CHAPTER 7

PROTOTYPE SYSTEM (version 1.0, version 1.1 and version 1.2)†

7.1. **Introduction**

An expert system is an artificial intelligence software. So, software engineering issues should be relevant during the development of such a system. Generally speaking, Software engineering considers such issues so that one can develop a quality system to the users' satisfaction with less efforts, time and cost. In addition, clarity, modifiability and maintainability should be more transparent. Worthwhile to note that expert system development is the first and foremost Software engineering [1]. This is reflected in the importance of such issues as portability, integration, data base access, fielding, maintainability, robustness, reliability, concurrent access, performance, user interface, debugging support, and documentation. Two important contributions of ES-technology might be pointed out here (i) it has shown how to encode knowledge explicity and declaratively rather than implicity and procedurally, and thereby making programs more understandable and maintainable; and (ii) it is the pioneer of the new software development strategy of prototyping and refinement as opposed to the classical phase refinement approach.

Perhaps the most difficult part of constructing a large software system is deciding exactly what to construct. Requirements analysis, as software engineers call it, is the most crucial phase in the life of a project. An error in this phase can not only add to the time required for completing the project, but also lead to a delayed product that was not required in the first place [2].

The difficulty arises from two sources. Typically, the would-be users do not quite know what they want, at least not until they have tried out some version of the program. Compounding this difficulty is the fact that the planner of any software design activity does not have an exhaustive repertoire of questions that will yield him the necessary information. Neither can he be sure that the specifications he has derived are complete; chances are, they are not. Rapid prototyping has been touted as a way of this deadlock [3].

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† This is based on the publication [Modelling,, Measurement and Control, C, vol. 31, no.2,1992,13-24; Advances in Modelling and Analysis,B, vol.26, no.1, 1993,13-28; and CSI Communications, May 1997,15-21, ibid June 1997, 21-25] of the author.

In the next section we have discussed the concepts of prototying and prototyping cycle. In section 7.3, a comparison has been made for phase refinement with prototyping approach. In section 7.4, the evolution stages of an expert system have been discussed. Sections 7.5, 7.6 and 7.7 present prototype (version 1.0), prototype (version 1.1) and prototype (version 1.2) respectively for users. In section 7.8, our conclusions and discussion are summarized.

7.2. **Prototyping and prototyping cycle**

Prototyping is the process of developing a scaled-down version of a system to use in building a full-scale system. The primary purpose of prototyping is to reduce time and expense in building quality systems. Prototyping mandates a philosophy of incremental system development that includes end users in the assessment of emerging system capabilities. Increased participation of end users leads to faster system development and ultimately to more useful systems [4]. Although recent innovations in prototyping [4-6], suggests the importance of end-user involvement, they do not go far enough to bring the end user into software development.

In contrast to traditional prototyping, knowledge engineering techniques commonly employ domain experts (experts in the problem area) as representative end users [7]. Prototype development in knowledge engineering sessions progresses through incremental refinement of a domain model, typically extending over two or more years.

Fig. 7.1 illustrates the iterative prototyping cycle [8]. The user and the designer work together to define the requirements and specifications for the critical parts of the envisioned system. The designer then constructs a model or prototype of the system in a prototype description language at the specification level. The resulting prototype is a partial representation of the system, including only those attributes necessary for meeting the requirements. It serves as an aid in analysis and design rather than as production software.

During demonstrations of the prototype, the user evaluates the prototype's actual behavior against its expected behavior. If the prototype fails to execute properly, the user identifies problems and works with the designer to redefine the requirements. This process continues until the user determines that the prototype successfully captures the critical aspects of the envisioned system.

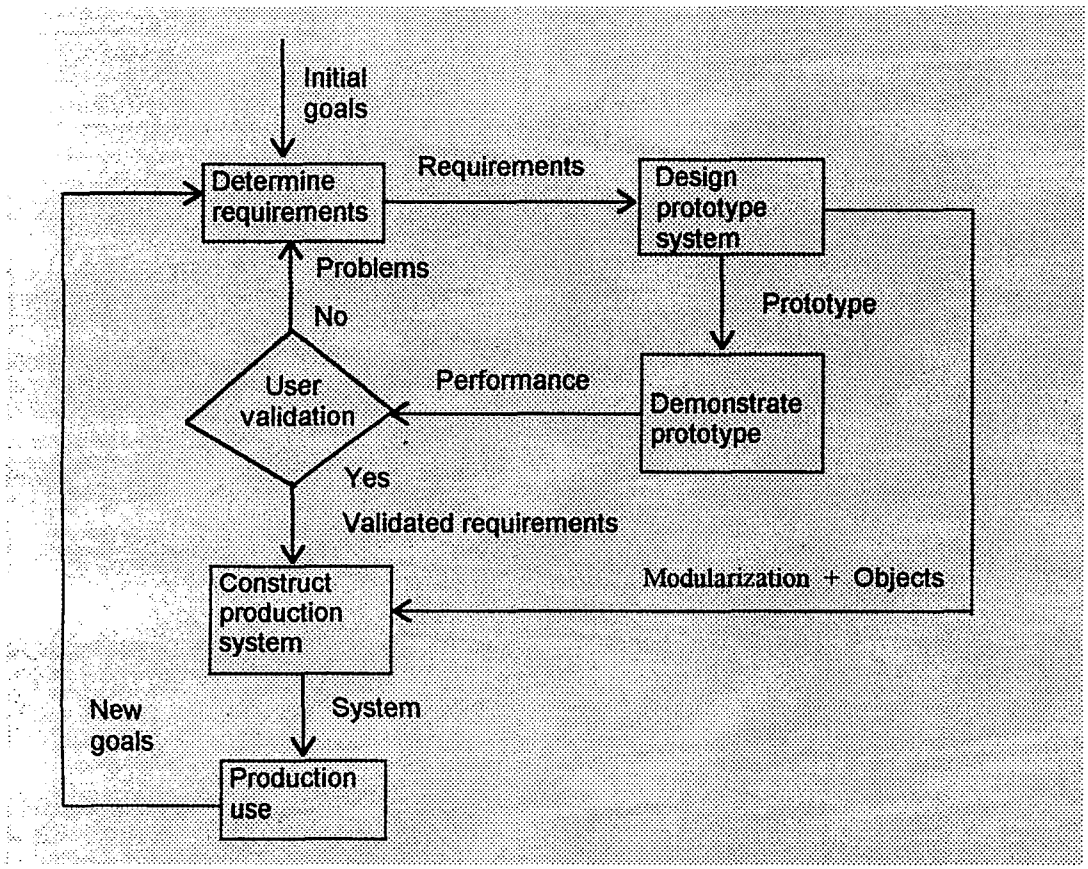

Fig. 7.1 The prototyping cycle

The designer uses the validated requirements as basis for designing the production software. Additional work is often needed to construct a production version of the system. For example, the prototype :

a) might not include all aspects of the intended system,

b) might have been implemented using resources that will not be available in the actual operating environment,

c) might not be able to handle the full workload of the intended system, or

d) might meet its timing constraints only with respect to linearly scaled simulated time.

Experience with production use of a delivered system often leads to new customer goals, triggering further iterations of the prototyping cycle.

7.3. **Phase refinement vs. prototyping**[1]

The classical phase refinement approach of system design is criticized for its high expense and long time for development of quality systems. Prototyping has been proposed for system development which reduce time and cost substantially. Prototyping is a paradigm which consists of some non-standard concepts and suggests increased participation of end users. Prototypes are subject to frequent and repeated changes to incorporate the suggestions from the human experts as well as from the end users. To find the benefits of prototyping than a conventional approach one has to apply : computer aided prototyping and object-oriented prototyping [8]. The first one provides mechanical assistance and the second one provides conceptual simplicity. To make the prototypes more flexible as well as achieve automation easier, O-O approach may be suitable.

While the above analysis might lead one to believe that the prototyping paradigm has all the good things in connection with the development of quality systems, the paradigm does have some bottlenecks. After evaluating the software request one has to determine whether the software to be developed is a good candidate for prototyping. Not all software is amenable to prototyping. Owing to poor project discipline, prototyping may increase cost and time. A number of prototyping candidacy factors [9] can be defined : application area, application complexity, customer characteristics and project characteristics. In general, any application that creates dynamic visual displays, interacts heavily with a human or demands combinatorial processing that must be developed in an evolutionary fashion is a candidate for prototyping [10].

It may be obvious to state that for a problem domain of large and varied knowledge base, an expert system should be developed in an evolutionary framework. In the evolution of an expert system, the designers usually follow five stages as identified by Waterman [11] which are : Demonstration prototype, Research prototype, Field prototype, Production model and Commercial system. Prototyping may have an adverse impact on modifiability and maintainability of knowledge bases since these may be patched and modified several times during the process of evolution of an expert system to get it in its commercial form. This may, however, be overcome by the use of O-O approach. As the system grows, the major changes will be with the addition of new objects or deletion of old objects rather than modifying the old objects. In this respect O-O approach is considered very useful for rapid prototyping.

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[1] This is based on the publication [Proc. Nat. Conf. on Software Engineering and its Application, Hyderabad, India, August 23-25, 1996, 127-134] of the author.

7.4. **Stages of expert system evolution** [11]

Waterman identifies the following **five** stages in the evolution of an expert system :

Development Stage	Description
Demonstration prototype	The system solves a portion of the problem undertaken, suggesting that the approach is viable and system development is achievable.
Research prototype	The system displays credible performance on the entire problem but may be fragile due to incomplete testing and revision.
Field prototype	The system displays good performance with adequate reliability and has been revised based on extensive testing in the user environment.
Production model	The system exhibits high quality, reliable, fast and efficient performance in the user environment.
Commercial system	The system is a production model being used on a regular commercial basis.

7.5. **Prototype (version 1.0)**

The architectural components of this prototype system are shown in fig.7.2

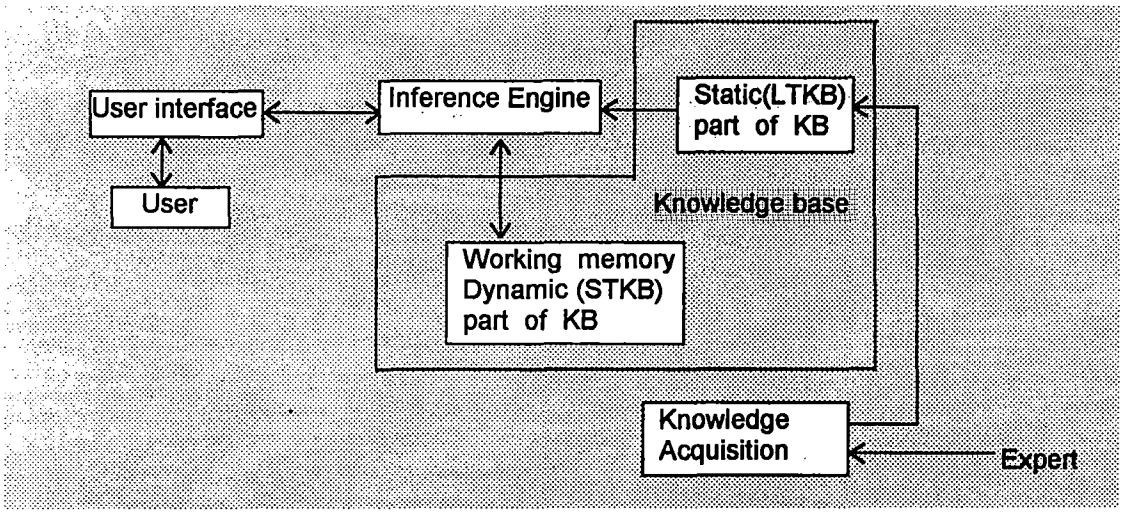

Fig.7. 2 Architectural components of the prototype system

During the implementation of its first version, we have taken the Turbo Prolog as an implementation language.The prime reason of using Prolog is its fast prototyping capability of developing expert systems [12]. In addition, the following characteristics of Prolog are attractive as an implementation tool : (1) In-built inference mechanism which expedites initial prototype development of the system, (2) Separation between knowledge base and inference mechanism, (3) Static and dynamic knowledge bases, (4) Declarative as well as some procedural knowledge can be intermixed, (5) Supports modular and structured programming to achieve good modifiability, (6) Table look-up scheme for fuzzification and the defuzzification processes can be easily implemented using TURBO-PROLOG's list-structure. The details of selecting an appropriate tool for developing an expert system has been provided in **chapter 10**. The program can be run on IBM-compatible personal computers. During the total system development, we have taken care of the "five-stage" development suggestions of Buchanan et. al. [5] discussed in **chapter 5**. Let us now give a portion of the knowledge base used in the expert system.

```
/*  A prototyped-object-oriented expert system for Child Growth and Development  */
/*                          by                                                   */
/*  A. K. Saha, Pampa Mondal and R. K. Samanta          */
/*  North  Bengal University, Pin - 734 430, INDIA      */
/*          A portion  of  Knowledge base               */
Title : -
write (" A CONSULTATION SYSTEM  FOR  CHILD GROWTH AND  DEVELOPMENT "), nl.
query (group_1) :-
  write("give the age in words  "), readln(A), nl,
  openwrite(defficiency,"deff.dat"),
  test(axial_muscle_tone,A),
  test(muscle_tone_of_limbs,A),
  test(spontaneous_gestures,A),
  test(primary_reflexes,A),
  test(visual,A),
  test(gripping,A),
  test(relation,A),
  test(emotional_and_social_development,A),
  test(language,A),
  test(rhythms,A),
  test(eeg,A),
  closefile(defficiency).
  test(axial_muscle_tone,one):-
  nl,write("Axial muscle tone:"),nl,
  make,
  write("Answers should be 1 for +ve reply & 0 for -ve reply "),nl,
  ask(pulledup_sitting),
  write("Does the head drop (1/0)?"),nl,
  readchar(Reply),
  remember(Reply),
  compare(Reply),
  ask(prone),
  write("Does the baby turn head from side to side  when  proned ? "),
  readchar(Ans),nl,
  remember(Ans),
  compare(Ans),
  make,
  make.
```

In version 1.0, the measure of inexactness in the knowledge base has not been taken into consideration. We have taken here the case of one month baby only. This may easily be extended to more months.

7.5.1. **A typical consultation session**

In our systems, we have used a dynamic database so that the results of one consultation for a particular child can be retained, if we wish, for further reference. This can be done by the use of either the built-in-predicate 'asserta' or by 'assertz'. We now present some sample consultation sessions. During the consultation, the system takes input from parents of the child under investigation in terms of "Yes / No". For example : "IS YOUR CHILD SLEEPS ABOUT 21 HOURS ?". After all the answers received from the parents the following types of screen will appear :

ONE MONTH

Press any key to continue		
Activity	: Expected value	: Data From Parent Of the Baby Under Study
** '1' stands for +ve sign & '0' stands for -ve sign '-' implies non-existance of value		
Axial Muscle Tone	:	: a('-')
pulled up, sitting	: Head drops	: a('1')
prone	: Turns head side to side	: a('1')
held back against examiner	:	: a('-')
	:	: a('-')
Muscle Tone of Limbs	:	: a('-')
spontaneous lying down	: Flexion	: a('1')
	: Hypertonia	: a('1')
	: Adductor Angle : 30^0	: a('0')
	: Popliteal Angle : 90^0	: a('1')
	:	: a('-')
held standing	: Reflex straightening	: a('1')
	:	: a('-')

In this way, three or four screens will be displayed. At last we shall get the desired comments about the child under study. We give two such consultation sessions for two different samples.

Child 1 / Consultation Session-1

A CONSULTATION SYSTEM FOR CHILD GROWTH AND DEVELOPMENT

Name of the baby : Prasun Sen
Father's name : Mr. P. Sen
Mother's name : Mrs. Chandra Sen
Age of the baby : One Month
Address : Silver Jubili Road, Cooch Behar.

The child has the following defficiencies in activity :

Rhythms :
Sleeps less than 21 hours
Would you like another consultation (y/n)?

Child 2 / Consultation Session-2

A CONSULTATION SYSTEM FOR CHILD GROWTH AND DEVELOPMENT

Name of the baby : Arup Ghatak
Father's name : Mr. Anil Chandra Ghatak
Mother's name : Mrs. Tripti Ghatak
Age of the baby : One Month
Address : Subhas Pally, Siliguri.

Conclusion :

The growth of the baby is expected to be normal.
Would you like another consultation (y/n)?

7.6. **Prototype (version 1.1)**

The system that we have developed has the following characteristic features. These include (1) modularity and structuredness and object-oriented (O-O) knowledge representation, (2) dealing with uncertainty, (3) contains static and dynamic data bases of knowledge which offers an added intelligent activity of the system, (4) portability, and (5) modifiability.

7.6.1. **Modularity, structuredness** and **O-O knowledge representation**

Managing a data base of knowledge is very difficult if the domain knowledge is vast. Structuredness and modularity of knowledge is necessary to handle a large knowledge base [13]. Classical methods of knowledge representation such as OAV-triplets, semantic networks, rules and frames are not suitable enough for achieving structuredness and modularity [14]. It may be worthwhile to use object-oriented approach in this context where declarative as well as procedural knowledge can be mixed. Structuredness and modularity should be achieved in both the stages of system development such as in design phase and in implementation phase. In our design phase, we have represented knowledge in different forms including object-oriented approach and this can easily be observed from **chapter 6**. In the implementation phase, we have used Turbo Prolog as an implementation language for the system development. In Turbo Prolog, modular and structured programming may be achieved [15]. The sense of mixing declarative as well as procedural knowledge of object-oriented approach may be achieved through Prolog in a restricted manner.

7.6.2. **Uncertainty in information**

In real world, we have the experience that sometimes either we have no knowledge about an object or we have some incomplete or uncertain knowledge about the object. There are different approaches for dealing with these uncertain situations. Namely, certainty factors, probability, fuzzy logic, the Dempster / Shafer theory of evidence and nonmonotonic reasoning. The details of inexactness have been considered in **chapter 8**. In this version, we have used the certainty factors method to deal with the uncertainty or lack of confidence in **MYCIN** style. If we have a hypothesis h based on an evidence e, then from some simple assumptions of certainty theory we may define "measure of belief" and "measure of disbelief". We write :

MB(h | e), the measure of belief of a hypothesis h based on an evidence e, and
MD(h | e), the measure of disbelief of a hypothesis h on an evidence e.

Now,

while MD(h | e) = 0, $1 > MB(h \mid e) > 0$, or
while MB(h | e) = 0, $1 > MD(h \mid e) > 0$.

We now combine

MB(h | e) and MD(h | e) to get the certainty factor as

$$CF(h \mid e) = MB(h \mid e) - MD(h \mid e).$$

In a rule-based system, one certainty factor is attached to each premise. These certainty factors are combined to get the overall certainty of the inference as follows. If p1 and p2 are two premises of an inference, then the combined certainty factors are :

CF (p1 and p2) = min (CF(p1), CF(p2)), and
CF (p1 or p2) = max (CF(p1), CF(p2)).

The combined certainty factor (CF) of the premises obtained from the above combining rules is multiplied by the originally assumed CF of the inference to get the new CF of the inference. In our design, as original value, we have taken CF = 1 for all premises and thereby CF = 1 for the inferences also. During the actual consultation session, we may give variable CFs to different premises. It calculates every CFs of inferences from these CFs of premises according to the above rules.

7.6.3. **Static and dynamic knowledge bases**

Normally, a Prolog program is a static data base of knowledge. Once you compile it, you essentially "freeze" the knowledge in the database [15]. But sometimes it is necessary to remember the results or facts of a previous consultation session for better comparison, specially in a diagnostic problem. Prolog can remember these facts which can be stored in a secondary storage device. As when needed, this knowledge base can be called in dynamically and this information will be a part of total knowledge base. This facility in the system makes it more useful and a kind of intelligencia is flavoured.

7.6.4. **Portability**

To have its increased usage an expert system is expected to be portable. This essentially means that the system can be run on different types of target machines which can be procured at low cost and can be transported easily to different remote health centres. Moreover, the recurring expenditure should be low in terms of power consumption, maintenance etc. During the system development, one has to select a software development tool to satisfy the said purpose. For example, one may suitably select PROLOG / LISP or an ES-shell or a tool-kit based on PC running under MS-DOS. Summarily, a low cost and easily manageable by the end users PC-based system is being proposed here. This portability feature should certainly encourage the usage issue discussed in **chapter 1(section 1. 3. 2)**. It should be easier then for doctors who already have hardwares with them to procure this system. This may require a small upgradation rather than procuring specialised LISP-based machines or AI workstations.

7.6.5. **Modifiability**

The knowledge in database may be changed due to different reasons. An existing system should easily and quickly incorporate these changes. Our system has been designed in a modular fashion and is capable to incorporate easy and a quick modification.

7.6.6. **Implementation**

For implementation we have taken the language Turbo Prolog. The system may work on an IBM-compatible personal computers. We now give below a portion of the knowledge base used in the expert system.

```
/* A prototype expert system for Child Growth and Development */
/*                          by                                */
/*          Pampa Mondal, A. K. Saha and R. K. Samanta        */
/*        North Bengal University, Pin - 734 430, INDIA       */
/*              A portion of Knowledge base                   */
Title :-
write (" A CONSULTATION SYSTEM FOR CHILD GROWTH AND DEVELOPMENT "), nl.
query (group_1) :-
 write("give the age in words "), readln(A), nl,
 write("Ans to be >0 & <1 for +ve reply & 0 for -ve reply"),nl,
 openwrite(defficiency,"deff.dat"),
 test(axial_muscle_tone,A),
 test(muscle_tone_of_limbs,A),
 test(spontaneous_gestures,A),
 test(primary_reflexes,A),
 test(visual,A),
 test(gripping,A),
 test(relation,A),
 test(emotional_and_social_development,A),
 test(language,A),
 test(rhythms,A),
 test(eeg,A),
 closefile(defficiency).
 test(axial_muscle_tone,one):-
 nl,write("Axial muscle tone:"),nl,
 make,
 ask(pulledup_sitting),
 write("Does the head drop?"),nl,
 readln(Reply),
 remember(Reply),
 make,
 ask(prone),
 write("Does the baby turn head from side to side when proned ? "),
 readln(Ans),nl,
 remember(Ans),
 minimum(Reply,Ans),
 readreal(Val),
 certainty_factor(Val),
 make,
 make.
```

In the process, different certanity factors of premises are supplied in actual runs. The system will ask for these factors and we should supply these from parents' informations about the child. It will calculate the certainty factors of the inferences of its own from the supplied factors of the premises. For a typical analysis, we have considered those activities as "highly likely abnormal" whose certainty factors are less than 0.6 . To compare the performance of the child's current data with the previous consultation date, we preserve facts / results of one previous session. During the current session we compare the current CFs with the previous CFs. It calculates the percentage of increase or decrease or no change of performance and which may be displayed, if required. Again, for a typical conclusion, it calculates the overall performance and will display a message like "The growth has increased in 20% cases". The variation in activity by 10% has been considered negligible. Then it draws a general conclusion like "The growth of the baby is expected to be highly likely normal" and will ask for another consultation, if required.

7.6.7. **A typical consultation session**

We give here an important portion of a typical consultation session for a child of age less than two months.

```
A CONSULTATION SYSTEM FOR CHILD GROWTH AND DEVELOPMENT

Reference Number    : r1-o8-18
Name                : Jayanta Chowdhury
Father's name       : Mr. Sushil Chowdhuri
Mother's name       : Mrs. Dipti Chowdhuri
Address             : Netaji Road, Alipurduar
Age                 : One Month and 14 days

                                  Press any key to continue
```

CERTAINTY FACTORS

ACTIVITY	Current value on 25/07/91	Previous value on 18/07/91	Comments
Axial Muscle Tone	0.8	0.7	Increased by 10%
Muscle Tone of Limbs	0.7	0.8	Decreased by 10%
Spontaneous Gestures	0.8	0.6	Increased by 20%
Primary Reflexes	0.9	0.8	Increased by 10%
Visual	0.6	0.5	Increased by 10%
Gripping	-	-	No change
Relation	0.9	0.8	Increased by 10%
Emotional and Social Development	0.7	0.7	No change
Language	-	-	No change
Rhythms	0.7	0.5	Increased by 20%
EEG	0.9	0.8	Increased by 10%

Press any key to continue

A CONSULTATION SYSTEM FOR CHILD GROWTH AND DEVELOPMENT

The growth has increased in 18.18% cases
The variations in activities upto 10% has been neglected

Conclusion :

The growth of the baby is expected to be highly likely normal.
Would you like another consultation (y/n)?

7.7. **Prototype (version 1.2)**

This version 1.2 of our prototype system incorporates explanation tracing procedure, nonmonotonic reasoning procedure and certainty factor revision procedure. Different problem domains require different mixing of techniques and KR schemes at per the requirements the domain lays on an expert system. In most of the situations, one can't find any suitable existing architecture to meet all the requirements of the problem domain. It may be worthwhile to use one's own architecture. For the present paediatric problem domain there is no suitable existing architecture available to meet all the requirements as identified in **section 5.4**. This leads us to build our own architecture.

7.7.1 **General description**

The architectural components of our system is shown in fig. 7.3. There are two key aspects involved in the process of design an expert system : Knowledge Base(s) and Inference Engine. The knowledge gathered from domain experts is stored in knowledge base (KB). The KB consists of two parts : static part and dynamic part. The static part is relatively fixed over time. The dynamic part is capable of adding new facts or facts can be removed from the KB as when required. After entering the relevant knowledge, one can save the KB(s) in the external storage for later use.

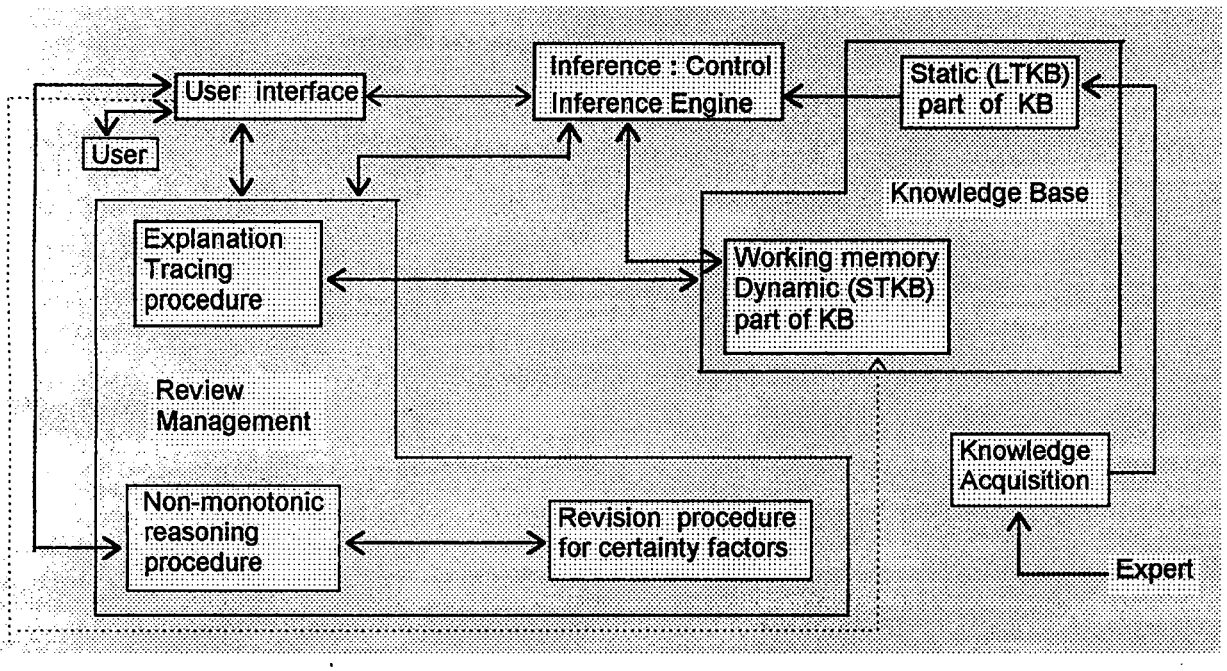

Fig. 7.3 Architectural components of the system

The inference engine uses LTKB and STKB to infer new facts. Backward reasoning process has been used here which favours the needs of the application domain. It has been shown below that the inference engine uses depth-first scanning but with an 'improved back tracking'.

A user interacts with the system with the user interface of the system. Through this module different quaries are served by the system initiated by the inference engine. The total review management is transparent to the user through this particular module. All accesses by a user to KB and review management module are through inference engine. However, logical access is presented through broken line of fig. 7.3. Knowledge acquisition module is responsible for enhancing the system knowledge by the knowledge engineer as when acquired from domain experts.

A more detail discussion on the organization of the knowledge base, the inference engine and review management is provided in the following sub-sections.

7.7.2. **Knowledge Base**

The domain experts provide the knowledge of the problem area. After extracting the necessary knowledge from the domain experts, one has to implement that knowledge in a correct and efficient knowledge base. It is the most important part of the expert system which is made separated from the inference engine with some well-known advantages. The knowledge base consists of two parts : static part and dynamic part. The static part of the knowledge base does not change over time on long term basis which may be termed as long-term knowledge base (LTKB). The dynamic part of the knowledge base is used from where facts can be added to or facts can be removed from the knowledge base as when required. This dynamic part is used on short-term basis which may be termed as short-term knowledge base (STKB). Facts obtained from the user during consultation session that apply only to the current consultation are stored in this dynamic part. This STKB may act as a part of the nonmonotonic reasoning process. This STKB also helps in achieving 'improved backtracking' which will be explained in **sub-section** 7.7.3. The dynamic knowledge base is stored in memory with the static knowledge base. One can save the dynamic as well as static knowledge base in a secondary storage device for later use.

7.7.3. **Inference Engine**

The inference engine has two functions : inference and control. Inference is the basic formal reasoning process which involves matching and unification. Such inference operates by modus-ponens. The control function determines the order in which the rules are tested and what happens when a rule succeeds or fails. The control function must also handle the well-known problem of conflict resolution. The

inference engine scans the rules using backward chaining during the consultation process; i.e. starts at the goal and works backward. In this type of application of medical diagnosis, backward chaining is useful because the questioning is guranteed to follow the focused goal conclusion. The scanning used in our application is limited to depth-first nature. As a general principle, all rules relative to a particular goal are scanned as deeply as possible for a solution before it backtracks and tries an alternative goal. However, we may control that backtracking using STKB and using some control rules. The STKB also helps in eliminating repetitive questioning during consultation session. This results in considerable speed up during inferencing. For the purpose, in the design we have added some control aspects using some control rules that are not a part of the knowledge base proper. The static knowledge base, then really contains two types of rules : knowledge base rules and control rules. Using some control structures we may eliminate certain search paths in problem space resulting in 'improved backtracking' provided that sufficient domain knowledge is available. The overhead of conventional chronological backtracking where no prior knowledge about the prospective backtrack point is available, can be much reduced using 'improved backtracking'.

7.7.4. **Review Management**

A review on the conclusions can be made during the consultation sessions. Under the general heading of review management, there are mainly three procedures involved, namely, Explanation tracing procedure, Nonmonotonic reasoning procedure and Certainty factor revision procedure. The Explanation tracing procedure provides explanations to mainly 'How' a conclusion has been achieved. The system may provide a sequence of 'fired rules' to achieve a particular goal. ' WHAT IF' type of review is provided with a combination of nonmonotonic reasoning and certainty factor revision procedure. ' WHAT IF' review can be used to find out WHAT conclusion will be deduced IF certain certainty factors are changed.

7.7.5. **Analysing Process**

To initiate its analysis activity, an expert system requires some initial information about the application domain. The future courses of actions are taken depending upon these informations, the initial set of facts. The system applies rules on these facts and new facts are generated. Recursive application of this process leads to the goal, if satisfied. Dynamically generated new facts / results are stored in STKB for comparison, explained later on. In the process, different certainty factors of premises are supplied in actual runs. The system will ask for these factors and we should supply these from parents' informations about the child. It will calculate the certainty factors of the inferences of its own from the supplied factors of the premises. For a typical analysis, we have considered those activities as "highly likely abnormal" whose certainty factors

are less than 0.6. To compare the performance of the child's current data with the previous consultation date, we preserve facts / results of one previous session in STKB. During the current session we compare the current CFs with the previous CFs. It calculates the percentage of increase or decrease or no change of performance of a child. This activity comparison is essential to comment on the overall performance profile of a child. For a typical conclusion, it calculates the overall performance and will display a message like "The growth has decreased in 45% cases". The variation in activity by 10% has been considered negligible. Then it draws a general conclusion like "The growth of the baby is expected to be abnormal". It is essential then to know the activites which are abnormal for the child. The system displays those abnormal activities which should get special attention for treatment. In addition, user may want to see the tracing of reasoning to goal for his / her satisfaction. The system may display the firing rules with their corresponding CFs. This tracing of reasoning to goal also helps a medical professional to get an idea about the sequence of firing rules with CFs for further actions. If one is not satisfied with the conclusion, he / she may want to change the CF of a rule at this stage. The supply of subjective informations by the parents / guardians of a child needs this revision of certainty factors. The system accommodates this revision and a fresh conclusion will be drawn. If the user is fully satisfied with the conclusion drawn, it will move to the next session, if desired by the user.

7.7.6. **Consulting the system**

We now present an excerpt from a typical consultation session with the system.

```
                    WELCOME TO
THE CONSULTATION SYSTEM FOR CHILD GROWTH AND DEVELOPMENT

    Reference Number    : r3 - 6 - 13
    Name of the baby    : Jai
    Father's Name       : Dhajen
    Mother's Name       : Mira
    Address             : Shibmandir
    Age                 : One Month

                                  Press any key to continue ...
```

Do you want to compare certainty factors (y/n) ? y

Certainty Factors			
Activity	Current value on 13/6/1994	Previous value on 12/5/1994	Comments
Axial muscle tone	0.3	0.8	Decreased by 50%
Muscle tone of limbs	0.6	0.9	Decreased by 30%
Spontaneous gestures	0.6	0.8	Decreased by 20%
Visual	0.6	0.9	Decreased by 30%
Gripping	-	-	No change
Relation	0.7	0.8	Decreased by 10%
Activity	0.79	0.8	Decreased by 1%
Language	-	-	No change
Rhythem	0.7	0.8	Decreased by 10%
EEG	0.99	0.9	Increased by 9%
			Press any key to continue ...

Do you want to know the general conclusion (y/n) ? y

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Growth of the baby decreasing in 45.45% cases.
The variation upto 10% has been neglected.

CONCLUSION

The growth of the baby is expected to be abnormal.
The activities which are most abnormal for the child:
Axial_Muscle_Tone

Press any key to continue ...

Do you want to trace of reasoning to goal (y/n)? y

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Following sequence of rules leads to conclusion :
query(group_1, one)
activity(axial_ muscle_ tone,one)
by firing rule 'minm' :
Mininum value is : 0.3
i.e. CF of the above rule is : 0.3
activity(muscle_ tone_ of_ limbs, one)
by firing rule 'minm' :
Minimum value is : 0. 6
by firing rule 'minm1' :
Minimum value is : 0. 6
by firing rule 'minm2' :
Minimum value is : 0. 6
by firing rule 'minm3' :
Minimum value is : 0. 6
i.e. CF of the above rule is : 0. 6
activity(spontaneous_ gestures, one)
by firing rule 'minm' :
Minimum value is : 0. 8

Press any key to see next ...

:
:

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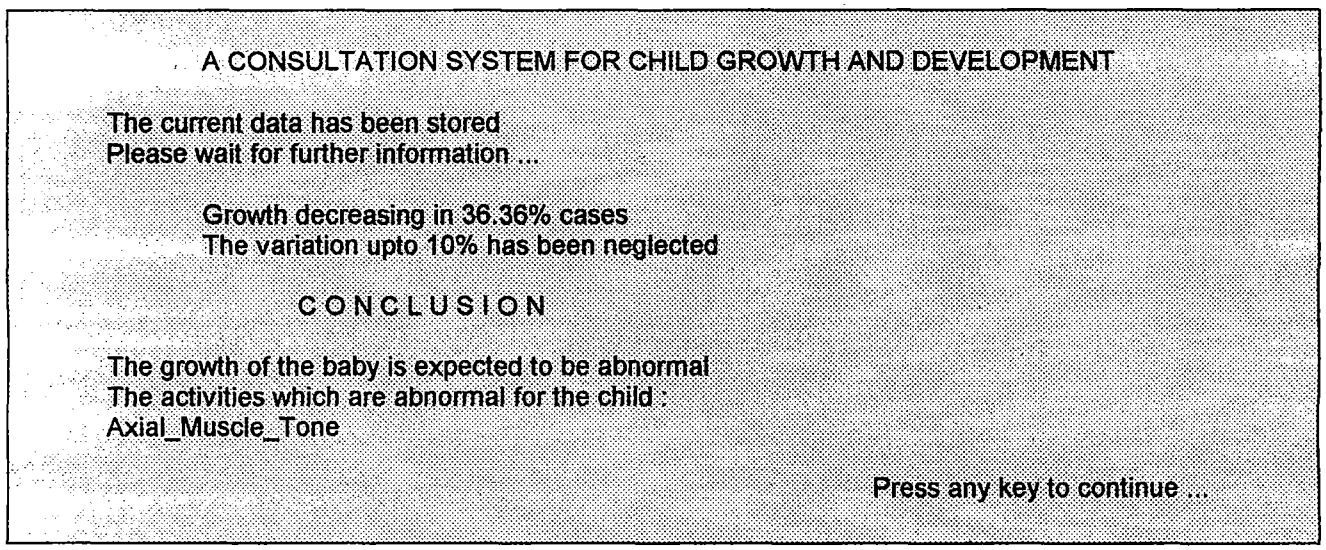
:
:

By firing 'comparing - factor' it concludes :
Growth of the baby decreasing in 45.45% cases

Press any key to continue ...

Hope you are satisfied (y/n) ? n
Do you want to change current value of any certainty factor
(y/n) ? y
To change the CF of an activity, give the activity no : 3
Enter new CF : 0.8
Do you want to change more (y/n) ? n



Do you want to trace of reasoning to goal (y/n) ? n
Hope you are satisfied (y/n) ? y
Do you want to consult further (y/n) ? n
Good bye friend ! See you !

The above excerpt clearly demonstrates how you can interact with the system. The reply from the system is displayed through screen-based frames for compactness of relevent informations.

7.8. **Conclusions and Discussion**

This chapter provides prototypes of our developed system. A small review of prototyping and prototyping cycles have been provided. A comparison has been made between phase refinement and prototyping. Five stages in the evolution of an expert system as identified by Waterman have been discussed. The gradual development of prototypes have been presented. The architectural modifications of the system have been presented and discussed. Typical consultation sessions have been presented.

Uncertainty in informations has been considered in terms of certainty factors. Other fuzzy informations have not been dealt with and leaves scope for refinement. To worth mention, some medical diagnostic expert systems like cadiag-2 have used fuzzy reasoning in their design. However, the present system contains static as well as dynamic databases which offers an additional intelligent activity of the system. The system can easily adapt itself with changing information and it is also portable. Last of all, we must mention that the system in its present form may not be used in a real medical diagnosis which needs more standarization. The standarization may be

achieved through users' participation and through the knowledge acquisition of different experts in the domain. The issue of system validation and testing has been provided at the later stages of our development in **chapter 11**.

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