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Software Design, & Imperfect Knowledge: Types, Models, & Challenges

Manohar Lal (Kaushik)

School of Computer & Inf. Sciences
Indira Gandhi National Open University, New Delhi-110068, India
Email: prof.manohar.lal@gmail.com

Meenakshi Sridhar

Department of Computer Science
Rajdhani College (Univ. of Delhi), New Delhi-110015, India
Email: meenakshi.sridhar.sharma@gmail.com

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Abstract: The imperfection of human knowledge is, on one hand, an inevitable fact in view of (i)the finite and discrete human mental faculties, and(ii)the infinite and continuous Nature all around us, the knowledge of which the human beings are required to have for survival. On the other hand, the imperfection is a problem for scientists to understand properly the various natural phenomena, and for engineers to design and develop appropriate technologies. Also, for appropriate design of software, knowledge of various aspects of the relevant available knowledge of the problem domain and its environment, including the types of imperfection in the available knowledge is essential. Inappropriate design may lead to disastrous consequences, as has happened in the case of some critical applications.

In this paper, first of all, we enumerate various significant types of possible imperfections in human knowledge, along with the types of problem domains in which each of these frequently occurs. Then discuss different mathematical/computational models developed to handle the imperfection of knowledge of respective problem domains. Knowledge of appropriate imperfection-model match is essential for designing robust software, and to avoid disasters in critical applications.

The mathematical approaches/models/theories for handling these different types of imperfections in knowledge include probability theory, fuzzy set theory; fuzzy measures and its special cases belief measure, plausibility measure, probability measure, possibility and necessity measures, Modal logics, belief models, Rough Set Theory, Chaos theory, neural networks, genetic algorithms, and swarm intelligence etc. Despite availability of these models, the solving of many types of problems is still challenging. All these issues are discussed in the paper.

Keywords: Software design, Imprecise Knowledge, Probability Theory, Fuzzy Theory, Rough Set Theory, Chaos Theory, Modal Logic, Paraconsistent Logic.

1. Introduction

Informally, Knowledge may be considered as justified true belief, or, as the basis of human intelligence, which in turn, is the capability to apply knowledge for appropriate action in a given situation. However, the concept of 'knowledge' is quite vast covering almost every aspect of human experience and of academic pursuit. Hence or otherwise, it is quite vague being classified as factual or procedural; implicit, tacit or explicit; a priori or a posterior; being informal to highly formal such as mathematical and computational knowledge, and being considered as from unconscious, subconscious to conscious. Its subject matter is of concern to from highly theoretical disciplines like philosophy to highly practical disciplines like Artificial Intelligence. In this paper, our concern with it is from the point of view of effective problem solving using computational means, i. e. solving problems optimally using mathematical and computational models and within that also using appropriate models for handling imperfection of knowledge. Knowledge of appropriate imperfection-model match is essential in order to get appropriate computational solutions, and to avoid disasters in critical applications. The rest of the paper is structured as follows.

The discussion starts with some 'why' questions: Why Knowledge? Why knowledge of Imperfect Knowledge? and Why Mathematical Models of Imperfect Knowledge? Next, some relevant 'how' questions are discussed: How knowledge is derived? How it is stored in human mind? and how it is expressed and communicated?

As Whitehead, quoted above points out that knowledge is a process-it is hardly perfectly achieved it is mostly imperfect. The next three topics discussed are types of imperfections in Knowledge, mathematical models for handling imperfections, and major challenges to modelling of knowledge.

Discussion of challenges to modelling of knowledge include challenge due to randomness in Nature, due to Fuzziness in Natural Languages; challenge of modelling (Human) Common Sense, challenge of modelling unconscious knowledge; and challenges due to other human capabilities, e.g. creativity & strategy-making.

2. 'Why' Questions About Knowledge

Next, we briefly discuss, with quite simple examples, significance of knowledge in everyday life, in general, and in academics in particular.

2.1. Why Knowledge?: In academic disciplines, knowledge of tools, techniques, domain of concern etc. are essential to solve problems concerning the field. However, in computer science, there is an additional reason: During 1930's, a number of pioneers of computer revolution, including Gödel, Church, Kleene, Turing and Post, proved that only a very small fraction of the problems we human beings encounter are solvable by purely algorithmic/ computational means; rest are unsolvable by algorithmic means. Of course, rest of the problems may be solved by exploiting the knowledge of the problem domain. One of the aspects of Artificial Intelligence is to attempt to solve unsolvable problems by exploiting the knowledge of the problem domain.

2.2. Why knowledge is generally imperfect?: As pointed out above first by Whitehead & then by Sowa, knowledge is essentially imperfect. Human knowledge may be generally imperfect in view of the facts: (i) human mental faculties are the finite and discrete, and (ii) Nature all around us the knowledge of which the human beings are required to have for survival is the infinite and continuous.

Even from our everyday experience, imperfection of our knowledge is quite evident, e. g. in the simple case of tossing of an unbiased coin, where the outcome domain is known (deterministic) as {Head, Tail}, and is very small, the knowledge about the next outcome is not certain, rather, cannot be certain knowledge is imperfect. Next, significance of having knowledge of imperfectness of knowledge for obtaining appropriate solutions of our problems is discussed briefly.

2.3. Why knowledge of Imperfect knowledge for computational solutions?: Software developed with idealistic assumptions of perfectness of the knowledge of problem domain will be fragile, i.e. not robust. Designing software for a particular problem domain assuming knowledge of the problem domain as perfect is like designing a car for roads having completely smooth surface, having no left/right turns, no up/ down movements, no possibility of animals straying on road etc. With these assumptions, one may design a car with no indicators, no gears, minimal brakes. But such a car will fail on actual roads.

Also, software domains are much more complex than roads for cars. Further, software is inherently much more fragile as compared to mechanical and electronic devices. Eiffel Tower has 2.5 million nuts and bolts, if even hundreds of nuts/bolts are removed, there may be hardly any damage to the tower. However, an average software contains millions of lines, and even if a single comma, or any other character is removed, whole software is generally completely damaged, or at least, it malfunctions.

Fragility of software and complexity of problem domains, have led to hundreds of disasters including the following one. On June 4, 1996 an unmanned Ariane 5 rocket launched by the European Space Agency exploded just forty seconds after lift-off. The rocket was on its first voyage, after a decade of development costing 7 billion.

During inquiry later on, it was found that the cause of the failure was a software error, rather oversight in the inertial reference system, caused by the lack/ignorance of knowledge that conversion of a 64-bit floating point number to a 16-bit signed integer (in coprocessor) will lose accuracy in representation. The accident happened because of lack of knowledge, or, because of not using of the knowledge of the fact that while transferring 64-bit numbers to 16-bit numbers, there will be round-off/ truncation error. And this error, though small in the beginning, will lead to major error after hundreds of executions involving the erroneous number, and hence will result in completely different number from the expected one.

2.4. Why Mathematical Model?: In order to solve any problem with the help of computers, first a computational model of the problem domain, and of the intended solution is required to be developed. For this purpose, first, a mathematical model of the solution is developed, which then is examined for its computational aspects including feasibility and efficiency.

2.5. Why Mathematical Models of Imperfect Knowledge?: On a brief look at the progression of problem domains explored for computer applications, it is found that initially, around 1950, computers were used mainly for studying and modelling of the physical universe, extended later to for other physical sciences, where the quality of knowledge is reasonably good/perfect. Later, applications to biological and life sciences were attempted. And now, computers are used for studying and modelling, among other fields, of social sciences, which are very complex as compared to the physical sciences. Quality of available knowledge from physical sciences to life sciences to social sciences is gradually changing from perfect knowledge to imperfect knowledge [Eusepi & Preston, 2018], [Stillwagon, 2019] & [Frydman, 2007].

In the near future, Cyber-Physical-Social Systems (CPSS)are being attempted to model as cyber-replica of our natural-artificial-social world, including social, economic, cultural, scientific and technological aspects of human life [Kaushik & Sridhar, 2021]. The domain of each of CPSS is to be truly Sowa's knowledge soup, involving all types of imperfections of knowledge (to be discussed). In order to obtain reasonably good solutions in CPSS, appropriate models of various types of imperfections of knowledge are required.

3. Types of Imperfection of Knowledge

In this section, we briefly discuss some possible types of imperfection of knowledge.

3.1. Uncertain knowledge: The knowledge is uncertain, when, e.g., it is about (i) diagnoses of problems/diseases, (ii) predictions (e. g. about weather), (iii) historical facts (possibly biased) and (iv) conclusions based on sampled data.

Also, knowledge, in respect of each of the following types of scientific matters, is uncertain: (i) the path of an electron in an atom, (ii) existence of the most fundamental particles, (iii) existence of life somewhere other than earth, and (iv) existence of other universes having different physical/chemical/biological properties and having phenomena different from the ones known to humanity.

3.2. Incomplete knowledge: Sampled data for a massive phenomenon is, by its definition, incomplete representation of the phenomenon. So is the knowledge of a natural phenomenon based on any scientific model/theory/explanation of the phenomenon, e.g., based on Newton's theory (because a theory is finite representation of large, generally infinite, phenomenon). History, how so ever detailed it is, is about only some aspects, say political or scientific etc., and further, for each aspect also it cannot be complete representation, in fine detail, of the whole past.

3.3. Vague/ fuzzy Knowledge: The knowledge is vague when there is difficulty of making sharp or precise distinctions in the problem domain,

e. g. when knowledge involves linguistic/qualitative variables, like tall, Fast.

(i) Tall/short: In India, males of heights 5’ 10’ and 6’3” both are called tall, without any distinction. A person of height 5’ 9’’ may be tall in India, and not tall in U.S.A.
(ii) Fast/ slow: An email, if does not reach within 5 minutes, then it is slow; a conventional mail, if reaches within 2 days, it is fast. Other terms used for vagueness include fuzziness, indistinctiveness, unclearness, and sharpless-ness

3.4. Imprecise/Approximate/inexact knowledge: Imprecision arises when values of a continuous/real variable like time, length and area are attempted to be represented in terms of some computer/discrete numbers. In such cases, the values in the range $[n - \varepsilon, n + \varepsilon]$, where n is an integer and ε is machine-epsilon, all are represented by the single value n. In electronic watches/ computers, howsoever precise the time may be, it is still approximate/imprecise

3.5. Ambiguous knowledge: Knowledge is said to be ambiguous, when a phrase or sentence involved in it may have many possible interpretations/ meanings, which may be resolved by context, e. g. the word ‘bank’. It may be river front, or it may be a financial institution. Another example of ambiguous knowledge involves the phrase ‘for a long time’, e. g. in

(i) Dinosaurs ruled the earth for a long period (about millions of years)
(ii) It has not rained for a long period (say about six months),
(iii) I had to wait for the doctor for a long period (at most, about six hours).

Thus, the phrase ‘for a long time’ may represent periods of time ranging from a few hours to millions of years. Other terms used for ambiguity include divergence, one-to-many relationship, non-specificity and generality. It may be noted that the three terms viz. vague, imprecise and ambiguous are distinct.

3.6. Paradoxical/Inconsistent knowledge: Knowledge is said to be paradoxical or inconsistent when a given set of statements constituting knowledge, involves mutually conflicting statements. Social sciences, at least, are full of inconsistent theories.

Even sciences always had/have inconsistencies/controversies, e.g. (i) Geo-centric vs. Helio-centric world (Aristotle vs. Galileo) (ii) Dalton’s atomic theory, and now sub-atomic theories (iii) Uni-verse vs multi-verse (each universe having its own physics, chemistry etc.), (iv) Even theory of light is inconsistent: light is both a wave and particle (and hence, not a wave).

3.7. Subjective knowledge: Knowledge is said to be subjective when source of the knowledge is also significant component of the knowledge. For example, the knowledge, generally in the form of beliefs and opinions, in respect of political and economic state of a country, varies from person to person, and hence is subjective.

3.8. Dynamic knowledge: Knowledge is dynamic when problem domain changes with time, the knowledge becomes imperfect when the changes are too subtle or too fast to be captured by human beings or by the system meant for monitoring changes.

It may be noted that the above-mentioned types are neither exhaustive, nor mutually exclusive. A knowledge piece may involve more than one of the above-mentioned types. In the Section 4, different mathematical models that have been developed for handling various types of imperfection are briefly discussed.

In order to know better which mathematical model (to be discussed) is more appropriate for a given type of imperfection, we need to know (i) How the knowledge of a phenomenon is acquired? (ii) How this knowledge is stored in mind? (iii) How this knowledge is expressed and communicated? and (iv) Why & how the knowledge has to be imperfect?

4. 'How' Questions About Knowledge

The 'How' discussion is initiated with

4.1. How the knowledge of a phenomenon is acquired?: Main sources of human knowledge include

(i) Induction: It is the process of drawing a conclusion or a piece of knowledge from a finite number of observed instances. Most of the knowledge of scientific, both physical & social, disciplines is acquired through induction.

(ii) Deduction: It is the process of drawing a conclusion or a piece of knowledge by applying some well-known rules of logical inference to statements already accepted as pieces of knowledge (axioms & postulates). Most of the mathematical knowledge is derived through deduction. But knowledge acquired through deduction need not be perfect knowledge. The assumed statements (axioms etc.) used to derive new knowledge through

deduction, may not be true. One needs to remember that theorem is as good as are its axioms.
(iii) By Authority/ through experts (including human beings and stored knowledge in books & research journals etc.). Next, we discuss

4.2. How knowledge is expressed and communicated?: Major modes, at the top, of communicating knowledge, include

(i) Natural Languages
(ii) Semi-formal languages, specially in academic disciplines, involving technical terms, mathematical formulae etc. (e. g. each of 'relation' 'function' and 'category' has distinct meaning in Mathematics, or mass-energy equivalence: $E = mc^2$ in physics)
(iii) Formal languages, including programming languages.

4.3. How the knowledge is stored in mind?: At the top level, knowledge is stored in mind as
(i) Unconscious knowledge
(ii) Conscious knowledge
(iii) common-sense knowledge (most of it is acquired unconsciously, and used both consciously & consciously)
(I) Unconscious knowledge/capabilities: a part of which is purely-procedural (for human beings), e. g. habits, vague intuitions and gut feelings. Purely-procedural knowledge is repeatedly used & experienced. But, underlying brain-mind mechanisms for acquiring such knowledge, are not explainable/ communicable to others, as in each of the following cases:
(a) How a poem is composed by a poet?
(b) How a novel research idea strikes? (Idea of gravitation from falling apple; Newton could not have explained the brain-mind mechanisms which led to the idea);
(c) How a tasty, but novel, dish is prepared by an expert cook?

Unconscious knowledge is not communicable to others. Unconscious knowledge is a sort of firmware device which is part of the brain-mind type system, where the device is automatically switched on without explicit command (or remains always switched on), without its code being executed in the main/ conscious part of the processor.

(i) Conscious knowledge: Conscious part is that which can be explained and /or communicated. However, through some complex mechanisms, firmware (both hardware & software) keeps modified continuously. It may be noted that only conscious knowledge may be imbedded in machine, not necessarily whole of it. Next, we discuss types of conscious knowledge.

Types of Conscious knowledge

(i) visualizable/ image-like form: An image, whether of a scene from the real world or purely creation of the human mind, is continuous, and possibly limitless. On the other hand, human capability for communication through some language (even within equivalence of meaning) is only finite and discrete; and computer is also a finite and discrete system. Hence, visualizable knowledge may not be communicated in entirety to the computer through some symbolic means. History deals some aspects, e.g. political and only some people, say, leaders.

(ii) Verbalisable/ symbolizable (use of surrogates) form: communicable to other human beings,

(iii) rational thought: justifiable/ rationalizable form. It allows to store, rather derive, potentially infinite facts (knowledge pieces) through finitely many axioms (assumed statements) and rules of derivation. E.g., Euclidean & non-Euclidean Geometries, Number theory, Real Analysis, Newtonian Mechanics, other physical theories.

(iv) Mathematical:(abstraction, symbolization, logical reasoning etc.), including mathematical theories and mathematical models.

(v) Formalizable: that part of conscious knowledge which is or can be put, through human efforts, in a form readable by a computer, which may or may not be computer-executable.

(vi) Two Computational theories and computable models:

(vii) computer-executable form: that part of conscious procedural knowledge which is or can be put, through human efforts, in a form of computer program which is first computer readable and then is such that the instructions in the program can be acted upon by a computer system. However, the execution of program may not terminate. The difference between a computable/executable model and non-computable formal model is somewhat analogous to that of a person who may read/understand a recipe for preparing a dish, but may not be able to actually prepare the dish.

(viii) Computer-decidable/feasible/answerable form: The main difference between computer-executable form and computer-decidable form is that for a given type of problem expected to solvable by computer-executable model, for the computer-decidable model, the computer must terminate after finite number of steps; however, for the computer-executable model, the computer may not terminate after finite number of steps.

(i) Common Sense (acquired mostly unconsciously, used both unconsciously & consciously)

(i) Most of it is acquired unconsciously through interaction with the world around

(ii) It forms a very large part of human knowledge

(iii) This implicit knowledge has to be explicated for embedding it into the machine.

Common Sense has two components:
(i) Common sense knowledge (body of facts)
(ii) Common sense reasoning
(iii a) Some Common sense knowledge/ facts:
(i) A person dies only once
(ii) All parts of body of a person are, where the person is
(iii) A stone is not hurt when hit, but a dog is hurt when hit
(iv) Only a living entity can feel hungry and eat
(v) Water flows downhill
(vi) A rope is used to pull, but not to push

Millions of such facts are stored in our mind, most of which are acquired unconsciously, and used unconsciously and consciously for making decisions and solving problems.

(iii b) Commonsense reasoning includes naive physics: humans' natural understanding of the physical world.

This type of common sense includes much knowledge whose domain overlaps that of the exact sciences but differs from it epistemologically (different type of knowledge). Naïve physics is about making decisions based on (qualitative) judgment instead of exact (quantitative) measurements and using formulae of physics. For example, when crossing a busy road in a metropolitan city like Delhi (where there is no red light), we just judge, when to cross, and then actually cross it, most the time successfully, without using the physics formula $s= u\ t+ (1/2)\ a\ t^2$, for each of the vehicles coming in our direction, after knowing their distances to determine their times to reach near us.

We will discuss later that the task of embedding of Common sense in machine has been found to be quite challenging and not satisfactory so far. Partial reason for it is that common sense is used without much conscious effort on our part, whereas for embedding a capability in machine, serious conscious effort, in knowing various aspects of the capability, is required.

4.4. Major Sources of imperfections in knowledge

(a) One of the major reasons of imperfection of human knowledge is that Knowledge is product of human mind an image in the mind of the objective world around, and human mind is finite and discrete which is required to store the image of the objective world, which, in turn, is infinite, continuous and dynamic. Hence, image in mind can be, and actually is, only an approximation of the objective world: neither it is nor it can ever be exact/ complete.

(b) Also, perception and judgment are basic (human) tools for acquiring Knowledge, both of which are imprecise. E. g., earlier, through perception, it was considered that the Earth is flat, and it is the center of universe. Similarly, judgment drawing conclusion or making decisions by not going through complete conscious efforts is common source of our knowledge. But such knowledge cannot be perfect.

(c) Randomness in Nature. A phenomenon is called random if it can be performed repeatedly under essentially same conditions, and the resulting outcome is uncertain in spite of the fact that the set of all possible outcomes is known in advance, e. g. tossing a coin. The phenomenon/concept of randomness has been a subject-matter of philosophical controversy: Niels Bohr, among others, believed that randomness is objective, i. e., randomness is a characteristic of Nature, whereas Einstein, among others, considered randomness as subjective, i. e. a consequence of limitation of either current human knowledge or limitation of human intellectual capacity. For example, `each of the following is random

(i) number of children that will be born in a period,

(ii) number of persons falling ill in a given month,

(iii) As mentioned earlier, even for some simple activity like tossing a coin, the outcome is not knowable before actually tossing the coin and noting the result of toss, despite knowing that the result is to be in the small set {Head, Tail}. The result is intrinsically random and is not because of limitation of human mind.

(iv) motion of an electron in an atom

(d) Natural Language and representation & communication of Knowledge: It is well-known fact that Natural Languages express human feelings of joy, sorrow, humour and surprise etc. quite satisfactorily, specially, through various figures of speech (e. g. metaphor, simile, irony, euphemism and hyperbole etc.). However, these figures of speech make a natural language ambiguous, vague, imprecise, and even inconsistent, and hence make a natural language unsuitable as a mathematical or scientific language, where objectivity, clear and consistent meaning is foremost concern. Actually, during 19th& 20th centuries, investigations in the fundamental reasons for crises in mathematics, use of natural language in definitions & proofs was found to be one of the main culprits.

5. Mathematical Models for Handling Imperfections

First of all, we enumerate various types of models/theories according to some criteria, and then briefly discuss some of these in detail. The models may be categorized as follows

(i) probability theory, fuzzy set theory; fuzzy measures and its special cases belief measure, plausibility measure, probability measure, possibility and necessity measures all of which are symbolic and primarily numeric, but may involve inductive and/or deductive reasoning in the matter of providing rules or discovering rules.

(ii) Modal logics, belief models and non-monotonic logics are mainly non-numeric, symbolic and follow deductive approaches.

(iii) Rough set theory, primarily an inductive approach.

(iv) Chaos theory, primarily a deductive.

[Li 2008], [Sowa 2000], [Munakata 2008], [Smets 1999] & [Gensler 2012]

Next, we mention briefly imperfectness-handling aspect of some of these models.

(i) Probability theory (Jacob Bernoulli, 1654) is the main mathematical tool to handle the problem of randomness.

(ii) Fuzzy theory (Zadeh, 1965)) was proposed to handle the problem of vagueness. It provides sort of technique of 'continuization', i. e. extending discrete concept like truthfulness as true/ false to truthfulness of various degrees. For example, the concept corresponding to 'Young / old' is extended by considering a 30-year-old man: is .7 young and .3 old.

(iii) Rough Set Theory (Powlak, 1982) is an approach of simplifying massive data through the concept of equivalence class, e.g. framing time-table for thousands of students is done by designing it for (class, subject) equivalence classes. It is primarily an inductive approach for finding significant attributes for classification

(iv) Chaos Theory handles the imperfection in situations in which appearances are irregular, but underlying rules are deterministic, i. e. it is a mathematical model for handling imperfectness found in Chaotic system a dynamical system, in which minor differences in initial data may lead to substantial changes in the behavior of the dynamical system. For example, Indian Institute of Advanced Studies (IIAS), Shimla is pan-Indian: of the two rivulets around it, one goes to Bay of Bengal, and other to Arabian Sea.

A substantial part of our knowledge is not factual but in the form of commands, obligations, possibilities etc. Models to handle these types of knowledge include

(i) Modal Logics, which deal with necessity (it necessarily happens, say, in nature) and possibility (it possibly happens, say, in nature)

(ii) Deontic and Imperative Logics, which deal with respectively permissible/ obligatory and commands, e. g. religious injunctions, or military commands: Do this, don't do that.
(iv) Belief Logic are non-monotonic reasoning systems, to handle beliefs, which may or may not be true and/or justified required to constitute knowledge.

The models discussed above are meant to handle imperfections of knowledge, but only for consistent domains, i. e. domains containing no pair p and p of mutually contradicting statements. However, in real-life situations, specially, when the knowledge-base is too large, such pairs may occur frequently. Next, we discuss briefly models handling inconsistent knowledge.

Paraconsistent Logics: In the classical/ conventional logical systems, if in an argument an inconsistency i. e. a formula of the form $(p \wedge p)$, for any proposition p is deduced, then the axiomatic system becomes worthless in the sense that any statement, irrespective of whether it is true or false, can be concluded as true.

A Logic is said to be explosive (or, ex contradictione quodlibet (ECQ)) in the sense that according to it any arbitrary statement can be concluded as true from a contradiction A and ¬A. Classical logics and many other logics are explosive/ ECQ.

This is a serious deficiency in the conventional logics in the sense that the practical life is full of inconsistencies. Using classical logic, we cannot draw any meaningful conclusion regarding practical life.

A paraconsistent logic is a logic concerned with studying and developing inconsistency-tolerant systems of logic. The logic accommodates inconsistency in a controlled way that treats inconsistent information as potentially informative. However, the classical logic is not rejected outright by paraconsistent logicians: the validity of classical inferences, is usually accepted, in consistent contexts. The rejection of ECQ is motivated by the need of isolating an inconsistency without its spreading everywhere.

There are a number of systems of Paraconsistent Logic including Discussive Logic, Non-Adjunctive Systems, Preservationism, Adaptive Logics, Logics of Formal Inconsistency, Many-Valued Logics and Relevant Logics.

6. Challenging Domains For Modelling

Out of the various domains concerning acquiring, possessing, representing or storing of knowledge either in human mind or in machine, for computational modelling & processing purpose, the following three have been found quite challenging
(i) Natural Language,
(ii) Common Sense knowledge, and
(iii) Knowledge stored Unconsciously.

6.1. Modelling & Processing the Unconscious Knowledge: Out of the three mentioned above for modelling, the most challenging one is unconsciousness knowledge. The reason for the challenge lies in the fact that on one hand, the unconscious knowledge, by definition, is not conscious. But on the other hand, for developing model of a phenomenon, it is must to have its knowledge consciously.

Recent contributions to modelling the Unconsciousness, though nowhere being satisfactory, include Global Workspace Theory (GWT) proposed in [Baars 1988, 1997 & 2002]; Cognitive Architecture, LIDA developed in [Baars 2009] & [Franklin 2007a, 2006 & 2007 b]; Unconscious Thought Theory (UTT) proposed in [Dijksterhuis 2006].

6.2. Modelling & Processing the Common Sense: The role common sense plays in our everyday life on one hand, and the difficulty of its embedding in machine, on the other hand, is well explained by Earnest Davis in Commonsense reasoning and Commonsense Knowledge in AI [Davis& Marcus, 2015].

The degree of difficulty of embedding common sense in machine can be judged from the following fact about the second approach, viz. handcrafting large common-sense bases. To embed common sense knowledge in machine, an AI project CYC was initiated in July 984by Douglas Lenat and its Stable release 6.1 became available on 27 November 2017; and it is still going on.

6.3. Modelling & Processing the Natural Language: Out of the challenging domains for modelling, Natural Language Processing is the most successful one. In this respect, two instances are quoted here.

(i) Google Translate

(i) is a free multilingual machine translation service developed by Google, to translate text.
(ii) supports over 100 languages at various levels,

(iii) translates more than 100 billion words a day, and
(iv) serves over 500 million people daily.

(ii) Microsoft Edge

(i) is a web browser developed by Microsoft? It was first released for Windows 10 in 2015, and for macOS in 2019
(ii) can speak out English eBooks to the reader of the books, which can be reasonably understood by a listener. The reader need not read the book. In stead, she may just listen it being spoken by Microsoft Edge.

7. Conclusion

Knowledge plays a significant role in solving problems in general, and solving complex problems computationally in particular. However, most of the (human) knowledge is essentially imperfect. Also, there are numerous types of imperfection in our knowledge. And, each type has to be handled properly generally by some specific approach, or using some particular type of model. Not taking into consideration the fact of imperfection of knowledge, and/or of appropriate type-model matching, lead to quite useless solutions, and even disastrous consequences. In this respect, a number of relevant issues were discussed including types of imperfection of knowledge, how and why there are imperfections in our knowledge, various available models for handling imperfections, and appropriate (imperfection-type, model) matching are discussed. Finally, the challenging problems in this respect are briefly discussed.

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