MS RESEARCH THESIS

KNOWLEDGE WAREHOUSE FRAMEWORK:

A new direction towards decision support system for executive management

Supervised By:

Prof. Dr. Maqbool ud din Sheikh
COMSATS Islamabad campus.

Submitted by:

Tasleem ud din
312-FAS/MSCS/F06

International Islamic University
Faculty of Basic & Applied Sciences,
Department of Computer Science, Islamabad.
2006- 2008.

14-07-2010

MS
658.4038011
TAK

1. Decision support systems
2. Artificial intelligence

DATA ENTERED

FINAL APPROVAL

This thesis entitled

KNOWLEDGE WAREHOUSE FRAMEWORK:
A new direction towards decision support system for executive management

By Mr. Tasleem ud din

has been approved by Faculty of Basic and Applied Sciences, IIUI.

Supervisor _____
Prof. Dr Maqbool uddin Shaikh

External Examiner _____
Prof. Dr Jamil Ahmed

Internal Examiner _____
Asst. Prof. Mr Imran Saeed

ABSTRACT

Decision Support Systems (DSS) helps the management in making accurate and timely decisions for successful business operations. Data Warehouse (DW) is one of the solutions for decision-making process in a business organization. But it only store data for managerial purpose and has no intelligent mechanism for decision making. This raises the issue of knowledge storage in organization for high capability decision support. Problem also arises during accessing of knowledge from different sources and comprehensively integration of knowledge. So a new generation knowledge enabled system is needed to store the knowledge along with data and information.

A framework of knowledge warehouse is introduced, which is enhanced form of data warehouse. It provides the infrastructure needed to capture, cleanse, store, organize, leverage, and disseminate not only data and information but also knowledge. The basic goal of knowledge warehouse is to provide a platform to obtain consistent and adequate knowledge for efficient decision making. In this work, focus is on explicit knowledge. Tacit and remaining sources of knowledge can be part of future work.

Two algorithms have been proposed to capture, integrate and store data / knowledge form two different sources i.e. semantic net and frames. First algorithm captures the data / knowledge from the knowledge representation format (semantic network / frame) and store it into object text file. Then by using second algorithm we have merged and integrated the above files into a third object text file. Then by using the loading tool we can load this file into knowledge storage module. A common storage format based on objects is also proposed to store the data / knowledge.

The proposed architecture of knowledge warehouse in this research would be new direction towards the decision support system for executive managers based on knowledge.

ACKNOWLEDGMENTS

First of all I thanks to Allah for giving me courage and ability to complete this task on time. I also want to thanks to my parents and wife for their encouragement, support for all times through out the research thesis.

I would like to express my sincere gratitude to my supervisor, **Prof. Dr MAQBOOL UDDIN SHAIKH**, without whom this research work would not have been possible.

16/7/2008

Tasleem ud din

TABLE OF CONTENTS

LIST OF FIGURES

Number **Page**

CHAPTER 1. INTRODUCTION

1.1 Motivation and Challenges

Management Information System (MIS) has become the essential part of the business, as it enhances the productivity and manageability. Complex decision making in limited time compel executive manger towards the implementation of MIS in organizations. Management support systems are technologies designed to support the managerial works and can be used independently or in combination.

Management Information System leads to Decision Support System (DSS) use data, models and possible knowledge for solution of semi structured and unstructured problems. DSS are specific class of computerized information system that support business and organization decision making activates. DSS help the management in making accurate and timely decisions, which lead to successful business that not only increase the productivity but also increase the profit of the business.

Data Warehouse (DW) is gradually gaining fame as data repository system for enterprises. It is best solution for decision-making process in a business organization. Top level management of the organization requires historical, summarized and consolidated data for efficient decision-making process provided by data warehouse. Data warehousing is up to date architectures for strategic decision making. It gives tools for executives of business to methodically organize, understand, and use data to make advanced decisions. It has been analyzed that data warehouse is an infrastructure used to extract, cleanse and store large amount of business data from different operational systems into a common storage format. Then different tool are use to produce efficient and accurate response to user query [3].

In the current era of knowledge-driven society, knowledge is a critical resource, which needs to be leveraged and utilized optimally. Information and communication technology has been the key in the Knowledge Management (KM) process. A technology-driven organization needs to leverage KM process efficiently to be effective and competitive. Such organizations tend to capture tacit knowledge using various IT-based technologies

like data mining and make this knowledge explicit and available in public domain for intellectual consumption. Information repositories, such as knowledge centered libraries have begun to appreciate the power of the KM systems and are investing their critical resources in terms of manpower and technologies to make them technology driven. The functions of information professionals are undergoing drastic changes in terms of moving beyond cataloguing and sorting to include providing customized information to individual requirements. Therefore, information professionals, today, need to be intellectually equipped to leverage KM systems to provide required customized services efficiently [5].

There are a number of challenges / research questions facing in this area of knowledge management, which includes knowledge creation, knowledge acquisition, knowledge modeling, knowledge storage, knowledge dissemination and retrieval, knowledge maintenance, knowledge transfer, and application of Information Technology to knowledge management were cited in [5,9,10]. Which are given below?

1. How new knowledge can be created in organization?
2. How much the organization culture facilitates and cultivate in knowledge creation process?
3. How much knowledge is being utilized for organizational benefits?
4. How tacit and explicit knowledge can be captured from different sources?
5. How hesitation, because of insecurity and fear of losing knowledge, of people in organization can be removed?
6. How we can collect expertise, experiences, skills, and capturing of other form of tacit knowledge.
7. In which common format knowledge will be stored from different sources?
8. How lack of integration of the various standard knowledge representation formalisms can be resolved in knowledge storage?
9. How knowledge can be refined and merged from different source before storage.
10. What and how much incentives organization provides to encourage knowledge sharing and contribution?

11. How the different form of knowledge can be interchange like tacit to explicit knowledge form.
12. How we can use and retrieve the stored knowledge effectively and perfectly?
13. How knowledge can be transferred among organizational units in efficient manner?
14. Does the application of Information technology transfer knowledge among individuals within and between groups? If so then up to what degree and level?
15. What type of strategies, technical and organizational, facilities in knowledge transfer effectively?
16. What steps are required by organization to promote knowledge application available?
17. How we assure that individuals of organization trust knowledge captured using information technology, as they don't know the creator / originator of knowledge.
18. How we can share knowledge and transfer the experience of individuals to benefit the organization.
19. How efficient knowledge management system is developed to extract knowledge from different sources and transform into machine understandable format?

It has been seen from the above that still number of problems exits in the knowledge creation, management, storage, transfer etc. So there is lot of scope to explore and research in the area of knowledge management.

1.2 Background

Knowledge is available in two forms i.e. tacit and explicit. It can be transformed from one form to other to utilize it more beneficially according to requirement. Four steps involved in the process of knowledge conversion are; Socialization, Articulation, Integration and Internalization [17]. These processes have been discussed in detail in chapter 2.

Modern computer technologies can not replace humans, but can support them in their efforts to better understand situations and codify knowledge. These technologies are capable for dissemination of information around the organization. Usage of Multimedia introduced new ways for encouraging inter-departmental collaboration. Implementation of Information Technology infrastructure in an organization has changed the traditional structures for knowledge sharing. Knowledge Management not only requires technological, organizational and interpersonal skills, but it also needs the involvement of every employee of the business. Every employee should have at least basic competence in handling information and using IT tools such as document management system, email etc.

A number of technologies support the knowledge management process. It includes Decision Support Systems (DSS), Information Technology (IT), Artificial Intelligence (AI), Expert Systems [1]. Other technologies that support the knowledge management are audio conferences, document management system, online databases, collaborative work support tools, corporate yellow pages and experts, data mining tool , email, help desk applications, video conference, portals, information retrieval engines [30]. Usually knowledge base sophisticated systems use intelligent search agents, case-based reasoning and neural networks used for data mining. Following is the detail of some of important ones.

Business Intelligence

Business Intelligence (BI) is the new emerging filed in information technology. BI is a technical process of innovation in the data warehousing and business intelligence space. BI involves acquiring data, information and / or knowledge from variety of sources and utilizes these in decisions making.
According to C.M, Olszak

"*BI is a set of concepts, methods and processes that aim at not only improving business decisions but also at supporting realization of an enterprise's strategy*" [38].

Intelligent exploration, integration, aggregation and a multidimensional analysis of data originating from different information resources are the main task of BI. By using above mentioned techniques and technologies magnitude of data warehouse and BI systems can be increased [1].

Data Mining

Data mining is searching through existing data. This search is done to discover unknown relations / patterns in the data in the data warehouse. Knowledge mining is finding of unknown knowledge in databases. It is the process that uses statistical, mathematical, artificial intelligence and machine learning techniques to extract and identify useful information and subsequent knowledge from large databases.

Artificial Intelligence

According to R. Knight, E. Rich AI is defined as

"It is the study of how to make computer do things which, at the moment, people do better" [41].

Today's novel applications, such as banking system and telephone system use AI as key field. Misuse of credit card in banking system can be rectified and detected by the use of AI technology. It enhances the capabilities of existing applications and databases by adding logic, knowledge and reasoning [33]. Major area of AI include expert systems, natural language processing, neural networks, case base reasoning, genetic algorithms, speech understanding, intelligent robotics, computer vision, fuzzy logics, intelligent agent, intelligent computer aided instruction and neural computation [1].

Expert System

Expert system is concerned with the problem solving aspects of human expertise. It is a computer application which aims to replicate the reasoning of an expert in solving fairly complex real-world problems where lessons learnt from experience play an important part [32]. Well-designed systems use analytical abilities and reproduce the reasoning processes to solve specific problems. The system takes the role of a coach or an assistant, providing guidance and suggestions about the problem in hand [1].

Three major components of expert system are the knowledge base, inference engine, and user interface. Knowledge base contains knowledge in form of fact and rules to solve the problems [34]. The brain of the expert system is the inference engine which involves a set of routines which carry out deductive reasoning by applying the know-how inside the knowledge base. And finally user interface is provided to manage the dialogue with the user, typically via a standard computer terminal. Typical forms of expert systems are rule base expert systems, frame base systems, hybrid systems, model base systems, ready made and real time systems [1].

1.3 Problem Statement

In data warehouse, data is gathered from different operational systems and loaded it into data warehouse using different ways. Then different reporting tools and templates are used to access this stored data [31]. So we can say that data warehouses store data but do not store knowledge directly. Data warehouse is basically used to provide information to knowledge workers for efficient decision making based on solid foundation of facts. But in practice, only a fraction of the needed information exists on computers as employees of the firm keep vast majority of knowledge in their minds [8].

The current state of data warehousing raises the issue of knowledge storage for high capability decision support. Problems also arise during access of knowledge from different sources like frame, semantic network, decision table, decision tree, scripts etc and comprehensively integration of knowledge. In this research, efforts are made to

sketch the architecture of Knowledge Warehouse that will stores data, information and knowledge as well. It will capture knowledge from two sources i.e. frames, semantic network; other sources can be added in future work. This acquire knowledge will be transformed into Meta knowledge using transformation algorithm. Then this transformed Meta knowledge will be called knowledge warehouse. We also have proposed knowledge storage format (i.e. object base) to store the data and knowledge in knowledge warehouse.

1.4 Proposed Solution

In this research work, solution of the above mentioned research problem is provided by sketching the architecture of a Knowledge Warehouse. The proposed infrastructure will not only store data but also knowledge. It will be capable to provide same services for knowledge which a data Warehouse provides for data. The key purpose of knowledge warehouse is to facilitate the decision maker(s), in access of knowledge from different sources and it's comprehensive integration with storage support, to improve his / her decision making.

Generally, knowledge in the organizations is represented in the forms like decision trees / tables, frames, logics, semantic networks, knowledge map, scripts and use cases etc. In our architecture, we will get knowledge from two (semantic networks and frames) of the above mentioned sources. This acquired knowledge will be transformed into common format using the transformation algorithm into an object text file. We will have one transformation algorithm for each of the representation source. Then, generated object text file , in our case we have two files one from frame and second from semantic network, will be integrated and merged into a single object text file by using another algorithm. Then this transformed Meta knowledge will be called knowledge warehouse and will be accessed by developing tools in future. The storage format of knowledge in the knowledge warehouse also has been proposed.

1.5 Thesis Outline

This thesis consists of six chapters. First chapter is about introduction and background of the problem. Second chapter describes the knowledge representation sources, knowledge creation and management process, with detail of data warehouse decision support systems. In this chapter, existing generic architecture of knowledge ware house also has been discussed with its limitations. In chapter three, focus is on problem domain i.e. Knowledge Warehouse (KW) in detail. Different scenarios have been where we can implement KW. Fourth chapter introduces the proposed knowledge warehouse architecture and algorithms with proposed storage format, called Knowledge Warehouse. Fifth chapter is about the flow chart of algorithms and implementation of case study. Lastly chapter six describes conclusion and future work.

CHAPTER 2: LITERATURE SURVEY

2.1 Introduction

Knowledge representation and management is the sub area of Artificial Intelligence. It relates to design and implement different representing information from various sources. Knowledge acquired from the experts or from a set of data must be represented in a format that is understandable by human beings and executable on computers. Then this knowledge is used in computer programs to derive information, make future planes and solve the problems concerning human expertises.

2.1.1 Knowledge Representation

There are different ways to represent knowledge. Some important of them are following.

- Frames
- Object Oriented Representation
- Semantic Networks
- Decision Tables
- Decision Trees
- Production Rules
- Scripts
- Use Cases
- Relation Databases
- Knowledge Map
- O-A-V TRIPLET

2.1.1.1 Frames

Frame was proposed by Marvin Minskey in 1970. It is a data structure used to store knowledge of a particular object. A special hierarchical structure is used to organize knowledge in it. We can say that frame is special type of directed graph. It is widely used

in applications of objects oriented programming for Artificial Intelligent and Expert System [1].

Frames structure provides concise structural representation of knowledge in a natural manner. In contrast to other representation methods like decision trees, semantic net, it encompasses complex objects, entire situations, or a managerial problem as a single entity.

Content of Frame

A frame consist of two following basic elements

- Slots
- Facets.

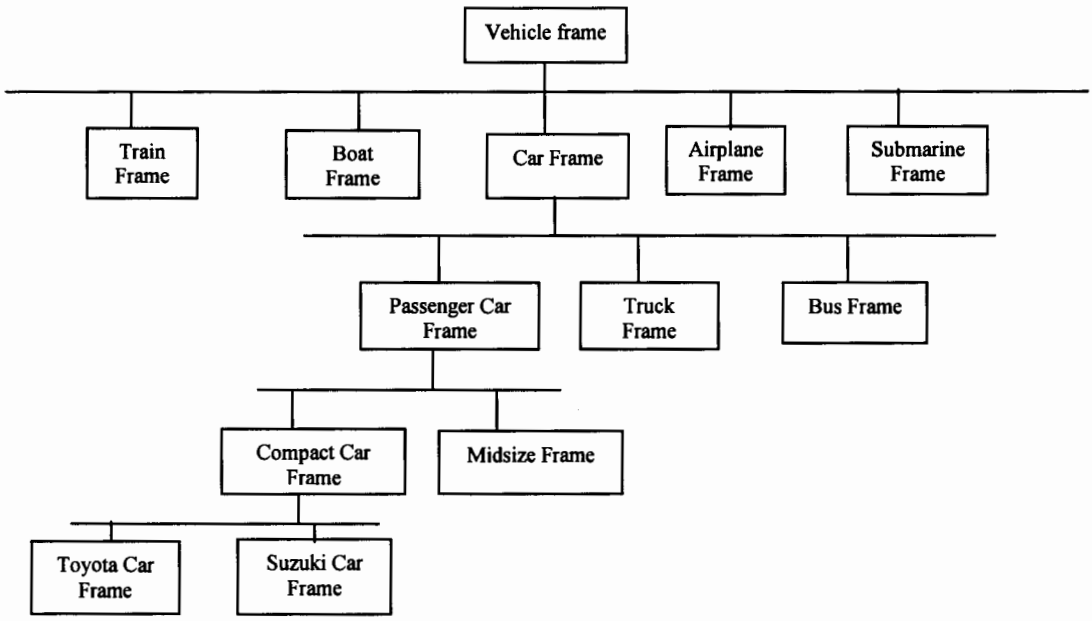


Fig 2.1: Frame representation of vehicles [1]

A slot is set of attributes that describes the characterizes of object in frame. For example, in the car frame, slots can be wheelbase, no of doors and color. Each slot can has one or more facets. A facet describes some knowledge or procedural information about the attribute in the slot. For example, gas mileage can be procedural information in car frame used to calculate the gas consumed per kilometer.

Hierarchy and Inheritance in Frames

In knowledge base systems, based on AI, number of frames are linked together to show their relationship in a certain manner to form hierarchy and inheritance. For example, in figure 2.1 vehicle frame is the top of the tree called "root" is the highest level of abstraction. Next level frames like train, boat, car, airplane and submarine are called child of parent fames "vehicle" and form is- a relationship following certain hierarchy. We can say that every parent is child of higher level parent. Frames, Toyota and Suzuki car, are at bottom level called leaves of tree.

2.1.1.2 Object Oriented Representation

Object Oriented (OO) paradigm is built on the foundation laid by the structured programming concept and data abstraction.

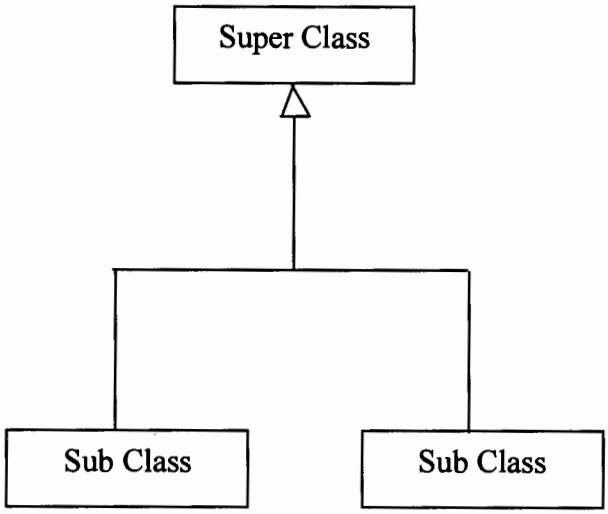


Figure 2.2: Inheritance in Object Oriented Paradigm [39]

The fundamental idea behind object oriented programming is to combine into a single unit both data and function that operate on that data. Such unit is called object. Main features of OO representation include object, classes, abstraction, encapsulation, inheritance, polymorphism, new data type and reusability [7].

2.1.1.3 Semantic Networks

Semantic networks were first defined by Ross Quillian in 1968. It is special case of directed graph to represent knowledge structure; frequently used in artificial intelligence systems. It depicts knowledge graphically using nodes and links (arcs or arrows) between nodes. Nodes represent concepts or object, while links are used to represent the relationship between the nodes. Some of the common relationships used by arcs are "is-a" or "has-a" to show inheritance and composition respectively [1].

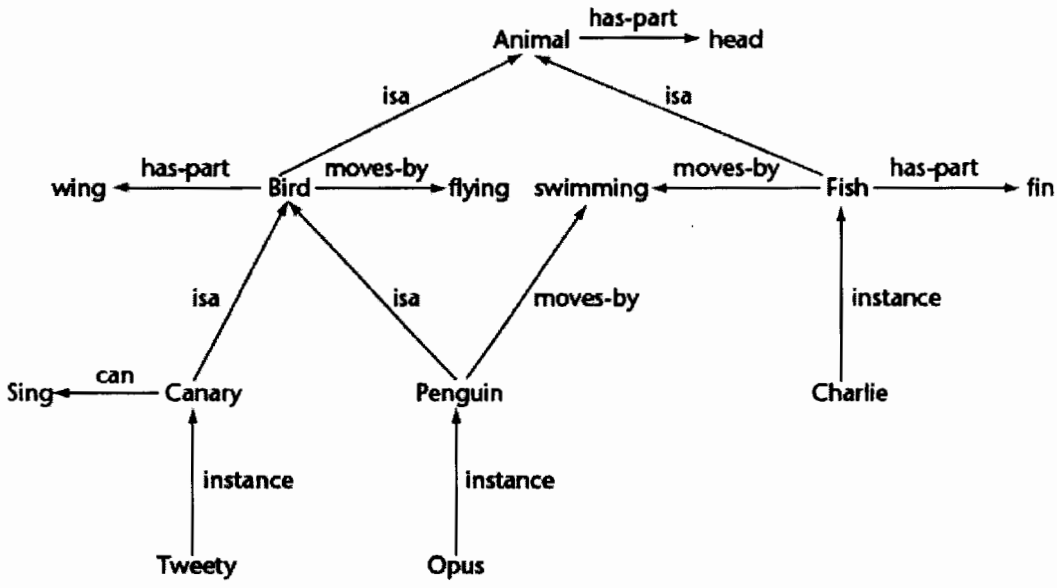


Fig 2.3: A semantic representation of knowledge [40]

A simple semantic network of birds and animals is shown in figure 2.3. In this representation, some of the nodes represent categories like fish, bird, and animal; while some represent individual like tweety. Relationship like "is-a" or "has-a" between the nodes (bird-canary and bird-wing) has been represented by using arcs. So in this way detailed information about objects can be represented.

2.1.1.4 Decision Table

Decision tables are used to store data and knowledge in tabular form using rows and columns [16]. Second name of decision table is logic tables. They are the best choice to represent the data and knowledge as they are quick and easy to understand and program [1]. A decision table's four components are; condition stubs, condition entries, action stubs and action entries

In figure 2.5, a decision table of employee in payroll system is show with relevant rules performed under certain conditions in conditional stub.

	Conditions/ Courses of Action	Rules					
		1	2	3	4	5	6
Condition Stubs	Employee type	S	H	S	H	S	H
	Hours worked	<40	<40	40	40	>40	>40
Action Stubs	Pay base salary	X		X		X	
	Calculate hourly wage		X		X		X
	Calculate overtime						X
	Produce Absence Report		X				

Fig: 2.4 Complete decision table for payroll system

2.1.1.5 Decision Tree

It is hierarchical representation of knowledge relationships composed of nodes and links. Nodes represent goals while links are used for decisions. In [1], decision trees can simplify the knowledge acquisition process and are more natural than frames and rule knowledge representation techniques. We can easily extract knowledge from tree using computer programs and then can convert into production rule. In figure 2.5, a decision tree representation is shown based on age.

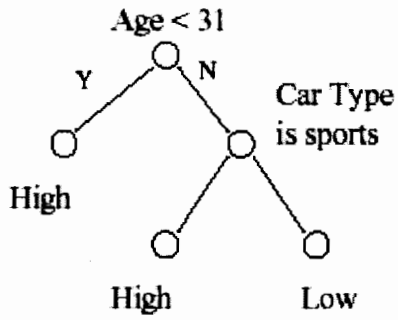


Fig 2.5: A decision tree representation

2.1.1.6 Production Rules

In production rules, knowledge is represented in condition- action pairs [1]. Whenever, IF condition occurs THEN some action will be performed. It means when some of the condition comes true then the relevant action should be initiated. For example, in real while driving a car you have to stop if the signal is red and will go when signal is green. Here signal color is condition which executes the relevant action. Knowledge base system consists of set of rules that can be developed and modified independently of other rules.

Different production rules can exit e.g.

```
If     Marks  > 90 then        Print A Grade

Else if Marks > 80 then       Print B Grade

Else if Marks > 70 then       Print C Grade

Else if Marks > 50 then       Print D Grade

Else if Marks < 50 then       Print F Grade

End if
```

In the above example, we have set of production rules to calculate the grade of student. It will show the student grade base on his / her marks.

2.1.1.7 Scripts

It is useful knowledge representation structure design to represent activities rather than objects [40]. It is particularly help full in stereotypical situations and daily base event that people face every day in their lives and describes the sequences of events [1].

The five basic components of script are entry conditions, props, roles, tracks and scenes. Entry condition is the first component that that must be satisfied before events can occurs or be valid. Objects use in the sequences of events are called pros while people involved in script are called Roles. Track refers to the variation that might occurs in particular script. Lastly, scenes describe the actual sequence of event that occurs [1].

Restaurant is the best example of script where all activities occurs when some one visit the restaurant. Here money, food, menu and tables are called pros; while hungry person and chef are roles.

2.1.1.8 Use Cases

Use cases are used during the analysis phase of a project and provide the description of how system will be used. It is used to identify and partition system functionality and separate system into two components i.e. Actors and Use Cases.

Actors are the users (people or devices) of the system, such as humans, other computers, pieces of hardware, or even other software systems, also called roles. The only criteria for the actor that communicate with the system must be external to the system. It will supply stimuli to that part of the system, and must receive outputs from it [15].

Use cases are responsible to describe the manner in which an actor interacts with the system. This behavior is described textually. So we can conclude that use case is a written text or narrative used to describe the role of the actor when interact with system. In figure 2.6, sales clerk and customer are the actors while check out item is the use case of the sales system.

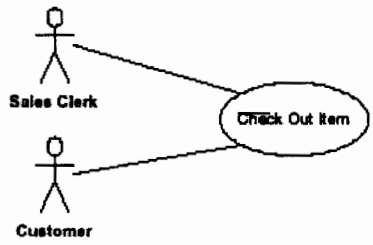


Fig 2.6: Use case of sales system

2.1.1.9 Relational Database

The relational database was first introduced by E. F. Codd at IBM in 1970. In [14], a relation database is defined as

"A relational database is a collection of data items organized as a set of formally described tables from which data can be accessed or reassembled in many different ways without having to reorganize the database tables".

Structured Query Language (SQL) is used to create database and relation structures, perform data management tasks such as insertion, deletion and modification [4]. It also provides statements such as select to query the complex information from a relational database.

Roll no	Name	Class	Fee	City
1234	Ali	MBA	20000	RWP
1235	Noman	BBA	15000	LHR
1236	Wakeel	MBA	20000	RWP
1237	Nadeem	MCS	30000	KRI
1238	Nida	BCS	25000	LHR

Fig 2.7: Student data representation in relational form

2.1.1.10 O-A-V Triplet

This knowledge representation is used to represent Object, Attributes, and Values (O-A-V triplet). Object is a physical concept for which we are storing information. Every object has set of attribute which stores the characteristics or properties of that object. Finally, values are the measures of attributes. An object may consist of several attributes.

In figure 2.8, we have O-A-V triplets representation of a house. In this, house is treated as an object having attributes such as bedrooms and color with related values. An object of O-A-V triplets can be used in frame and semantic network representations [1].

Object	Attribute	Values
House	Bedrooms	2,3,4 and so on
House	Color	Green, white and so on
Admission to a university	Grade point average	3.0, 3.4 and so on
Inventory control	Level of inventory	14,30,45 and so on
Bedroom	Size	9,10,12 and so on

Fig 2.8: Representative O-A-V Items [1]

2.1.1.11 Knowledge Map

In [9] Speel et al. defined knowledge as *"Knowledge mapping is the process, methods and tools for analyzing knowledge areas in order to discover features or meaning and to visualize theses in comprehensive, transparent form, such that business relevant features are clearly highlighted."*

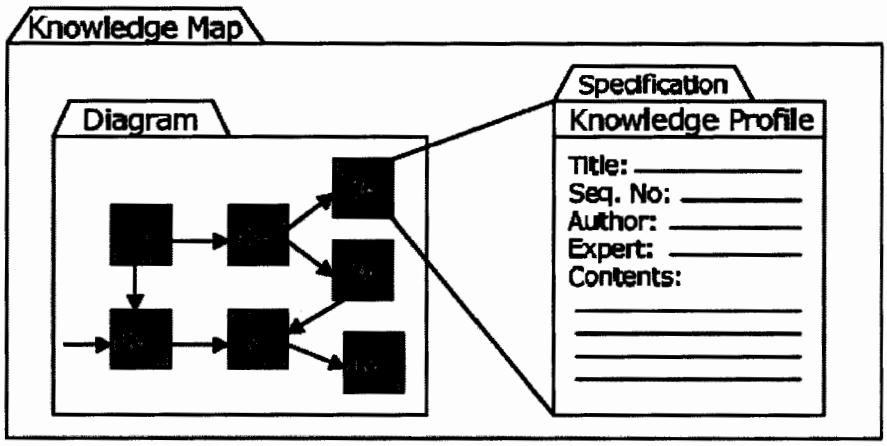


Fig 2.9: A conceptual model of Knowledge Map [9]

Knowledge map is the visual representation of tacit and explicit knowledge such as experiences, methods, and process, judgments with in the organization. It includes circle

or images connected by lines, each labeled, to form the hierarchical view of knowledge[1].

In figure 2.9 a knowledge map consists of two components; diagram and specification. Diagram is the graphical representation of knowledge using nodes and link; while specification is the extracted knowledge from the knowledge map.

2.1.2 Knowledge Management

According to E.Turban, J .E.Aronson and Liang

"Knowledge management is the process of transforming information and intellectual assets into enduring value. It is the process that helps organizations identify, select, organize, disseminate, and transfer important information and expertise that are part of organization's memory and that typically reside with in the organization in an unstructured manner. The structuring of knowledge enables effective and efficient problem solving, dynamic learning, strategic planning and decision-making "[1].

In fact, in real life every one does knowledge management in some context. A student who arranges his / her books or notes of different subject is one example of knowledge management. In an organization, a clerk commonly who uses a word processor to store and retrieve explicit knowledge is also example of knowledge management. Now-a- days organizations use different knowledge management system tools such as document management system, email, relational database systems to store and process the information.

In [11], three basic three elements involve in knowledge management are given below.

1) Prepare knowledge for usage.
2) Utilization of knowledge
3) Knowledge protection.

First point requires capturing, organizing, storing and updating knowledge. Second point describes how to utilize knowledge; it involves knowledge query, manipulation, analysis, reporting and transmission. Third and last step is protection of knowledge from unauthorized users access and safety in case of system of system crash.

The benefits that individuals and organizations may get through the use of knowledge management are time saving, cost saving, improved decision making etc.

2.1.2.1 Knowledge Management System

Knowledge used by the individual and organization is well managed with the use of Knowledge Management System (KMS).

According to E.Turban KMS can be defined as

"Knowledge Management System (KMS) is systematic process used to manage the knowledge. It refers to the use of modern information technologies (e.g. internet, intranet, extranet, lotus notes, software filters, agents, data warehouses) to systemize, enhance and expedite intra and inter firm knowledge management. Several technologies have contributed to significant advances in knowledge management tools. Some of them are Artificial Intelligence, Intelligent Agents, Knowledge discovery in databases and Extensible Markup Language (XML) "[1].

2.1.2.2 Knowledge Management Process

Knowledge management processes are used to enable and facilitate the knowledge creation, sharing for the benefit of the organization. In [5], the processes of knowledge management are 1) knowledge generation 2) knowledge organization 3) knowledge

storage 4) knowledge transfer and 5) knowledge utilization. All these processes are carried out in a spiral way. In figure 2.11, ICT tool are mentioned used in KM process.

KM process	ICT Tools
Knowledge generation	Brainstorming applications Electronic support systems Video conferencing Discussion boards
Knowledge organization	Electronic publishing technology Document management Web search engines Help-desk technologies
Knowledge storage	Expert systems Database technologies Web-mapping tools Electronic publishing technology
Knowledge transfer	
Tacit to tacit	Bulletin boards Video conferencing Brainstorming applications
Tacit to explicit	Database technologies Data warehousing Data mining
Explicit to explicit	Document management systems Group decision-support systems Groupware/computer-supported system
Explicit to tacit	Database technologies Data warehousing Web search engines Data mining
Knowledge utilization	Decision-support systems Simulation software Artificial neural networks

Fig 2.10: Knowledge Management Process with ICT tools [10]

2.1.2.3 Types of Knowledge

Basically two types of knowledge exist.

- Explicit Knowledge
- Tacit Knowledge

Explicit knowledge

It is the form of knowledge that can be codified and stored in computer systems. This type of knowledge can be distributed to the others independently. It consist of white papers, polices, procedural guides, reports, strategies etc. [1]. For example, how to register a student in institute would be documented in a university prospects. Leaky knowledge is another name of explicit knowledge.

Tacit knowledge

Tacit knowledge is the form of knowledge difficult to store and codify. It involves trade skill and secrets, mental maps, insights, wisdom, expertise, know how of people and process in organization through present and past experiences [1]. In short we can say that, this type of knowledge belongs to personalities and is difficult to communicate and formalize. It is also referred as embedded knowledge.

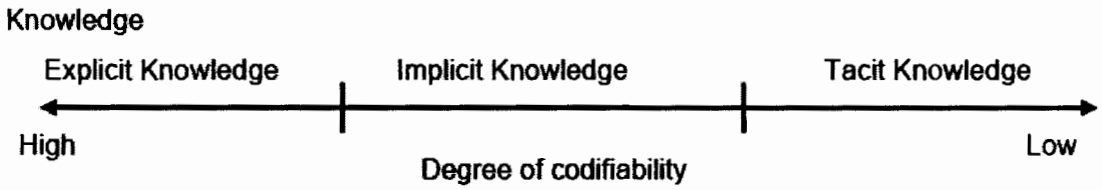


Fig 2.11: Dimensional classification of knowledge [12]

2.1.2.4 Knowledge Creation and Conversion

In organization knowledge can exist in explicit and tacit form. Knowledge can be enhanced by creating new contents or replacing existing knowledge. Knowledge can be converted from one form to other form in a spiral way.

Following four steps are involved in the process of knowledge conversion [8].

- Socialization
- Articulation/ Externalization
- Internalization
- Combination / Integration

Socialization (Tacit to tacit knowledge conversion)

"Socialization is the process of sharing the tacit knowledge such as experiences, technical skills, expertise, understanding, know-how, acumen, skill trade mental maps etc"[17]. For example, a person can learn skill or expertise through the observation, imitating and practicing while working with his master. Information technology (IT) plays important role to share the tacit knowledge. For example, using IT a digitized film of a process once stored, can be made available on internet for any time. Now this digital film can be shared and access any time by the decision maker [8].

Articulation (Tacit to explicit knowledge conversion)

"Articulation is the method of transforming tacit knowledge to explicit knowledge" [17]. This process of transformation is accomplished by the use of specification of model instances, mathematical model and brainstorming.

Integration / Combination (Explicit to explicit knowledge conversion)

"In the process of integration several types of explicit knowledge are combined to create new patterns and relations "[17]. The example of integration is given below.

"Analysis of multiple and related 'what-if' cases of a mathematical model to find new relationships, or meta-model, that determine the key factors of the model to influence the decision can be one example of integration / combination " [8].

Internalization (Explicit to tacit knowledge conversion)

"Internalization is a process of converting explicit knowledge into tacit knowledge" [8]. It helps the knowledge work in learning and discovers the knowledge specific to his / Her problem[17].

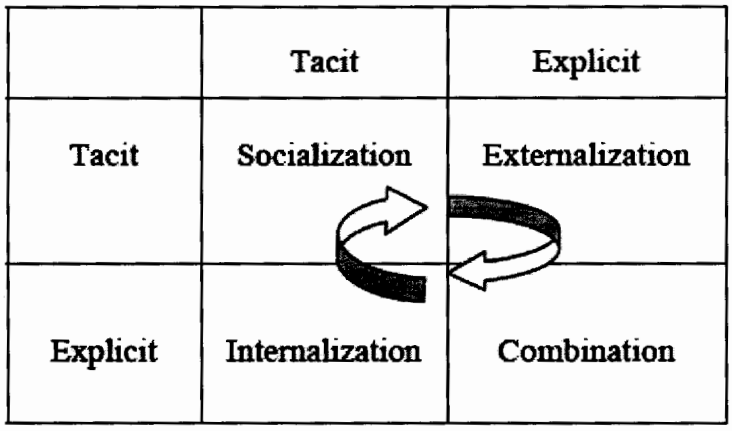


Fig 2.12: Knowledge conversion and spiral of knowledge [13]

2.1.3 Data Warehouse

Data Warehouse (DW) is gradually gaining fame as data repository system for enterprises. It is up to date architectures for strategic decision making. It gives tools for executives of business to methodically organize, understand, and use data to make advanced decisions. It has been analyzed that data warehouse is an infrastructure used to

extract, cleanse and store large amount of business data from different operational systems into a common storage format. Then different tool are use to produce efficient and accurate response to user query [3].

Data warehouse is best solution for decision-making process in a business organization. Top level management of the organization requires historical, summarized and consolidated data for efficient decision-making process provided by data warehouse. The normal size of data warehouse varies from hundreds of gigabytes to terabytes. The queries on data warehouse are ad hoc and multi faced. Different scans, joins, and aggregates are performed in querying the data warehouse. Query throughput determines the success of data warehousing project. The response time is also more significant factor than transaction throughput [2].

R. Kimball defines Data warehouse as

"It is a copy of transactional data specifically structured for querying and analysis" [25].

Bill Inmon, considered to be the father of data ware house provide the following definition

"It is subject-oriented, integrated, nonvolatile and time variant collection of data in support of management's decisions" [3].

Subject-Oriented Data Collections

In Online Transactional Processing (OLTP) systems, data is organized around the applications of the company. For example, when we store data for the order processing system in an application it will provide the over all functionally like stock checking, receiving orders, billing etc [2]. But in data warehousing, data is organized by the detailed subject such as customer, policy, premium, and claim for an insurance company. The major subject areas for the manufacture company may be vendor, product, order and

raw material [3]. Subject orient nature of data warehouse provides more comprehensive view of the organization and help to improve decision making [1].

Data Integration

In data warehouse, data has to be loaded from different sources and formats. Data loaded from these sources must be in homogenous format. So in data integration data has to checked, cleaned, converted, reformatted, re-sequenced into a unique desirable format. So at the end, data has a single physical corporate image [2].

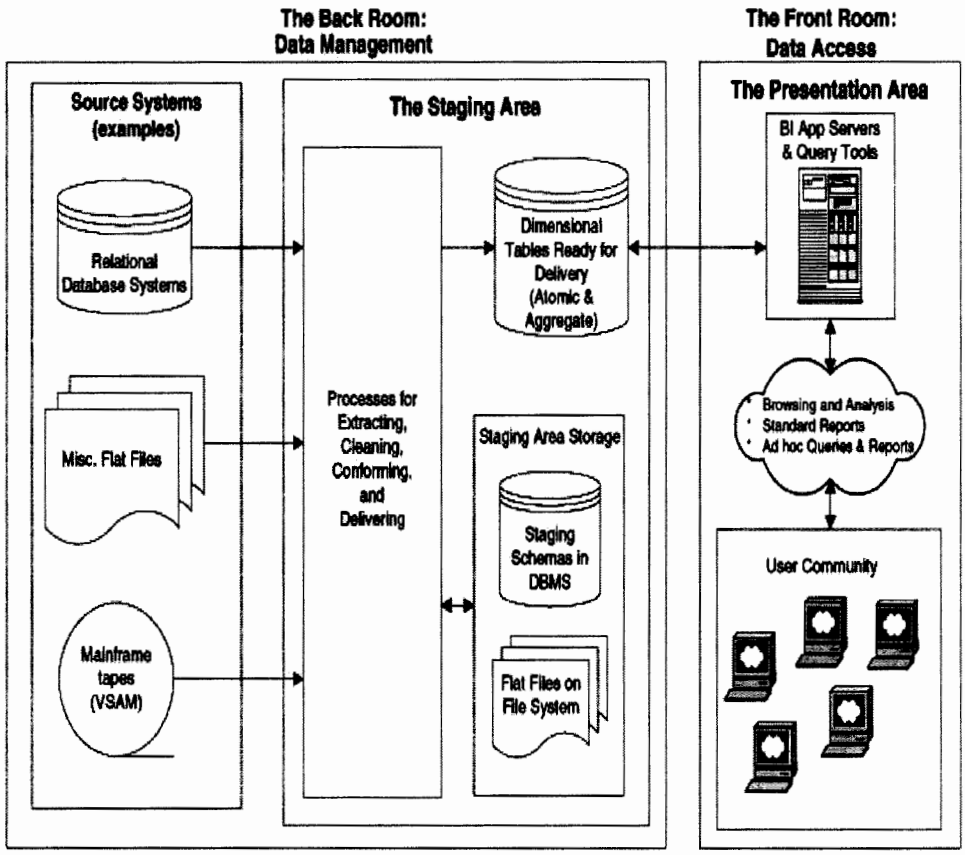


Fig 2.13: Data Warehouse Architecture [4]

Non-Volatile Data Collections

In OLTP systems, we can modify data after insertion but in data warehouse it is neither changed nor removed. Instead, when data in the data warehouse is loaded, it is loaded in a snapshot, static format. When subsequent changes occur, a new snapshot record is written. In doing so a history of data is kept in the data warehouse [3].

Time-Variant Data Collections

Data in the data warehouse is correct with some reference of time. Every record in the data warehouse has time stamp associated with it. In OLTP system, the contents changes with the passage of time i.e. updates such as student fee, bank balance of customer, mobile phone balance. But in data warehouse as data is load that moment becomes the time stamp of data. In OLTP systems, 60-to-90-day time horizon is normal; while in data warehouse this time can be in years i.e. 5-to-10-year. So we can easily conclude that data warehouse contains much more history than any other environment [3]

Goals of Data warehouse

Following are the important goals of data warehouse

- The data warehouse must make an organization's information easily accessible.
- The data warehouse must present the organization's information consistently.
- The data warehouse must be adaptive and resilient to change.
- The data warehouse must be a secure to protect our information assets.
- The data warehouse must serve as the foundation for improved decision making.
- The business community must accept the data warehouse if it is to be deemed successful.

We can say that data warehouse is blend of technologies with the following features

- Take all data from different operational system.
- If necessary, add relevant data from industry.
- Transform all data and bring into uniform format.
- Integrate all data as single entity.
- Store data in a format supporting easy access for decision support.
- Create performance enhancement indices.
- Implement performance enhancement joins.
- Run ad-hoc queries with low selectivity

2.1.3.1 Data Warehouse and OLAP

Online Analytical Processing (OLAP) is a framework, not a physical database design or implementation technique. It is highly or partially demoralized implementation but OLTP is fully normalized. A data warehouse without an OLAP tool is nearly unthinkable. Data warehousing and OLAP are essential element of Decision support system (DSS). Data warehouse provide the best support for analysis while OLAP carries the analysis task. Although there is more to OLAP technology that data warehousing, the classic statement of OLAP is "decision making is an iterative process, which must involve the users". So we can conclude that OLAP system keep the user's record and assist the users in performing the routine operation tasks of their daily work. OLAP systems on the other hand generate information that users require to do the non routine parts of their jobs. OLAP system deal with unpredicted circumstance.

There are many operations, which are important in OLAP such as

- It uses multilevel aggregation for analytical processing, instead of record level access.
- Selection and projection are the crucial operation for responding query

- Re-orienting the multidimensional view of data is also valuable operation of OLAP

Data warehouses are implemented through different implementation methods. These factors compel the designer to implement data warehouses separately from traditional databases. Implementation of OLAP can be done by using multidimensional Relational OLAP, hybrid OLAP, relational OLAP and DOLAP.

2.1.3.2 Administration and Management Tools

We have end to end tool for the specialized operation. These tools perform the operation like data extraction data from difference sources, cleaning, transforming and integration of extracted data, loading / refreshing data into the data warehouse from different sources.

A data warehouse requires tools to support the administration and management of such complex environment. These tools are relatively scarce, especially those that are well integrated with the various types of metadata and day to day operation of data warehouse. The data warehouse administration and management tool must be capable of supporting the following tasks [4].

- Monitoring data loading from different source.
- Data quality and integrity checks.
- Managing and updating Meta data.
- Monitoring database performance to ensure efficient query response times and recourses utilization.
- Purging data.
- Implementing recovery following failure.
- Security management.
- Auditing data warehouse usage to provide user change back information.
- Maintaining efficient data storage management.

- Replicating, sub setting and distributing data

Back End Tools

Several tools are available for data extraction. There are also a number of cleaning tools. There are utilities for loading data as well as for refreshing warehouses. Standard interfaces are used to extract data from "external" sources. These interfaces include:

- Informix Enterprise Gateway
- Information Builders EDA / Structured Query Language (SQL)
- Object Database Connectivity (ODBC)
- Oracle Open Connect
- Sybase Enterprise Connect

2.1.3.3 Multidimensional design methodology /Conceptual data model

It is a simpler logical model optimized for decision support. It plays an important role in data warehouse design. The foundation of multidimensional is facts and dimension tables. Facts are numeric measures such as sales; while dimensions are source of inserting constraints and are descriptive textual information such as product.

For multidimensional modeling two schemes are available.

- Star Schema
- Snowflake Schema

Star Schema

A star schema is generally used to design data model of the data warehouse. It is best choice of design because of demoralized nature of data in data warehouse and with fewer

join operations involve. In star schema, we have one fact table and set of dimension tales. Each dimension in this model has primary key and corresponds to one of the component in multipart key of fact table. So at the end, the structure forms the shape of star like schema.

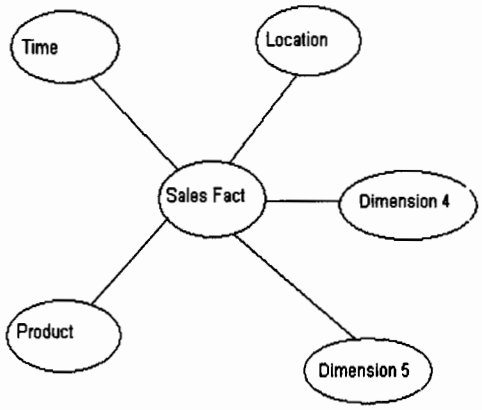


Fig 2.14: Star schema [27]

Snowflake Schema

When a de-normalized dimension table becomes very large and penalizes the star join operation then star schema might suffer performance problems. Conversely, sometimes a small outer-level dimension table does not incur a significant join cost because it can be permanently stored in a memory buffer. Furthermore, because a star structure exists at the center of a snowflake, an efficient star join can be used to satisfy part of a query. Finally, some queries will not access data from outer-level dimension tables. These queries effectively execute against a star schema that contains smaller dimension tables. Therefore, under some circumstances, a snowflake schema is more efficient than a star schema.

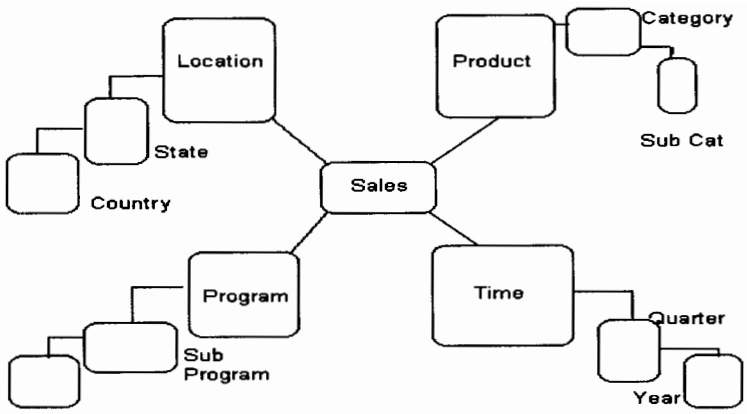


Fig 2.15: Snowflake schema [27]

2.2 Related Research

The past research has focused on the topic of knowledge warehouse, but clearly, more needs to be done. In the paper [8] the authors H.R. Nemati, D. M. Steiger, L S. Iyer and R. T. Herschel focused the need of knowledge warehouse that provides the infrastructure needed to capture, cleanse, store, organize, leverage, and disseminate not only data and information but also the knowledge of the firm. The proposed architecture is very generic and data extraction is only from transaction processing system with much work remaining.

According to [8], the Knowledge warehouse (KW) goals suggest the following functionality

"1. KW should has ability to efficiently generate, store, retrieve and, in general, manage explicit knowledge in various forms

2. It should be able to store, execute and manage the analysis tasks and their supporting technologies with minimal interaction and cognitive requirements from the decision maker

3. *Should be able to update the knowledge via a feedback loop of validated analysis output."*

To fulfill these goals and functional requirement, a basic architecture of knowledge warehouse is proposed.

This knowledge ware house proposed by Nemati has six components.

"1. Data / knowledge acquisition module.
2. *The two feedback loops.*
3. *The extraction, transformation and loading module.*
4. *A knowledge warehouse storage module.*
5. *The analysis workbench.*
6. *A communication manager/ user interface module."*

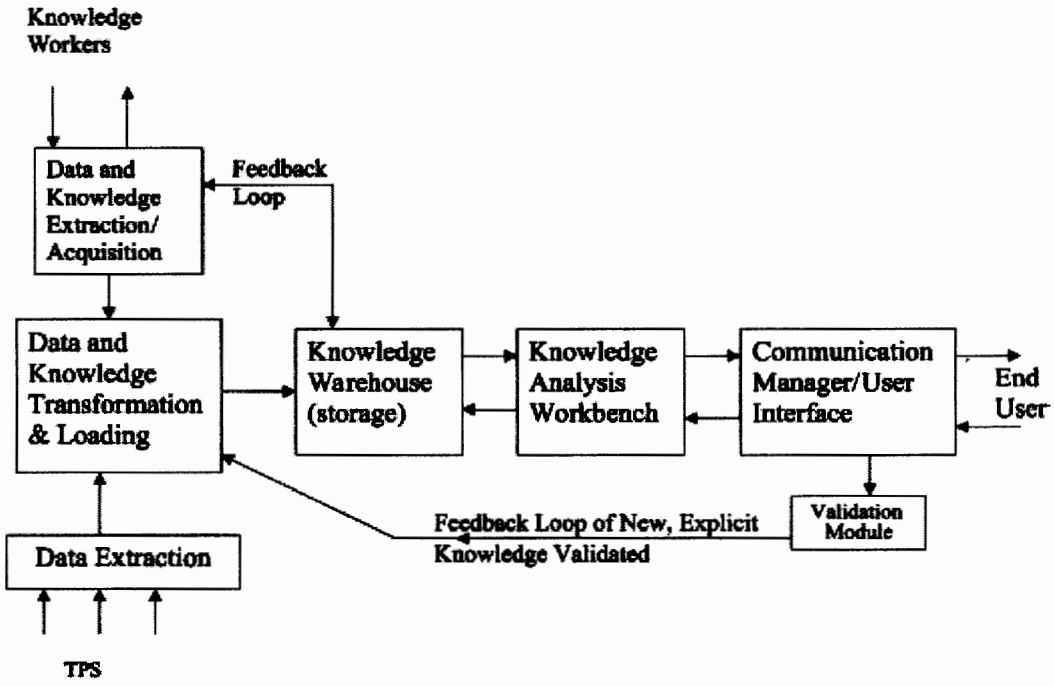


Fig 2.17: Knowledge warehouse basic architecture [8]

In [8] just the basic architecture is given and prototype for the proposed KW architecture is beyond the scope of the papers. It is future agreed that development and implementation of KW may involve extensive amount of organization's efforts and time in term of months or even years. Knowledge warehouse project is a highly financed project i.e. it requires a huge amount, normally in millions of dollars.

In this research we have focused on the implementation of the knowledge warehouse. This would be the first step towards this direction and will explore further implementation issues for future researchers.

2.3 Limitations

The existing architecture of the Knowledge Warehouse (KW) by Nemtai in [8] has the following limitations.

1. The exiting architecture of KW is basic and at abstract level.
2. How knowledge will be captured, codified and cataloged from different sources like frames, semantic nets, decision table etc?
3. How the captured knowledge will be merged and integrated?
4. How the knowledge will be refined before storing in knowledge warehouse?
5. How the maintenance of the knowledge warehouse can be made more simple and easier?
6. How knowledge will be transformed into a common format from all the sources?
7. What will be the knowledge storage structure and format?
8. How the stored knowledge will be accessed and processed in knowledge warehouse?
9. How the knowledge will be enhanced in the knowledge warehouse using different technologies?

2.4 Summary

In this chapter we have seen the different structure of knowledge representation i.e. frames, semantic nets, decision trees etc. Then we have viewed that how we can create new knowledge from the existing knowledge through four steps i.e. socialization, articulation, Internalization and Integration and knowledge management process. After that Data warehouse, popular decision support system, has been observed with architecture in detail. We also have seen the basic and abstract level architecture of existing knowledge warehouse by Nameti.

We already have seen the limitation of the existing architecture and in coming chapter going to purpose the new frame work of knowledge warehouse which would be capable to store the data and knowledge as well. In coming chapter we will also discuss the scenario i.e. education sector where we will apply knowledge warehouse.

CHAPTER 3. REQUIREMENT ANALYSIS

3.1 Introduction

Data, information and knowledge are the term commonly used in an organization. Before going into detail of the problem, first we will explore the difference between the terms data, information and knowledge. Then we will have problem detail.

3.1.1 Data, Information, and Knowledge

Data is the collection of raw fact and figures usually formatted in a special way. Data is used to collect the information which term is used for knowledge. Data is available is different forms such as numbers, text, graphics, sound, dates and pictures. Examples of data are name, age, joining date etc.

"Information is the result of processing, gathering, manipulating and organizing data in a way that adds to the knowledge of the receiver" [1]. Examples of information are average and percentage etc.

Knowledge is processed form of information and can be stored in form of set of rules and relationship.

According to Klein

"Work procedures and processes, precedents, details and conceptual relationships between topics in a domain are the components of knowledge in a knowledge-based system"[49].

In relation data base it is in the form of text or number; while in knowledge base system represented in the form of an expert's rules. Other forms of knowledge accessed and processed by computers are business rule, expert knowledge, procedures etc.

One example of data, information and knowledge can be a road map. Here data is detail deriving directions from place to another. Information is different instructions by traffic

police to slow down traffic because of road construction ahead. At the end, knowledge is awareness of back-roads route [1].

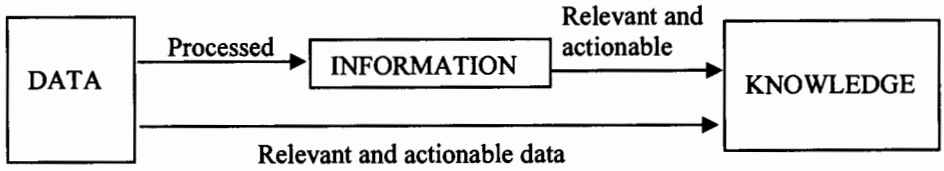


Figure 3.1: Data, Information and Knowledge [1]

3.1.2 Problems in Data warehouse

Data Warehouse (DW) is gradually gaining fame as data repository system for enterprises. It is used to store the data for decision making from different sources. In data warehouse, data is gathered from different operational system and loaded it into data warehouse using different ways [2]. Then different reporting tools and templates are used to access stored data. [31]. So we can say that data warehouses store data but do not store knowledge directly. It deals with read only data and manipulate data for managerial purpose. It also has no intelligent mechanism for decision making.

Data warehouse is mostly used to handle subject oriented jobs and support strategic decision in contrast to the online transaction process (OLTP) systems. Data warehouse is basically used to provide information to knowledge workers for efficient decision making based on solid foundation of facts. But in practice, only a fraction of the needed information exists on computers as employees of the firm keep vast majority of knowledge in their minds [8].

Employees and consultants are main repository of enterprise knowledge but organization loses this knowledge when the employee retires or leave. The current state of data warehouse raises the following issues of storing knowledge for high capability decision support, comprehensively integration and support of knowledge production [31]. More-

ever, Structured Query Language (SQL) used in data warehouse is exclusively designed for database queries. It is good enough for data managing but not suitable for knowledge handling.

3.1.3 Organizational Knowledge

In business organization employees, management and consultants, are main repository of organizational knowledge in the business organization. Organization can lose the important knowledge in case employee resigns death or retirement. So this knowledge must remain in organization in case of any above scenario. Procedure manuals can store rules and processes. Programs and databases are also used to store knowledge. Many firms have been using computer programs for processing of business activities for a couple of decades. A well-organized, proper, detailed and comprehensive documentation is necessary for handling business activities through computers. These manuals help in locating the knowledge. These manuals also make the knowledge understandable. Without documentation, codes of computer programs contain the business process knowledge.

The knowledge repository of organization enables it to elucidate, forecast and predict events in different situations [31]. The knowledge in the knowledge repository is validated by using different rules and tests. So we can say that quality of knowledge will depend on tendency of validation rules and tests. This knowledge will improve organizational performance in term of business administration, operations, intelligence and management [3].

3.1.4 Why Knowledge Warehouse?

Knowledge warehouse is a new direction towards decision support systems after data warehouse. We can say it is the enhanced form of data warehouse. The knowledge warehouse will use the data / knowledge for decision making while data warehouse uses

data for this purpose. It will also provide the intelligent mechanism for the decision making based on data / knowledge in the knowledge warehouse.

Organizations have the information, data / knowledge in different forms coming from different sources such as semantic networks, frames, knowledge map, production rules, decision table, decision trees, scripts, use cases etc. Theses knowledge representation techniques have advantage and disadvantages. For example semantic networks are easy to follow hierarchy and easy to trace associations, flexile but at the same time have disadvantage like node might be ambiguous, difficult to program. Similarly production rules have simple syntax, easy to understand, flexible and highly modular but are inefficient for the large systems. It is also impossible to represent all the knowledge of organization in form of rules. Further, if a given rule is changed then there may be ripple effect.

Currently data warehouses are the latest form of decision support system but it raises the issue of knowledge storage for high capability decision support. It also has no intelligent mechanism for decision making. Problem also arises during access of knowledge from different sources like frame, semantic network, decision table, decision tree, scripts etc and comprehensively integration of knowledge into a common format.

As the knowledge warehouse is new field in this era, number of issues has to be solved yet. Theoretical and technical issues make the field of knowledge warehousing more challenging.

Some of the important issues are

1. What will be the comprehensive architecture of Knowledge Warehouse i.e. size and scope of knowledge components in a knowledge warehouse?
2. How knowledge will be capture, codify and catalog from difference sources like frames, semantic nets, knowledge map, decision tree, decision table, script, use case etc.

3. What will be the knowledge storage format?
4. How knowledge will be transformed into a common format from all the sources?
5. How the captured knowledge will be merged and integrated?
6. What would be the processes to remove inconsistencies and redundancies from data / knowledge coming from different sources?
7. How the maintenance of the knowledge warehouse can be made more simple and easier?
8. How the knowledge will be analyzed / mined in knowledge warehouse?
9. How knowledge will be enhanced in the knowledge warehouse?

In this research, efforts are made to sketch the architecture of Knowledge Warehouse that will stores data, information and knowledge as well. It will capture knowledge from two sources i.e. frames, semantic network; other sources can be added in future work. The acquired knowledge will be transformed into Meta knowledge using transformation algorithm. Then this transformed Meta knowledge will be called knowledge warehouse. We also have proposed knowledge storage format (i.e. object base) to store the data and knowledge in knowledge warehouse.

3.2 Critical Scenarios

In current age of computers, we need to achieve both costs down as well as high quality products services. In order to solve the problems more efficiently and effectively, we need to integrate wide range of knowledge in the form of knowledge warehouse. So here comes the need of knowledge warehouse of any organization whether it is profitable or not.

Executive managers make query based on different facts, knowledge which are coming from different sources and in different formats. So it is a critical issue to handle the situation. Therefore, it is very crucial to have data/ knowledge warehouse system in an organization. When we have data/ knowledge in Meta data/ knowledge form then it may

lead to access a query in decision making in an efficient way provided an intelligent mechanism or agent is available.

Knowledge warehouses can be applied in different area and scenarios. For example we can apply knowledge warehouse in education, health, media or any type of business or organization.

3.3 Focus of research

In this research work, we are focusing on higher level of education. As we know that universities are the main instruments of society for the constant pursuit of knowledge. Knowledge management in educational settings should provide a set of designs for linking people, processes, and technologies and discuss how organizations can promote policies and practices that help people share and manage knowledge. In universities we have academic and organization knowledge as well. Academic knowledge is the primary purpose of universities and colleges. Organizational knowledge refers to knowledge of the overall business of an institution: its strength and weaknesses, the markets it serves, and the factors critical to organizational success [37].

In this research we have taken a virtual university campus as test case of our knowledge warehouse. However, our proposed knowledge warehouse is able to work in all situation cases with minor adjustment.

Virtual University of Pakistan is government university established in 2000 to promote the on line education in Pakistan. The model of university is based on three major components i.e. university campuses, internet and virtual television network. University teachers deliver the lectures through using own four virtual TV channels. This enthusiasm in web-based education is primarily driven by cost savings and bottom line net profits to student and institutions as well.

In university web-based masters, bachelor and diploma level courses are being offered. Regardless of all the benefits reported, difficulties are still encountered by students. In fact, past experience since 2000 university campuses show that the web environment for learning is not appropriate for everyone. Normally students take admission with out knowing the basic knowledge of university and study mode. There is no mechanism which guides the students to choose best degree program according to their qualification and background. So result leads to disconnection of studies from students even in first semester. It wastes the time and money of the student and effect the reputation of campus and university as well. Therefore, the primary question should be "who is appropriate to take web-based courses?" What guidance is being offered to the students at campus and university level in choosing the correct degree program for the future? This of course is in the context of success as it relates to enhanced learning experience and improved performance.

So we will solve the problem by developing a knowledge warehouse of virtual university campus which will guide and help the students in taking best discipline. This knowledge warehouse identifies unfavorable conditions for success to the student and suggests remedial activities to enhance the student's success.

3.4 Summary

In this chapter, difference between data, information and knowledge has been discussed. Problem domain also has seen in detail i.e. knowledge warehouse very deeply and justified why it is required? As I have said that knowledge warehouse will be independent of any filed or organization. In this research we are taking Virtual University Campus as a test case of knowledge warehouse. In the coming chapter we will sketch the architecture of knowledge warehouse with proposed algorithms to capture data/ knowledge.

CHAPTER 4: SYSTEM ARCHITECHTURE

4.1 Introduction

Knowledge is valuable asset of organization in this era. Once knowledge becomes available, it has to be leveraged to affect the organization bottom level. It should be enhanced like any other asset. Retaining and applying knowledge enable an organization to know what to do, how to do and when to do it. In data warehouse, data is gathered from different operational system and loaded it into data warehouse using different ways [2]. Then reporting tools and templates are used to access the stored data in efficient manner. So we can say that data warehouses store data but do not store knowledge directly. Data warehouse is basically used to provide information to knowledge workers for efficient decision making based on solid foundation of facts [8]. We can say that data warehousing are "mid-game" activities and help to make knowledge available. So we needed a new generation of knowledge base system which will store data and knowledge as well.

In knowledge management we have systematic process for capturing, integrating, organizing and communicating knowledge accumulated by organization [2]. Knowledge management system may store different types of knowledge i.e., both tacit and explicit knowledge. The different forms of knowledge may stored in KMS are text streams, decision tree, mathematical models frames, semantic nets, binary large objects, production rules etc. A knowledge management system stores all such knowledge in a knowledge repository call knowledge warehouse. The knowledge ware house must contain the information of knowledge about it self called Meta knowledge [8]. This stored Meta knowledge will be same as Meta data in data warehouse.

4.2 Proposed Knowledge Warehouse Architecture

In this research work, architecture of knowledge warehouse has been proposed. It will provide the infrastructure to store knowledge along with data and information. It will be capable to provide the same services for knowledge which data warehouse provides for data. It will facilitate the decision maker(s), in access of knowledge from different sources like decision trees/ tables, frames, logics, semantic networks and use cases etc

and it's comprehensively integration with storage support, to improve his / her decision making.

In this research work, because of time limitation we have selected two different sources of knowledge i.e. semantic networks and frames. An algorithm has been developed to extract data / knowledge from these sources.

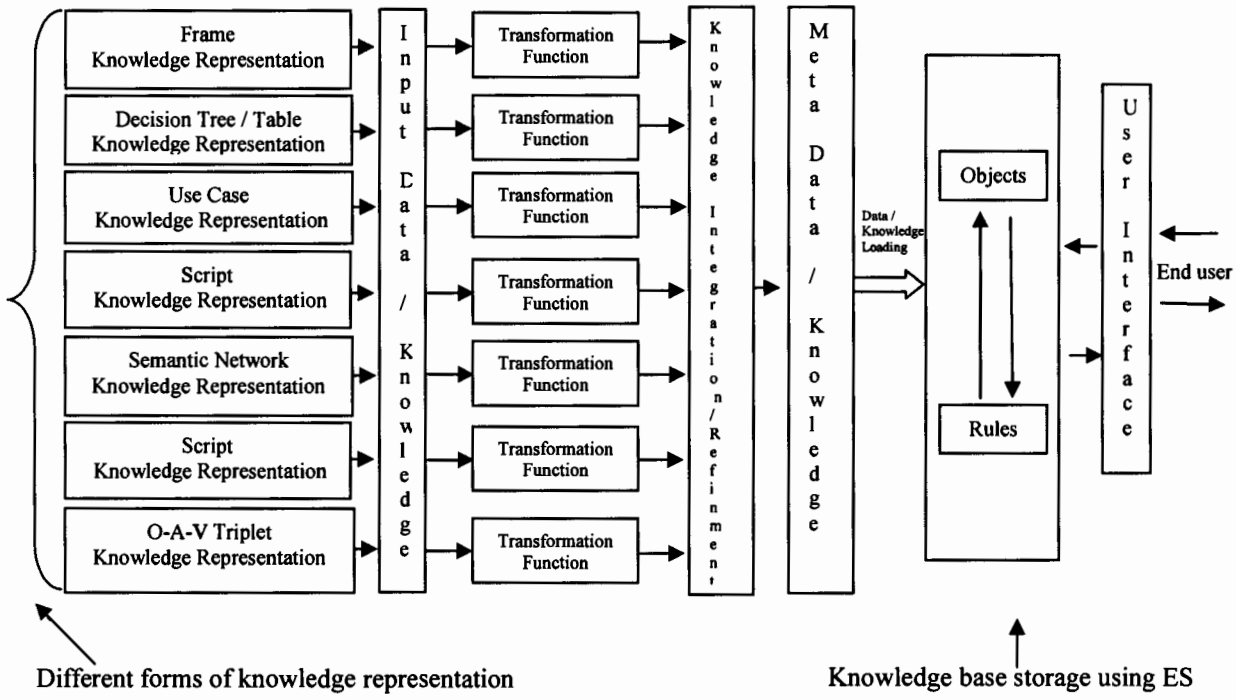


Fig: 4.1 Proposed Knowledge warehouse Architecture

The proposed architecture, shown in fig 4.1, has five main components 1) data / knowledge acquisition module 2) Transformation Algorithm / function 3) Knowledge Refinement and Integration Module 4) Knowledge storage module and 5) User interface module. Detail of each component is given below.

4.2.1 Data / Knowledge Acquisition Module

Knowledge acquisition is the process of extracting, structuring and organizing knowledge from one or more sources such as frames, semantic nets, knowledge map, scripts, use case etc. The knowledge acquired from the above sources can further be use as facts / rules and heuristics for a decision support system i.e. expert system. In order to acquire knowledge for the knowledge warehouse, an algorithm has been written that will capture the data / knowledge from the above mentioned sources and store it into an object text file. In most of the cases, we have to write separate transformation function for each of the knowledge sources.

4.2.2 Transformation Function / Algorithm

Data / knowledge loaded from different sources must be homogenous. This is where transformation is required. Transformation algorithm/ function is the process of transforming data / knowledge from different sources to desirable object oriented form.
In this research, transformation algorithms / functions are required to extract data / knowledge from the sources like decision table / tree, knowledge map, production rules, semantic network, script etc. and converted it into a common desirable knowledge format, which is object base. Detail of the algorithm is as under.

Algorithm 1: Frames_Semantic to_Object_Text_File:

This algorithm will convert a knowledge structure (semantic networks or frame) into an object text file having object name, attribute, procedures, generalization (super classes and subclasses), composition, aggregation, association and relationship.

Input: A Semantic network or Frame Knowledge structure "KS".
Output: An Object text file "OTF".

BEGIN

1- Get a node from KS and store into node1.Write node1 under heading "object name" in OTF.
2- Get attributes and procedures of node1
   If found

Write attribute(s) under heading "attribute(s)" and procedure under "procedure" heading in OTF.

End if

3- If the "node1" is linked with the other node "node2" then

A. Report relationship found

B. If label between node1 and node2 is *"is a"* then

[Generalization / is-a / a kind of]

a) Report inheritance found

b) If node1 is "to" node2 then

i. Superclass = node2

ii. Relationship = node1-node2 (1 1)

iii. Write node2 under heading "super class(s)" and node1-node2 (1 1) under heading relationship(s) if not listed in OTF.

Else [node1 is "from" node2]

i. Subclass =node2

ii. Relation ship = node1-node2 (1 n)

iii. write node2 under heading "sub classes(s)" and node1-node2 (1 n) under heading relationship(s) if not listed in OTF

End if

Else if label between node1 an

d node 2 is "a-part-of or has-a" then

[Aggregation / a-part-of / part-whole]

a) Report aggregation found

b) If node1 is "to" node2 then

i. Relation ship = node1-node2(1 n)

ii. Write node 2 under heading "aggregation" and node1-node2 (1 n) under heading relationships(s) if not listed in OTF.

Else [node1 is "from" node2]

i. Relation ship = node1-node2 (0 n)

ii. Write node2 under heading "aggregation" and node1-node2 (0 n) under heading relationships(s) if not listed in OTF.

End if

Else if label between node1 and node 2 is "owns/belong-to/others" then

[Association / owns]

a) Report association found
b) Relation ship = node1-node2(1 n)
c) Write node2 under heading "association" and node1-node2 (1 n) under heading relationships(s) if not listed in OTF.

End if [End of main if]

4- Repeat step 3 for all the nodes connected with node1

[End of process for one knowledge node]

5- Do step 1- 4 for all the nodes in KS.

End

4.2.3 Knowledge Refinement and Integration Module

When we acquire data / knowledge from the different sources using the transformation function, then the acquired data / knowledge should be merge and integrate before storing into knowledge warehouse storage module. The purpose of this step is data / knowledge coming from different sources using transformation functions has to be verified against inconsistencies and redundancies. In this research, an algorithm is written which will merge and integrate the data / knowledge from two object text file to a single object text file.

Algorithm 2: Merge_Integrate_SemanticNet_Frames

This algorithm will merge and integrate two object text file giving third one. TEMP is a variable to store the value temporally.

Input: Semantic networks file in source object text file1 "OTF1"
Frames file in source object text file2 "OTF2"

Output:

An object text file "OTF3" having merged and integrated contents of OTF1 and OTF2.

Begin

1- Open OTF1 and OTF2 for input, OTF3 for out put.
2- Read heading "object name" and its contents into TEMP from OTF1 and write TEMP under the heading "object name" in OTF3.
3- Read all head heading "attribute(s)", "procedure(s)", "subclasse(s)", "super classes", "composition", "association", "aggregation" and respective contents of object TEMP from OTF1 and write into OTF3.
4- Search TEMP in OTF2
5- If found then
    i. Report object found in other file also.
    ii. Write contents of TEMP into OTF3 under respective heading if missing.

    End if.
6- Do step 2-5 for all the objects in OTF1.
7- Read heading "object name" and its contents into TEMP from OTF2
8- Search TEMP in OTF3
9- If found then

        Report contents of object already written in OTF3.

    Else

Read all heading and respective contents of TEMP and write into OTF3.

End if

10- Do step 7-9 for all the objects in OTF2.

End

4.2.4 Knowledge Warehouse Storage

It is the key part of knowledge warehouse architecture based on objects oriented knowledge management system i.e. expert system. The storage of knowledge in knowledge warehouse will be the combination of objects and rules applied to the objects.

We have chosen object base approach due to following reasons.

- Objects can be reused. Once written and debugged then can be used in different applications. In [29], reusing software components which are already available facilitates rapid software development and promotes the production of additional components.
- Objects can integrate the existing knowledge with it own Meta knowledge and methods, it also include the analysis task. [8].
- The object oriented approach reduces the complexity in the implementation of system through modularizations.
- Object approach also facilitate in managing technology, its key features like overloading, encapsulation enables changing in implementation technologies transparent to the user [8]. Overloading feature allows the user to use single user-specified command to call multiple implementation of specified task. So it will reduce the burden of decision maker with independent execution calls.
- The internal design of the object is localized so that it does not depend on the internal design of another component [28].

4.2.5 User Interface

The basic purpose of user interface to provide the flexible communication between the user and knowledge warehouse (KW). The user will interact with KW based on expert system via this graphic interface to solve his / problem. Then the query processor translate natural language query by the decision maker into machine executable language.

4.3 Summary

In this chapter, a new architecture / frame work of knowledge warehouse has been proposed. It will be capable to store the data and knowledge as well. Major components of KW are data / knowledge module, transformation algorithms, knowledge refinement and integration module, knowledge storage module and user interface.

Data / knowledge will be acquired form different sources and will be transformed into common desirable object base format using transformation function. Then this transformed data / knowledge from different sources will be merged and integrated to remove the redundancies and inconsistencies in knowledge refinement process using algorithm. This refined data / knowledge will be stored into an object base knowledge management system i.e. expert system. User interface will be responsible to provide communication between user and Knowledge stored in KW.

CHAPTER 5: IMPLEMENTATION

5.1 Introduction

In this chapter we will apply our proposed knowledge warehouse architecture to the virtual university campus. We have discussed the scenario in detail in chapter 3 that we want to have knowledge warehouse of university campus to guide the students to choose best degree program for them based on their qualification and skills. University campus has knowledge available in different form i.e. semantic net, knowledge map, decision trees, frames, production rules etc. According to our thesis scope we will acquire data / knowledge from two sources, frames and semantic networks, other sources can be added later.

First step is a manual process of acquiring data / knowledge from the above mentioned sources using the transformation algorithm1: Frames_Semantic_to_Object_TextFile, which is same for both of the sources. The data / knowledge acquired from semantic network and frames will be stored into to object files object text file1 and object text file2 respectively. Second step will be the knowledge refinement and integration that will refine, integrate and merge acquired data / knowledge into a single object text file3 using the algorithm2: Merge_Integrate_SemanticNet_Frames. Now we will have Meta data / knowledge in form of object. In future work we will load this file into the knowledge warehouse storage based on expert system, combination of objects and production rule, and this stored knowledge will be accessed by the user interface.

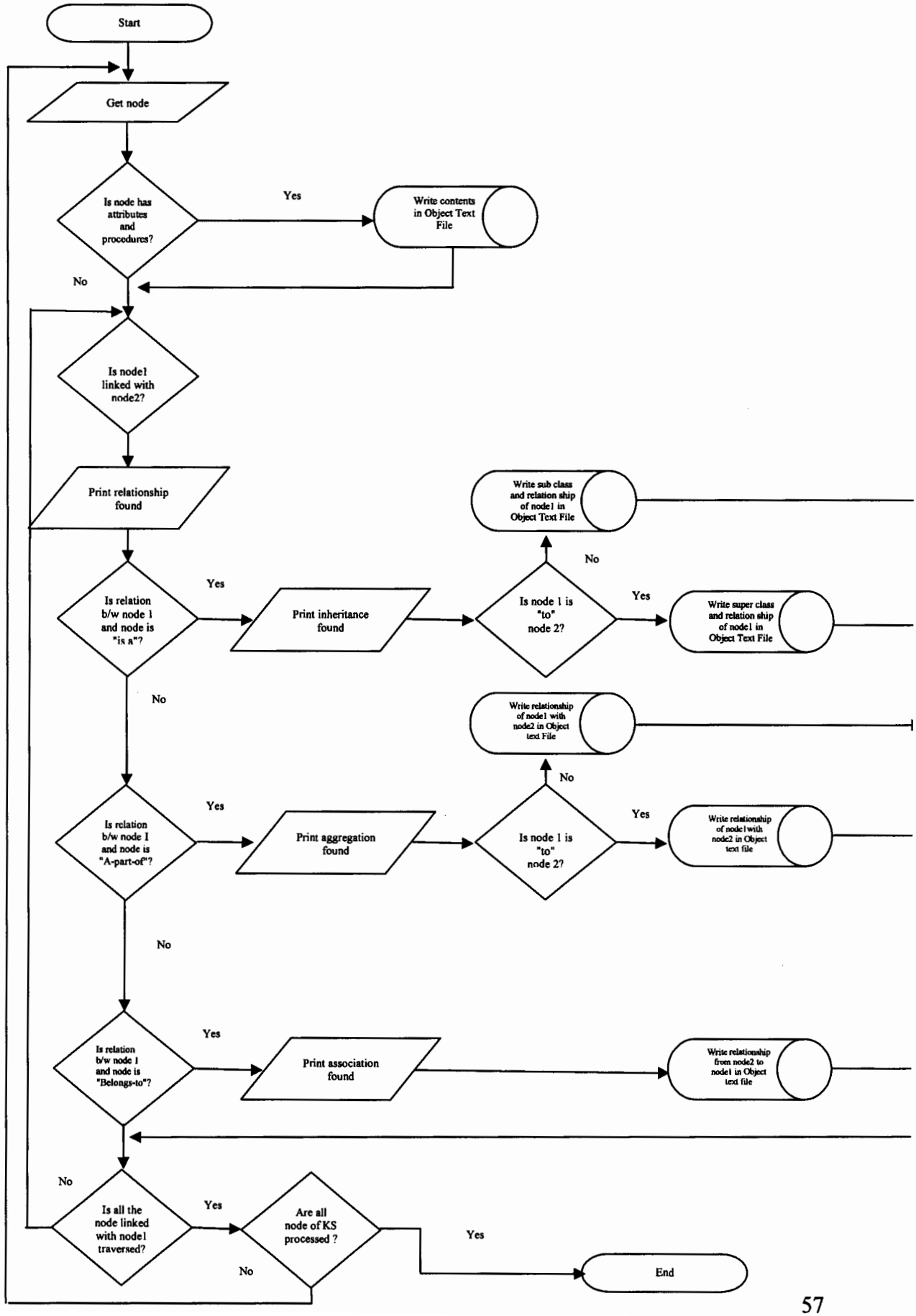
5.2 Flow charts of Extract, Transfer, Merge and Integrate Algorithms

Flowchart is used to represent the nature and flow of process graphically with predefined shapes. In this research work two algorithms have been written to extract, transfer, merge and integrate data / knowledge.

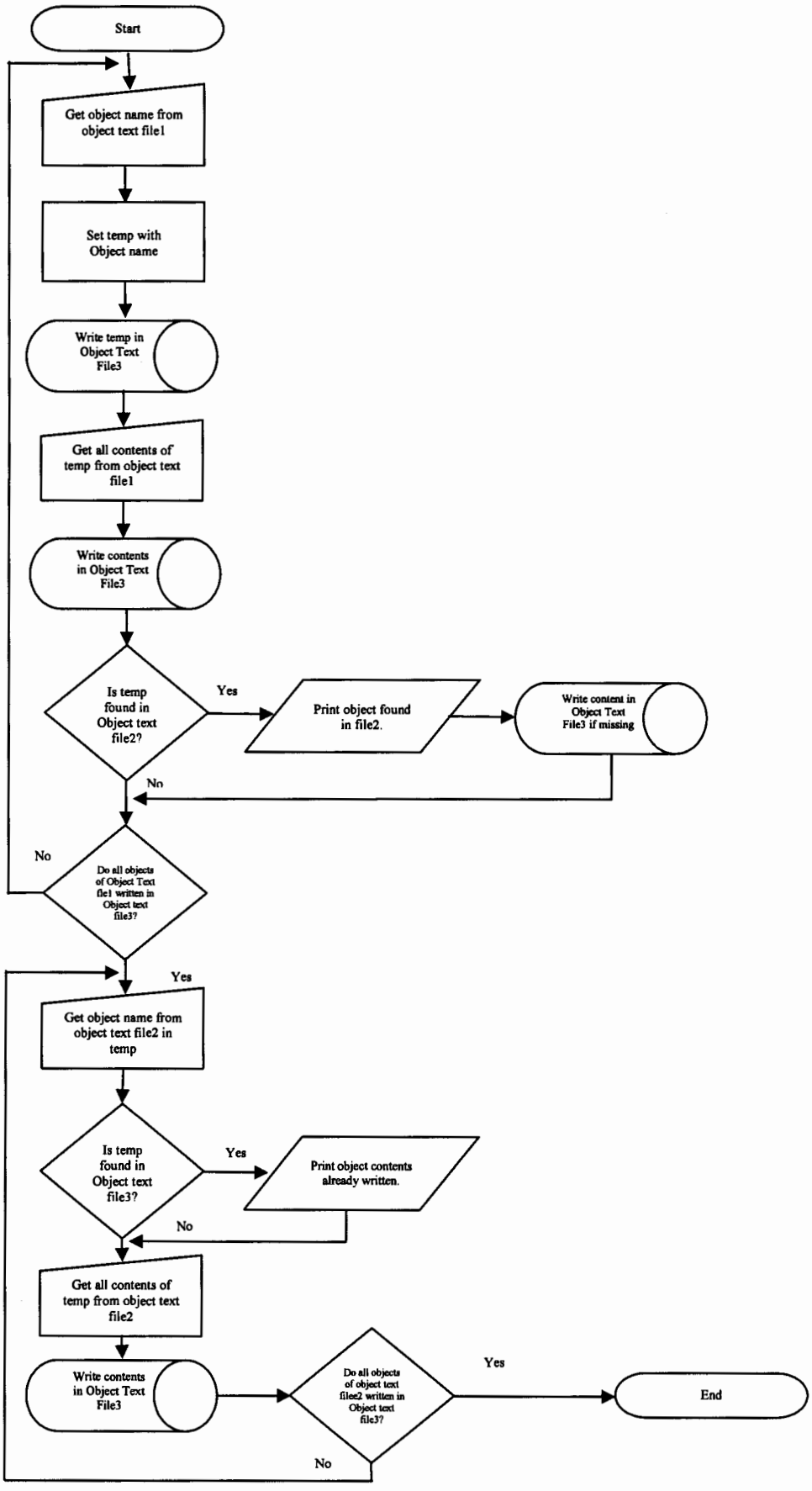
1) Algorithm 1: Frames_semantic to_Object_Text_File
2) Algorithm 2: Merge_Integrate_SemanticNet_Frames

Flow charts of the above algorithms are given below.

5.2.1 Flow chart of Algorithm 1: Frames_semantic to_Object_Text_File:



5.2.2 Flow chart of algorithm 2: Merge_Integrate_SemanticNet_Frames



5.3 Implementation of case study of Virtual University campus

Knowledge warehouses can be used in many fields for decision-making such as decision-making in government departments, in business organizations or even in universities. In this case study we will develop the knowledge warehouse of virtual university. As I described in chapter 3 that Virtual University model is based on three major components i.e. university campuses, internet and virtual television network. Often this system is confusing for the student and effect the efficiently performance of the students. We want to develop the knowledge ware house of virtual university to help and guide in choosing the best degree program for them. It will improve the performance of the student and identifies unfavorable conditions for success to the student and suggests remedial activities to enhance the student's success.

We have university data / knowledge available from different sources like semantic network, frames, script, decision tree etc. According to our scope we will acquire knowledge from two of the source i.e. semantic network and frame representation.

We will use our proposed algorithm to acquire data/ knowledge from the mentioned sources and will convert it to the object

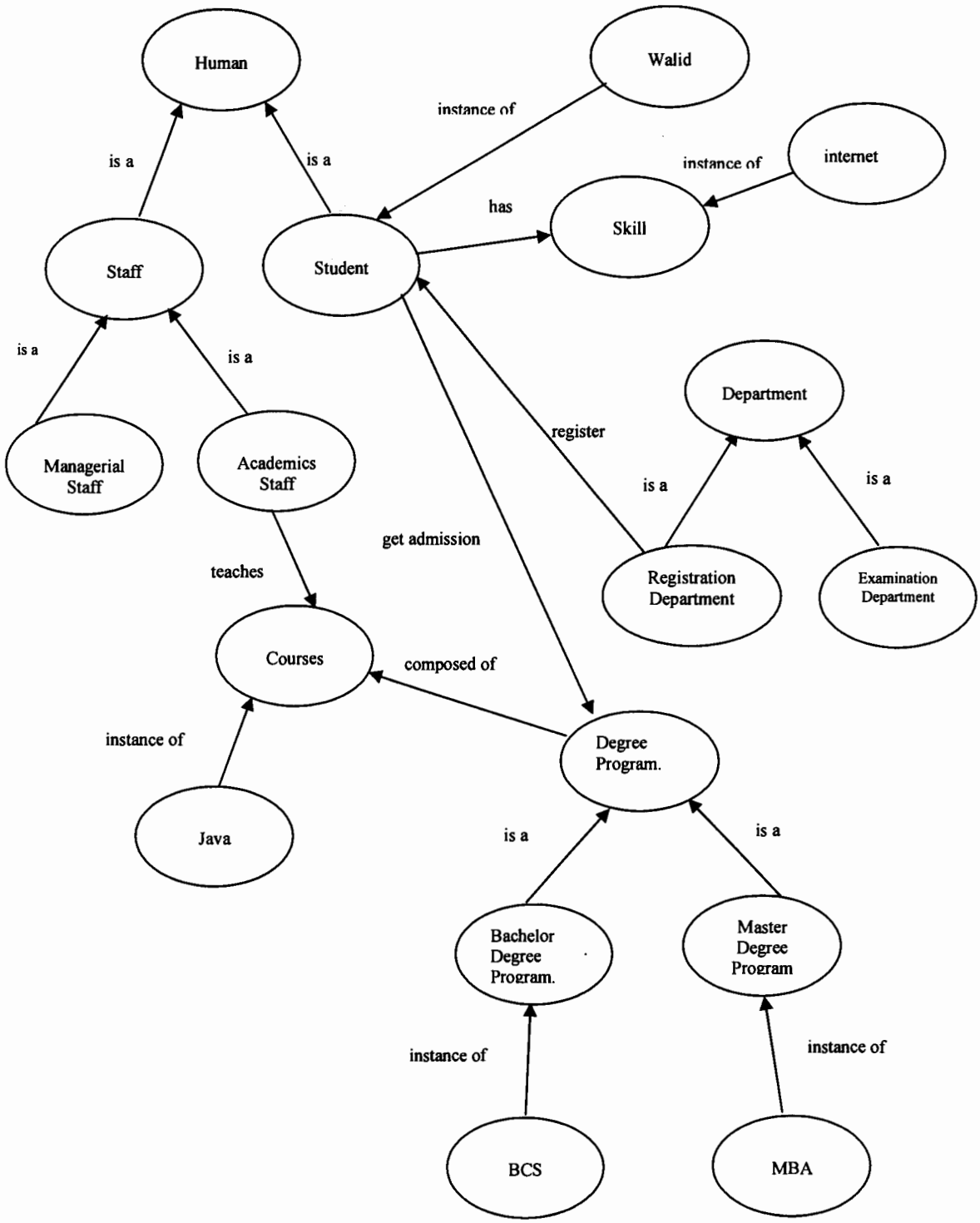


Fig 5.1 : Semantic network representation of Virtual University of Pakistan Campus

Now we will apply the algorithm1: Frames_semantic to_Object_Text_File to extracting data/ knowledge from semantic network. This algorithm will generates object list with all attributes, procedures, generalization (super classes and subclasses), composition, aggregation, association and relationship and save all output in the form of a text file named as object text file "OTF1". A file containing all the information is given below.

Object Text File1"OTF1" of Semantic Network
Using Algorithm1: Frames_semantic to_Object_Text_File

Object name

Human

Subclass

Staff

Student

Relationship

Human-Staff (1 n)

Human-Student (1 n)

Object name

Staff

Subclass

Academics Staff

Managerial Staff

Relationship

Staff-Academics Staff (1 n)

Staff-Managerial Staff (1 n)

Object name

Managerial Staff

Superclass

Staff

Relationship

Managerial Staff-Staff (1 1)

Object name

Academics Staff

Superclass

Staff

Association

Courses

Relationship

Academics Staff-Staff (1 1)

Academics Staff-Course (1 n)

Object name

Student

Superclass

Human

Association

Registration Department

Degree Program

Aggregation

Skills

Relationship

Student-Human (1 1)

Student-Registration Department (1 n)

Student-Skills (1 n)

Student-Degree Program (1 n)

Object name

Skills

Aggregation

Student

Relationship

Skill-Student (0 n)

Object name

Department

Subclass

Registration Department

Examination Department

Relationship

Department-Registration Department (1 n)

Department-Examination Department (1 n)

Object name

Examination Department

Superclass

Department

Relationship

Examination Department-Department (1 1)

Object name

Registration Department

Superclass

Department

Relationship

Registration Department- Department (1 1)

Object name

Courses

Aggregation

Degree Program

Association

Academics Staff

Relationship

Course-Academics Staff (1 n)

Course- Degree Program (0 n)

Object name

Degree Program

Subclass

Bachelor Degree Program

Master Degree Program

Association

Student

Aggregation

Courses

Relationship

Degree Program- Bachelor Degree Program (1 n)

Degree Program- Master Degree Program (1 n)

Degree Program-Student (1 n)

Degree Program-Course (1 n)

Object name

Bachelor Degree Program

Superclass

Degree Program

Relationship

Bachelor Degree Program - Degree Program (1 1)

Object name

Master Degree Program

Superclass

Degree Program

Relationship

Master Degree Program- Degree Program (1 1)

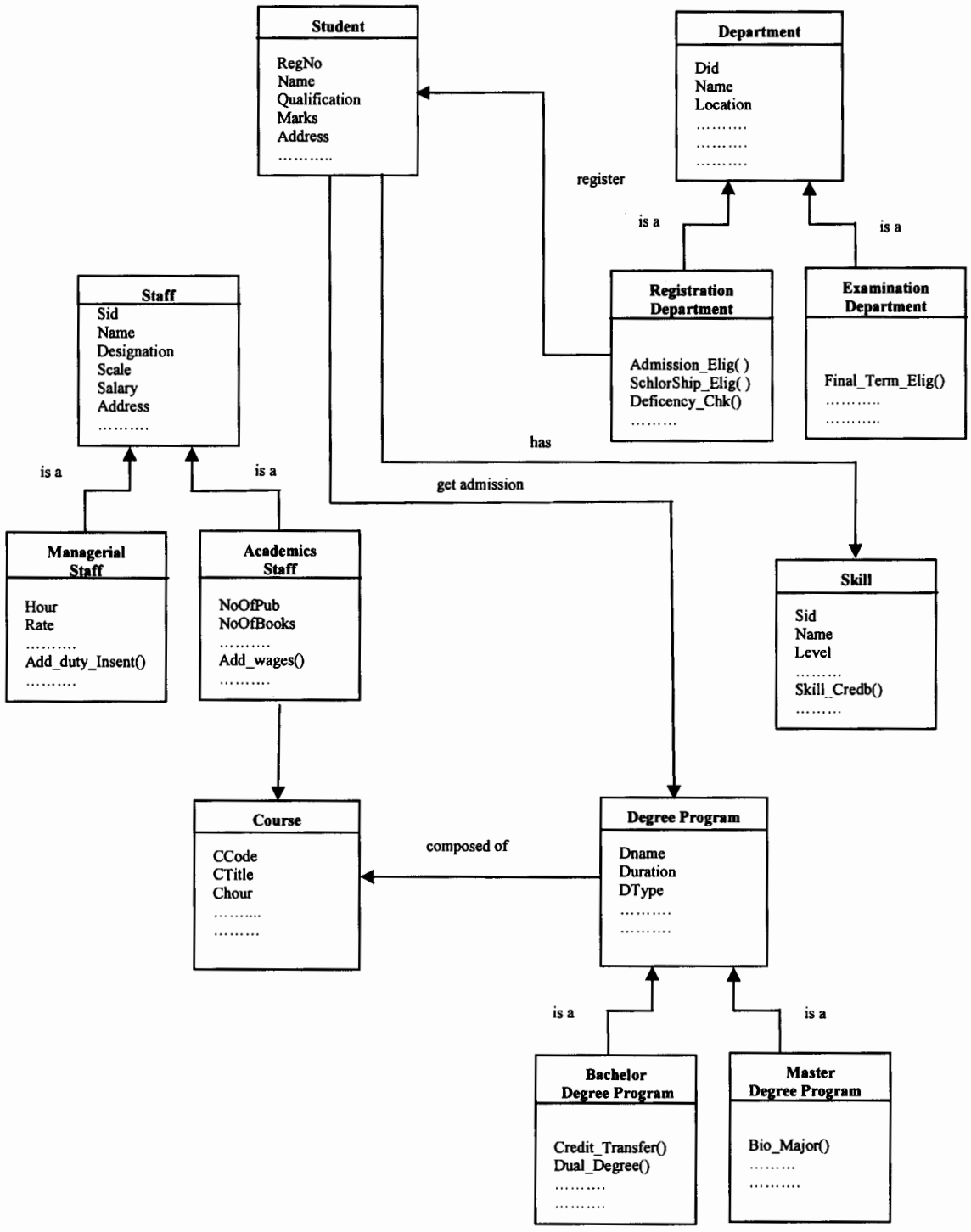


Fig 5.2: Frame Representation of Virtual University of Pakistan Campus.

Now, we will apply the algorithm1: Frames_semantic to_Object_Text_File to extracting data/ knowledge from Frame. This algorithm will generates object list with all attributes, procedures, generalization (super classes and subclasses), composition, aggregation, association and relationship and save all output in the form of a text file named as object text file "OTF2". A file containing all the information is given below.

Object Text File2"OTF2" of Frames
Using Algorithm1: Frames_semantic to_Object_Text_File

Object name

Staff

Attribute(s)

Sid

Name

Designation

Scale

Salary

Address

Subclass

Academics Staff

Managerial Staff

Relationship

Staff-Academics Staff (1 n)

Staff-Managerial Staff (1 n)

Object name

Managerial Staff

Attribute(s)

Hour

Rate

Procedure(s)

Add_duty_Insent()

Superclass

Staff

Relationship

Managerial Staff-Staff (1 1)

Object name

Academics Staff

Attribute(s)

NoOfPub

NoOfBooks

Procedure(s)

Add_wages()

Superclass

Staff

Association

Courses

Relationship

Academics Staff-Staff (1 1)

Academics Staff-Course (1 n)

Object name

Student

Attribute(s)

RegNo

Name

Qualification

Marks

Address

Association

Registration Department

Degree Program

Aggregation

Skills

Relationship

Student-Registration Department (1 n)

Student-Degree Program (1 n)

Student-Skills (1 n)

Object name

Skills

Attribute(s)

Sid

Name

Level

Procedure(s)

Skill_Credb()

Aggregation

Student

Relationship

Skills-Student (0 n)

Object name

Department

Attribute(s)

Did

Name

Location

Subclass

Registration Department

Examination Department

Relationship

Department-Registration Department (1 n)

Department-Examination Department (1 n)

Object name

Examination Department

Procedure(s)

Final_Term_Elig()

Superclass

Department

Relationship

Examination Department- Department (1 1)

Object name

Registration Department

Procedure(s)

Admission_Elig( )

SchlorShip_Elig( )

Deficency_Chk()

Superclass

Department

Relationship

Registration Department- Department (1 1)

Object name

Courses

Attribute(s)

CCode

CTitle

Chour

Aggregation

Degree Program

Association

Academics Staff

Relationship

Course-Academics Staff (1 n)

Course-Degree Program (0 n)

Object name

Degree Program

Attribute(s)

Dname

Duration

DType

Subclass

Bachelor Degree Program

Master Degree Program

Association

Student

Aggregation

Courses

Relationship

Degree Program- Bachelor Degree Program (1 n)

Degree Program- Master Degree Program (1 n)

Degree Program-Student (1 n)

Degree Program-Course (1 n)

Object name

Bachelor Degree Program

Procedure(s)

Credit_Transfer()

Dual_Degree()

Superclass

Degree Program

Relationship

Bachelor Degree Program-Degree Program (1 1)

Object name

Master Degree Program

Procedure(s)

Bio_Major()

Superclass

Degree Program

Relationship

Master Degree Program-Degree Program (1 1)

Now, we will apply the algorithm2: Merge_Integrate_SemanticNet_Frames to refine, merge and integrate contents of files containing semantic network object text file "OTF1 and frames object text file "OTF2" giving a third object text file "OTF3". A file containing all the information is given below.

Object Text File3"OTF3" of Frame and Semantic net

Using Algorithm 2: Merge_Integrate_SemanticNet_Frames

Object name

Human

Subclass

Staff

Student

Relationship

Human-Staff (1 n)

Human-Student (1 n)

Object name

Staff

Attribute(s)

Sid

Name

Designation

Scale

Salary

Address

Subclass

Academics Staff

Managerial Staff

Superclass

Human

Relationship

Staff-Academics Staff (1 n)

Staff-Managerial Staff (1 n)

Staff-Human (1 1)

Object name

Managerial Staff

Attribute(s)

Hour

Rate

Procedure(s)

Add_duty_Insent()

Superclass

Staff

Relationship

Managerial Staff-Staff (1 1)

Object name

Academics Staff

Attribute(s)

NoOfPub

NoOfBooks

Procedure(s)

Add_wages()

Superclass

Staff

Association

Courses

Relationship

Academics Staff-Staff (1 1)

Academics Staff-Course (1 n)

Object name

Student

Attribute(s)

RegNo

Name

Qualification

Marks

Address

Superclass

Human

Association

Registration Department

Degree Program

Aggregation

Skills

Relationship

Student-Registration Department (1 n)

Student-Degree Program (1 n)

Student-Skills (1 n)

Student-Human (1 1)

Object name

Skills

Attribute(s)

Sid

Name

Level

Procedure(s)

Skill_Credb()

Aggregation

Student

Relationship

Skills-Student (0 n)

Object name

Department

Attribute(s)

Did

Name

Location

Subclass

Registration Department

Examination Department

Relationship

Department-Registration Department (1 n)

Department-Examination Department (1 n)

Object name

Examination Department

Procedure(s)

Final_Term_Elig()

Superclass

Department

Relationship

Examination Department-Department (1 1)

Object name

Registration Department

Procedure(s)

Admission_Elig( )

SchlorShip_Elig( )

Deficency_Chk()

Superclass

Department

Relationship

Registration Department-Department (1 1)

Object name

Courses

Attribute(s)

CCode

CTitle

Chour

Aggregation

Degree Program

Association

Academics Staff

Relationship

Course-Academics Staff (1 n)

Course- Degree Program (0 n)

Object name

Degree Program

Attribute(s)

Dname
Duration
DType

Subclass

Bachelor Degree Program

Master Degree Program

Association

Student

Courses

Relationship

Degree Program- Bachelor Degree Program (1 n)

Degree Program- Master Degree Program (1 n)

Degree Program-Student (1 n)

Degree Program-Course (1 n)

Object name

Bachelor Degree Program

Procedure(s)

Credit_Transfer()

Dual_Degree()

Superclass

Degree Program

Relationship

Bachelor Degree Program- Degree Program (1 1)

Object name

Master Degree Program

Procedure(s)

Bio_Major()

Superclass

Degree Program

Relationship

Master Degree Program- Degree Program (1 1)

5.4 Knowledge Warehouse Storage

Now we have extracted data / knowledge and stored it into third file named OTF3. In the same way in future work we can extract production rules from the decision trees / table and will loaded in the knowledge warehouse storage. This storage can be processed by integration of objects and production rule using expert system (ES) [28]. The knowledge base in ES will be the combination of facts and production rules. The facts will be represented as objects that describe the characteristics and behavior. Rules are represented as operations to query these characteristics of objects.

5.5 Summary

In this chapter, proposed algorithms have been applied on Virtual University Campus. Two sources of data / knowledge have been taken i.e. semantic net and frame. First we have extracted the data / knowledge from knowledge structures using algorithm 1 in to a common desired format i.e. object oriented. This algorithm will place data / knowledge into two object text file; one for frames and second for semantic net. Then we have merged and integrated these object files into a third object file.

In this research thesis we have taken knowledge from two sources but in future we have to take production rules from the decision tables and trees to complete the knowledge ware house storage.

CHAPTER 6. CONCLUSION AND FUTURE WORK

6.1 Introduction

Knowledge warehouse is a useful tool for decision making in the modern era. It provides the infrastructure needed to capture, cleanse, store, organize, leverage, and disseminate not only data and information but also knowledge. The basic goal of knowledge warehouse is to provide a platform to obtain consistent and adequate knowledge for efficient decision making. We can say that it will provide the same service for knowledge that a data warehouse does for data. A true knowledge warehouse should store and process both type of knowledge (i.e. tacit and explicit) to facilitate the decision maker in decision making. However in this research paper we have focused on the explicit knowledge. Tacit and remaining sources of knowledge can be part of future work.

Explicit knowledge can be captured from different sources like sources decision trees/ tables, frames, logics, semantic networks and use cases etc. Access of knowledge from different sources and it's comprehensive integration with storage support is very important for efficient decision making. Due to limitation of time we have proposed two algorithms that capture, integrate and store data / knowledge form two different sources i.e. semantic net and frames. First algorithm captures the data/ knowledge from the knowledge representation format (semantic network / frame) and store it into object text file "OTF". Then by using second algorithm we have merged and integrated the above files into a third object text file. Then by using the loading tool we can load this file into knowledge storage module.

We also have proposed knowledge storage format (i.e. object base) to store the data and knowledge in knowledge warehouse. This storage format is proposed due to object reusability, independence, modularity and overloading nature. All these features of object ease / help in creation of large and complex system.

1.2 Improvements

Knowledge warehouse concept was initiated by Nemtai in 2003, but the proposed architecture was very basic and at abstract level [8]. In our proposed architecture we explain how we can capture knowledge from the existing sources i.e. frames, semantic nets, decision tree, knowledge map etc. We have given a comprehensive architecture of knowledge warehouse. Transformation algorithms / functions are introduced used to extract data / knowledge from sources, frames and semantic nets, and covert it into common desired format of object base.

In this research work we have written two algorithms; one is used to capture data / knowledge from above mentioned sources and covert the acquired knowledge into common desired format of object base; Second algorithm is use to merge and integrate the acquired knowledge in two files into a single object text file. We also have shown the knowledge storage mechanism of knowledge warehouse.

6.3 Future Work

Knowledge warehouse in new concept in this era and is next step from data warehouse. We have initiated a step towards the practical implementation of knowledge warehouse but a lot work has to be done in future. For a complete knowledge warehouse following are issues and challenges which should be taken in account in future. Further research can be done on

- Tacit and explicit knowledge can be added and integrated from more sources, so we require more algorithms to write for different knowledge structures.
- Automation tool to covert knowledge into object text file.
- Implementation and maintenance issues.
- Security issues of the proposed architecture.
- Storage structure can be improved by ontology.

REFERENCES

[1] E.Turban, J.E.Aronson, and Liang. (2006) "Decision support system and Intelligent", 7th Ed., India: Prentice Hall.

[2] P. Ponnaiah .(2003) "Data warehousing fundamentals" , 3rd Ed. , India: Wiley Intersience.

[3] William H. Inmon, (2006) Building the Data warehouse, 4th Ed. , India : Wiley Intersience.

[4] T.Conolly, C. Begg, (2005) Database Systems, 3rd Ed , India : Pearson Education.

[5] Jayanta Kumar Tripathy, Nihar Kanta Patra, Manas Ranjan Pani (2007) "Leveraging Knowledge Management: Challenges for the Information Professional" In: DESIDOC Bulletin of Information Technology, Vol. 27, No. 6: 65-73

[6] O. S. Sitompul , S. A. Noah .(2006). "A Transformation-oriented Methodology to Knowledge-based Conceptual Data Warehouse Design" In: Journal of Computer Science 2 (5): 460-465.

[7] Grady Booch. (2002) Object Oriented analysis and design with application, 2nd Ed., USA: Addison Wesley.

[8] H.R. Nemati, David M., Lakshmi S. Iyer, R.T. Herschel (2002) "Knowledge warehouse: an architectural integration of knowledge management, decision support, artificial intelligence and data warehousing' In: Decision Support Systems 33: 143–161

[9] Suyeon Kim, Euiho Suh and Hyunseok Hwang (2004) " Building the knowledge map: an industrial case study" In: Journal of knowledge management Vol. 7 No. 2 :34-45

[10] Maryam Alavi, Dorothy E. Leidner "Knowledge Management And Knowledge Management Systems (2001): Conceptual Foundations And Research Issues" In : MIS Quarterly Vol. 25 No. 1

[11] Won Kim, Seung Soo Park "Knowledge Management: A careful look (2007) " In: Journal of Object technology Vol. 2 No 1

[12] Bertolt Meyer, Kozo Sugiyama "The concept of knowledge in KM:A dimensional model (2007)" In : Journal of Knowledge Management, Volume 10, No 6.

[13] Firas M. Alkhaldi , Mohammad Olaimat "Knowledge Conversion and Transfer: A Mathematical Interpretation (2006)" In : Interdisciplinary Journal of Information, Knowledge, and Management, Volume 1.

[14] Relational database, Tech Target http://searchsqlserver.techtarget.com/sDefinition/0,,sid87_gci212885,00.html accessed on November 22, 2007.

[15] UML Use case diagrams, Engineering NB http://www.objectmentor.com/resources/articles/usecases.pdf accessed on December 06, 2007.

[16] Logic Gem, Catalyst Development Corporation http://www.catalyst.com/support/help/logicgem/index.html?page=html%2Ftopic6.htm accessed on December 15, 2007.

[17] Zhang ,Hong, Liag, Yin "A knowledge warehouse system for enterprise resource planning systems.(2006)" In :Systems Research and Behavioral Science

[18] Marek J. Druzdzel ,Roger R. Flynn "Decision Support Systems(2002) " Jozen Stefan Institute

[19] Marko Bohance "What is decision Support Systems(2002)" In : Encyclopedia of Library and Information Science

[20] Decision support system, Information builder http://www.informationbuilders.com/decision-support-systems-dss.htm accessed on June 23, June 2008.

[21] A.H. Simon (1977): "The New Science of Management Decision" , Prentice-Hall.

[22] Jolana Sebestyénová "Case-based Reasoning in Agent-based Decision Support System (2007)" In: Journal of Acta Polytechnica Hungarica, Vol. 4 No. 1 :127-138

[23] Decision support System, TECHFAQ www.tech.faq.com accessed on 23-6-2008.

[24] A Brief History of Decision Support Systems, Power, D.J. http://DSSResources.COM/history/dsshistory.html accessed on 23-6-2008

[25]R. Kimball, M, Rose 'The Data Warehouse Toolkit'. John Wiley, 1996.

[26] J. Han, Micheline Kamber "Data Mining: Concepts and Techniques" Morgan Kaufmann Publishers 2000.

[27] A, Abdullah "Data Warehousing" Virtual University of Pakistan' 2002.

[28] M.D.Hondat, K.Gybels, V.Jonckers "Seamless Integration of Rule-Based Knowledge and Object-Oriented Functionality with Linguistics Symbiosis (2004)"

In: Journal of ACM.

[29] N. Dlodlo, L. Hunter, C. Cele, R Meterlerkamp, A.F. Botaha(2007) "Integration of an object oriented approach and rule based reasoning in the design of a fabric fault advisory expert system" In: Fibers & Textiles in Eastern Europe vol. 15 3(62).

[30] M. Dfouni, A. Croteau "Choosing Technologies to Support Knowledge Creation (2004)" In: International Journal of Information Technology and Management.

[31]J.Firestone "Knowledge Base Management Systems and the Knowledge Warehouse: A Strawman (2000)" In: Executive Information System.

[32] Barrett, M.L. & Beerel, A.C. (1988) Expert Systems in Business: A Practical Approach, Lysia Limited, London.

[33] Artificial Intelligence: Realizing the ultimate promises of computing, NEC research institute, http://www.cs.washington.edu/homes/lazowkska/cra/ai.html

[34] Holthoff, T. "Expert librarian applications of expert systems to library technical services (1989)", Technical Services Quarterly 7, no. 1: 1-16.

[35]S. Chaudhuri, U. Dayal. "An Overview of Data Warehousing and OLAP Technology (1997)" In : SIGMOD Record, Vol. 26.

[36] J. Widom, "Research Problems in Data Warehousing (1995)". In : 4th Int'l Conference on Info. And Knowledge Management (CIKM).

[37] Y. M. Chou Yeh," The Implementation of Knowledge Management System in Taiwan's Higher Education (2005) " In: Journal of College Teaching & Learning Volume 2, No 9.

[38] C.M, Olszak. "The Purposes and Assumptions of Business Intelligence(2002)" In: Organizational SupportSystems. Katowice: Univerity of Economics.

[39] S.Bennett, J.Skelton, and K.Lunn. (2004) Outline UML,2nd Ed., India: Mittal Press.

[40] S.C.Shaprio. "Knowledge Representation (2002)" State University of New York, University of Buffalo, USA.

[41] R. Knight, E. Rich(1991) "Artificial Intelligence " , 2nd Ed. , India: Wiley Intersience.

[42] Klein, G.A. (1992). "Using Knowledge Engineering to Preserve Corporate Memory". In,R.R. Hoffman (Ed.) The Psychology of Expertise. New York: Springer-Verlag.