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A survey of expert systems in Singapore and the integration of multimedia technology and expert systems

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1. Introduction

Expert systems technologies have been widely adopted by different industries from the early 1980s. There have been examples of expert systems embedded in applications developed for the financial and banking sector, manufacturing, services and government. In section 2 of this paper, we present a scan of expert systems used in different sectors. Section 3 will cover the expert system tools and applications developed in the decade of the 1980s. Section 4 will present some of the ongoing expert systems related activities. Section 5 will extrapolate the present work to forecast the future types of expert systems that might be developed in the coming decade.

2. Expert systems developed in Singapore

There are several expert systems related activities in Singapore. Firstly, there are several institutions that offer expert systems related training. National University of Singapore and Nanyang technological University are two examples where there are expert systems related activities in several departments such as engineering and computer science. In these departments, there are a few courses related to either AI in general or ES in particular. However, the projects can range from a six months projects for undergraduates to a few years long project for masters and doctoral students.

Then there are special institutions such as the Institute of Systems Science (ISS) and Japan Singapore AI Center (JSAIC) that offer a range of courses (**See Table I**). The post graduate diploma course offered by the ISS is 11 months in duration and includes an industrial attachment during which the students carry out a (sometimes not so) small project. Students normally work in teams of two or three. The minimum eligibility is a graduate with preferably a couple of years experience. There are also short courses for both end user managers and technical people. These span over a few days and consist of both introductory material as well as guidelines for design.

Table I: List of special ES related courses offered in Singapore

Course	Institution	Duration	Who(*)
Post Graduate Dip in Knowledge Engineering	ISS	11 months	ISP
Business Applications of Neural Networks	ISS	3 days	ISP, ISM, EM
Fuzzy Systems	ISS	3 days	ISP, ISM, EM
Expert Systems for managers	ISS	3 days	ISM, EM
Developing Knowledge based systems	ISS	5 days	ISP, ISM
AI Applications in Financial Services	ISS	4 days	ISP, ISM, EM
Neural Networks Workshop	ISS	4 days	ISP, ISM

Course	Institution	Duration	Who(*)
Intelligent Systems for Managers	JSAIC	3 days	ISM, EM
Intelligent Systems for Business Professionals	JSAIC	3 days	All
Intelligent Systems for IT Professionals	JSAIC	14 weeks	ISP
Prototyping Intelligent systems	JSAIC	6 months	ISP

* who should attend
ISP _ Information System Practitioner
ISM _ Information System Manager
EM - Executives and Senior Managers

The courses offered by JSAIC are generally short in nature. Their longest post graduate course is about 14 weeks in duration. They offer these courses to practicing professionals from other areas of information technology.

There was an institution called Knowledge Engineering Resource Center (KERC), attached to the National Computer Board (NCB). They used to help novice users of expert systems technology by conducting prototyping projects. Their mission was to help the novice users of expert systems to understand and exploit the technology when it was new. KERC's mission has been achieved now that the technology is being used fairly extensively.

Table II lists a set of expert systems developed in Singapore. This list is sorted by the nature of industry. These expert systems have been developed by both private and public sector institutions. Among the public sector institutions, applied research labs such as ISS, GINTIC of NTU and Information Technology Institute (ITI) of the NCB have been playing a key role in helping local government and private organizations embrace and exploit expert system technologies. Banks, other financial institutions, and service providing companies have been the pioneering users of ES technology among the private sector organizations.

Table II: A sample list of expert systems developed in Singapore

System	Nature	Sector
A Neural Network Spot Rate Forecaster	Decision Supp	Finance
A Total integrated production system development environment	Scheduling	Manufac
Audit Expert System	Monitoring	Accoun
AuditPro	Diagnostics	Accoun
Autolayout Expert With Interactive Support (ALEXIS)	Design	Service
A visual navigation system for Mobile Robots	Vision	Manufac
Building Plans Processing System	Verification	Constru
Changi Airport Resource Allocation	Plan / Sched	Service
Classroom / course scheduler	Plan / Sched	Education
Connectionist Crane diagnostic ES	Diagnostics	Service
Connectionist ES for troubleshooting of Radar System	Diagnostics	Service
Credit Evaluation	Decision Supp	Banking
Development of a KR system for task level programming of Robots for high precision electronic assembly	Scheduling	Manufac

System	Nature	Sector
Diagnostic system for LAN	Diagnostics	IT
Dynamic Manpower Rostering System	Planning	Service
Energy cost Minimization	Planning	Service
Expert Autotuner for Multivariate control Applications	Optimization	Manufac
Expert System on Information system planning	Planning	IT
FETX real-time diagnostic System	Diagnostics	Service
Field Engineer Dispatching System	Scheduling	Service
Fire Safety Design Aid Expert System	Planning	Service
Fuzzy Neuro Shell	ES Tool	IT
Hitachi Diagnosis and Trouble Shooting System	Diagnostics	Manufac
Hospital Scheduler System	Scheduling	Health
INSIDE: Inertial Navigation System Interactive Diagnostic Expert	Diagnostics	Service
Intelligent distributed database query system	Retrieval	IT
Intelligent Fuzzy Logic Tutor	Training	Education
Intelligent Harmonized coding system	Decision Supp	Service
Japan-Singapore ICAI System	Training	Education
Loan Evaluation	Decision Supp	Banking
Manufacturing Planning and Scheduling	Plan / Sched	Manufac
Meal Planning expert System	Planning	Service
Personal Unix Tutor	Training	Education
PIXS Audit resource evaluation system	Decision Supp	Accoun
Public Transport Advisory System	Planning	Service
Rubicon	ES Tool	IT
Self Adjusting Fuzzy Diagnostic System	Diagnostics	IT
Ship Planning System	Planning	Service
Staff Selection	Decision Supp	HRM
Surveillance monitoring	Real-time	Security
Text Categorization and Understanding	NLP / routing	Banking
VLSI Implementation of an inference processor for approximate reasoning	ES Tool	IT

Legends:

Nature of expert system	Sector
Plan / Sched - Planning / Scheduling	Manufac - Manufacturing
NLP - Natural language Processing	HRM - Human Resource Management
Decision Supp - Decision Support	IT - Information Tech.
ES Tool - Expert System Tool	Account - Accounting
	Constru - Construction

Section 3. Expert Systems tools and applications developed in the decade of the 1980s.

Expert systems developed in Singapore during the 80s mostly used a rule based approach. They were either built using shells such as KEE, System M or occasionally developed in LISP. IN this section we give brief descriptions about Rubicon, a rule based expert system shell, and two applications - the airline meal planning system and the container loading expert system.

3.1. Rubicon

Rubicon was among the earliest expert systems tools developed in Singapore. It was a rule based expert system shell and was developed by the then Joint Software Engineering Program (JSEP). It was developed on the personal computer range of computer products.

3.2. The Airline meal planning system

A meal planning expert system was among the first to be developed into an operational expert system. This was a system developed for the Singapore Airlines by the Institute of Systems Science. This system helped plan the in flight meals for all the first and business class flights of the Singapore Airlines.

The objectives of this system were

- o To improve the customer satisfaction through better coordinated in-flight meals
- o To release the time of the executive chefs for more creative activities
- o To customize meals to suit the regional palates.

The success of this expert systems was partly due to the great cooperation extended to the development team by the executive chefs in SIA. The Chefs preferred to allow the expert system to plan the meals so that they could spend their time in more creative tasks. The system had several rules which addressed the preferred combination of dishes for a given meal and the type of dishes that should go across meals. The system also addressed the needs to plan meals depending on the point of departure / arrival. An initial system was delivered to Singapore Airlines in 1988.

The meal planning system has been successfully deployed within SIA and has since been rewritten from its original version into a more standard package integrated with other components of the in flight kitchen.

3.3. The Ship Planning System

This is possibly the best known ES application developed in Singapore. Figure 1 presents the architecture of the Ship Planning System. The objectives of this system are:

- o To reduce the planning time required by ship planners.
- o To improve the quality of plans
- o To ensure consistency in plans

The initial application addressed the task of loading containers from the berths of Post of Singapore Authority on to the ships. What the program did was to provide an initial ordering for the loading taking into several rules such as a chill box container cannot be placed next to the engine room and that the container to be deberthed first should not be

sitting below a container that was travelling farther. This project was a joint development effort between the Port of Singapore Authority and the Information Technology institute.

This expert system is said to have paid back the investment into its development within a couple of years. This system was given an innovative applications award by the AAAI.

This work lead to building of more expert systems for the Port of Singapore Authority. This included yard planning system which addressed how the containers should be stacked up in the shipyard so that the one that is required the soonest is placed closest to the place where it is required. As a total system, it schedules the discharging and loading operations of container ships calling at the Tanjong Pagar Container Terminal. The system allocates and schedules quay crane and yard operations in order to minimize turnaround time while satisfying a complex set of constraints. The system was delivered in April 1990 and is presently used to service over 80% of all container ships visiting the port.

3.4. CARAT: Changi Airport Resource Allocation Tool

Changi International Airport Services (CIAS) Pte Ltd. provides ground-handling services for various scheduled and unscheduled airlines the Singapore Changi Airport. Their services include cargo handling, ramp handling and aircraft line maintenance.

The application that was implemented addressed the ramp services to the airlines. Supervisors carry out initial manpower and equipment allocation based on a static plan. The static plan is arrived at using the scheduled arrival and departure times of various flights and a known availability of manpower. However flights do not always depart or arrive on schedule and not everyone turns up for work on all scheduled times either due to medical or other personal reasons. As a result there is also a dynamic planning which is based on actual times of arrival and departure of the flights at the airport and the manpower availability. The objective behind building the expert system was to improve the responsiveness to the changes in actual arrival and departures as well as to optimize the use of resources.

The project was carried through in three phases. The design and deployment of the currently used deployment form on the screen was carried out in phase 1. Phase 2 addressed the static planning given the initial flight, manpower and equipment status and the planning module was integrated to the online form. Dynamic planning in response to changes in flight arrivals and departures and manpower availability was addressed in the third stage.

4. Some recent expert systems activities

When rule based expert systems were used actively, they were found to be good for reasonable sized application domains. Knowledge acquisition remained to be a major difficulty. In the last two to three years, there have been several attempts in Singapore to use other new technologies such as neural networks which can base their inference on patterns as opposed to rules. INSIDE and INTELLIVEST are examples of a new generation of expert systems that are being built using neural network technology.

4.1. The INSIDE story

While the initial expert systems were all rule based, there have been some novel applications more recently. One such is an application developed by the Institute of Systems Science for the Singapore Airlines (SIA). This system is called INSIDE and

is a diagnostic expert system for repairing the Inertial Navigation System on the airplanes operated by SIA. Figure 2 presents the architecture of the INSIDE system.

The INS equipment is duplicated / triplicated in the airplanes. They do fail and the redundancy ensures the safety of passengers. Each of these units are expensive and hence the quicker they can be repaired, the less inventory the airlines need to maintain.

The objectives of INSIDE were

- o To reduce the time taken to repair INS equipment
- o To make use of historical data for repair
- o To integrate vendor's instructions for repair with the historical knowledge about faults

The INSIDE application used a three tier inference engine. The first tier of this expert system used neural networks to represent known cases of failures and the proven repair strategies. The second tier of the expert system contained some of the rules for test procedures provided by the supplier of the INS equipment. The third layer captured the exceptions to the knowledge represented in the first two layers.

INSIDE has significantly reduced the time to repair the INS equipment.

4.2. Forecasting Systems based on Neural networks

Institute of Systems Science developed a neural network based expert system called Intellivest. The general system used neural networks to learn the patterns of the relationship (represented by a curve) between two variables and use the patterns to forecast the next point in the curve. This was tried out in a number of applications. One such application is called Intellivest. Intellivest was developed to forecast the movement of Singapore Dollar against US dollar.

The strategy behind this development was to train a neural network on the past patterns of movement of the exchange rates. The training is verified by forecasting for known periods. If the results of the forecast for an already known period does not match or come within a prespecified threshold, then the training continues until the threshold is reached. This system was later tested for stock market projections and for forecasting energy consumption.

4.3. Human face recognition system

This system is called the Computer Aided Facial Image Inference and Retrieval (CAFIIR) system. The CAFIIR system is being developed for Mugshot and criminal investigation applications. The system will have coded or structured data such as the date of a crime and the identification number of the individual. It will also handled free form text description of the crime description and details. It has a repository of human faces.

The system is being built to present a ranked list of faces by using inference on multimedia data such as a face composite and text description.

5. Trends in Expert system development in Singapore

There is a general trend to build expert systems using both sophisticated technologies such as neural networks and multiple data types as in multimedia data. Classification research is the core technology that will be used by such applications. Hence, there is a significant attempt to acquire expertise in classification research for different media.

The other dimension in which the research and applications is likely to progress is to make use of a confluence of technologies rather than a single technology. For example, applications may make use of neural network technology for classification and case based reasoning for inferencing on different classes. Use of cognitive science research will be useful for determining prototypicality in a given class and also to understand how similarities should be calculated. This may be aided by building in information retrieval technologies that use fuzzy measures as the basis for deriving similarity measures. All these will form a part of a complex inference engine.

The applications for such a composite inferencing mechanism abound in many fields. They can range from a well understood application such as automated quality inspection in a manufacturing line to a much less structured application such as forecasting the movement of foreign exchange over a few days.

6. Integrating Multimedia technologies with expert systems

An example of an expert systems that integrates multimedia data is the CAFIIR application listed in section 4.3.

Multimedia data is made of aural and visual information. Any visual data is context sensitive. The object of attention depends on the number of objects in the visual presentation and the relative size and texture of an object with respect to the others. Also, some visual presentations can be so rich in their content that it might take several paragraphs of text to describe them. If they have to be represented or described by text such representation will be limited by the person creating the description.

Aural data on the other hand is ephemeral. Human beings tend to filter key words or cues in aural data and leave the rest out as noise words. This principle has been extensively used in the information retrieval technology. However, these keywords are not heard in isolation. There is a context sensitive link among the key words. For example, a sentence such as "to make a kill" may not always yield the same meaning. If it was in the context of a hunting expedition, it would mean killing a prey. If it was in the context of a game, it would mean a resounding victory.

6.1. Issues in the integration of MM and expert systems technologies.

There are several issues that need to be reviewed in the context of developing expert systems that use multimedia data. We list below, the issues with brief descriptions.

Feature extraction: In alphanumeric data feature extraction amounts to parsing word tokens. In Multimedia systems, there has to be a domain expert who should determine which factors will be of importance to the given application and how they should be extracted.

Classification: Text tokens are usually classified into parts of speech. The parts of speech in any language is a finite number and is common to all users of that language. The classification of multimedia data will be sensitive to the application concerned.

Indexing: Alphanumeric data has been indexed using B-trees or inverted files. However, indexing of multimedia data is application sensitive. For example a picture of a map can be indexed using a text description of the map or an R-tree depending on the application being developed. If the application is the retrieval of the whole picture then a text description can be used to index the map. If the application is to get smaller objects within the map, then an indexing scheme such as the R-tree has to be used.

Similarity measures: In traditional expert systems tools, similarity is tested through unification. Such unification is carried out through the binding of littorals, whether they are data or variables. In expert systems that use multimedia data the binding has to

be extended to other forms of data. The criteria for declaring a binding for non-text data to be either successful or not is not well defined.

Fuzzy Measures: Visual and aural data is sometimes described by users through fuzzy terms. For example, the eyes of a person may be described as "small" or "large". The ability to take such fuzzy measures as inputs and carry out inferencing on them is an issue in building expert systems that use multimedia data. A detailed description of how fuzzy measures have been incorporated into CAFIIR is explained in [NARA 93a]

Integrated retrieval: The ability to bring back multimedia data involves retrieval of respective individual media and then integrating them. The mapping between features in one media and the features or objects in other media may not be one to one.

All these issues need to be addressed in developing expert systems that use multimedia data.

6.2. The adaptive inference engine

Central to the integration of the ES and MM technologies is the need to develop an inference engine that can be adaptive to the context and the media type. Figure x shows one such inference engine. Such an engine will take context, media type and fuzzy measures into account before it can come out with inferences. The result of the inference will not be a simple yes/no answer but will be fuzzy in nature.

6.3. An architecture for developing an expert system with multimedia technology

An architecture for developing an expert system with multimedia data is presented in Figure 3. This architecture is explained in great detail in a forthcoming publication [NARA 93b]. The architecture outlines the different possible components in an integrated system. It is a check list in that every expert system that uses multimedia data may not have all the components in it. When users start designing an expert system they can decide whether to include a particular module or not.

6.4. An expert system application using multimedia data.

CAFIIR is an expert system application using multimedia data. It is a mugshot system which uses photographs and text records of criminal offenses. The process flow of the application is given in Figure 4. A witness' description results in a graphical sketch or a composite image along with the text descriptions. These are used as input to the system.

The system will extract features from both the image / sketch and
text. These will then be subjected to classification. Once classified, then the features are compared with features from representative photographs and cases. The adaptive inference engine capable of handling fuzzy values is useful for this purpose.

Once certain photographs and corresponding text are retrieved, they are ranked in the order of similarity to the given query. The CAFIIR system architecture is shown in Figure 5. This application is presently under development. More details on this application can be found in [WU 93].

7. Summary

Expert systems technologies have been used in Singapore in several different settings. There have been tangible benefits and paybacks derived from such uses. There are still several complex applications that require new forms of expert systems technologies to

be developed. The different research and development establishments in Singapore are investigating the new application requirements and responding with relevant research. Some of these research are likely to break new grounds and benefit the Singapore based organizations in sustaining and improving their competitive advantage.

8. References

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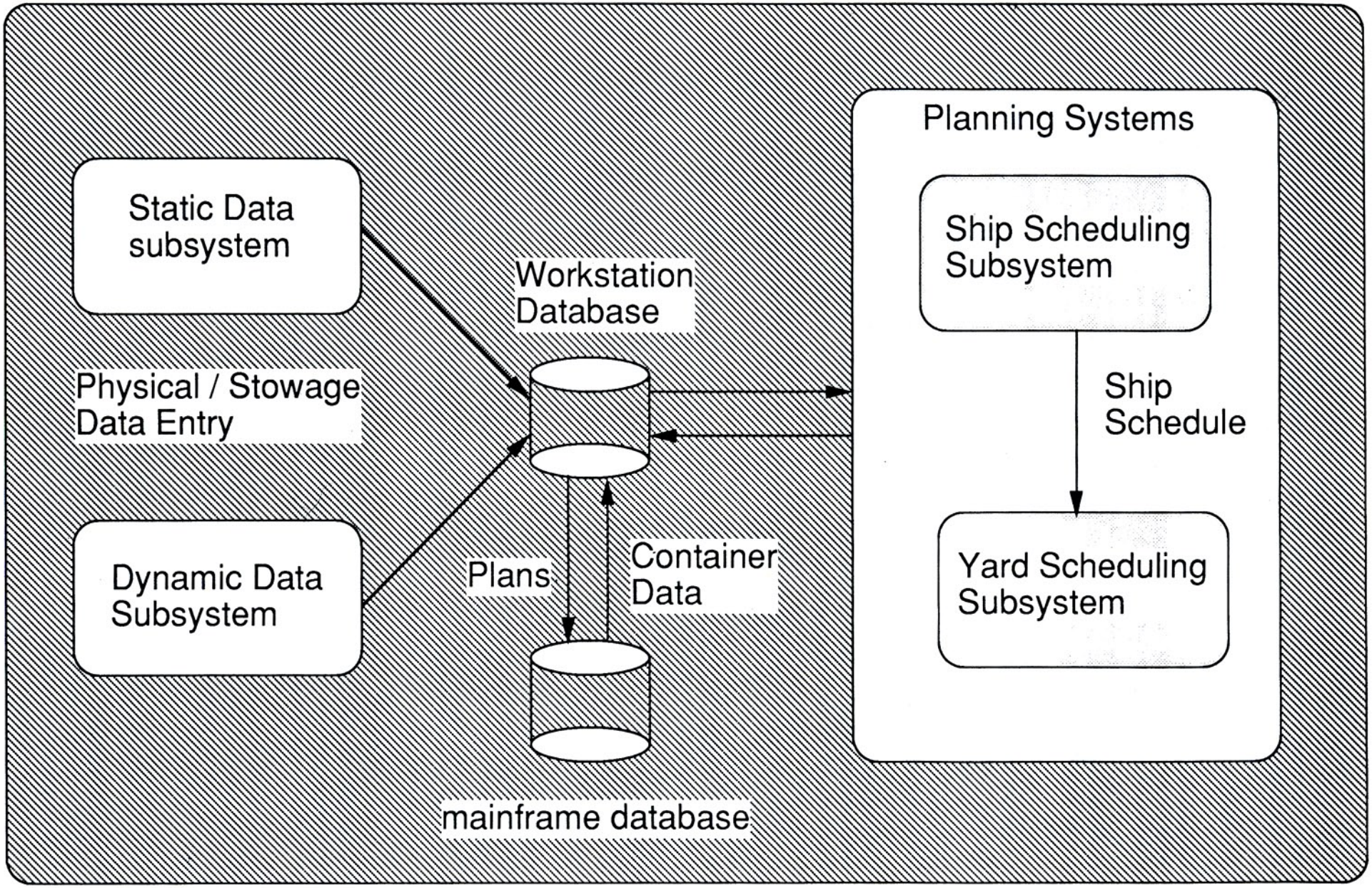

Figure 1. Architecture of the Ship Planning System

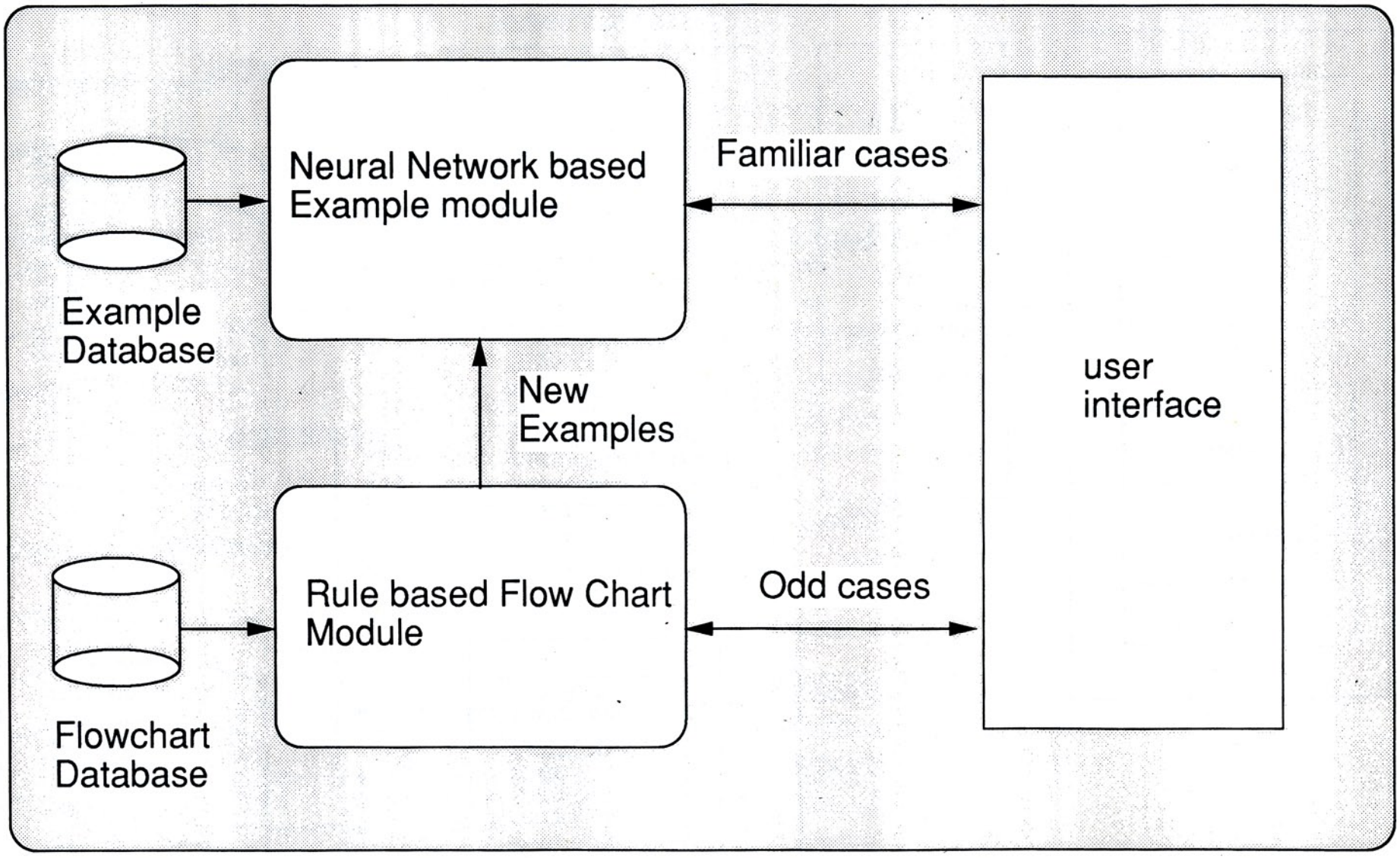

Figure 2. Architecture of the INSIDE system

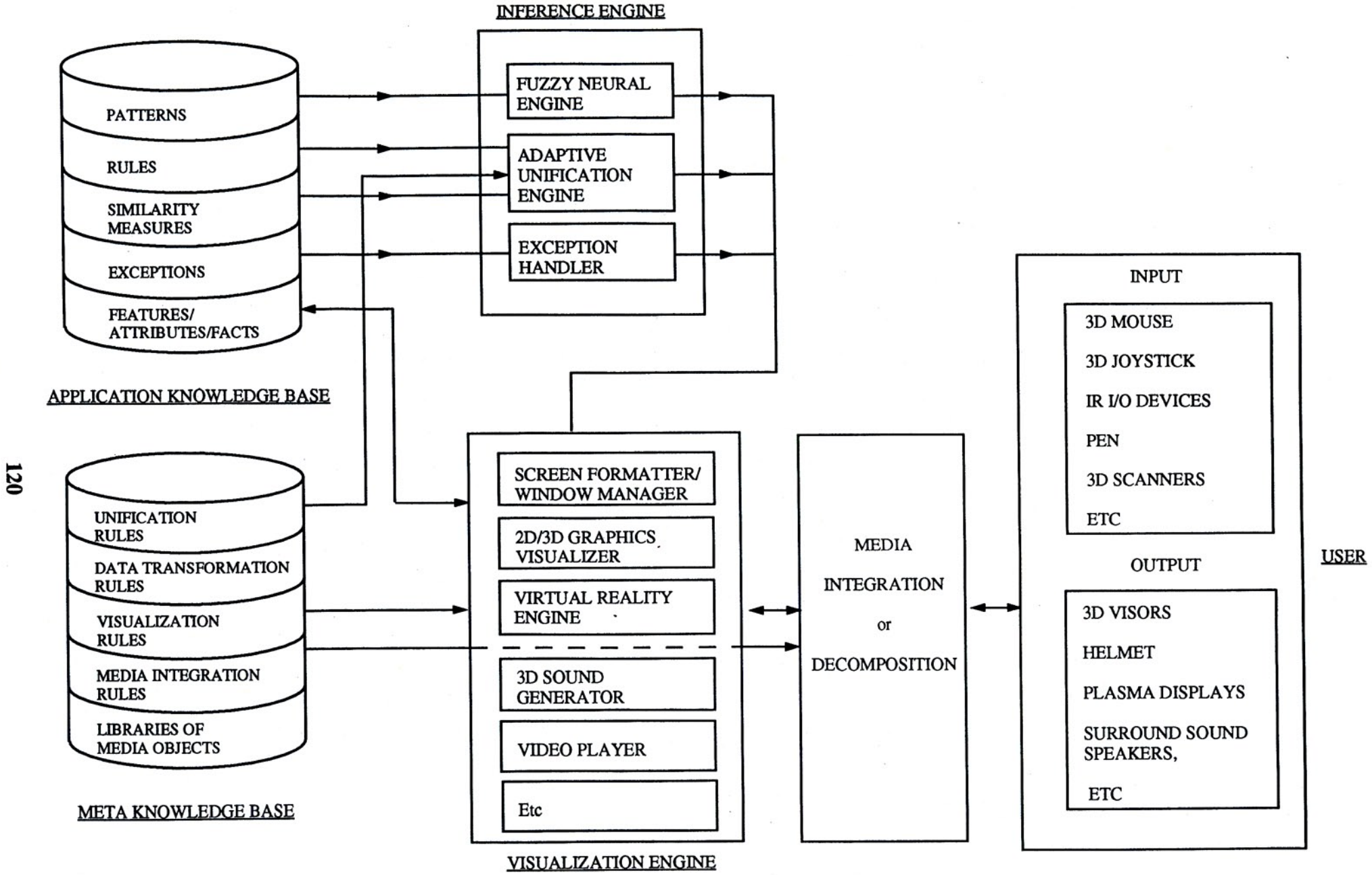

Figure 3. An architecture for an Expert System Tool for Multimedia Application.

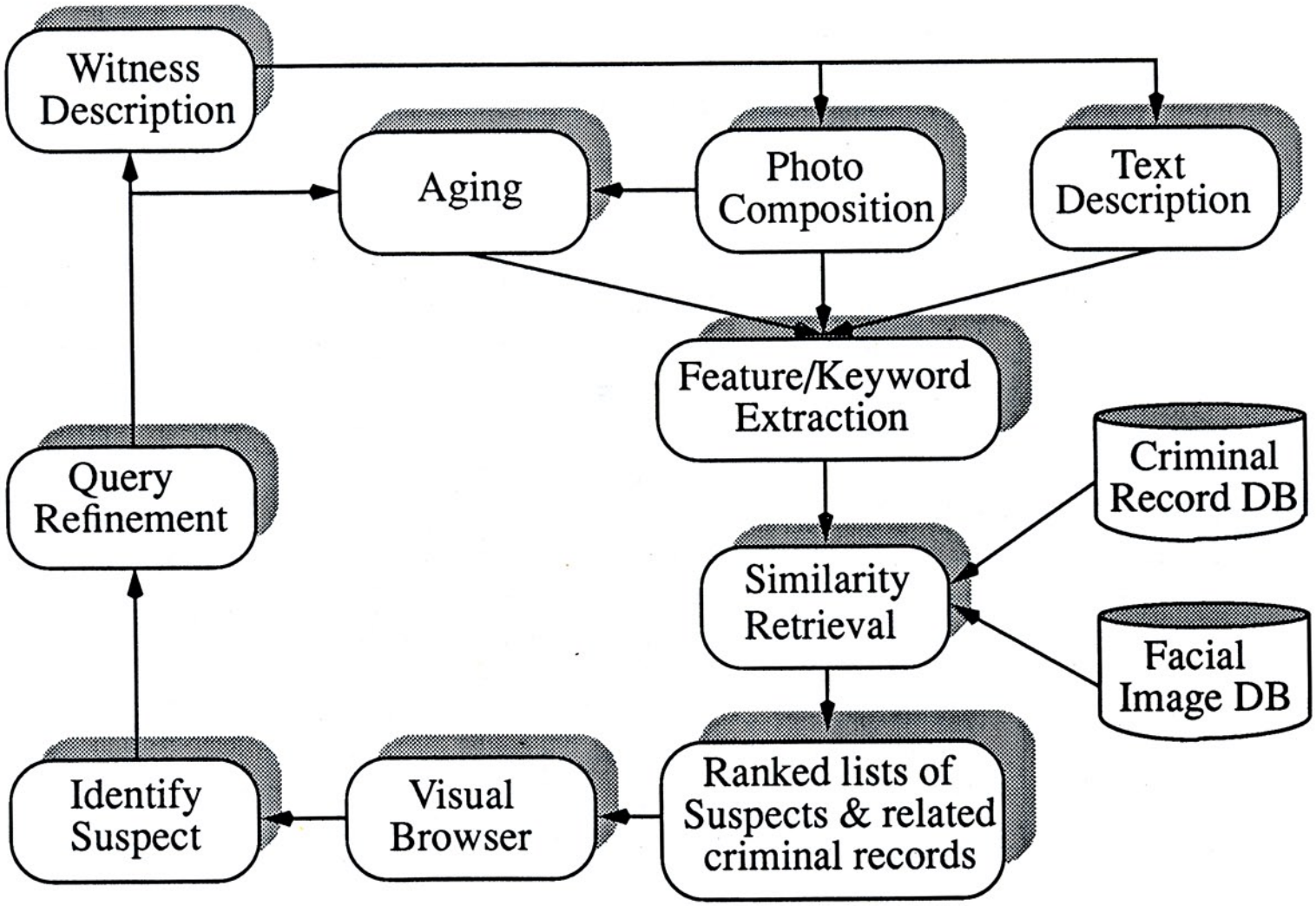

Figure 4. Functional Block Diagram of the CAFIIR System

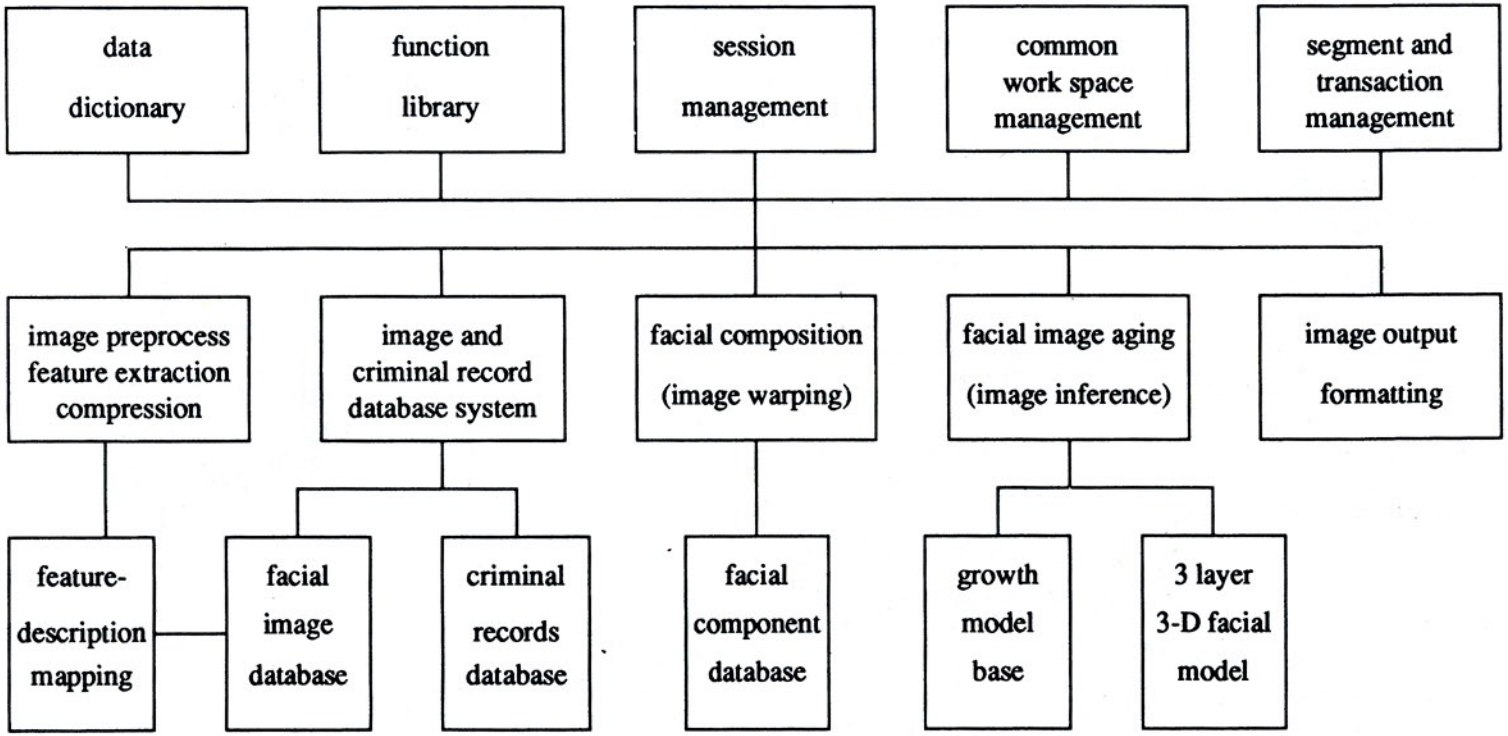

Figure 5. Block diagram of Computer-Aided Facial Image Inference and Retrieval System (CAFIIR)

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Dr. Arcot Desai Narasimhalu is a program manager at the Institute of Systems Science, National University of Singapore where he spearheads the Archival and Retrieval of Multimedia Information program. His responsibilities include setting the direction, identifying suitable applications, managing the development of research prototypes, protecting intellectual property rights and transferring technology. He is also responsible for coordinating the recruitment for the research group.

Dr. Narasimhalu is a member of the editorial boards of Pergamon press' Expert Systems with Applications, Information Processing and Management, ACM/Springer Verlag's Journal on Multimedia Systems and Singapore Computer Society's Journal on Information Technology. He has been the Program chair, Co-chair, Regional chair, and member of program committees of several regional and international conferences. He has also been the organizing chairperson for some conferences. He has published several technical papers in journals, books and conference proceedings. He has coedited Pergamon Press' book on "The Operational Expert Systems in the Far East Asia." He has been mentioned in the recent "Who is Who in the World." He has been a consultant to several organizations and regularly reviews papers for some of the IEEE and ACM journals.

Dr. Narasimhalu's present interests include Multimedia Systems, Multimedia archival and data management, Expert Systems, Heterogeneous database management, and Decision Support Systems. Dr. Narasimhalu has a Ph.D. in Electrical Engineering from the University of Hawaii. He had earlier earned a Masters of Technology degree in Electrical Engineering (light current) from the Indian Institute of Technology, Madras and Bachelor of Engineering degree in Electronics and Communications from the Madras University.

Dr. Narasimhalu worked with the R&D Labs of the Indian Telephone Industries from 1974 to 1980, was a visiting scientist with IBM Japan from 1984 to 1985 and has been with the Institute of Systems Science since 1985. He has about 20 years of cumulative research experience.