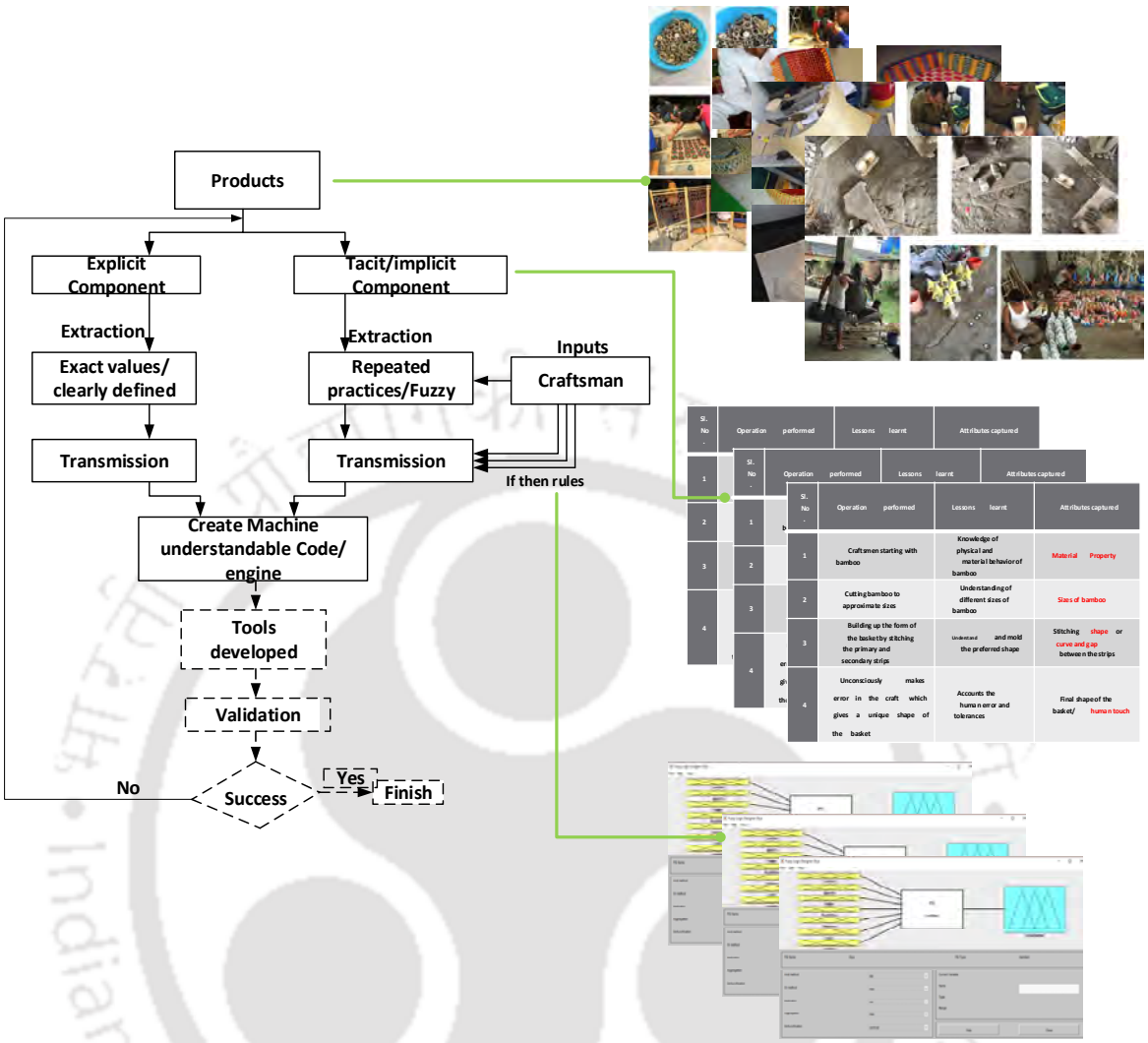


Fig. 4.50: Quick recap of the methodology followed in the research

The FIS system for all the models were developed by the inputs of the crafts and the shape and size of the crafts taken.

4.5 Summary of the chapter

In this chapter the detailed analysis of the craft objects chosen in chapter-3 is illustrated. Taking the case of Diya making, the fuzzy inference system was built and all other fuzzy inference system of the other craft cases were also built. To complete the understanding of the whole craft product transfer learning was applied to the craft cases which was chosen in the chapter-3. The next chapter test the validity of the fuzzy systems and the transfer learning model.

Chapter-5 Adapting machine learning to craft domain

Abstract**:** *This chapter uses the machine learning to the craft domain. The use case studies which was chosen in the chapter3 are used in this chapter. The different features extracted from the objects were used in studying the crafts.*

5.1 Introduction

In the previous section the fuzzy model was developed for the five case studies taken together. There were certain features which were identified in all the case studies but almost all the features were not included in the model. The shape and size features which was considered for the craft case studies taking into account the tacit knowledge of the craftsman. There were also certain other features which we were not able to consider in the fuzzy inference system developed in the section 4.3.

Though the fuzzy inference system categorizes the crafts objects with few features we required certain other features to identify the tacit knowledge.

Machine learning uses the data and produces a program to perform a task. The main aim our thesis is to capture and transfer the tacit knowledge of the craft object so we can use machine learning to capture the features which we were not able to do in the fuzzy inference model above. Machine learning is a branch of Artificial Intelligence which can be used to analyses the data and classify according to certain features. In our thesis the data which was captured from the craftsman in chapter 3 is a combination of both tacit and explicit components. Since we are considering the craft objects as a whole there are many features which can be captured.

Machine learning is concerned with developing algorithms that learn from experience, build models of the environment from the acquired knowledge, and use these models for prediction (Mehryar et.al., 2012). The tacit knowledge of the craftsman is vaguely defined, so machine learning tries to build and understand from the past experiences of the craftsman to approach a possible solution. There are various approaches in which the machine learning algorithm can be applied. The major two categories of approach are the supervised learning and the unsupervised learning.

In the supervised learning the model build is first trained with a required set of data and then the model can be used for prediction. Where as in the unsupervised learning there is no previous set of data in which the model is trained and the model learns from the current data inputted.

Some of the models which are developed using machine learning algorithm are given below:

Artificial Neural Network (ANN): It is a model which is inspired by the neurons in the biological brain. Each connection can transfer a signal like what each neuron in brain does. An artificial neuron that receives a signal can process it and then signal additional artificial neurons connected to it. The signal sent in the neuron is some real number and the output is computed by some non-linear function. The connections between artificial neurons are called edges. There is a weight associated between the different nodes and edges. The weight increases or decreases the strength of the signal at a connection. Artificial neurons may have a threshold such that the signal is only sent if the aggregate signal crosses that threshold. Typically, artificial neurons are aggregated into layers. Different layers may perform different kinds of transformations on their inputs. Signals travel from the first layer (the input layer), to the last layer (the output layer), possibly after traversing the layers multiple times.

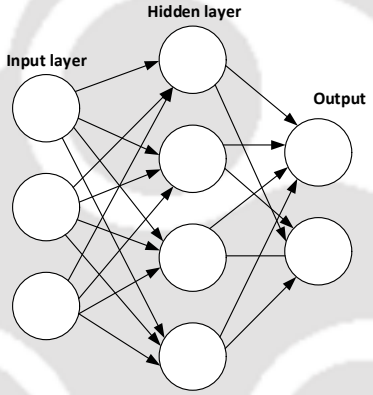


Fig. 5.1: A typical ANN network

Support vector machine (SVM): In this type of model the data is divided into different categories. It's a supervised machine learning technique where the training data is grouped into one of these categories of the model. SVM is sometimes called as Support vector Network.

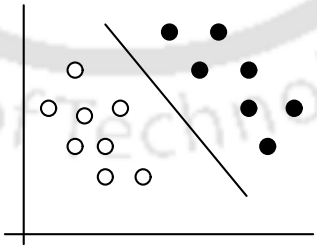


Fig. 5.2: A typical classification of SVM

Deep learning: It is a machine learning technique which uses a cascade of multiple layers of network like ANN to come to a conclusion. The learning can happen in supervised or unsupervised manner.

As the deep learning network consists of series of hidden layers so it becomes easier to classify the craft objects considered.

5.2 Transfer Learning for classification of craft

The next section of the chapter will describe the transfer learning code for the classification of the different craft case studies as described in chapter-3. MATLAB® is used for the transfer learning model. As discussed in the chapter-2 humans have an ability to transfer and understand knowledge unlike any other species in the world. The more related the task are the more it becomes easier to transfer that knowledge. Some of the simplest examples can be: Ability to ride a motor bike can be transferred to learning to drive a car easily. Ability to know how to play a piano can be transferred to easily learning jazz piano. The above cases show that we can easily take some aspects of the knowledge which we know to apply to learn a concept in a similar domain. So, we use transfer of knowledge from what we have known from the past.

Conventional machine learning algorithms were designed to work in isolation and solve a specific task. The models are built from scratch if there is a change in the features. So, transfer learning helps to bridge the gap and implement some of the previous learning to obtain a new desired objective. In our work we wanted to use some of the existing models' knowledge and implement the tacit knowledge obtained from the craftsman to achieve our objective of classification of crafts. Transfer learning can also be defined as "Situation where what has been learned in one setting is exploited to improve generalization in another setting" (Goodfellow et al, 2016). The traditional Machine Learning are isolated and are confined to a single task learning where knowledge (features) is not retained or collected. Where as in the transfer learning the learning of new task depends upon the previous learned tasks. This is illustrated in Fig.5.3.

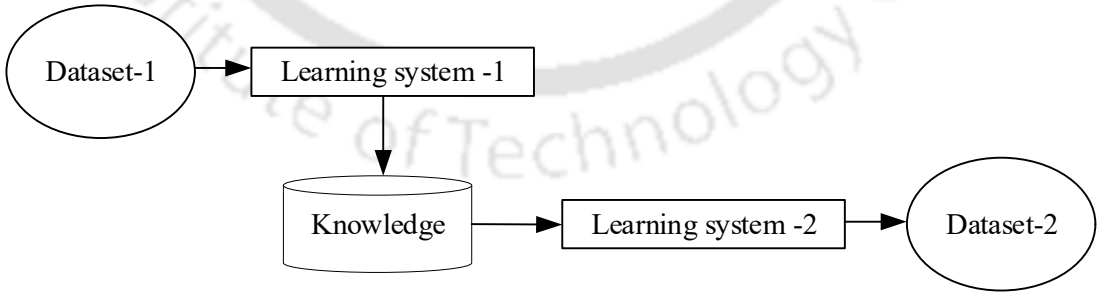


Fig.5.3: Transfer learning concept

Transfer learning involves a domain and a task in that domain (Pan et. al., 2010). The domain D consists of a feature space χ and a marginal probability distribution P(X) over the feature space, where $X= x_1,x_2,x_3,\ldots x_n \; \varepsilon \; \chi$.

For example, for classification of a documents with a bag of words representation, χ is a space of all the document representations, x_i is the i-th term vector corresponding to some document and X is the sample used for the training.

A task T can be defined as the two-element tuple of the label space γ and the objective function η . The objective function can also be denoted by P ($\gamma | \eta$).

Transfer learning is having the ability of utilizing the existing knowledge of a domain and applying some features of it to the new domain. Similar to the learning strategies discussed in the section-3.3. There are different ways in which the transfer learning can be applied. Fig. 5.4 gives strategies of transfer learning.

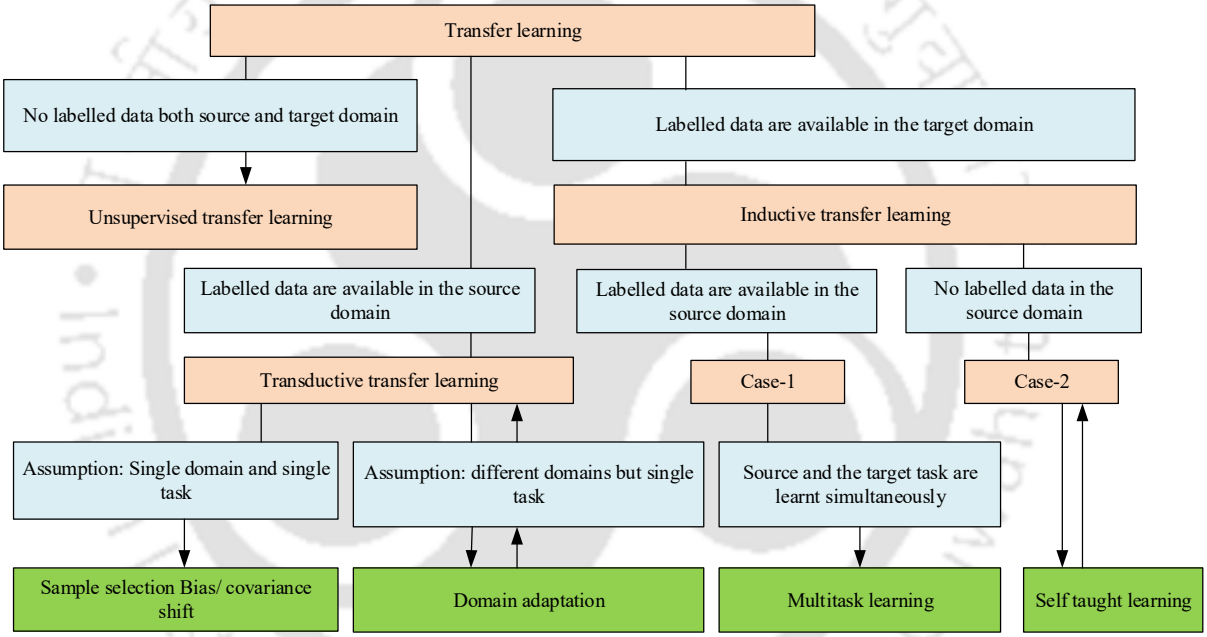


Fig. 5.4: Strategies of transfer learning (Pan et. al, 2010)

So, transfer learning can be categorized as follows:

Inductive transfer learning: In this case the source and the target domains are same but the target tasks are different from the source. The algorithms try to utilize the inductive biases of the source domain to help improve the target task. Depending upon whether the source domain contains labeled data or not, this can be further divided into two subcategories, similar to multitask learning and self-taught learning, respectively.

Unsupervised transfer learning: This setting is similar to inductive transfer itself, with a focus on unsupervised tasks in the target domain. The source and target domains are similar, but the tasks are different. In this scenario, labeled data is unavailable in either of the domains.

Transductive transfer learning: In this case, there are similarities between the source and target tasks, but the corresponding domains are different. In this setting, the source domain has a lot of labeled data, while the target domain has none. This can be further classified into subcategories, referring to settings where either the feature spaces are different or the marginal probabilities.

The idea for implementing the transfer learning for the craft problem here is to take the benefit of the pre-trained network and apply some of its features mixed with the tacit features of the craftsman and obtain the result.

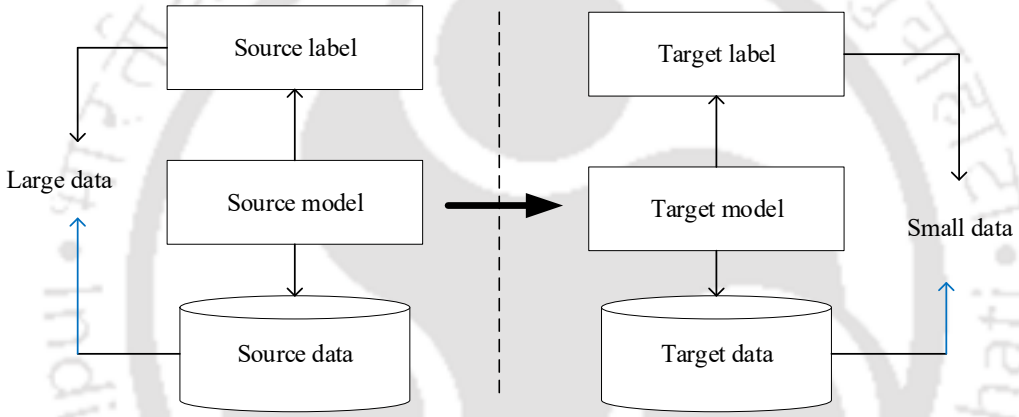


Fig. 5.5 Transfer learning from a source

Our main objective in this chapter is to apply the concept of machine learning to the captured knowledge of the craftsman and then recognize and categorize the objects obtained from the different craftsman. The data consists of five different craft categories as discussed in chapters 3 and 4.

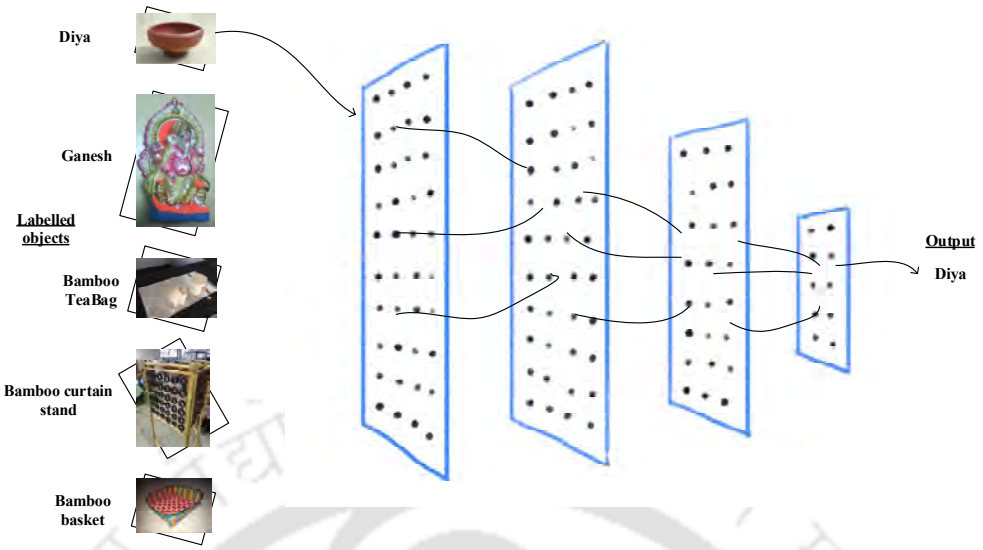


Fig. 5.6: Categorization of craft objects according to labelling

Building the datasets: The first step in the building the model of transfer learning is to import a pre-trained existing database. And then build the present model by extracting required features from that model. Researchers have built many pre-trained models like AlexNet, googleNet, mobilenetv2, Inception-V2, etc. Fine tuning an existing network with transfer learning reduces the computational time as well as helps in saving the costs of collecting a larger database. In our case we have used the pe-trained network AlexNet.

AlexNet has been trained on over millions of image objects and can classify images into 1000 object categories. The network can image as an input and can give the labels of the objects with certain probability. This was necessary for our case in which we wanted to capture all the knowledge in an object. Some of the knowledge which was present with the craftsman are transferred to the crafts built by them with certain passage of time and it gets replicated in the creations created by the craftsman.

Transfer learning is commonly used in deep learning applications. You can take a pretrained network and use it as a starting point to learn a new task. Fine-tuning a network with transfer learning is usually much faster and easier than training a network with randomly initialized weights from scratch. You can quickly transfer learned features to a new task using a smaller number of training images.

Fig. 5.7 explains the process of the transfer learning followed in the section.

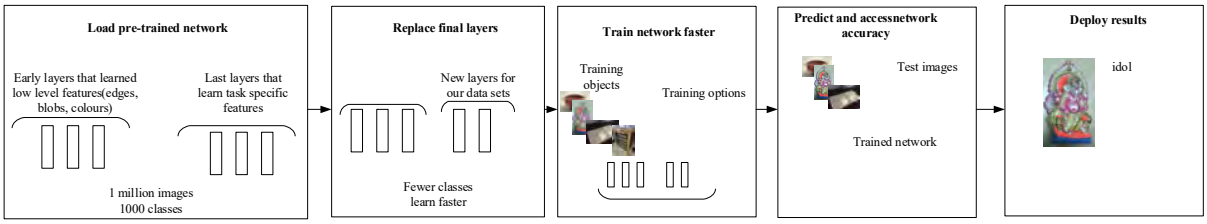


Fig. 5.7: The process of transfer learning followed in this section (Courtesy: MATLAB, 2019)

Loading the data. Unzip and load the new images as an image datastore in MATLAB. imageDatastore automatically labels the images based on folder names and stores the data as an ImageDatastore object. An image datastore enables you to store large image data, including data that does not fit in memory, and efficiently read batches of images during training of a convolutional neural network. The subsequent code in MATLAB is shown below:

```
unzip('Craft.zip');
imds = imageDatastore('Craft', ...
    'IncludeSubfolders',true, ...
    'LabelSource','foldernames');
```

Divide the data into training and validation data sets. Use 70% of the images for training and 30% for validation. splitEachLabel splits the images datastore into two new datastores. This code in the MATLAB is:

```
[imdsTrain,imdsValidation] = splitEachLabel(imds,0.7,'randomized');
```

The small dataset contains 70% of the images as training objects and 30% of objects for validation. The next few lines of the codes displays some of the sample objects. The code for above in MATLAB is:

```
numTrainImages = numel(imdsTrain.Labels);
idx = randperm(numTrainImages,16);
figure
for i = 1:16
    subplot(4,4,i)
    I = readimage(imdsTrain,idx(i));
    imshow(I)
end
```

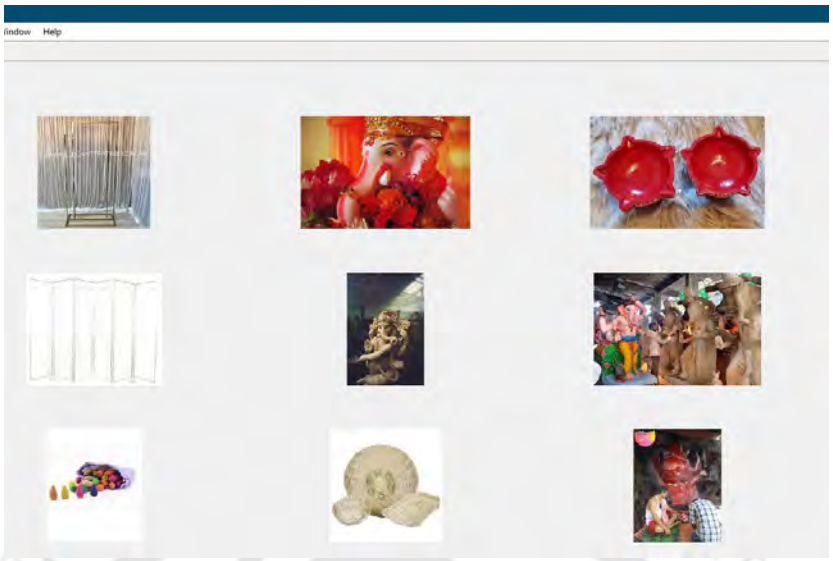


Fig. 5.8: Sample trained objects

Loading the pre-trained network. The pretrained network was then loaded into the system. The pre-trained network is then analyzed. The code in MATLAB for loading AlexNet is:

```
net = alexnet;
analyzeNetwork(net)
inputSize = net.Layers(1).InputSize
```

There were 25 layers in the network which was analyzed and a detailed information about the network layers can be seen in the Fig. 5.9 below.

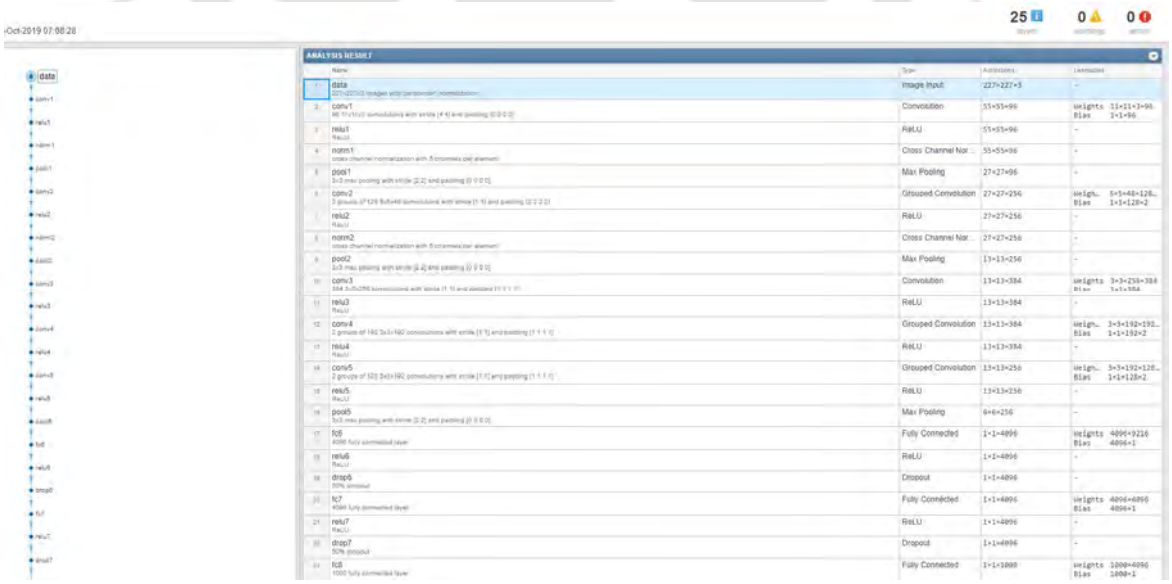


Fig. 5.9: Analysis of pre-trained AlexNet network.

Replacing the final layers. The last three layers of the pre-trained network were replaced with our craft-based layers. The code for the same can be:

```
layersTransfer = net.Layers(1:end-3);
```

The layers were replaced by a fully connected layer, a softmax layer and a classification output layer. The fully connected layer was set to same number of classes as required. In our case it was 5 craft classes. Accessing of the different layers code is:

```
numClasses = numel(categories(imdsTrain.Labels))
layers = [
layersTransfer
fullyConnectedLayer(numClasses,'WeightLearnRateFactor',20,'BiasLearnRateFactor
',20)
       softmaxLayer
       classificationLayer];
```

Training the network. The network required a size of 227 by 227 by 3 as input images. Therefore, the size of the database images which was different were translated using an augmented image datastore. The code is as follows:

```
pixelRange = [-30 30];
imageAugmenter = imageDataAugmenter( ...
    'RandXReflection',true, ...
    'RandXTranslation',pixelRange, ...
    'RandYTranslation',pixelRange);
augimdsTrain = augmentedImageDatastore(inputSize(1:2),imdsTrain, ...
    'DataAugmentation',imageAugmenter);
augimdsValidation = augmentedImageDatastore(inputSize(1:2),imdsValidation);
```

The training options for the earlier layers was specified and validated using the ValidationFrequency during the iterations. The code is as follows:

```
options = trainingOptions('sgdm', ...
    'MiniBatchSize',10, ...
    'MaxEpochs',6, ...
    'InitialLearnRate',1e-4, ...
    'Shuffle','every-epoch', ...
    'ValidationData',augimdsValidation, ...
    'ValidationFrequency',3, ...
    'Verbose',false, ...
    'Plots','training-progress');
netTransfer = trainNetwork(augimdsTrain,layers,options);
```

Fig. 5.10 shows the graph of validation vs training data frequencies of the craft database. Then the classification of the various objects was tested. A sample of the classified objects can be seen in the Fig. 5.11 below.

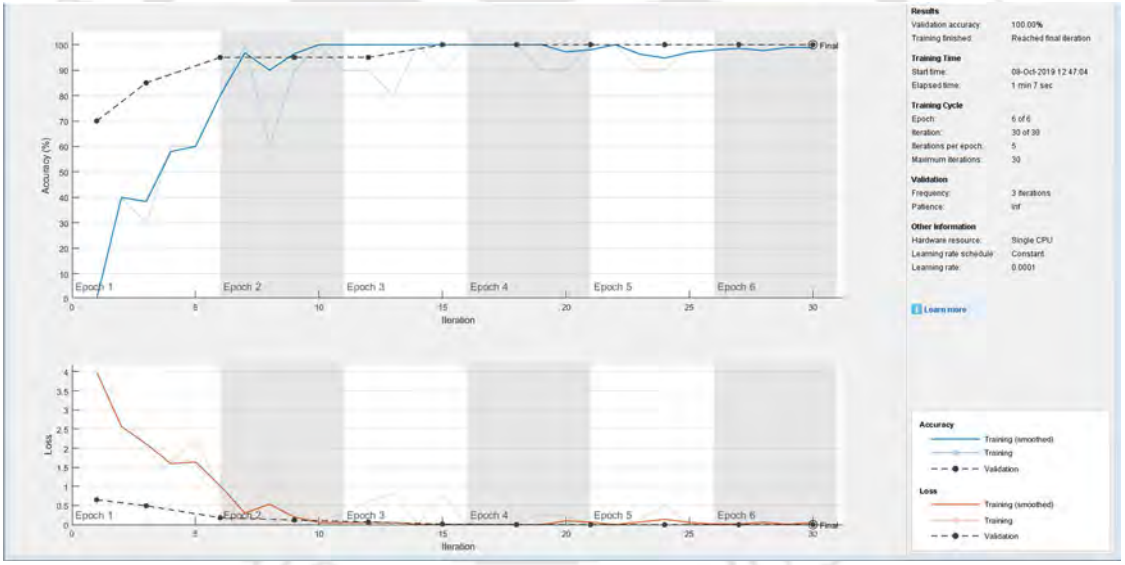


Fig. 5.10: Training Vs Validation craft data

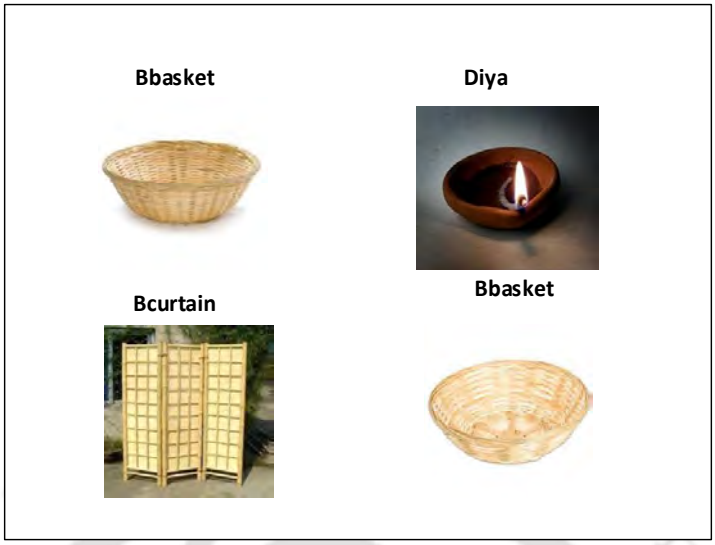


Fig. 5.11 Classification of the objects according to labels

```
[YPred,scores] = classify(netTransfer,augimdsValidation);
idx = randperm(numel(imdsValidation.Files),4);
figure
for i = 1:4
    subplot(2,2,i)
    I = readimage(imdsValidation,idx(i));
    imshow(I)
    label = YPred(idx(i));
    title(string(label));
end
YValidation = imdsValidation.Labels;
accuracy = mean(YPred == YValidation)
```

The final model was accurate enough to classify the objects into the labels predicted with an accuracy of 0.95.

The transfer learning method of modelling the craft case studies was helpful in predicting the crafts according to the labels and since it uses a pre-trained network, so there was less computational resource in usage (see Appendix-B for code). The pre-trained network contained many layers out of which only a few layers were modified to make it suitable for out dataset of craft images from the craft case studies. The program was successful in predicting the different craft objects considered in our case.

5.3 Summary of the chapter

The chapter illustrates the application of transfer learning method (a machine leaning approach) to identify the different knowledge features in the craft objects which include some of the tacit knowledge features discussed in previous chapters. Thus, a digital capture of the embedded tacit in the craft objects is established satisfying research question R2. The next chapter briefly describes a framework proposed for the tacit models developed and its application to different stakeholders.

Chapter-6 Validation of the model

Abstract**:** *This chapter describes the testing of the model which was developed in the chapter-4 with the help of the tacit knowledge of the craftsman. The chapter also describes the proposed framework and the stakeholder involved in this domain.*

6.1 Proposed framework and applications

Upon building of the FIS system and the transfer learning model for the all the 5 experimental craft product cases using the tacit knowledge of the craftsman a framework was proposed for its implementation. Fig.6.1 shows the proposed framework.

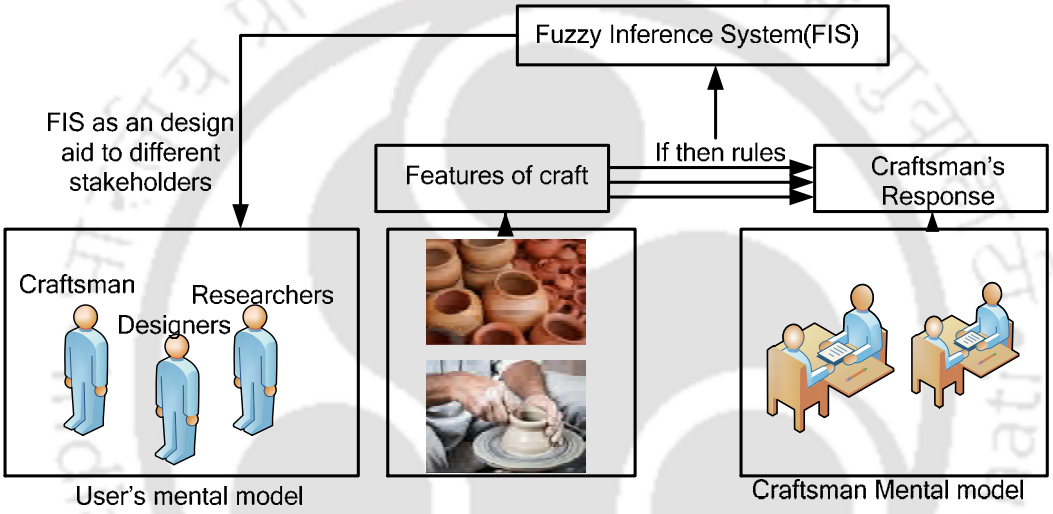


Fig. 6.1: Proposed framework of the FIS using the tacit knowledge of crafts and craftsman (Source: Author generated)

The framework shows the extraction of the features which are formed by the response of the craftsman. The FIS engine can be used for different stakeholders like the designers, researchers and craftsman as shown in the framework. The designers can use the engine to train a new generation of the designers who wanted to work on the crafts design. This can be done by the repeated identification of the craft model by the designers, so that features of it remains embedded as an experience in their min. This helps then to visualize the design while they are building a similar product. The cultural background also plays a major role in the mental model of the designers as they work on the project.

The aim of the framework is to see if the tacit knowledge of the craftsman is transferred to the digital format. By detecting the crafts objects and then classifying them into different categories, different changes in the features of the craft object can be noticed in the objects. This in turns helps to identify minute details which are present in the crafts which are embedded into them by the help of the tacit

knowledge of the craftsman. These details are the signatures marks in the designs of the craftsman working in the particular domain.

Researchers are the other stake holders mentioned in the framework. The frameworks explain the way the tacit knowledge of the craftsman applied using transfer learning and the IF THEN rules. This helps the researchers to add to the existing rule a new set of rules for the new craft products so that the new formed fuzzy logic can classify a greater number of craft items in the existence. The next sections describe the development implementation of fuzzy logic and the transfer learning model to the develop the application.

6.2 Application of the proposed framework to a usable tool

The FIS engine converted the tacit knowledge of the craftsman into the fuzzy values which was only the shape and the size of the product considered. The FIS system can aid the different people working and interested in the tacit knowledge management and capturing it in the crafts domain. The FIS system and the transfer learning model were able to classify the craft product in to different category.

One of the digital applications developed using the above FIS and the Vuforia® augmented reality platform is shown. The schematic diagram followed for the development of the digital tool is shown in the Fig. 6.2

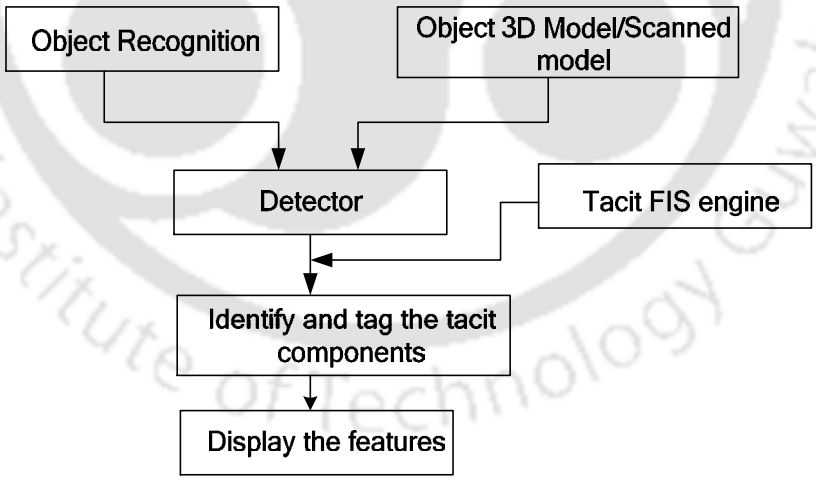


Fig. 6.2: Schematic diagram of the Craft app developed (Source: Author generated)

The first step in the diagram is the object which needs to be classified. This is done with the tacit FIS engine as well as the transfer leaning model described in the chapter-4. The craft object is classified into different tags which was developed by the helps of the ethnic origin as well as the tacit knowledge of the craftsman. The final step in the schematic diagram is the displaying of the

approximate features on the screen of the device or any other application connected. An example of the application was developed and was installed as an app in the android platform.

The users used the application, to see the details about crafts, the application was loaded into the android device. The application follows the schematic diagram as described in the Fig.6.2 above and tries to recognize the object through the camera of the device and the goes to the tacit FIS engine to extract the features present for the identified craft. The final output is shown on the screen of the device. One of the screen shots of the application is shown in the Fig 6.3 below.

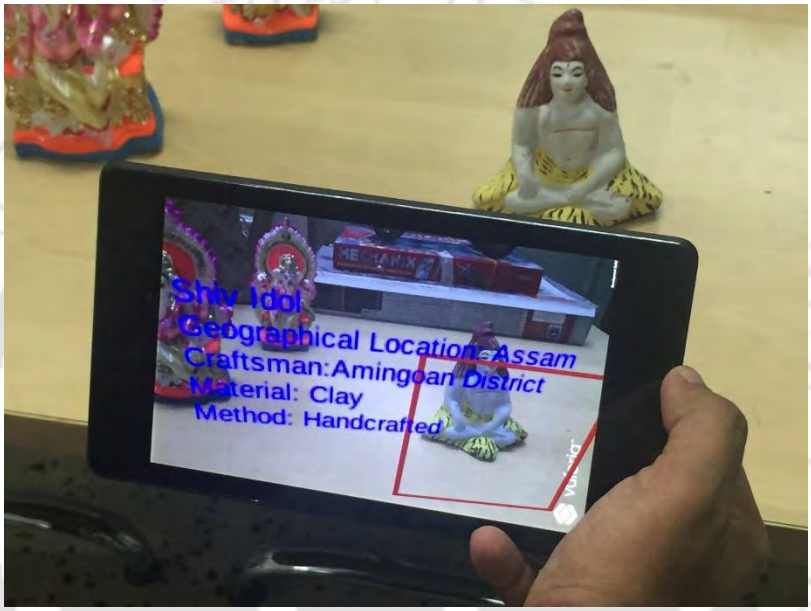


Fig 6.3: Screenshot of the application on the android device (Source: Author generated).

6.3 Transfer of tacit knowledge in usage

To test the application and see the transfer of the tacit knowledge with the help of the device an experiment was conducted.

The main aim of the experiment was to test and study the transfer of the tacit knowledge of the craftsman in the real-world application. The intent was to extract the tacit features and implement it in the modern-day objects.

Around 50 graduate designers were first given a brief introduction into the tacit knowledge and the process of capturing the tacit knowledge by ethnography and protocol analysis tool was briefed to them. Then the application was handed over to them to point out to different objects particularly the 5 craft case studies as mentioned in the thesis in chapter-3.

Result from the experiment.:

After a brief observation of different category of the craft objects, the designers were told to implement it in the modern-day objects in whatever form they wanted. It was observed that the designers were able to transfer some of the tacit knowledge found in the crafts objects to the modern everyday usage products. One of the designed products is shown in the Fig.6.4 by a designer. The product has certain features which was similar to the craft case studies. For example: the outer layer/holder is a weave as similar to the bamboo weave as in case study-1 in chapter-3. The water jug had outer covering made with clay to reduce the transfer of hear and provide a thermos effect. The upper portion of the jug is similar to the nose radius of the Diya which is easier to pour the water in a streamline fashion.

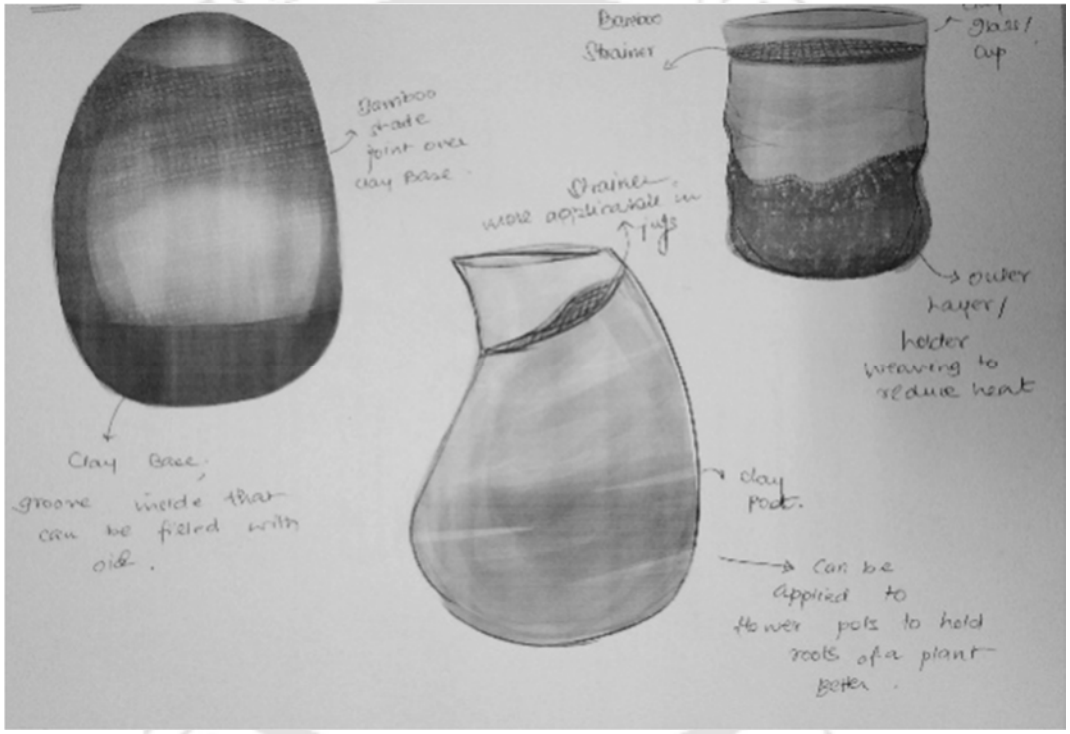


Fig.6.4: Application of tacit knowledge to modern jug for holding water (Source: Author generated)

Another example of the transfer of the tacit knowledge is shown in the Fig. 6.5.

Fig. 6.5: Embedded tacit features into modern day pen (Source: Author generated)

One of the designers tried to implement the bamboo and the designs on it to make a pattern in a pen. This was the simplest of application which can be seen and observed and the transfer of the tacit knowledge of the craftsman.

Fig. 6.6: Embedded tacit features into modern day water bottle (Source: Author generated)

Fig.6.6 shows another product which is a water bottle holder to hold water. The bottom of the water bottle is in the shape of the circular chips as was seen in the bamboo curtain stand case study. It serves as a stand to the water bottle if it is kept on a flat bed. Likewise, several ideas having the tacit instinct of the craftsman product were developed into the modern products.

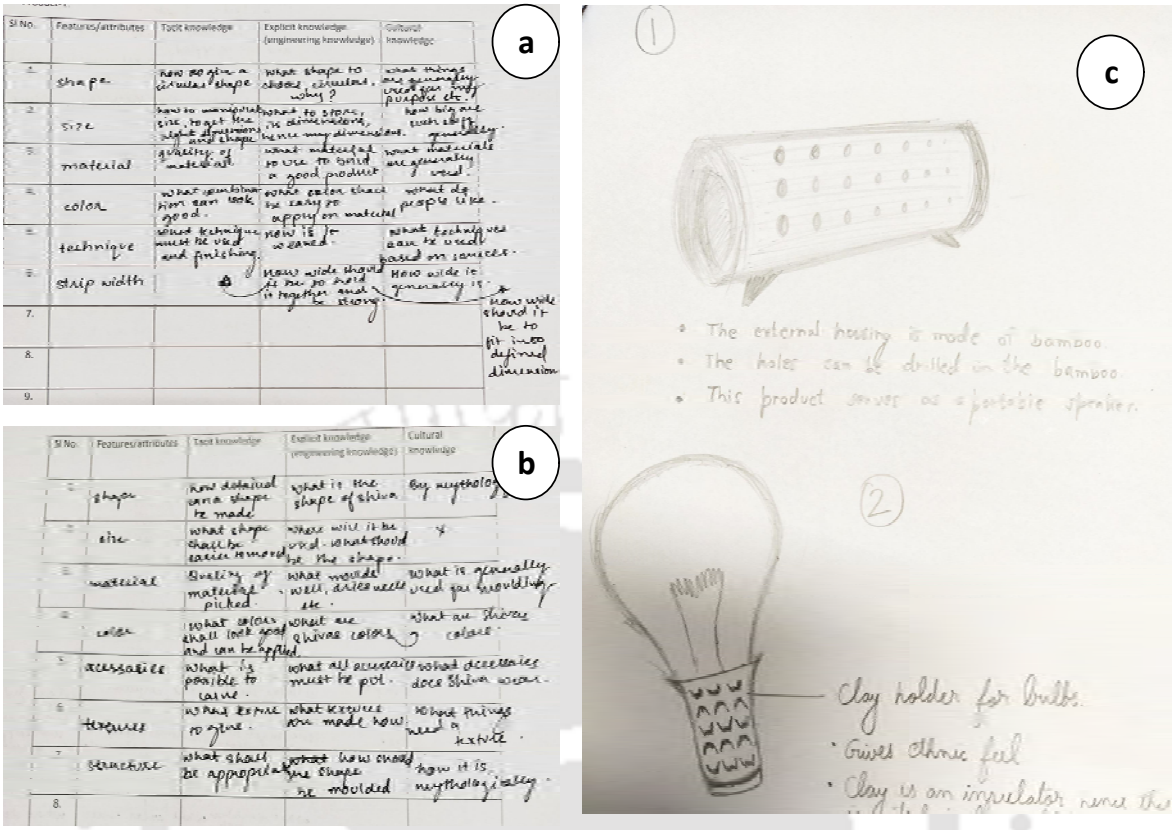


Fig. 6.7: a, b Tacit idea which are captured, c. the Implementation of the idea into product (speaker, light bulb holder).

Fig. 6.7 a, b illustrates the tacit knowledge which was captured from the crafts studies. Some of the questions and inferences drawn by the designer were

- How to get the desired shape of the craft?
- How detailed can the shape be made?
- How is it weaved?
- What is the material which are generally used in the crafts?
- What is the easier shape which can be made on this craft?

The gathered tacit knowledge was implemented to the designs of products as illustrated in Fig. 6.7 c. It shows the speaker which can be designed with features such as: the external housing made up of bamboo, some holes which are equidistant add to the aesthetic of the product. In the second product some features like: clay holding for the bulbs which gives an ethnic feeling as well as sustainable. Clay is insulator and more electrically stable, it can be used by the designers for interior decoration.

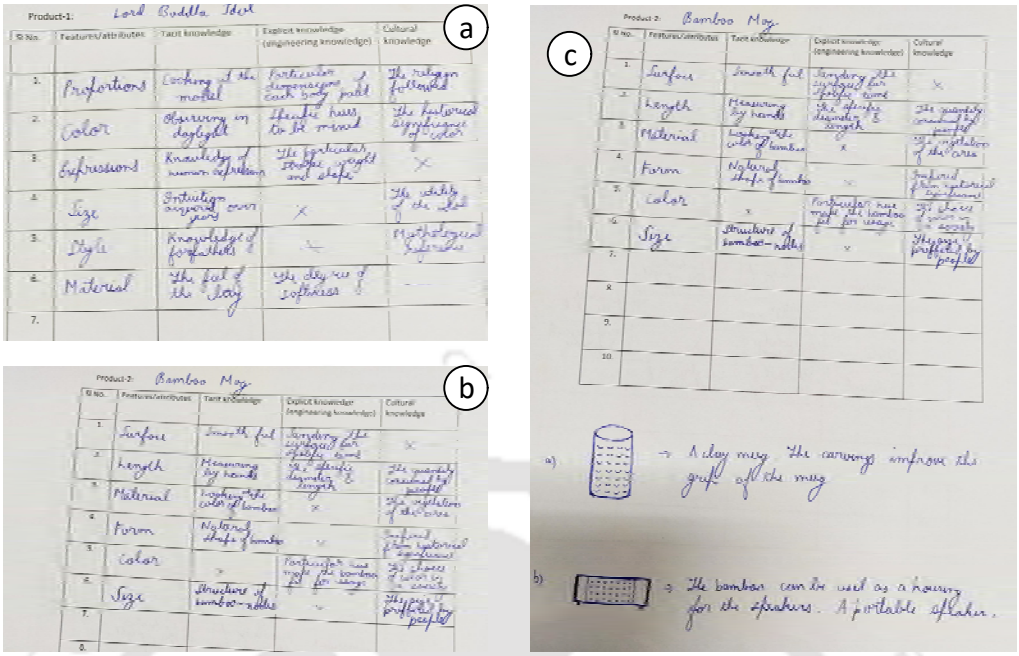


Fig. 6.8: a, b Tacit idea which are captured, c. the Implementation of the idea into product (Clay mug).

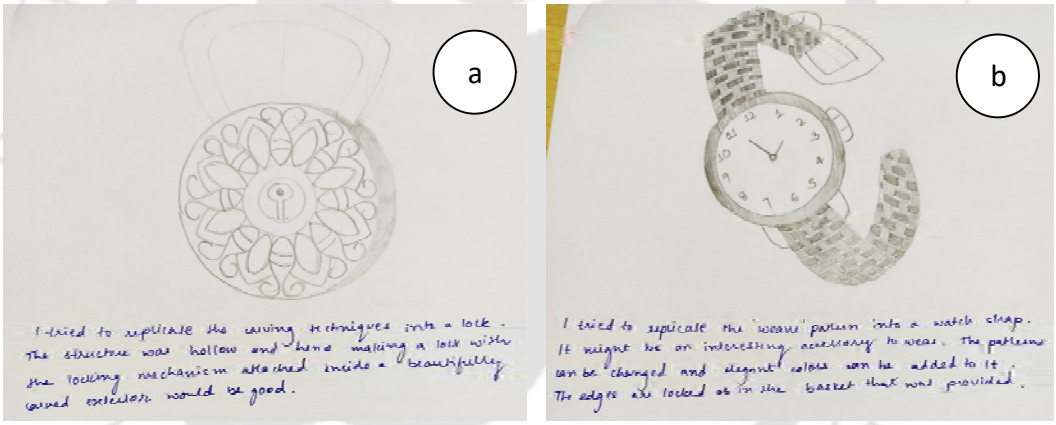


Fig. 6.9: a, b tacit features applied to lock and a watch design

Fig. 6.8 and 6.9 also illustrates some tacit features which are applied to the design of a clay mug, lock and modern watch.

6.4 Summary of the chapter

This chapter provides proposed framework which had the implementation of the FIS engine and the transfer learning developed in the previous chapter. The chapter also describes the application of the tacit FIS and object recognition using transfer learning. The validation in the transfer of tacit knowledge in the modern usage of the products can also be seen in this chapter.

Chapter-7 Discussions and Conclusion

Abstract: *In the previous chapter a proposed framework from the present thesis was discussed and the transfer of tacit knowledge was also discussed. This chapter highlights the contributions of the thesis in terms of both practical and theoretical ways. The conclusions are given at the end of the chapter*.

7.1 Discussion

The nature of the knowledge existing in the skill-based industry was discussed in the thesis particularly focusing on the craft domain. The difficulties in the transfer of these knowledge was also covered in this thesis. A major portion of the thesis was devoted into the identification of these knowledges namely tacit and the explicit knowledge.

After the identification of the knowledge bases the different craft products and the craftsman were identified for the study. The literature survey described that it was difficult to trap this knowledge which is tacit. But it also showed that way by which the knowledge was transferred from one form to another by Nonaka's model of knowledge transfer.

The major portions of the past work related to the tacit knowledge was carried out in the corporate sector and very little attention was given to the craft domain.

The research tries to build this narrow gap between the craft and the modern industrial sectors. The application of this tacit knowledge becomes very important if we are considering this sector which is surviving because of the skills of the craftsman.

These skills of the craftsman are important and they can be lost in the demise of the craftsman itself, so it was necessary to focus into this sector. The thesis tries to contribute to this area by building a healthy relation between the skill and the digital world which mainly consisted of modern-day gadgets and equipment.

Some of the points which can be noted down from this thesis are:

- Identifying the skills which are tacit in nature and trying to develop or transfer it for sustaining it.
- Since the skills and the crafts are having design elements in them, so identifying the design elements are also important for a researcher working in this area.
- A framework was proposed in the thesis which tried to identify the stakeholders in this area.
- A digital method was developed which included the FIS tacit engine and the object craft recognition using transfer learning.

- The existing richness of the culture in the crafts also plays a major role in its tacit component which was also discussed in this thesis.
- The application of the tacit knowledge of the craftsman to the modern-day product can help to make it active and alive.
- Tacit knowledge helps to build the confidence in the designer and the craftsman while performing a art or a design or making a craft.

7.2 Conclusion

The different research questions raised in the chapter-2 section 2.7.1 were

RQ1: How do we identify different components of knowledge (especially tacit knowledge) from live crafts and artefacts?

RQ2: How to Isolate and transfer tacit component from artefacts?

RQ3: How to program/digitize tacit knowledge component such that

- it can be utilized by a design researcher wanting to continue tacit knowledge and traditional crafts for the purpose of training a new generation of craftsman
- Common user can use it
- It is used by a heritage museum for identifying craft artefacts, categorizations and classification of crafts

For the research question R1 and R2 the thesis provided certain methods where protocol analysis was used in the extraction of the tacit knowledge which also involved the craftsman.

The research question R3 was also answered in the thesis by identifying the tacit knowledge and implementing the FIS model into it. The craft object classification was also carried out to identify all the features which was not done in the FIS model with the help of transfer learning.

The experience or the practice which a craftsman is similar to the tacit knowledge which is expressed as skills in his work are the once which we wanted to capture and transfer. This was achieved by implementing it in the modern-day products and thus proving that tacit knowledge can be transferred from one form to another.

Chapter-8 Contributions from the thesis

8.1 Consolidated findings of the research

The finding of the research are as follows:

1. The intangible cultural heritage is present in almost all the traditional craft artefacts. The identification of the cultural heritage requires a user to have a deep understanding of both the implicit as well as the explicit knowledge of the craft.
2. There is a lack of universal design heuristics to understand the tacit knowledge involved in the craft making process. It varies from one craft to another and is very complex in nature. There lacks a method to document and manage the tacit knowledge in the craft domain.
3. The study also suggested that there is a lack interest among the people towards craft artefacts due to mass produced goods and mass globalization.
4. The identification and implementation of the tacit knowledge from the crafts process towards modern day objects and digital tools give a brighter scope to creative product designs.

8.2 Limitation of the thesis and scope of future works

1. The study was only confined to the craft domain. It required multidisciplinary research groups and more time to capture and digitize related artefacts.
2. The fuzzy logic has to be written for other category of products in other domain taken for future, in a similar manner to make the system more robust.
3. Errors can occur during tacit knowledge capture and at system level during machine recognition.
4. Government policies can be implemented taking initiative to conserve crafts digitally.
5. The FIS system developed can be implemented to future modern-day products so that the tacit knowledge can be carried forward.

8.3 Major Contributions from the thesis

The four major contribution from the thesis are as follows:

1. The method to document and manage the tacit knowledge in the design was presented.
2. A step by step approach to identify, isolate, capture the handicraft and embed the tacit knowledge into the process was studied.

3. An AR (Augmented Reality) based tool to study the craft artefact for the designers, historians and craft restructure was developed.

The development of modern-day products embedding the tacit knowledge of the crafts was also achieved.

Appendix -A

Field work extract

Diya making work.

Researcher:

Arrives at the location to do the ethnography study on the craftsman. The location was besides the river banks of the Brahmaputra. The location of the craftsman is divided from the river by a roadway. The river bank of the Brahmaputra contains different varieties of soil, clay, sand as well as the gravels and stones.

Researcher:

As soon as I arrive at the location the craftsman was preparing to take up a task of making the diya as he had received an fresh order. He asks the craftsman for his name and took his permission for the ethnography study.

Craftsman:

My name is Manoj.

Researcher:

How many years have you been working in the pottery industry?

Craftsman:

It has been more than 20 years that I have been working on the pottery. This was from the time when I was in Bihar and then shifted to Assam.

Researcher:

Why did you shift to Assam?

Craftsman:

I shifted to Assam looking for better opportunities in this side of the country.

Researcher:

How many children are there for you?

Craftsman:

I have three children. One of them is helping me in the pottery works and the other two are engaged in taxi driving and Kirana shop.

Researcher:

Why did not they get and help you in the pottery industry?

Craftsman:

They wanted to do other work and so they did not take pottery work.

In the mean while Craftsman daughter-in-law brought the tea for both craftsman and the researcher. The craftsman workplace was a kutcha house made up of mud. The house had two racks which were also made up of mud. These racks were stacks of the pottery items. The items include the large pottery bases, pottery items needed during worship in Hindu temples, items which were needed during the cremation of dead bodies. The workplace has a pottery wheel which was made up of wood. This was similar to the wheel which was used in the old bullock carts. After finishing up the tea.

Researcher:

Where do you get orders from?

Craftsman:

I usually get order from the local tea vendors who require utensils called kullad. The orders range from 100-200 per day. The second case of orders are diyas from shops near temple. The third type of orders are from the cremation ground where they require the pottery pots for the religious activities.

Bamboo basket making process

The bamboo craft making process was carried as a workshop in the vicinity of IIT Guwahati, Assam. The master craftsman was from different states.

Researcher:

Sir, which part of the country do you belong?

Craftsman:

Sir, we are from the North-Eastern part of India. My hometown is in Tripura. We are a group of 4-5 bamboo craftsman who had followed our forefather in this tradition and have made this our primary profession.

Researcher:

How did you learn this craftsmanship?

Craftsman:

As, I told you that we had learn this craftsmanship from our forefathers. This started initially by observing them when they were working with the bamboo basket. Slowly with repeated practice I got perfection in this craftsman.

Researcher:

How many days it took you to get into perfection?

Craftsman:

It took me around 5-6 years to come into perfection. In the meantime, I would practice alongside with my father when he was working.

Researcher:

What according to you is a perfect bamboo basket?

Craftsman:

A perfect bamboo basket is uniform in its shape and beautiful to look at. The color combination and the placing of the strips of bamboo at a uniform width and form plays a major role during its making.

Researcher:

How do you decide which width of the bamboo strips to be taken?

Craftsman:

The bamboo is cut into certain strips according to the craft which you are making. The normal strips are 2-3 mm in thickness and can serve a purpose of a flat basket.

Researcher:

How do you color the strips of the bamboo? Which color do you use for it?

Craftsman:

We generally use natural colors prepared from plant in coloring the bamboo strips, but sometime we use the synthetic colors available in the market. We soak the bamboo strips in the color an then leave it to dry in the shade. We make sure that the strength and the straightness of the bamboo strip is maintained throughout the strips.

Researcher:

During the making of the basket, I observed that you are using water? why is it needed?

Craftsman:

The water used serves as a coolant and helps in bending the bamboo strip in a required angle which gives a particular shape to the basket.

Researcher:

What kind of tools do you use when you are working with bamboo?

Craftsman:

Generally, we use a sickle to cut the strips and make some uniform strips. Sometimes we also use bigger machine with a cutter to cut bigger pieces of bamboo. Once the bigger pieces are cut uniformly into smaller pieces we use smaller knives and sickle to obtain other strips.

Researcher:

How did you teach a new person these crafts?

Craftsman:

I encourage a new learner to practice the craft by himself by observing us when we are working.

Researcher:

How many baskets, do you make in a day?

Craftsman:

We are able to make around 30 baskets working for 4 hours in a day.

Researcher:

Which is the most easy and basic bamboo craft, I can make or learn now?

Craftsman:

You can start with a flat basket now. I will make the basket and you can follow me.

Curtain stand using bamboo-craft process

The place of work was visited by the researcher where the craftsman was working in the bamboo curtain.

Researcher: What is your age and name?

Craftsman: Sir, I am 18 years old and my name is Shafiqul.

Researcher: From how many years are you working in this profession?

Craftsman; I am working in this profession from past 6 years when I was young.

Researcher: How did you learn this profession?

Craftsman: Sir I learned it in this center under my master.

Researcher: Did you find any difficulty initially while learning this profession?

Craftsman: I was initially novice and was not able to apply my skills in bamboo works, but due to repeated practice I got fluency in my work and not can do it alone.

Researcher: Are you the sole earner of your family?

Craftsman: Sir, Yes

Researcher: How do you decide what size of the bamboo is required in the curtain stand?

Craftsman: Sir, we try to take a long and uniform structured bamboo which can give us maximum amount of circular chips. If a much larger bamboo curtain is required we take a similar bamboo stick and then cut into smaller chips.

Researcher: how do you cut the strips?

Craftsman: generally, we use local sickle which is very comfortable in cutting.

Bamboo Tea-bag process

The place of work was visited by the researcher. The bamboo tea bag craftsman was very minutely sewing the tea bag holder.

Researcher: Sir, I am a researcher and wanted to interact with you for few moments

Craftsman: Sure

Researcher: Sir from how many years are you in the bamboo craft making process?

Craftsman: I am engaged in this profession from past 15 years.

Researcher: Sir how to decide what kind of bamboo is needed in making this tea bag?

Craftsman: We need to see if the bamboo had enough width which can cover the whole tea-bag holder.

Researcher: Sir, how do we get this thickness of the bamboo strip?

Craftsman: We can get this thinness by minute cutting the bamboo strip with the help of a chisel.

Researcher: Sir is it easy to get this wafer?

Craftsman: Actually, I had practiced a lot before getting this perfect strip

Researcher: what else is needed in making the tea bag?

Craftsman: Apart from bamboo, a thread and skill is required in making the bag.

Appendix-B Transfer learning for craft object

The following is the code adapted for the transfer learning of the craft objects selected in this thesis. The code is written in MATLAB and is executed in an i5 processor having windows operating system, 6GB of RAM and 2GB of NVIDIA graphics card. The program starts with the loading of the pre-trained network AlexNet in deep learning. It has around eight different layers of Convolution Neural Network which filter and extract different features of the objects classes in which it was trained. Here we are considering five classes of the crafts.

```
%% Transfer Learning with MATLAB (Craft objects)
% In this code we use transfer learning to classify images into 1
% of 5 different craft categories:
%
% * Diya
% * Bamboo_basket
% * Bamboo_curtain
% * Bamboo_teabag
% * Clay_idol
%
% The images used in this example come from the case studies as described
%%in chapter-3 of this thesis
%% Accessing a pre-trained network
% Load in alexnet and inspect the different layers
%%
clear
%%
% The pre-trained network of alexnet is trained previously in the matlab;
net = alexnet;
layers = net.Layers
%% Create a datastore
% We used a datastore previously to read images in a loop. With % % %
%%ImageDatastore
% you can also label images, set a custom read function and split images
% into
% different sets.
%
% Create a datastore, including subdirectories and add labels based on
%%the
% filenames.
%%
%Instructor may have to adjust this for his own computer
path = 'C:\Users\Sai\Desktop\craft\LargerFiles ';
% username = input('Intructor Username: ','s');
filePrefix = [path,filesep,'LargeFiles']

filepath = [filePrefix,filesep,'04 - Images'];
imds = imageDatastore(filepath,...
    'IncludeSubfolders',true,...
    'LabelSource','foldernames');
label_class = unique(imds.Labels)
nl = length(label_class);
%% Look at some random images
% Generate random number < # of total images
randNum = randi(length(imds.Files));
```

```
% Read random image from the datastore and visualize
[imTemp,info] = readimage(imds,randNum);
imshow(imTemp)
title(string(info.Label),'Interpreter','none')
%% Set a Read Function
% Before classifying our images, we want to resize our images to fit our
%%network.
% With an image datastore, we can create a ReadFcn that will
%%automatically resize
% our images when we feed our datastore directly into our network.
%%
% We look at the first layer to see the size requirement
sizeRequirement = net.Layers(1).InputSize;
inputSize = sizeRequirement(1:2)

% Create anonymous function
imds.ReadFcn = @(img) imresize(imread(img),inputSize);
%% Splitting Image datastore into 3 sets:  | Train | Validate | Test |
% It is a best practice to split our data into a training, validation and
%%test
% set.
%
% * Training - used to train our network by establishing proper weights
%%that
% allow for accurate classification
% * Validation - a dataset that you test the network on after training. %
%%If the results are poor, retrain the network with different
%%hyperparameters and/or
% network architecture
% * Test - an unseen dataset that is used as an unbiased measurement of
&&network
% accuracy. Use this after you are happy with your validation
performance.
%
% There's no such thing as an ideal way to split your data, but people
%%often
% do a 70/15/15 split.
%%
[trainDS, valDS, testDS] =
splitEachLabel(imds,0.7,0.15,0.15,'randomized');
%% Modify the Network
% In transfer learning the majority of the layers stay the same. We need
to
% modify the last few layers to fit our specific dataset.
%
% * Fully Connected Layer - after all the convolution and max pooling
layers,
% which detect features, this layer does the "high-level-reasoning" using
its
% connection to all the activations in the previous layer.
% * Softmax Layer - Computes the scores that a given image receives for
each
% different category.
% * Classification Layer - Determines the highest score and categorizes
the
% image.
%%
```

```
numClasses = numel(unique(imds.Labels))

layers(end-2) = fullyConnectedLayer(numClasses,'Name',['fc'
num2str(numClasses)]);
layers(end) = classificationLayer('Name','classOut');
newLayers = layers
%% Set Training Options
% Set the hyperparameters for this neural network.
%%
trainOpts = trainingOptions('sgdm',...
    'InitialLearnRate',0.001,...
    'ValidationData',valDS,...
    'Plots','training-progress',...
    'MiniBatchSize', 64, 'MaxEpochs', 40, ...
    'ValidationPatience', 3, 'CheckpointPath','C:\Temp\checkpoint');

%% Train and Validate the Network
% Train the network with the training data and validate it with our
validation
% data set (note: this is done automatically thanks to our training
options).
% If the validation results are not adequate, tune hyperparameters and
try again.
%%
doTraining = true;

if doTraining
    disp('Initialization may take a minute before training begins');
    net_CraftObject = trainNetwork(trainDS, newLayers, trainOpts);
else
    currentDir = pwd;

    filepath = [filePrefix,filesep,'04 - CraftObject Network'];
    cd(filepath);

    load net_CraftObject.mat

    cd(currentDir);
end

%% Test the Network
% Once happy with validation results, test the network on the test
dataset
%%
doTest = false;

if doTest
    [labels, scores] = classify(net_CraftObject, testDS);
else
    load testResults.mat
end

% Calculate accuracy
accuracy = sum(labels == testDS.Labels)/numel(labels);

% Confusion Matrix - visual inspection of accuracy and error
tbl = table(labels,testDS.Labels,...
```

```
    'VariableNames', {'Predicted', 'Actual'});

figure('name','Confusion Matrix')
heatmap(tbl,'Actual','Predicted');

%% View Some of the Results
% Writing a script that will let view some of the images in the test
dataset
%%
randNum = randi(length(testDS.Files));
imOriginal = readimage(testDS,randNum);
imResized = imresize(imOriginal, inputSize);

actualLabel = testDS.Labels(randNum);
predictedLabel = classify(net_CraftObject,imResized);
imshow(imOriginal)
title(['Predicted: ' char(predictedLabel) '  Actual: '
char(actualLabel)],'Interpreter','none')

%% Try It with Random Internet Pictures
%%
URL = 'https://assets-news-
bcdn.dailyhunt.in/cmd/resize/400x400_60/fetchdata13/images/2f/72/af/2f72a
f443e8f59d6db41876f0cc6fb8b.jpg';
filename = 'diya.jpg';
websave(filename, URL);

im = imread(filename);
im = imresize(im, inputSize);
label = classify(net_CraftObject, im);
imshow(im);
title(['Predicted: ' char(label)],'Interpreter','none')
%%
%% End of the program
```

Appendix-C Publication

#	Name of Author/s	Paper Title	Conference/ Journal	Year	ISBN/ISSN
1.	Ojha SP, Yammiyavar, P	A fuzzy-based approach to identify tacit knowledge in craft objects	ICoRD'19 International Conference on Research into Design Indian Institute of Science, Bangalore, 9-11 January, 2019.	2019	Springer, Singapore, Online ISBN978-981-13-5977-4 https://doi.org/10.1007/978-981-13-5977-4_17
2.	Ojha, S.P, Yammiyavar, P	Ethnography and protocol analysis as a tool to identify tacit components in designed artifacts-case studies	14th International Conference on Humanizing Work and Work Environment HWWE-2016, NIT Jalandhar	2016	GIAP Journals, Feb 4, 2018, ISBN: 9789383006816.
3.	Ojha, S.P, Lingannavar R, and Yammiyavar P	A matrix framework proposal for evaluating innovation criteria of a design process output during product conceptualization	International Conference of Research into Design, Icord'17	2017	Springer, Singapore,2017, ISBN: 978-981-10-3517-3, https://doi.org/10.1007/978-981-10-3521-0_42
4.	Ojha, S.P, Yammiyavar, P	Methods to capture and model craftsmen's tacit knowledge in traditional designs	International Conference of Research into Design, Icord'17	2017	Springer, Singapore,2017 ISBN: 978-981-10-3517-3, https://doi.org/10.1007/978-981-10-3518-0_51
5.	Ojha, S.P, Lingannavar R, and Yammiyavar P	Scheme to implement the tacit knowledge of the craftsman into rapid prototypes	International conference on Trends in product life cycle modelling, synthesis, simulation, PLMSS, Hyderabad	Oct, 2015	Conference Proceedings

6.	Ojha, S.P, Yammiyavar, P	Role of language in transfer of tacit knowledge: Case study of bamboo crafts making industries in North East India	HWWE'15, International Conference on Humanizing Work and Work Environment 2015, 13th Indian Society of Ergonomics Annual Convention, IIT Bombay.	Dec-15, 2015	Springer, Singapore,2018, ISBN:978-981-10-4979-8, https://doi.org/10.1007/978-981-10-4980-4_41
7.	Ojha, S.P, Yammiyavar, P	Development of a System for pre-kitting operation in Smart-assembly	AMETI-2014, NERIST(Nirjuli), Itanagar	Dec-2014	Excel Publishers, ISBN: 9-789383-842957, Vol-I, pp-82-88
8.	Ojha, S.P, Yammiyavar, P	A Study of Craftsmanship micro-tasks for understanding and capturing tacit knowledge of artisans with intention to transfer it to machine coding	HWWE'14, International Ergonomics Conference-User Centered Design and Occupational Well-Being, Guwahati	Dec-2014	McGraw Hill Education, ISBN (13):978-93-392-1970-3, ISBN (10): 93-392-1970-8. pp 717-721.
9.	Ojha, S.P, Yammiyavar, P	Improving Sustainability by Capturing Tacit knowledge of Artisans as Digital Information for Design Process	Design for Sustainable Wellbeing and Empowerment 2014, DfWnE2014, IISc Bangalore	12-14 June, 2014	Volume 1 (pp. 355-362). ISBN (IISc Press): 978-81-925707-1-6, ISBN (TU Delft): 978-9496186-345-4
10.	Ojha, S.P, Yammiyavar, P	Smart Assembly Systems: Need for Future Products	National Conference in Recent Advancements in Mechanical Engineering (NCRAME'13), Nirjuli	11-Aug, 2013	Excel Publishers, ISBN: 978-93-82880-71-4, Vol-I, pp- 321-326

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