ARTIFICIAL INTELLIGENCE NOTES

REASONING METHODS

LECTURER:COŞKUN SÖNMEZ

REASONING

I)INTRODUCTION

As studies of artificial intelligence continue, it should become apparent that progres in solving the problems of AI closely parelleled the development of tools and technics for manipulating knowladge. First we must have a knowladge base then we need a computer program that will enable us to access the knowladge for the purpose of making inferences and decision and problem solving.The program is an algorithm that controls some reasoning process and it is usually referrred to as the inference engine or the control program. In rule based systems it is also referred to as the rule interpreter.

Logic may be considered the study of the rules of inference. Inference is the means by which we reason from given knowledge. Early AI researchers hope that they could provide the computer with fundamental postulates and rules of inference and then stand aside while the computer marched bravely forward , deducing or infering truth about earth.While this hope soon proved to be false, it did become clear that any moderately general AI system must include inference rules. Without such rules of logic , many problems would degenerate into exhaustive searches which would defeat even the most capable computer system.

II) KNOWLEDGE REPRESENTATION

Typical problem solving commonly reduced to :

*Knowledge representation and

*Search

We will start by looking at knowladge representation and then look how we reason with knowledge and then look at these topics in action.

What to represent?

Let us consider what kind of knowledge might need to be represent in AI systems.

Objects: Facts about objects in our world. e.g. Guitars have string trumpets are brass instrumens.

Events: Actions that occur in our world.e.g. Steve Vai played the guitar in Frank Zappas Band.

Performance: A behavior like playing guitar involves knowledge about how to do things.

Meta-knowledge: Knowledge about what we know.e.g. Bob's Robot who plans a trip. I know that it can read strect signs along a way to find out where it is.

Thus in solving problems in AI we must represent knowledge and there are two entities to deal with.

Facts: Truth about the real world and what we represent. This can be regarded as the knowledge level.

Representation of facts: We represent facts by sysmbols since we usually define the representation in terms of symbols that can be manipulated by programs.

We can structure these entities at two levels:

Knowledge level; at which facts are discribed.

Symbol level; at which representations of objects are defined in terms of symbols that can be manipulated by programs.

FACTS ===>   INTERNAL REPRESENTATIONS   <==> REASONING PROGRAMS

ENGLISH UNDERSTANDING   ↓ ↑   ENGLISH GENERATION

ENGLISH REPRESENTATIONS

English or natural language is an obvious way of representing and handling facts. Logic enables us to consider the following facts.

Spot is a dog → dog(spot)

We could infer that all dog have tails with.

$\forall$ X :dog(X) → hasatail(X)

We can deduce that

Has a tail(spot)

Using an appropriate backward mapping function the English sentence :

Spot has a tail can be generated.

Using Knowledge

We have briefly mentioned where knowledge is used in AI systems.Let us consider a little further to what applications and how knowledge may be used.

Learning: This is more than simply adding new facts to a knowledge base. New data may have to be classified prior to storage for easy retrieval. Interaction and inference with existing facts to avoid redundancy and replication in the knowledge and also so that facts can be updated.

Retriaval: The representation scheme used can have a critical effect on the efficiency of the method. Humans are very good at it. Many AI methods have tried to model human.

Reasoning: Infer facts from existing data.

If a system only knows :

Miles Davis is a Jazz Musician.

All jazz musicians can play their instruments well.

If things like 'Is Mikes David a Jazz musician? Or Can jazz musicians play their instruments well?' are asked then the answer is readily obtained from the data structures and procedures.

However a question like 'Can Miles David play his instruments well?' requires reasoning.

PROPOSITIONAL CALCULUS

The real value of formal logic to the field of AI lies in the generality of the propositions which may be expressed. In the digital logic examples we assume that the elements such as A and B each have logical values of 0 or 1 corresponding to the logically false or true condition.However, in propositional logic, the propositions may be any statement which can be evaluated as <u>true</u> or <u>false.</u> Examles of a few propositions illustrate the range of aplication of propositional logic:

*Mozart was a composer.

*A composer is a writer of music.

*A dog is an animal.

*The density of 1-ethyl-2-nitro-benzene is 1.126 g/ml.

*The site of culture is blood.

It's clear that deductive logic applied to the above set of propositions would enable an automated reasoning system to answer the question *Was Mozart a writer of music?* Even though this proposition was not explicitly stated. This is an example of Boolean postulate. Mozart belonged to the class of composer is contained in the *class of writers of music.*Therefore Mozart was a writer of music.

Consider the following three (not necessarily true) propositions:

p= Computer system X successfully passed the Turing Test

(p→q)= Successfully passing the Turing Test implies that machines can think.

q= Machines can think.

The logical relationship between these threepropositions is one of the most useful formal rules   of inference, *Modus ponens.*:

(p∧(p→q))→q

This can be easly understood in terms of its English equvalent : If passing the Turing Test implies that a machine can think AND a certain computer passed the Turing Test then the implication is that machines can think. While neither proposition has , infact , been proven true , te logical implication of proving , both propositions true is inescapable. The rule of *Modus ponens* has proven to be very valuable in the reduction of complex sets of logical statements. It's called the '→' elimination rule.

Propositional logic provides a clean, well-defined test bed for automating the inference process.Much of what we know about geometry was proven by Euclid using propositional logic.

PREDICATE CALCULUS

Predicate calculus is an extention and generalization of propositional calculus which provides more power and efficiency for making logical inferences. Propositional logic deals only with the truth value of complete statements and does not consider relationships or dependencies between objects.First-order predicate calculus .

Use of Predicates with Arguments:

Statements about induviduals , both by themseves and in relation to other individuals are called predicates. A predicate is applied to a specific number of arguments and has a value of either true or false when individuals are used as the arguments.Thus the predicate IS A COMPOSER is true when applied to the arguments MOZART and HAYDN. But false when applied to COLUMBUS. Lisp and Prolog provide many intrinsic predicate functionssuch as **equal?** , **atom?** , **member?**.These predicate functions answer the questions of weather two elements are equal, wheather an element is an atom and weather an element is a member of a list , respectively.

The general form for expressing predicates is :

Predicate(Arguments)

Is a megastar(Prince)

Are rich (Megastars)

Have fast cars (Rich people)

Consumes a lot of petrol(Fast cars)

Use of Variables and Qualifiers:

General statements about classes of objects may be made by introducing two qualifiers:

∀   ⇒ 'for all...'   (universal quantifier)

∃   ⇒ 'there exists '   (existencial quantifier)

Thus the general predicate , ' Megastars are rich.' may be expressed in predicate calculus as :

∀   m: megastar (m)→ rich(m)

Which may be translated ' For all individuals m , If m belongs to the megastar class , then m is rich.'

Predicate calculus extends the rules of propositional calculus with the concepts of predicates, quantification and inference rules for quantifiers.It is clear that predicate calculus has a great advantage over propositional calculus in its power of expression.This capability has made predicate calculus an essential technique in specific fields of AI such as automatic theorem proving.

III)HOW CAN WE REASON?

To a certain extendthis will depend on the chosen knowladge representation. Although a good knowledge representation scheme has to allow easy, natural, and plausable reasoning.Listed below are very broad methods of how we may reason.

1) Deductive Reasoning:

Deductive Reasoning is a process in which general premises are used to obtain a specific inference. Reasoning moves from a general principle to a specific conclusion.

Example:

Premise : I wash my car when the weather is good on weekends.

Premise: Today is Sunday and the weather is hot

Conclusion:Therefore, I will wash my car today.

To use deductive reasoning the problem must generally be formatted in this way.Once the format has been achieved , the conclusion must be valid if the premises are true.The whole idea is to develope new knowladge from previously given knowladge.

Starting with such a set of postulates, axioms, and definitions Euclid was able to prove 465 geometric propositions as the logical consequence of the input assumptions.

One of the basic rules of inference of deductive logic is the *modus ponens* rule. A formal English statement of this rule is :

If X is true and if X being true implies Y is true then Y is true.

$(X \wedge (X \rightarrow Y) \rightarrow Y$

Example:

All cats are felines.

Bosty is a cat.

I can deduce that <u>Bosty is a feline.</u>

Abduction is a form of deductive logic which provides only a 'plausible inference' . For instance:

If I read Smoking couses lung cancer and Frank died of lung cancer , I may infer that Frank was a smoker.Again this may or may not be true.Using statistics and probability theory , abduction may yield the most probable inference among many possible inferences.

Abductionis heuristic in the sense that it provides a plausible conclusion consistent with available information, but one which may in fact be wrong.

To illustrate how abduction works, consider following logical system consisting of a general rule and a specific proposition:

1) All succesful , entrepreneurial industrialists are rich persons.

2) John is a rich person.

If this was only information available, a plausible inference would be that John was a succesful , entrepreneurial industrialist.This conclusion could also be false since there are other roads to riches such as inheritance , the lottery...If we had a table of the income distribution of wealthy persons along with their personal histories, we could refine our abduction inference with the probability of the inference being true .

2)Inductive Reasoning A principle of reasoning to a conclusion about all members of a class from examination of only a few members of the class; broadly, reasoning from the particular to the general.

For example :

In 1998, The best model of Turkey is from İzmir

In 1999, The best model of Turkey is from İzmir

In 2000, The best model of Turkey is from İzmir

I would logically infer that all the girls from İzmir is beautiful. This may or may not be true. But it provides a useful generalization.

Another example :

$1 = 1^2$

$1+3 = 2^2$

$1+3+5 = 3^2$

$1+3+5+7 = 4^2$

and, by induction $\sum$ (n successive odd integers) $= n^2$

Another example :

Falcon can fly.

Canary can fly.

Gull can fly.

Conclusion: Birds can fly.

The outcome of the inductive reasoning process will frequently contain some measure of uncertainty because including all possible facts in the premises is usually impossible.

Deductive or inductive approaches are used in logic, rule-based systems, and frames.

3) Analogical Reasoning

Analogical reasoning assumes that when a question is asked, the answer can be derived by analogy.

Example :

Premise	:	All football teams gets 3 point when they win.
Question	:	How many points did GS take this weekend?
Conclusion	:	Because GS is a football team and won Antep they took 3 points.

Analogical reasoning is a type of verbalization of an internalized learning process. An individual uses processes that require an ability to recognize previously encountered experiences.

The use of this approach has not been exploited yet in AI field. However, case-based reasoning is an attempt.

4) Formal Reasoning

Formal reasoning involves syntactic manipulation of data structures to deduce new facts.
A typical example is the mathematical logic used in proving theorems in geometry.

5) Procedural Numeric Reasoning

Procedural numeric reasoning uses mathematical models or simulation to solve problems. Model-based reasoning is an example of this approach.

6) Generalization and Abstraction

Generalization and abstraction can be successfully used with both logical and semantic representation of knowledge.

7) Metalevel Reasoning

Metalevel reasoning involves "knowledge about what you know". Which approach to use, how successful the inference will be, depends to a great extent on which knowledge representation method is used. For example; reasoning by analogy can be more successful with semantic networks than with frames.

IV) REASONING WITH LOGIC

We utulize various rules of inference to manipulate the logical expressions to create new expressions.

Modus Ponens

If there is a rule "if A, then B," and if we know that A is true, then it is valid to conclude that B is also true.

$[A \text{ AND } (A \rightarrow B)] \rightarrow B$

Example :

A	:	It is rainy.
B	:	I will stay at home.
A→B	:	If is rainy, I will stay at home.

Modus Tollens

When B is known to be false, and if there is a rule "if A, then B," it is valid to conclude that A is also false.

Resolution

Resolution is a method of discovering whether a new fact is valid, given a set of logical statements. It is a method of "theorem proving". The resolution process, which can be computerized because of its well-formed structure, is applied to a pair of parent clauses to produce a derived new clause.

V) INFERENCING WITH RULES:
FORWARD AND BACKWARD CHAINING

Inferencing with rules involves implementation of the modus ponens and other inferencing approaches. The inference mechanism in most commercial expert systems uses the modus ponens approach.

Consider the example;

Rule 1 : IF the dollar falls, THEN interest rate increases.

premise   conclusion

If the premise is *true*, using modus ponens the conclusion of the rule is accepted as *true*. We say that Rule 1 "fires". Firing a rule occurs only when all of the rule's parts are satisfied (being either true or false). Then, the conclusion drawn is stored in the assertion base. The items in assertion base could be used to satisfy the premise of other rules. The true (or false) values for either portion of the rules can be obtained obtained by querying the user or by firing other rules. Testing a rule premise or conclusion can be as simple as matching a symbolic pattern in the rule to a similar pattern in the assertion base. This activity is referred to as **pattern matching**.

Every rule in the rule base can be checked to see if its premise or conclusion can be satisfied by previously made assertions. This process may be done in one of two directions; forward or backward, and wil continue until no more rules can fire, or until a goal is achieved.

Backward Chaining
Backward chaining is a goal-driven approach in which you start form an expectation of what is to happen (hypothesis), then seek evidence that supports (or contradicts) your expectation. Often this entails formulating and testing intermediate hypothesis (or subhypothesis).

Forward Chaining
Forward-chaining is a data-driven approach. In this approach we start from available information as it comes in, or from a basic idea, then try to draw conclusions.

Example : Suppose you want to travel from İstanbul to Diyarbakır and there are no direct voyages. There are two basic ways we shall discuss:

1: Start with all voyages that arrive at Diyarbakır and find where each voyage is originated. Continue the process until you find İstanbul. This search process is called *backward chaining*.

2: Start with all voyages that originate from İstanbul and mark their destination cities. Then look up all the voyages leaving these intermediate cities; continue the process until you find Diyarbakır. This search process is called *forward chaining*.

VI) MODEL-BASED REASONING
Model-based reasoning is based on knowledge of the structure and behavior of the devices the system is designed to understand. Model-based systems are especially useful in diagnosing equipment problems. The systems include a model of the device to be diagnosed that is then used to identify the cause(s) of the equipment's failure. Because they draw conclusions directly from knowledge of a device's structure and behavior, model-based expert systems are said to reason from "first principles".

The model-based system includes a model that simulates the structure and function of the machinery under diagnosis. Instead of reasoning only from observable values, those systems reason from first principles; that is, the systems know the machinery's internal processes. The systems can compute which state the machine is in rather than attempting to match such a state against complex symptoms (which a rule-based system will do).

Once signals are received from sensors, the expert system activates a simulation program that generates predicted values. These are compared againts the information provided by the sensors.As long as the actual data are within the rage of the predicted values (the "tolerans"), nothing is done. If actual data is outside the tolerans, a diagnosis is automatically performed. The result of the diagnosis may activate control commands to prevent the system from entering a dangerous state. This mode of reasoning is very important in intelligent robots.

Generally speaking, model-based representations are combined with other representation and inference techniques to achieve a synergistic effect. Two types of model-based systems are available: static representations which deal with situations that are relatively stable, and dynamic representations, which deal with situations involving variability.

VII) CASE-BASED REASONING
In CBR terminology a case usually denotes a problem situation. A previously experienced situation which has been captured and learned in a way that it can be reused in the solving of future problems is referred to as a past case , previous case, stored case .Correspondingly a new case or unsolved case is the description of new problem to be solved . Case based reasoning is cyclic and integrated processof solving problem, learning from this experience , solving a new problem, etc.

When an attempto solve a problem fails, the reason for the failure is identified and remembered in order to avoid the same mistake in the future.

Case-based reasoning,, follows a process that it;

*finds those cases in memory that solved problems similar to the current problem
*adapts the previous solution or solutions to fit the current problem, taking into account any difference between the current and previous situations.
Finding relevant cases involves:
*characterizing the input problem, by assigning the appropriate features to it,
*retrieving the cases from the memory with those features, and
*picking the case or cases that match the input best.

VIII) TOPICS IN REASONING
Monotonic Versus Nonmonotonic Reasoning
Monotonic reasoning is static, in other words the truth of the statement doesn't change when any new information is added. While most ES deal with monotonic reasoning, in real life we frequently deal with nonmonotonic reasoning. In these situations the truth of a statement can change when a new information is added.
Reasoning with Uncertainty
In many cases reasoning is done in an uncertain environment. The reasoning methodologies need to be supplemented with procedures to handle the uncertainties.
Shallow and Deep Representation of Knowledge
Deep representation of knowledge is much more complex when compared with shallow representation. Deep representation systems perform inference using relations represented by networks or frames. Its implementation is much more difficult. Shallow representation is also called surface representation, it doesn't involve deeper-level reasoning. Rule-based representation is an example for shallow representation. Deep representation approach allows deeper-level reasoning such as abstraction and analogy; this is an important expert activity. As a result, in expert systems deep representation is much more involved than surface systems.
Semantic Networks
Semantic networks can be used for both knowledge organization and inferencing. Once a semantic network has been constructed, it can be used for problem solving. The computer uses various search and pattern matching techniques to find the answer, by starting from a particular node which is determined by the question.
Blackboard Approach
In blackboard approach, expertise is divided among subdomains and each subdomain can use different reasoning techniques. The blackboard is used to integrate the various lines of reasoning.
Inheritance Methods
There are several methods of inheritance, like propagating knowledge base changes within inheritance hierarchies, the truth maintenance paradigm, or hypothetical reasoning which is also called what-if reasoning.
Pattern Matching
Pattern matching works with semantic networks, frames, or rules. Patterns can take many forms. A pattern may be kind of frame or may be used to invoke heuristics. Using pattern matching may limit the time which computer spends searching through its rules and testing them on the problem. The quality of development tools is frequently recognized by their pattern matching capability.
Metarules
Metarules are the rules about rules. They are used for deciding about which rules to use next. Metarules make the knowledge base harder to read and understand because one metarule affects the sequence in which all other rules are called.
Conflict Resolution
Conflict resolution refers to a situation in which the computer needs to select a rule from several rules that apply. Conflict resolution instructions are stored in the inference engine and they can be found in several ES development tools

Which Reasoning Process to Use

The true power of an expert system is in effective management of the reasoning process by utilizing the appropriate components of the knowledge base and the inference engine. Several paradigms for controlling the inferencing process are available and each has its advantages and disadvantages. Forward chaining and backward chaining are most popular paradigms. Conflict resolution also plays an important part in many cases. Some systems offer using rule-scheduling process and some provide syntactic tools to control the rule execution.

IX) USES:
*Tactical planning
*Political analysis
*Situation assessment
*Legal planning
*Diagnosis
*Fraud detection
*Design/Configuration
*Message classification

XI) REFERENCES

Artificial Intelligence : A Knowladge Based Approach ;Morris W.Firebaugh, 1988
Artificial intelligence / Elaine Rich, Kevin Knight. New York : McGraw-Hill, c1991
Catalogue of artificial intelligence techniques / ed. Alan Bundy Berlin : Springer-Verlag, c1990