Review of Commonsense Reasoning

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Abstract

The aim of this paper is to review *Commonsense Reasoning.* This work is an effort to summarize the efforts of Artificial Intelligence researchers to devise solutions to the problem of giving *commonsense* to computers and programs.

Scope of this work

The present work is a *passive* review. This implies that no *critical examination* of the approaches has been included. The proposals and suggestions to the problem are summarized as originally proposed.

[1]

[1] This is the Version 1.0 of the report, which was prepared during my research internship in 2007-08 at Indian Statistical Institute, Kolkata (http://www.isical.ac.in) under Prof. Kumar Sankar Ray. I am publishing this report for public use on 14th May, 2009 in the hope that it will be useful to anyone unaware of this field of Artificial Intelligence.
If you want to use (or even enhance) this report (except for personal use) in any form, please contact amitsaha.in@gmail.com and I shall be happy to help you through it. Please note that the information in this report is updated till April, 2008. Further developments in the field have not been reflected.

In case you find any factual errors, please let me know.

Contents

1 Introduction

Artificial Intelligence researchers all over the world has long cherished the dream of developing systems with 'commonsense' – the millions of basic facts and understandings possessed by most people and often oblivious to themselves. If systems are to be given 'commonsense' they need to be equipped with the adequate amount of 'commonsense knowledge' and 'commonsense reasoning' – the power to reason with that knowledge. Thus, we see that the problem of giving 'commonsense' to systems is actually giving them both 'commonsense knowledge' and 'commonsense reasoning'. It is also easy to observe that 'commonsense reasoning' is only possible if the systems possess adequate amount of 'commonsense knowledge'.

In this paper a broad treatment is given to the problem of 'commonsense reasoning' and the issues related to the amassment of 'commonsense knowledge' is dealt to a very limited extent. Also, we shall concentrate on the *theoretical* aspects of the subject. In the subsequent subsections and sections we shall acquaint ourselves with the problem at hand, the solutions proposed so far and then finally review some applications which show commonsense.

1.1 What is Commonsense Reasoning?

McCarthy [1] proposes that 'a program has commonsense if it automatically draws for itself a sufficiently wide class of immediate consequences of anything it is told and what it already knows.' It is also observed that [2], 'commonsense inferencing involves many types of reasoning, including analogical, statistical, logical and heuristic methods'. The real world is a constant source of partial, incomplete, ambiguous, implicit information and humans are constantly being subjected to new, often unknown and unexpected challenges – social, personal and environmental – and they manage to survive using their world knowledge – a large part of which we call 'commonsense'. The human mind is the role-model in the pursuit to give 'commonsense' to computing systems.

1.2 Why give computers Commonsense?

Modern computers, though adept at various specialized tasks show an uncomfortably low level of ignorance towards 'basic' facts – which seems to be 'hard coded' and 'present from birth' in human beings. This has led most scientific observers to suspect that they could never have genuine minds [3]. [4] points out that to make computers easier to use we must give them a better commonsense understanding of the people and the world we live in. McCarthy [1]tries to put forward his vision in this statement 'Our ultimate objective is to make programs that learn from their experiences as effectively as humans do'.

Why do modern machines behave in such a limited way? Minsky [4] identifies that most programs today has only way of dealing with things. When faced with a new situation for which they have not been programmed for, they fail – causing large scale damage – economic, physical or otherwise. This is basically been due to the limited ways we have been programming them:

A. We program them only for specialized jobs without giving them any more 'general knowledge' [5]

B. The programs specify "what" the computer should do without telling it which "goals" to achieve. The computer has no idea whether the intended goal was achieved at all, or to what extent was it achieved. [3]

McCarthy [1] also identifies the different ways humans and machines are instructed. Whereas humans are mainly instructed in declarative sentences describing the situations in which action is required, a machine is instructed mainly in the form of a sequence of imperative sentences.

Giving computers 'commonsense' would mean giving them the power to think and reason in situations for which they have not been programmed for, computers with 'commonsense' will understand our needs better and make it more pleasant for us to work with them.

1.3 How difficult is the problem at hand?

Traditionally, 'Commonsense Reasoning' has been one of the oldest and most difficult problems in Artificial Intelligence. Before we set on to assess the difficulties to design a 'Commonsense Computing System', let us first try to analyze the features desired in such a system. McCarthy [1] points out some desired features of which a central point is "Interesting changes in behavior must be expressible in a simple way." This is the problem of knowledge presentation – to convey something to the system, we need to first find a way to represent it. Such was the importance of this problem that this was the sole issue addresses in McCarthy's *Advice Taker*[1].

Various researchers at different points of time has pointed out several difficulties that were faced or could possibly be faced in designing such a system :

A. McCarthy's Commonsense Informatic Situation [6]

B. Commonsense knowledge is often implicit, whereas knowledge needed to solve well-formulated difficult problems is often explicit. Any commonsense problem that one looks at touches on many different types of knowledge encompassing aspects of commonsense reasoning. Implicit knowledge must first must be made explicit, which is a task requiring a serious knowledge engineering effort. [6, 7]

C. Minsky [4] infers that "the trouble with compuer today is they're always starting from scratch. To make them more worth dealing with, we'll have to aim toward supplying them with great libraries of commonsense knowledge like the ones inside our children's heads"

D. Domain knowledge [6]

[7] summarizes two strategies that has been adopted for tackling these very hard problems:

A. One group of researchers have methodically and painstakingly worked on "foundation problems and have come up with sufficiently powerful and expressive alternatives to or extensions of classical logics".

B. Attempts to encode vast amount of facts to form a huge commonsense knowledgebase.

1.4 Building blocks of Commonsense Reasoning

Minsky [4] identifies the basic constituents of 'Commonsense Reasoning' as:

A. "Huge collection of hard earned ideas" – which form the commonsense knowledgebase.

B. Effective ways to retrieve and apply the relevant knowledge when faced with a situation "using multitude of exceptions as rules". This encompasses the requirement of resources such as:

   Choosing an appropriate representation for a situation and often multiple representations for the same situation
   Negative Expertise
   Knowledge retrieval
   Self-reflection

Coming back to (A) above, Minsky [3] rejects the idea of 'searching the web' to extract knowledge because it does not 'explicitly display the knowledge one needs for understanding what all those texts mean'. He also contends the need for a new learning method as all the previous learning methods have 'tapered off' due to the following major problems:

i. Optimization paradox

ii. Investment principle

iii. Parallel processing paradox

However with the web as a medium, researchers have embarked on projects to ask the public for help. The 'Cyc' project [8] and 'OpenMind Commonsense' [9]are two such prominent projects which have made steady progress towards building a large scale commonsense knowledgebase.

As far as the knowledge representation is concerned, a common consensus among the researchers [6] is that "Human versatility must emerge from a large scale architecture of diversity in which each of several different reasoning mechanisms and representations can help overcome the deficiency of the other ones".

1.5 Formalizing Commonsense Reasoning

As [6] observes, there has been a relative paucity of results in the field of commonsense reasoning. However this in no way reflects the considerable effort towards the cause which was started by McCarthy almost half a century ago!

Formalizing commonsense reasoning presents a variety of challenges[7, 10]

A. To develop a formal language that is sufficiently powerful and expressive.

B. Capture the many millions of facts people know and reason with.

C. Correctly encode this information as sentences in a logic

D. Construct a system that will use its knowledge efficiently

E. Invent a formalism that will conveniently express people's commonsense knowledge about concurrent events.

2 Efforts to implement Commonsense Reasoning

McCarthy [1] made the first attempt to implement commonsense reasoning in 1959. Since then, Artificial Intelligence researchers have been trying to invent ways of automating commonsense reasoning. Extensions to existing theories and novel ideas have been proposed and implemented. One community of researchers have tried to use mathematical logic and its extensions, while the other community which believes that the human mind is too complex to represent using mathematical logic has devised non logical methods to automate commonsense reasoning. The most prominent methods of both domains are summarized in the next subsections.

2.1 McCarthy's efforts to formalize Commonsense Reasoning

In the earliest attempt to implement a program with commonsense [1] , McCarthy proposes to use a "suitable formal language (most likely a part of predicate calculus)" for the purpose of his program *Advice Taker* [1]. In the 1960s he alongwith Patrick J. Hayes introduced 'Situation Calculus' [11] – a logic formalism for commonsense reasoning. Sometime later he identified "Circumscription" [12] as a tool to implement commonsense reasoning. He reasoned that since commonsense reasoning is non-monotonic, circumscription is an effective tool for the purpose. Later on, he also proposed extensions to circumscription [13] so as to be applicable to the formal expression of commonsense facts. In a position paper [14] he reviews all his efforts to formalize commonsense reasoning.

2.2 Fuzzy Logic

Zadeh [15] observed that "The conventional knowledge representation techniques based on the use of predicate calculus and related methods are not well suited for the representation of commonsense knowledge because the predicates in propositions which represent commonsense knowledge, do not in general have crisp denotations" and hence proposed "A theory of commonsense knowledge" [15] based on Fuzzy Logic [16].

He introduced the concept of *dispositions* . A disposition is a proposition which is preponderantly but necessarily always true. It can be viewed as a proposition with suppressed, or more generally implicit *fuzzy quantifiers.* To deal with dispositions, two principal components – *test-score semantics* [17] and *Syllogistic reasoning* [zadeh4] are employed. Test-score semantics is used for the knowledge representation of commonsense knowledge and Syllogistic reasoning is employed to enable reasoning with the information resident in the knowledgebase.

Kouzeni,Sammat [18] discusses a *Fuzzy Neural Network* based implementation of Commonsense reasoning, inspired by Zadeh.

Nguyen, Kreinovich [19] suggests possible modifications of classical fuzzy logic to facilitate commonsense reasoning. They also suggest a future formalism for describing human reasoning based on the synthesis of Fuzzy Logic, Linear logic and Logic Programming.

2.3 Event Calculus

The Event Calculus is a logical mechanism that infers what is true when given when and what actions do. A event calculus based logical formalism for commonsense reasoning is proposed in [20] and a broader treatment of the subject is given in [21]. Several problems that perform automated commonsense reasoning have been constructed. These programs rely on various solvers and provers, namely logic programming languages, SAT solver and first order automated theorem provers.

2.4 Multi-agent Cognitive Architecture

Commonsense computing researchers at the MIT Media Lab are working on a large scale multi-agent, multi-layered system for computing commonsense- *The Emotion Machine* [3]. Based heavily on the *The Society of Mind* [22], the central idea behind the architecture is that the source of human resourcefulness and robustness is the diversity of our *cognitive process*

The major features of the architecture being developed are summarized below :

A. **Agents:** "*Every mind is really a society of mind*" [22]. The term *agent* is used to refer to the simplest individuals that populate such societies of mind. Each agent is on the scale of a typical component of a computer program like a simple subroutine or data structure and as with the components of the computer programs, agents can be connected and composed into larger systems called *societies of agents* . Agents perform the kinds of functions specifically involved in mental activities such as expecting, predicting, reviewing, remembering, debugging, acting, comparing, and generalizing.

B. **Many ways-to-think:** Ordinary Commonsense Reasoning involves a tremendous array of more specialized *ways-to-think.* The architecture under consideration is not a single kind of 'machine', based on a single type of algorithm or methods of reasoning. Special *self-reflective* agents called *critics* and *selectors* are responsible for choosing more than one way-to-think. At any point of time, only a subset of the agents is active and produces a *specific way-to-think.* A new collection of agents 'create' a new way-to-think. This idea originally evolved from the *k-lines* concept of Minsky's *Society of Mind* theory.

C. **Multiple Realms of thinking:** Day-to-day commonsense tasks involve reasoning in a large number of *domains* or realms. A set of minimalist realms of thinking – spatial, physical, bodily, psychology, social, reflective, dominion - are considered for implementation in the architecture under consideration [2].

D. **Panalogies :** When the current way of thinking becomes ineffective or fails, the architecture tries to switch to another, more effective ways of thinking by making use of *panalogies (derived from Parallel Analogies).*Such a mechanism allows agents that represent similar information to synchronize automatically what they *know.* Thus, when the architecture selects a new way-to-think, instead of having to start from scratch, it will find many of its agents already prepared for the situation. Some methods of *panalogy* used are Event Panalogy, Model panalogy, theory panalogy, Realm panalogy [2, 4]

   A. **Multiple layers of reflection:** The architecture has the ability to reflect and think about its own abilities, and improve them over time. This makes it a highly *self-aware* system. The *reflective* capabilities of the system are implemented as six different layers or levels [2]

   B. **Varieties of Mental critics:** Reactive critics, Deliberate critics, Reflective critics, self-reflective critics are the different types of *mental critics* – special agents whose task is to notice problems in other agents – used in the architecture [2].

   C. **Learning and Endowment of Knowledge:** The primary mechanism of learning in the architecture are the formulation of new *critics* and *selectors* and the evolution of *k-lines* into new ways to think [2]

3 Applications with Commonsense

Imagine today's all powerful and all conquering applications, computing devices, mobile phones equipped with commonsense – cell phones which do not disturb us during a meeting "automagically" even if we forget to turn it into 'silent' mode, search engines which can look *beyond* and *between* the search query to retrieve results for us which we did not mention *explicitly,* computers which understands when it users are tired. Applications with commonsense enable an entirely new breed of applications, ones that are actually *smart* in the sense of understanding the user's situation and goals somewhat like a real person would.

Commonsense allows software agents to be more pro-active by letting them infer the likely goals of the user and ways to help the user achieve those goals. A plethora of *really smart* applications which would have been dismissed as figments of imaginations not long ago are soon becoming a reality as the recent efforts have shown.

Liebermann et. al. [23] summarizes some of the efforts at the MIT Media Lab in designing applications with commonsense.

Some other applications *having* commonsense are demonstrated elsewhere in [24, 25]

4 Conclusion

This paper introduces *Commonsense Reasoning* to researchers who are new to this field. Though by no means a complete account of the problem, this review shall give a first hand knowledge of the problem to interested people so that they can work further on this subject.

5 Further Work

Considering this as a starting point, future work in this field would be to a more detailed, critical review of works that have been identified during the course of this review, the issues of acquiring commonsense knowledge, practical commonsense reasoning tools and a plethora of new and exciting prospects. The possibilities are endless!

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