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Common Sense

Artificial Intelligence

Common sense, topics : Introduction, Common sense knowledge and reasoning, how to teach commonsense to a computer; Formalization of common sense reasoning - initial attempts of late 60's and early, renewed attempts in late 70's and 80's to recent time; Physical world - modeling the qualitative world, reasoning with qualitative information; Common Sense Ontologies - time, space, material; Memory organization - short term memory (STM), long term memory (LTM).

Common Sense

Artificial Intelligence

Topics

(Lecture 42 , 1 hours)

Slides

Common Sense

What is Common Sense ?

- Common sense is the mental skills that most people share.
- Common Sense is ability to analyze a situation based on its context, using millions of integrated pieces of common knowledge.
- John McCarthy was the first to talk about commonsense reasoning in his paper in 1959, explains that a program has commonsense if it automatically deduces for itself sufficiently wide class of immediate consequences of any thing it is told and what it already knows.
- Common sense is what people come to know in the process of growing and living in the world *(R.Elio, 2002)*.
- Common sense knowledge includes the basic facts about events and their effects, facts about knowledge and how it is obtained, facts about beliefs and desires. It includes the basic facts about material objects and their properties *(John McCarthy, 1990)*.
- Currently, computers lack common sense .

1. Introduction

Commonsense is ability to analyze a situation based on its context, using millions of integrated pieces of common knowledge. Ability to use common sense knowledge depends on being able to do commonsense reasoning. Commonsense Reasoning is a central part of intelligent behavior.

Formalizing the commonsense knowledge for even simple reasoning problem is a huge task. The reason is that, the most commonsense knowledge is implicit in contrast to expert/specialist knowledge, which is usually explicit. Therefore making commonsense reasoning system is making this knowledge explicit.

Example : Everyone knows that dropping a glass of water, the glass will break and water will spill on podium. However, this information is not obtained by formula or equation for a falling body or equations governing fluid flow.

The goal of the formal commonsense reasoning community is to encode this implicit knowledge using formal logic.

Computers and ordinary real life - issues ?

Computers do many remarkable things. Computer programs can play chess at the level of best players. But no computer program match the capabilities of a three year old child at recognizing objects or can draw simple conclusions about ordinary life. Building machines that can think the way any average person can is a distant reality.

Why computers can not think about the world as any person can ?

Where the problem lies ?

There are two basic types of knowledge. One is the specialist's knowledge which mathematicians, scientists and engineers possess. The other type is the commonsense knowledge which every one has, even a small 6-year–old child. The need is to teach the computer to reason about the world (commonsense knowledge). The researchers have not yet reached to any consensus on many related issues. McCarthy suggested to use logic to represent the knowledge. Understanding common sense capability is an active area of research in artificial intelligence.

1.1 Commonsense Knowledge and Reasoning

Common sense facts and methods are very little understood today. Extending this understanding is the key problem the AI researchers are facing. *John McCarthy (1984)* identified as common sense as :

Common sense knowledge - what every one knows.

Common sense reasoning - ability to use common sense knowledge.

- **Common Sense Knowledge**

  What one can express as a fact using a richer ontology.

  Examples

  ‡ Every person is younger than the person's mother

  ‡ People do not like being repeatedly interrupted

  ‡ If you hold a knife by its blade then the blade may cut you

  ‡ If you drop paper into a flame then the paper will burn

  ‡ You start getting hungry again a few hours after eating a meal

  ‡ People go to parties to meet new people

  ‡ People generally sleep at night

  Here the problem is , how to give computers these millions of ordinary pieces of knowledge that every person learns by adulthood.

- **Common Sense Reasoning**

  What one builds as a reasoning method into his program.

  Examples

  ‡ If you have a problem, think of a past situation where you solved a similar problem.

  ‡ If you take an action, anticipate what might happen next

  ‡ If you fail at something, imagine how you might have done things differently .

  ‡ If you observe an event, try to infer what prior event might have caused it.

  ‡ If you see an object, wonder if anyone owns it

  ‡ If someone does something, ask yourself what the person's purpose was in doing that.

  Here the problem is, how to give computers the capacity for commonsense reasoning, the ways to use the commonsense knowledge to solve the various problems we encounter every day.

1.2 How to Teach Commonsense to a Computer

There is no clear answer for to this question.

Presently, there is no program that can match the common sense reasoning powers of a 5 year old child. The problem was noticed long ago by John McCarthy. We do not yet have enough ideas about how to represent, organize, and use much of commonsense knowledge, let alone build a machine that could learn automatically on its own".

- Some believe that, prior understanding is not necessary to build a machine, and intelligence can be made to emerge from some generic learning.
- Others feel that, unless we can acquire some experience in manually engineering systems with common sense, we will not be able to build learning machines that can automatically learn common sense.

- **Building Human Commonsense Knowledge Base**

  Stated below, the two ongoing AI projects for assembling comprehensive ontology and knowledge base of everyday common sense knowledge with the goal of enabling AI applications to perform human-like reasoning.

  Project CYC : A commonsense knowledge base, building since two decades, has collected 1.5 million pieces of commonsense knowledge, still far away from several hundred million required; the project faces a challenge because such a large database cannot be engineered by any one group.

  Project Open Mind : A common sense knowledge base, building since 1999, has accumulated more than 700,000 facts from over 15,000 contributors; the knowledge collected by has enabled many research projects at MIT and elsewhere.

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The CYC and Open Mind projects are ensuring enough commonsense knowledge so as to work in a given environment enabling AI applications to perform human-like reasoning.

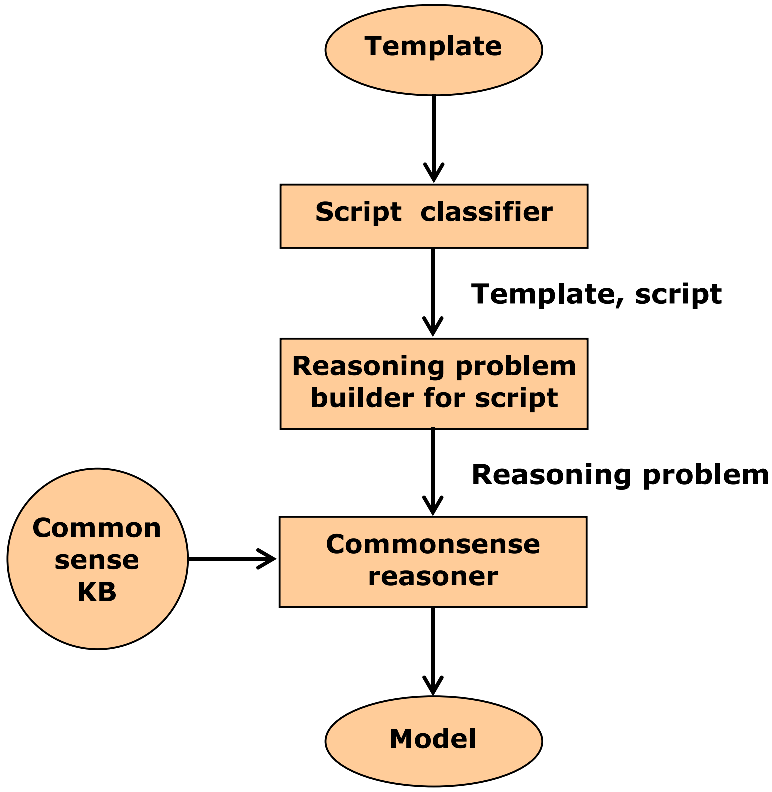
Next comes the Common Sense Reasoning :

It is what one builds as a reasoning method into his program, a very complex task. We want computer to do reasoning as human does. Human does reasoning in different ways and the one which is **Logic Reasoning** (deductive, inductive, abductive), is of main concern in AI reasoning system. The logic reasoning can accomplish the task of common sense reasoning. For instance :

- Predicate logic can represent knowledge about objects, facts, rules,
- Frames can describe everyday objects
- Scripts can describe typical sequences of events
- Non-monotonic logics can support default reasoning,

- **Example of Commonsense System Architecture** (Mueller, 2004)

  The system takes as input a template produced by information extraction system about certain aspects of a scenario.



Commonsense System Architecture

- The template is a frame with slots and slots fillers
- The template is fed to a script classifier, which classifies what script is active in the template.
- The template and the script are passed to a reasoning problem builder specific to the script, which converts the template into a commonsense reasoning problem.
- The problem and a commonsense knowledge base are passed to a commonsense reasoner. It infers and fills in missing details to produce a model of the input text.
- The model provides a deeper representation of the input, than is provided by the template alone.

2. Formalization of Common Sense Reasoning

Commonsense reasoning is a central part of human behavior; no real intelligence is possible without it. The ultimate goal of artificially intelligent systems is that they exhibit commonsense behavior.

For the computers, the commonsense reasoning is not an easy task, indeed a very complex task, we all perform about every day world.

Example : There are chess-playing programs that beat champions, and there are expert systems that assist in clinical diagnosis, but there is no program that reason about how far one must bend over to put on one's socks.

The reason is expert knowledge is usually explicit, but most commonsense knowledge is implicit. Therefore, one of the prerequisites for developing commonsense reasoning systems is making this knowledge explicit.

John McCarthy (1990) identified commonsense reasoning as human ability to use common sense knowledge.

Mueller (2006) defines commonsense reasoning as a process, taking information about certain aspects of a scenario in the world and making inference about other aspects of the scenario based on our commonsense knowledge or knowledge about how the world works.

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To formalize commonsense reasoning, we need to construct representations for commonsense knowledge and inference algorithms to manipulate that knowledge. McCarthy in 1959 was first to put forward the idea of using a formal logic as the representation language for a commonsense reasoning system, with the reasoning done by deductive inference.

Robert C. Moore in his article, *"Automatic Deduction for Commonsense Reasoning: An Overview"*, explained the issues involved in drawing conclusions by means of deductive inference from bodies of commonsense knowledge represented by logical formulas. This article contains first a review of initial attempts of late 60's and early 70's – failures and disappointments, and then the renewed attempts in late 70's and 80's to recent time - how domain-specific control information can offer a solution to the difficulties, the relationship of automatic deduction to the new field of "logic programming" and issues that arise while extending automatic-deduction techniques to nonstandard logic.

Note : Just to complete this section, the issues, arguments and the solutions offered his article (Robert C. Moore, technical note 239, april 1981, Sri International Menlo park CA Artificial intelligence center) are put very briefly in next three slides.

2.1 Initial attempts of late 60's and early 70's

failures and disappointments

Many researchers, (Black, Robinson, Green and others) made serious attempt to implement McCarthy's idea, but faced difficulties because :

- search space generated by the resolution method was growing exponentially with the number of formulas used to describe a problem; the problems of moderate complexity could not be solved in reasonable time.
- several domain-independent heuristics proposed to deal with this search space issue, proved too week to produce satisfactory results.

The failures resulted from two constraints the researchers had imposed:
(a) attempted to use only uniform, domain-independent, proof procedures; and (b) tried to force all reasoning and problem - solving behavior into the framework of logical deduction.
There were widespread condemnation of any use of logic or deduction in commonsense reasoning or problem solving.

However, the interest in deduction-based approaches to commonsense reasoning did not go away, rather revived in late 70's.

2.2 Renewed attempts in late 70's and 80's to recent time

The revival of interest in deduction-based approaches to commonsense reasoning, is noticed since late 70's, from the work of many researchers (McDermott, Doyle, Moore, Bobrow and others), because, the recognition of some important class of problems resist solution by any other method. The understanding came from following issues :

- **Representation Formalism based on Logic**
  - If one decides to use a representation formalism based on logic, it may not be necessary to use general deductive methods to manipulate expressions in the formalism. If the description (object, properties, relations) of a problem situation is complete the we can answer any question by evaluation; deduction is unnecessary.
  - Representation formalism based on logic gives us the ability to express many kind of generalization, even when we do not have a complete description of the problem situation. Using deduction to manipulate expression in the representation formalism allows us to ask logically complex queries of a knowledge base containing such generalization, even when we cannot "evaluate" a query directly.
  - AI inference systems, not based on automatic deduction technique, but has a knowledge representation formalism that is capable of handling the kinds of incomplete information, that people can understand, must at least be able to say that something has a certain property without saying which thing has that property.

Thus, any representation formalism that has these capabilities will be an extension of classical first-order logic, and any inference system that can deal adequately with these kinds of generalization will have to have at least the capabilities of an automatic-deduction system.

- **Need for Specific Control Information**

  - The difficulties with domain-independent problem solver on automatic-deduction techniques is that many possible inferences can be drawn at any one time. Finding relevant inferences to a particular problem can be impossible, unless domain-specific guidance is supplied to control the deductive process.
  - In search processes, information about whether to use facts in a forward-chaining or back-chaining manner for efficient system performance. The deductive process can be bidirectional, partly working forward from facts to new one, partly working backward from goals to sub-goals, and meeting somewhere in between. Early theorem-proving systems used every facts both ways, leading to highly redundant searches. More sophisticated methods can eliminated these redundancies.

- **Logic Programming**

  - One factor that can greatly affect the efficiency of deductive reasoning is the way in which a body of knowledge is formalized. Logically equivalent formalization can have radically different behavior when used with standard deduction techniques. This led to the development of Logic programming and the creation of a new languages such as Prolog.
  - Prolog combines the use of logic as a representation language with efficient deduction technique, based on backward inference process (goal directed) which allows to consider a set of formulas as program. Prolog is now most widely used logic programming language. Originally logic programming was conceived as a subset of classical logic, it was soon extended with some non-classical features, in particular negation as failure. Prolog tries to prove **p**; if **p** can not be proved , then the goal **not p** succeeds, and vice versa. This simple feature of Prolog has been used to achieve non-monotonic behavior.

- **Automatic deduction in nonstandard logics**

  - The classical first-order logic is the most general logic for which automatic-deduction techniques are well developed. However, many commonsense concepts, are treated in nonstandard, either higher-order or non-classical logics. This presents a problem and require reformulating representation in nonstandard logics in terms of logically equivalent representations in classical first-order logic. One type of nonstandard logic that has received much attention is non-monotonic logic.

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Note : The approaches to the representation formalism for commonsense reasoning are mentioned in the previous few slides. However, in our previous lectures on "Knowledge Representation" and "Reasoning System", the slides illustrated with example each of these approaches. The following were covered :

- Logic as a KR Language for Reasoning - a formal system in which the formulas or sentences have true or false values.
- Propositional Logic (PL) - a declarative sentence either TRUE or FALSE.
- Predicate Logic Quantifiers - to make a statement about a collection of objects and to state that an object does exist without naming it.
- Resolution – a procedure, produces proofs by refutation or contradiction.
- KR Using Rules - production rules, semantic net and frames; forward and backward reasoning - ways to generate new knowledge.
- Logic Programming - a formalism for specifying a computation in terms of logical relations, Prolog program,
- Non-monotonic logic – where the truth of a proposition may change when new information (axioms) are added.

3. Physical World

People know a great deal about how the physical world works. Most people, have no notion of the "laws of physics" that govern this world, yet they

- can predict that a falling ball will bounce many times before come to halt.
- can predict the projection of cricket ball and even catch it.
- know a pendulum swings back and fore finally coming to rest in the middle.

How can we build a computer program to do such reasoning ?

One answer is to program the equations governing the physical motion of the objects. But most people do not know these equations and also do not have exact numerical measures, yet they can predict what will happen in physical situations. This means people seem to reason more abstractly that the equations would. Here comes qualitative physics, to understand how to build and reason with abstract, number less representation.

Researchers are therefore motivated towards :

- Modeling the qualitative World and
- Reasoning with qualitative information

- **Modeling the Qualitative World**

  Qualitative physics seeks to understand physical processes by building models that may have following entities:

Variables	A restricted set of values, e.g. temperature as { frozen, between, boiling }.
Quantity Spaces	A small set of discreet values.
Rate of Change	Values at different times, modeled qualitatively, e.g. { decreasing, steady, increasing }.
Expressions	Combination of variables.
Equations	Assignment of expression to variables.
States	Sets of variables, whose values change over time.

- **Example : Qualitative Algebra - addition**

  Describe the volume of glass as **{empty, between, full }** .

  When two qualitative values are added together then :

  empty + empty = empty

  empty + between = between

  empty + full = full

  between + between = { between, full, overflow }

  between + full = { between, over flow }

  full + full = { full, over flow }

- **Reasoning with Qualitative Information**

Reasoning with qualitative information is often called qualitative simulation. The basic idea is :

- ‡ Construct a sequence of discrete episodes that occur as qualitative variable.
- ‡ States are linked by qualitative rules that may be general.
- ‡ Rules may be applied to many objects simultaneously as they may all influence each other.
- ‡ Ambiguity may arise so split outcomes into different paths.
- ‡ A network of all possible states and transitions for a qualitative system is called an envisionment (mental images). There are often many paths through an envisionment. Each path is called history.
- ‡ Programs must know how to represent the behavior of many kinds of processes, materials and the world in which they act.

4. Common Sense Ontologies

Some concepts are fundamental to common sense reasoning.

A computer program that interacts with the real world must be able to reason about things like time, space and materials. On each of these, here some thought is presented. *[Details with examples are available in the text book - "Artificial Intelligence", by Elaine Rich and Kevin Knight]*

- **Time**

  The most basic notion of time is events. Events occur during intervals over continuous spaces of time. An interval has a start and end point and a duration between them.

  Intervals can be related to one another as :

  is-before, is-after, meets, is-met-by, starts, is-started-by, during, contains, ends, is-ended-by and equals.

  We can build a axioms with intervals to describe events in time.

- **Space**

The Blocks World is a simple example of what we can model and describe space. However common sense notions such as :

place object **x** near object **y**

are not accommodated.

Objects have a spatial extent while events have a temporal extent. We may try to extend of common sense theory of time. But, space is 3D and has many more relationships than those for time so it is not a good idea.

Another approach is view objects and space at various levels of abstraction. For example, we can view most printed circuit boards as being a 2D object.

Choosing a representation means selecting relevant properties at particular levels of granularity. For instance we can define relations over spaces such as inside, adjacent etc. We can also define relations for curves, lines, surfaces, planes and volumes. e.g. along, across, perpendicular etc.

- **Material**

Describe the properties of materials as :

‡ You cannot walk on water.

‡ If you knock a cup of coffee over what happens?

‡ If you pour a full kettle into a cup what happens?

‡ You can squeeze a sponge but not a brick.

The Liquids provide many interesting points, such as, the space occupied by them. Thus we can define their properties such as:

‡ Capacity - a bound to an amount of liquid.

‡ Amount - volume occupied by a liquid.

‡ Full - if amount equals capacity.

Other properties that materials can posses include:

‡ Free - if a space is not wholly contained inside another object.

‡ Surround - if enclosed by a very thin free space.

‡ Rigid

‡ Flexible

‡ Particulate - e.g. sand

5. Memory Organization

Memory is central to common sense behavior and also the basis for learning. Human memory is still not fully understood however psychologists have proposed several ideas.

- **Short term memory (STM) :**
  Only a few items at a time can be held here;
  perceptual information are stored directly here.

- **Long term memory (LTM) :**
  Capacity for storage is very large and fairly permanent;
  LTM is often divided further as :

  - Episodic memory **:**
    Contains information about personal experiences.

  - Semantic memory **:**
    General facts with no personal meaning, e.g. Birds fly;
    useful in natural language understanding.

6. References : Textbooks

1. *"Artificial Intelligence", by Elaine Rich and Kevin Knight, (2006), McGraw Hill companies Inc., Chapter 19, page 529-545.*

2. *"AI: A New Synthesis", by Nils J. Nilsson, (1998), Morgan Kaufmann Inc., Chapter 18, Page 301-314.*

3. *Related documents from open source, mainly internet. An exhaustive list is being prepared for inclusion at a later date.*