

University Of Aberdeen

Knowledge Representation and Reasoning

Assessment 2

Submitted By: Avinash Bagul

Id: 51987820

Table of Contents

1	Part One:	4
1.1	Introduction	4
1.2	History of Expression of Knowledge	4
1.3	Requirements for Expressing Knowledge	4
1.3.1	Representational Adequacy	4
1.3.2	Inferential Adequacy	5
1.3.3	Acquisition Efficiency	5
1.4	Reaction to Expression of Knowledge	5
1.4.1	Positive Reaction	5
1.4.2	Negative Reactions	5
1.4.3	Personal Views	5
1.5	Applications of Expression of Knowledge	6
2	Part Two:	7
2.1	Introduction	7
2.2	History of Resolution	7
2.3	Reaction to Resolution	7
2.3.1	Positive	7
2.3.2	Negative	8
2.3.3	Personal Views on Resolution	8
2.4	Applications of Resolution	8
3	Part Three:	9
3.1	Introduction	9
3.1.1	Introduction to Procedural Controls	9
3.1.2	Introduction to Rules	9
3.1.3	Introduction to Object Oriented Representations	9
3.1.4	Introduction to Structured Descriptions	9
3.1.5	Introduction to Inheritance	9
3.2	History	9
3.2.1	History of Procedural Controls	9
3.2.2	History of Rules	9
3.2.3	History of Object Oriented Representations	10
3.2.4	History of Structured Descriptions	10
3.2.5	History of Inheritance	10
3.3	Reactions	10

3.3.1	Reaction to Procedural Control	10
3.3.2	Reaction to Rules	10
3.3.3	Reaction to Object Oriented Representation	11
3.3.4	Reaction to Structured Descriptions	11
3.3.5	Reaction to Inheritance	12
3.3.6	Personal Views	12
3.4	Applications	12
3.4.1	Applications of Procedural Control	12
3.4.2	Applications of Rules	12
3.4.3	Applications of Object Oriented Representation	12
3.4.4	Applications of Structural Description	13
3.4.5	Applications of Inheritance	13
4	Part Four:	14
4.1	Systems Architecture	14
4.2	Systems Architecture of Extended System	15
4.3	Summary and Recommendation for Which System to Choose	16
4.3.1	What is New System?	16
4.3.2	How it is better than Initial System?	16
4.3.3	Why should you choose Extended System?	16
5	Bibliography	17

1 Part One:

1.1 Introduction

Expression of Knowledge in knowledge representation and reasoning is an important part of Artificial Intelligence which aims to design a representation system which can capture information to be used for complex problem solving.

Expression of knowledge is propositions and relations explained by the sentences in the knowledge base to be the beliefs of our agent. Knowledge base have collection of these sentences which are declarative in nature.

Expression of knowledge is achieved when we have a set of predicates from knowledge base which is crucial for domain representation, description of the object types and n-ary predicates which express relationships. Usually represented using atomic sentences and negations of atomic sentences.

Expression of knowledge is crucially important in the field of artificial intelligence as it provides information about the world to an agent in such a way that it can understand and make decisions based on the understanding. It also enables machine to learn from the experiences so that machine behave intelligently like a human being.

Knowledge is expressed as set of rules which are compared with collection of facts. In the if-then statement, when the first part is satisfied by the facts then the action in the second portion is executed.

1.2 History of Expression of Knowledge

General Problem solver (GPS) system developed by Allen Newell and Herbert A. Simon in 1959 is one of the earliest work in knowledge representation. (Wikipedia, 2020). The system would start with a goal and then divide the goal into sub-goals to make strategies which can achieve each sub-goal.

Knowledge was categorized into declarative knowledge, procedural knowledge, Meta-knowledge, heuristic knowledge and structural knowledge. During the 1970s expert systems were developed as a result of cognitive revolution in psychology and focus of AI on expression of knowledge. Researchers developed the concept of frame-based languages during the late 1980s.

There are several research projects going on Semantic Web which is currently the most active area of knowledge representation.

1.3 Requirements for Expressing Knowledge

There are four main requirements for expressing knowledge:

1.3.1 Representational Adequacy

Ability to express all kinds of knowledge which might be required in the domain.

1.3.2 Inferential Adequacy

It is the ability to manipulate the presentation structures for inference of new structures.

It is the ability to incorporate additional data and information into the knowledge structure which can be further used to infer efficient knowledge in in most promising direction.

1.3.3 Acquisition Efficiency

Ability to acquire new information easily. New information given by knowledge engineer is acceptable, but agent should be able to control its own knowledge acquisitions.

1.4 Reaction to Expression of Knowledge

1.4.1 Positive Reaction

- It is very expressive, everything can be virtually expressed in **natural language**.
- **Database** is a good way of efficiently representing data, database can be built traditionally to deal with large and complex data.
- **FOL** (First Order Logic) is very expressive and has well defined syntax and semantics.
- **Rule Based Systems** are very expressive and the rules lead to a degree of modularity, probabilistic reasoning can be achieved by handling certainty factors.

1.4.2 Negative Reactions

- In **natural language**, the structure of sentences is less uniform and hence sometimes leads to ambiguity.
- Only simple aspects of the problem domain can be considered in **database**.
- In **FOL** there is no efficient procedure to process knowledge.
- Rule Based Systems are not always the best and they lack in precise semantics for the rules.

1.4.3 Personal Views

❖ Positive Views

- Expression of knowledge removes the constraints in a problem. It can reveal the impact of an object or relation to the object or other relations.
- Expression of knowledge allows problems to be concise.
- Virtually most of the Knowledge Representation Languages have a reasoning or inference engine as part of the system, which allows to make new inferences and assert new knowledge.
- In Natural language is extremely expressive and virtually everything can be expressed like real world situations, pictures, symbols, emotions and reasoning.

❖ Negative Views

- Knowledge representation uses First Order Logic which has two main drawbacks, one is, it is difficult to use as it is intimidating for many developers. Another issue is the practicality of implementation. Some statements in FOL can cause system to not terminate.
- Both syntax and semantics are very complicated and hard to understand.

1.5 Applications of Expression of Knowledge

❖ Expert Systems

Expert systems is software which attempts to provide an answer to a problem in a specific domain. It is the sub-field of artificial intelligence. Expression of knowledge plays important role in expert systems for giving correct answer to the given problem as it represent the knowledge in a very systematic, logical and understandable way. The knowledge is initially provided by an expert human being of the particular domain.

❖ Decision Support Systems

Decision Support Systems are the information system which supports the decision making in areas like business and organizations. They prove of a great importance in making the right choice and the decisions. Used in stock market analysis and property purchase management.

❖ Medical Expert System

Medical expert systems are artificial intelligent system which is trained with the real life cases to perform complicated task. So, it is very important for knowledge to be expressed correctly and efficiently.

❖ Fault diagnosis and troubleshooting systems

To pin point the faults and errors in the system, knowledge representation plays a vital role as it has information of predicates which can tell what causes fault in the system looking at the relation between what's wrong and what's the possibility. Same is the trouble shooting, if the cause is known, knowledge base has answers to solve the problem.

❖ Help desk systems

Help desk systems are often found in most of the apps and websites now a days. This help desk system is an intelligent software which can respond to the user queries efficiently and give the proper guidance and service.

2 Part Two:

2.1 Introduction

Resolution is the inference rule for sentences in propositional logic and First Order Logic (FOL). Resolution allows to tell whether the propositional formula is satisfied or proving that first order formula is unsatisfied.

Resolvent is the clause produced by resolution. When resolution is merged with a search algorithm, resolution produce a good algorithm which decides if the propositional formula is satisfied. This technique of resolution use proof by contradiction and it is based on the fact that sentences in propositional logic can be transformed into CNF (conjunctive Normal Form). (Wikipedia, 2020)

In Knowledge Representation like First Order Logic, rules are applied on the clauses repeatedly by the resolution. So, if provided with Knowledge base and question, the resolution algorithm will give answer for the question if it is true or false. (Hyde, 2010)

Resolution plays important role in Artificial Intelligence as it allows the logical agent to reason about the real world. Resolution uses proof by contradiction and proof by refutation. (Hyde, 2010)

Steps for resolution include conversion of facts to FOL, then this FOL is converted to CNF (conjunctive normal form), proof by contradiction and unification or we can say representation (resolution graph).

2.2 History of Resolution

The constant efforts made in the field of AI in its early age was automatic theorem proving, but it failed due to lack proper technique. The resolution technique was invented in 1965 by a mathematician Alan Robinson. After this invention resolution became the foundation for automatic theorem proving.

Resolution is based on mathematical logic which allows automatic reasoning in the field of Artificial Intelligence.

Paramodulation is another technique like resolution for reasoning on sets of clauses, where the predicate symbol is equality. The main aim of this technique is to reduce the system to atoms. (Wikipedia, 2020)

2.3 Reaction to Resolution

2.3.1 Positive

- Resolution allows automated theorem proving and refutation theorem proving.
- It supports propositional logic and First Order Logic.
- When it is coupled with search algorithm it gives an algorithm to determine the satisfiability.
- In FOL, the traditional syllogism of logical inference is reduced to a single line rule by resolution.

2.3.2 Negative

- Resolution may need more time to resolve a knowledge base with large number of clauses. As more processing time can lead to less efficient systems in terms of Artificial Intelligence.
- Paramodulation is another technique for reasoning.
- Resolution might sometimes fail in a very large problem.

2.3.3 Personal Views on Resolution

Resolution finds a very important place in the field of Artificial Intelligence especially in first-order logic and reasoning.

❖ Positive

- As Artificial Intelligence mainly focus on automation, where resolution allows us to do automatic theorem proving and reasoning which proves of a vital importance in the field of Artificial Intelligence.
- Resolution graph represents a resultant clause that can be deduced by techniques equivalent to resolution.

❖ Negative

- Though resolution has proven to be of great importance but sometimes it fails to work for large problems.

2.4 Applications of Resolution

- **CARINE** (Computer Aided Reasoning Engine) is a theorem prover based on resolution which was built for the study of strategies delayed clause construction (DCC) and attribute sequences (ATS) in depth-first search algorithm. (Wikipedia, 2018)
- An automatic theorem prover for first order logic known as Vampire was developed by the Department of Computer Science at the University of Manchester. It has won the “world cup for theorem provers” eleven times in 1999 and from 2001 to 2010. (Wikipedia, 2020)
- **SNARK** (SRI’s New Automated Reasoning Kit) is a theorem prover built by SRI International for multi sorted first-order logic applications in Software engineering and Artificial Intelligence. (Wikipedia, 2018)
- Resolution plays important role in forward chaining and backward chaining.
- Resolution allows the automatic theorem proving in field of Artificial Intelligence and Mathematics.
- It has huge application in Theorem Provers like CARINE, Vampire, SNARK, Otter, Prover9 and SPASS. (Wikipedia, 2020)

3 Part Three:

3.1 Introduction

3.1.1 Introduction to Procedural Controls

Theorem proving method like Resolution are domain independent. Facts can be expressed in first-order logic. The automated theorem proving mechanism, logically try every possibility in knowledge base to look for answers for a query. It is not always computationally feasible to try everything. In this cases certain changes can be made to avoid unwanted factors in answering the query.

3.1.2 Introduction to Rules

Rules are also called as condition-action rules. A rule base system contain rules of the following form:

If <condition> then <conclusion>

Rules can be evaluated by forward chaining and backward chaining.

3.1.3 Introduction to Object Oriented Representations

In Object Oriented Representations sentences are grouped, structured and organized. Object Oriented Representations in knowledge base can correspond with the user interface.

3.1.4 Introduction to Structured Descriptions

Objects from O-O- representation fall into some category, this categories can be more specific. Generalization of objects is common with simple name and even with complex description. Objects can have multiple parts and the relationship among the object part is very important for it to be considered as member of a category. (Aberdeen, 2020)

3.1.5 Introduction to Inheritance

Hierarchy of objects allows to avoid repeated representation of knowledge. Different type of objects are organized in a hierarchical way just like they are found in the real world.

3.2 History

3.2.1 History of Procedural Controls

The concept of Procedural Control was developed by the center of Artificial intelligence at SRI International in 1980s. Australian Artificial Intelligence Institute implemented advanced form of procedural control in 1990s.

For reasoning, procedural control helps to determine the method to represent knowledge where user does not know how the knowledge will be used. All the possible logical tries are made to find the answer based on the query which is computationally not efficient.

3.2.2 History of Rules

Rules in production system are more commonly known as production rules. As a general mechanism for computation production systems were proposed in the year 1943. Rules in production system are simple conditions with if-then statement, where if a condition is satisfied

then the action is triggered. Action on the right side of statement is performed if the left hand side condition is satisfied.

These rules are the basic and the fundamental bits of many computation and expert systems. Rules also define the direction of reasoning i.e. forward and backward Chaining.

3.2.3 History of Object Oriented Representations

Information in the knowledge base should be organized properly, for a large knowledge base it is crucially important to have a structural and organized information for ease of use and efficiency of the system. Object Oriented Representation allows the information in the knowledge base represented in a structured and organized way as it has object for the similar kind of information which can be grouped together and retrieved easily with the help of object.

The concept of Object Oriented Programming was first listed by Alan Kay in 1966. In Object Oriented representation the sentences are grouped and well organized. This concept helps in reducing duplicate data and increasing the efficiency as the data is well classified under objects which can be reused.

3.2.4 History of Structured Descriptions

Structured Descriptions allows the objects in object oriented representation to be well categorized. When this objects are grouped together based on their type, it becomes more descriptive and usable. It plays important role in effective representation and reasoning.

3.2.5 History of Inheritance

Inheritance is a concept widely known and used in almost every real life applications. This concept was introduced in Object Oriented Programming in 1969. This idea was used for knowledge representation in 1977. Inheritance is an object based approach to structure things in hierarchical form for better organization and representation of knowledge base. Inheritance also support classification, generalization and abstraction.

3.3 Reactions

3.3.1 Reaction to Procedural Control

❖ Positive

- Procedural Control made knowledge representation and reasoning easy and efficient.
- It allows reusability.
- It allows simplicity of controlling the reasoning.
- It was praised for allowing control for reasoning.

❖ Negative

- Main drawback is that the procedural control pays more focus towards the operation and less focus on the information.
- It may avoid useful information when trying to find the answers for a given query.

3.3.2 Reaction to Rules

Information was collected from (BrainKart, 2020)

❖ **Positive**

- Rules are foundation for many expert systems.
- Rules are transparent and easily applicable in every system.
- Production rule provides modularity.
- Production rules are easily modifiable.
- Rules can handle uncertainty.
- Rules are knowledge intensive as rule is just written as normal English sentence, it does not contain any procedural information.
- Rules can be combined together easily with the help Boolean operators.
- Rules can elaborate a complete sequence of condition and action in one statement.

❖ **Negative**

- Large knowledge base can lead to large number of rules which can later be the cause of ambiguity. Hence it can be inefficient for large knowledge base and large number of production rules.
- Rules lead to opacity, this problem arrives when rules are combined.
- Rules have absence of learning as they do not store any kind of result or information for future use.
- Adding new rule to knowledge base can lead to conflicts between the existing rules.

3.3.3 Reaction to Object Oriented Representation

❖ **Positive**

- Object-Oriented paradigm is efficient and suitable for systems with real world applications.
- For developing Knowledge Base systems Object Oriented Representation should be the primary approach. (Walczak, 1998)
- It focus more on data than structured control.
- It allows effective management of system complexity with the use of modularity.
- It can be upgraded from small to large knowledge base easily.

❖ **Negative**

- Showing relationship between object is hard in a single diagram.
- Functionality is limited with objects, this may cause problems for systems which are procedural or computational in nature.
- Object oriented concept has absence of ontology. (Walczak, 1998)

3.3.4 Reaction to Structured Descriptions

❖ **Positive**

- Structured description is highly expressive.
- It can work with large knowledge base size.

❖ **Negative**

- Structured descriptions or description logic is less expressive than First Order Logic.

3.3.5 Reaction to Inheritance

❖ Positive

- Among many positive reaction, Inheritance was praised for reusability, extensibility, reliability and maintainability.
- It reduce the duplication.
- Representation is more organized and well maintained.

❖ Negative

- Inheritance face the problem of ambiguity and sometimes redundancy.
- Unnecessary coupling can occur between object and class.

3.3.6 Personal Views

As discussed above there are so many positive and negative reactions towards procedural control, rules, object oriented representation, structural description and inheritance. Everything has a drawback but when we compare advantages of the discussed topics with the disadvantages we can see that, some concepts like rules, object oriented representation descriptive logic and inheritance have more benefits and help in better and efficient representation of the knowledge base. I personally think Inheritance is the best so far, as it gives a classical, structured and hierarchical way of representation which ultimately makes the overall knowledge base efficient and accessible.

Object based concept in object oriented representation is useful as the information in the knowledge base is organized based on the objects, this objects separates the information as per category and makes it accessible easily where descriptive logic organize this objects based on their category and similarity for more classical way of representation.

3.4 Applications

3.4.1 Applications of Procedural Control

- Real-time Network monitor and Management System used by Telecom Australia. (Rao, 1991)
- Backup solution in case of complete failure of surveillance based systems.
- In aerodrome control zones. (SkyBrary, 2019)

3.4.2 Applications of Rules

- Rules are used in many production systems.
- Production rules find application in development of expert systems and artificial intelligence systems.
- Production rules are also used in Fuzzy Logic systems.
- Rules find application in automatic problem solving systems such as fault detection and troubleshooting.

3.4.3 Applications of Object Oriented Representation

- Used in development of Expert Systems and systems which use knowledge representation.
- Object oriented representation has application in Natural Language Understanding systems.

- Application in many Artificial Intelligence systems for better knowledge representation and adequate efficiency of the systems.

3.4.4 Applications of Structural Description

- Interface to a database: Structural description can provide high level view of the data based on objects.
- Working memory for a production system: Descriptive logic can be used to reason about taxonomy and inheritance of properties.
- Assertion and classification for monitoring: Increment changes to a knowledge base can be monitored with some atomic concepts.
- Contradiction detection in configuration: DL that allow contradictory concepts, it can alert the user when detected.

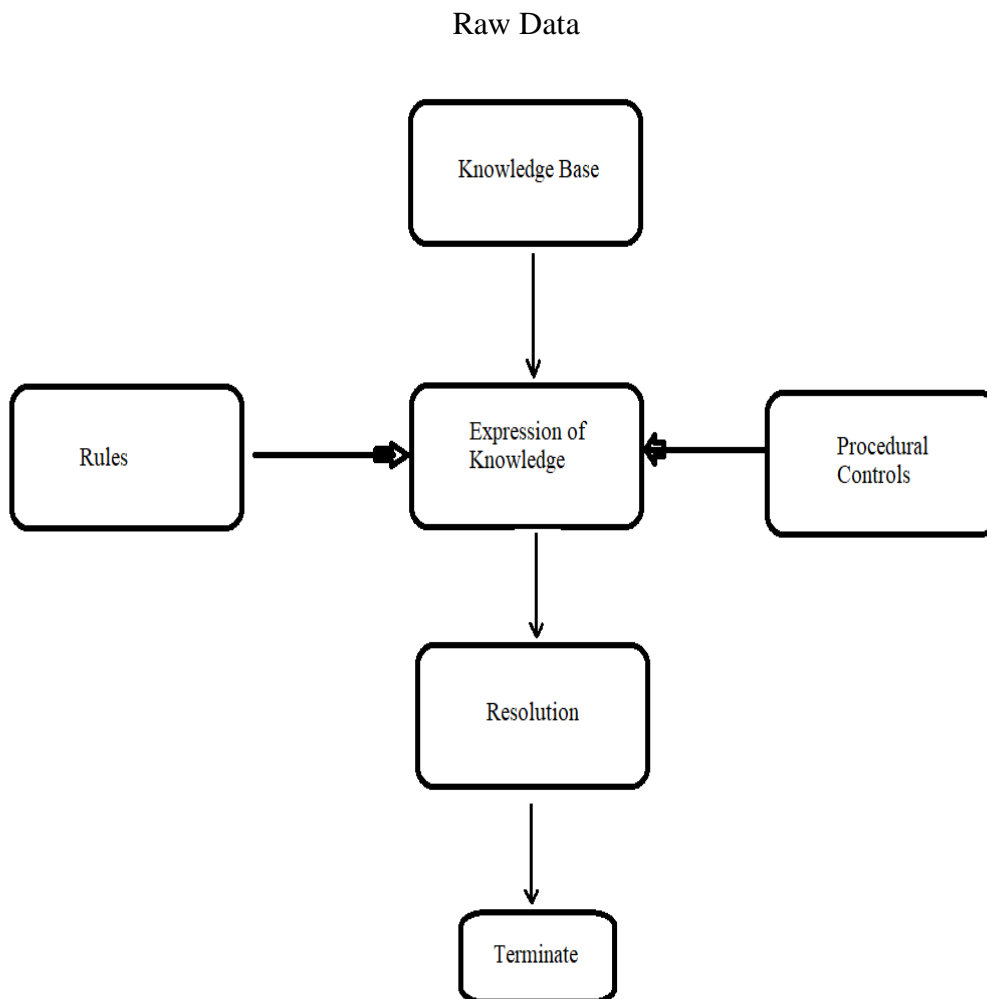
3.4.5 Applications of Inheritance

- Used in the object oriented systems which are more focused towards well organized and hierarchical information.
- Used in systems where redundant information can cause problems as inheritance reduces the redundancy.
- It is considered to be one of the best approach for knowledge representation for development of object oriented systems.

4 Part Four:

4.1 Systems Architecture

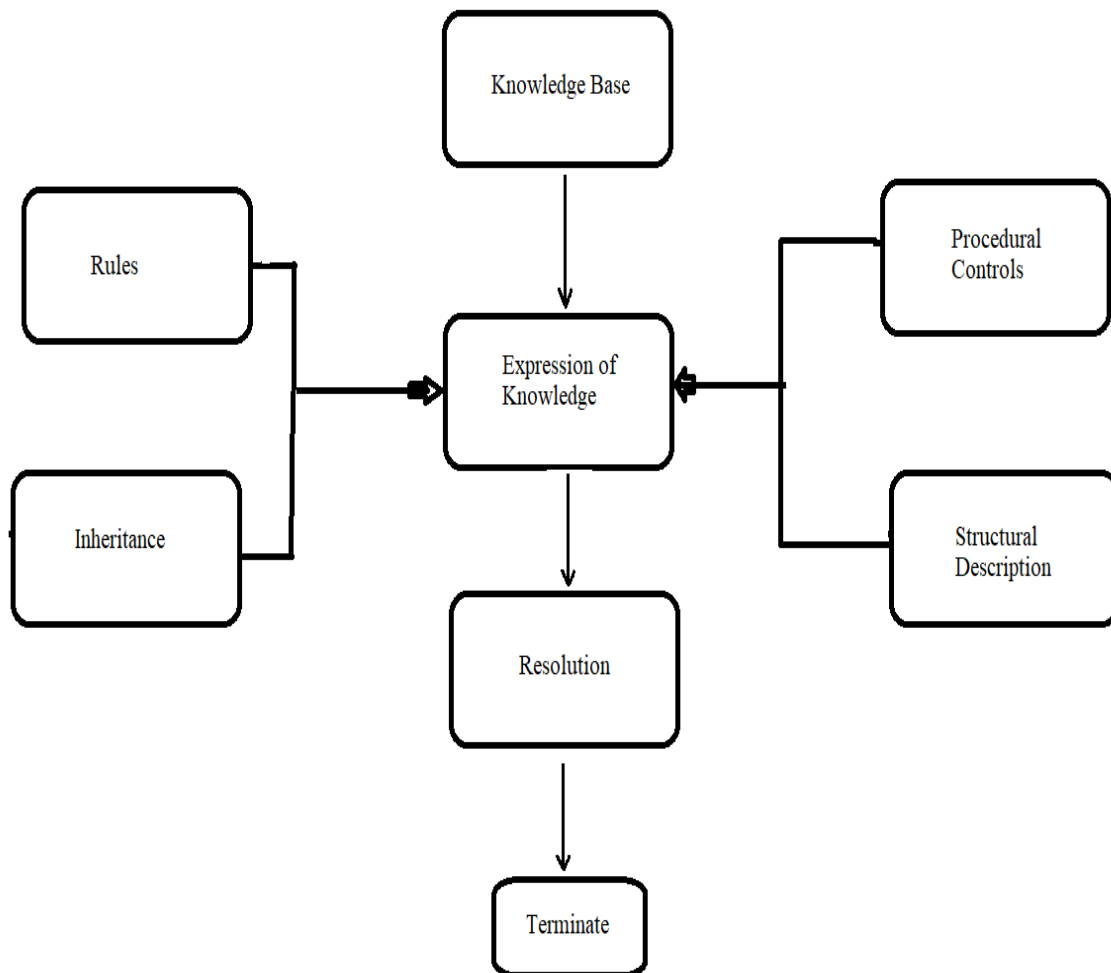
The system architecture for the fundamental system has all the requirements given by the client i.e. Rules and Procedural Control.



We are given with the raw data and hence our system should be able to represent and use the data in efficient way so we will apply Rules and procedural controls as per the requirement given by the client.

4.2 Systems Architecture of Extended System

As our new Designed system implements other methods for representation of Knowledge base and the new added features are the Inheritance and Structural description. It makes system more reliable and efficient as compared with the initially proposed system.



Addition of new features give better results as the implemented techniques are known for their performance and advantages. Object Oriented Representation is always considered better than the structural representation.

4.3 Summary and Recommendation for Which System to Choose

4.3.1 What is New System?

New Extended design of system is based on the Object Oriented Representation concept which include inheritance and structural Description. Addition of this features makes the system more reliable and efficient in terms of handling raw data and operations.

4.3.2 How it is better than Initial System?

Due to consideration of Object Oriented Approach for representation of knowledge base makes the system efficient in terms of handling and understanding information. As the input data is raw, lots of processing is needed to extract the information, so to avoid ambiguity and faults in the information it is better to opt for object oriented approach which organizes data in a very structured and organized way using objects. It is better than the initial system because in initial system we use rules and procedural control which leads to ambiguity especially when the knowledge base has raw and unprocessed or structured data. Information security is another issue for the initial base system.

4.3.3 Why should you choose Extended System?

Extended system will give you following benefits:

- The developed system will be modular (Object Oriented Approach)
- System will be reusable and information will be easy to access and process.
- Maintainability of system will be easy and effective.
- Raw data from the knowledge base will be well organized under objects in hierarchical way.
- Any redundant piece of information in the knowledge base will be removed by inheritance thus making the system more reliable.
- Information hiding can be achieved in new system.

Base system can do most of the tasks but it may not perform much better, maintainability is issue, it is hard task to modify structural systems. Handling large amount of data with the help of production rules might slow down the system and produce ambiguous results.

Object Oriented Approach is a well-known and highly implemented approach for Knowledge Representation and Reasoning Systems. Objects can categorize the information and improve overall stability of the software in terms of speed, large data, maintainability, reusability and security.

Extended system can handle large amount of data and guarantee better performance than the performance expected from the structural approach. Information security is key feature in the new system along with the increased speed and performance due to modular approach. From any perspective, new extended design of the system is better than the initially designed base system. Our firm highly recommend you to choose new system.

5 Bibliography

Aberdeen, U. o., 2020. *University of Aberdeen*. [Online]
Available at: www.abdn.ac.uk
[Accessed 21 Feb 2020].

BrainKart, 2020. *Production System: Characteristics, Features , Disadvantages*. [Online]
Available at: https://www.brainkart.com/article/Production-System--Characteristics,-Features-,-Disadvantages_8871/
[Accessed 21 Feb 2020].

Hyde, 2010. *AI Resolution*. [Online]
Available at: www.cs.nott.ac.uk/~pszrq/files/10IAIresolution.pdf
[Accessed 19 Feb 2020].

Rao, A. S. ,. M. P. G., 1991. *Intelligent Real-Time Network Management*. [Online]
Available at: <https://citeseerx.ist.psu.edu/viewdoc/summary?doi=10.1.1.48.3297>
[Accessed 22 Feb 2020].

SkyBrary, 2019. *Skybrary*. [Online]
Available at: https://www.skybrary.aero/index.php/Procedural_Control
[Accessed 25 Feb 2020].

Walczak, 1998. Knowledge acquisition and knowledge representation with class: the objectoriented paradigm. *Expert Systems with Applications*, pp. 235-244.

Wikipedia, 2018. *CARINE*. [Online]
Available at: <https://en.wikipedia.org/w/index.php?title=CARINE&oldid=851928891>
[Accessed 21 Feb 2020].

Wikipedia, 2018. *SNARK (theorem prover)*. [Online]
Available at: [https://en.wikipedia.org/w/index.php?title=SNARK_\(theorem_prover\)&oldid=838937830](https://en.wikipedia.org/w/index.php?title=SNARK_(theorem_prover)&oldid=838937830)
[Accessed 21 Feb 2020].

Wikipedia, 2020. *Knowledge representation and reasoning*. [Online]
Available at: https://en.wikipedia.org/w/index.php?title=Knowledge_representation_and_reasoning&oldid=941473775
[Accessed 21 Feb 2020].

Wikipedia, 2020. *Resolution*. [Online]
Available at: [https://en.wikipedia.org/w/index.php?title=Resolution_\(logic\)&oldid=941555063](https://en.wikipedia.org/w/index.php?title=Resolution_(logic)&oldid=941555063)
[Accessed 20 Feb 2020].

Wikipedia, 2020. *Vampire (Theorem Prover)*. [Online]
Available at: [https://en.wikipedia.org/w/index.php?title=Vampire_\(theorem_prover\)&oldid=933771504](https://en.wikipedia.org/w/index.php?title=Vampire_(theorem_prover)&oldid=933771504)
[Accessed 21 Feb 2020].

