INDIAN INSTITUTE OF INFORMATION TECHNOLOGY

Knowledge Representation and Reasoning

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Knowledge Representation and Reasoning (KR)

- KR builds on the fundamental thesis that knowledge can be represented in an explicit declarative form, suitable for processing by dedicated symbolic reasoning engines.
- Exploitation of knowledge implicitly through semantically grounded inference mechanisms.
- Well-established and lively field of research within AI
- KR has contributed to the theory and practice of various areas in AI,
  - agents, automated planning and natural language processing,
  - fields beyond AI: data management, semantic web, verification, software engineering, robotics, computational biology, and cyber security.

https://kr.org

KR conference series

- Leading forum for presentation of progress in the theory and principles underlying the representation and computational management of knowledge.
  - Papers presenting novel results on the principles of KR that clearly contribute to the formal foundations of relevant problems or show the applicability of results to implemented or implementable systems.
  - Papers from other areas that show clear use of, or contributions to, the principles and practice of KR.
  - Reports from the field of applications, experiments, developments, and tests

https://kr.org

KR conference series

KR and Reasoning conferences deal with the following topics.

1. Topics in logical theory and the theory of computation, including
   a. Nonmonotonic logic
   b. Complexity theory
2. Studies in application areas, including
   a. Temporal reasoning
   b. Formalisms for reasoning about planning, action and change, and causality
   c. Meta reasoning
   d. Reasoning about context
   e. Reasoning about values and desires
   f. Reasoning about the mental states of other agents, and especially about knowledge and belief
   g. Spatial reasoning
   h. Reasoning about vagueness

Stanford Encyclopedia of Philosophy **Logic and Artificial Intelligence** https://plato.stanford.edu/entries/logic-ai/

KR conference series

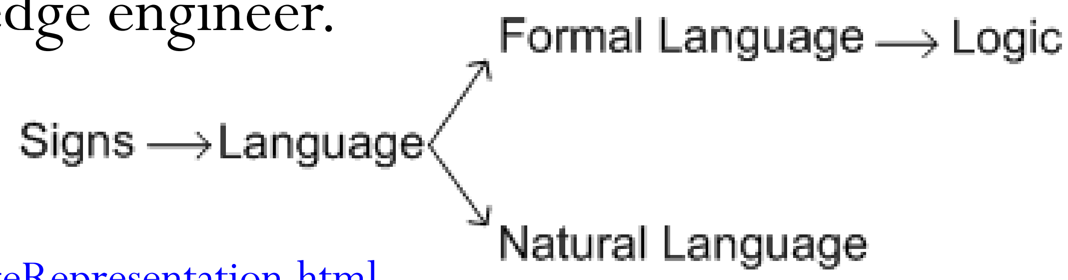
KR and Reasoning conferences deal with the following topics.

3. Argumentation and argumentation theory
4. Aggregation problems of many kinds, such as the integration of conflicting knowledge sources
5. Studies in application techniques, including
   a. Logic programming
   b. Description logics
   c. Theorem proving
   d. Model construction
6. Studies of large-scale applications, including
   a. Cognitive robotics
   b. Merging, updating, and correcting knowledge bases

Stanford Encyclopedia of Philosophy **Logic and Artificial Intelligence** https://plato.stanford.edu/entries/logic-ai/

Knowledge Sharing

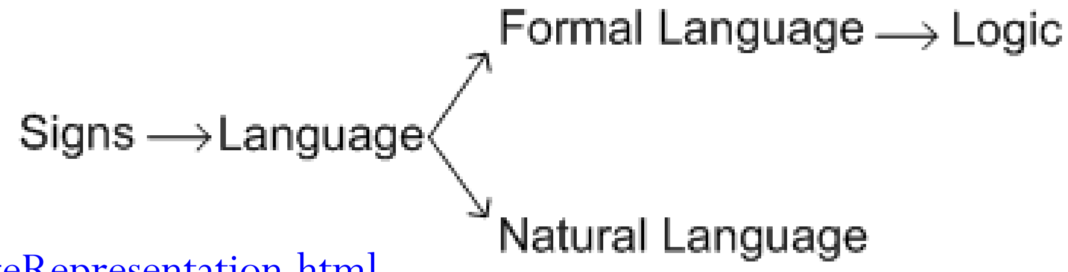
- **Social agents** gets access to more than the knowledge it has been able to build up
- Agents have access to more than individual experiences and even unprecedented situations can be resolved satisfactorily.
- Knowledge exchange mechanisms based on signs and thus studied by Semiotics.
- **Semiotics:** the study of signs and symbols and their use or interpretation.
- **Symbols** are **surrogates** (takes place of something else) for the external things.
- Symbols and links between them form a model of the external system that can be manipulated to simulate it or reason about it.
- Useful to Application designer or Knowledge engineer.



https://rhizomik.net/html/~roberto/thesis/html/KnowledgeRepresentation.html

Knowledge Sharing

- **Ambiguity** also allows exploration of new possibilities because knowledge is not confined in a restrictive immutable form.
- **Example: DNA** and **Metaphors** (used in place of another to suggest a likeness or analogy between them)
  - produces a new interpretation of a previous representation inside a particular context
- **Knowledge engineers** who manage knowledge tools.
- **Domain experts** who understand the application domain.
- Domain experts should be able to read and verify the domain definitions and rules written by knowledge engineers.



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Knowledge Representations

- The knowledge accumulations in the knowledge management systems can be
  - **Logic:** provides the formal structure and rules of inference.
  - **Ontology:** defines the kinds of things that exist in the application domain.
  - **Computation:** supports the applications that distinguish knowledge representation from pure philosophy.
- Application of Knowledge Representation techniques are enormous.
- Computers provides powerful processors of more or less rich information sources.
- Interpretation of the results is carried out by the agents (or human users).

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Knowledge Representations

- KR is used in Artificial Intelligence System
- Knowledge is more than the sum of its Knowledge Representation.
- **World Wide Web** is becoming the biggest accumulation of knowledge.
- Application of logic and ontology to the task of constructing computable models of some domain.
- **Logic** and **Ontology** provide the formalization mechanisms required to make expressive models.
- Computational resources provide great quantities of knowledge expressed that can be automated.

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Knowledge Representation Principles

- **Surrogate** (takes place of something else): symbols are used to represent external things that cannot be stored in a computer, i.e. physical objects, events, and relationships.
- **Set of ontological commitments:** Ontology determines the categories of things that exist or may exist in an application domain.
- **Fragmentary theory of intelligent reasoning:** To support reasoning about modelled things in a domain, behavior and interactions. Explicit axioms or compiled into computable programs.
- **Medium for efficient computation:** Encode knowledge in a form that can be processed efficiently by the available computing equipment (hardware and programming).
- **Medium for human expression:** KR language facilitate communication between the Knowledge engineer and the domain expert.

https://rhizomik.net/html/~roberto/thesis/html/KnowledgeRepresentation.html

R. Davis, H.S. & Szolovits, P.: "What is knowledge representation?". AI Magazine, Vol. 14, No. 1, pp. 17-33, 1993

Levels of representation

- KRs range from computer-oriented forms to conceptual ones nearer to those present in our real-world models.
- Five knowledge levels can be established using this criterion:

Computer Oriented

  - Implementational: computer level includes data structures such as atoms, pointers, lists and other programming notations.
  - Logical: symbolic logic like propositions, predicates, variables, quantifiers and Boolean operations are included.
  - Epistemological: defining concept types with subtypes, inheritance, and structuring relations.
  - Conceptual: semantic relations, linguistic roles, objects and actions.
  - Linguistic: computers distant level, it deals with arbitrary concepts, words and expressions of natural languages.

Real World

https://rhizomik.net/html/~roberto/thesis/html/KnowledgeRepresentation.html

Brachman, R.J.: "On the Epistemological Status of Semantic Networks". In Findlet, N.V. (ed.): "Associative Networks: Representation and Use of Knowledge by Computers". Academic Press, pp. 3-50, 1979

Logic (universal language & mathematical principles)

- **Vocabulary:** collection of symbols represented as chars, words, icons, or even sounds.
  - **Logical symbols:** they are domain-independent, e.g. quantifiers like "∀" or connectives like "∧".
  - **Constants:** these are domain dependent and identify individuals, properties or relations in the application domain, or universe of discourse. E.g. “car number”, “mobile number”
  - **Variables:** they are unbounded symbols whose range of application is governed by quantifiers.
  - **Punctuation:** utility symbols that separate or group other symbols, e.g. commas and parenthesis.
- **Syntax:** a logic grammar rules that determine how symbols combine to form well-formed sentences.
- **Semantics:** to make meaningful statements that determines how the constants and variables relate to things in the universe of discourse. to distinguish true statements from false.
- **Inference:** to get something more than a notation. Rules that determine how patterns are generated from others. Reasoning mechanisms automation to generate new knowledge from previous one.

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Model checking

- Given a **Knowledge Base (KB)**, does sentence S hold?
- Basically generate and test:
  - Generate all the possible models
  - Consider the models M in which KB is TRUE
  - If $\forall M$ S, then S is **provably true**
  - If $\forall M$ $\neg S$, then S is **provably false**
  - Otherwise ($\exists M1$ S $\wedge$ $\exists M2$ $\neg S$): S is **satisfiable** but neither provably true or provably false

Generalized Logic

- General case: **Given**
  - **atomic sentences** $P_1, P_2, \ldots, P_N$
  - **implication sentence** $(Q_1 \wedge Q_2 \wedge \ldots \wedge Q_N) \rightarrow R$
    - $Q_1, \ldots, Q_N$ and R are atomic sentences
  - **substitution** $\text{subst}(\theta, P_i) = \text{subst}(\theta, Q_i)$ for $i=1,\ldots,N$
  - **Derive new sentence: subst(θ, R)**
- Substitutions
  - $\text{subst}(\theta, \alpha)$ denotes the result of applying a set of substitutions defined by θ to the sentence α
  - A substitution list $\theta = \{v_1/t_1, v_2/t_2, \ldots, v_n/t_n\}$ means to replace all occurrences of variable symbol v_i by term t_i
  - Substitutions are made in left-to-right order in the list
  - subst({x/IceCream, y/Ziggy}, eats(y,x)) = eats(Ziggy, IceCream)

Knowledge Base (KB) example

- KB:
  - allergies(X) $\rightarrow$ sneeze(X)
  - cat(Y) $\wedge$ allergic-to-cats(X) $\rightarrow$ allergies(X)
  - cat(Felix)
  - allergic-to-cats(Lise)
- Goal:
  - sneeze(Lise)

Knowledge base Agent

function KB-AGENT(*percept*) **returns** an *action*
  persistent: *KB*, a knowledge base
    t, a counter, initially 0, indicating time

  TELL(*KB*, MAKE-PERCEPT-SENTENCE(*percept*, *t*))
  action ← ASK(*KB*, MAKE-ACTION-QUERY(*t*))
  TELL(*KB*, MAKE-ACTION-SENTENCE(*action*, *t*))
  $t \leftarrow t + 1$
  return *action*

Figure 7.1 A generic knowledge-based agent. Given a percept, the agent adds the percept to its knowledge base, asks the knowledge base for the best action, and tells the knowledge base that it has in fact taken that action.

Knowledge engineering

- Modeling the “right” conditions and the “right” effects at the “right” level of abstraction is very difficult
- Knowledge engineering create and maintain knowledge bases for intelligent reasoning
  - **Logic** is a great knowledge representation language for many AI problems
  - **Propositional logic** is the simple foundation and fine for some AI problems
  - **First order logic** (FOL) is much more expressive as a KR language and more commonly used in AI
  - **Variations**: horn logic, higher order logic, three-valued logic, probabilistic logics, etc.
- Automated knowledge acquisition and machine learning tools can fill the gap.
- Intelligent systems should be able to **learn**
  - about the conditions and effects, just like we do!
  - when to pay attention to, or reason about, certain aspects of processes, depending on the context!

ขอบคุณ

Thai

Grazie

Italian

תודה רבה

Hebrew

धन्यवादः

Sanskrit

ಧನ್ಯವಾದಗಳು

Kannada

Ευχαριστώ

Greek

Thank You

English

Gracias

Spanish

Спасибо

Russian

Obrigado

Portuguese

شكراً

Arabic

https://sites.google.com/site/animeshchaturvedi07

Merci

French

多謝

Traditional Chinese

धन्यवाद

Hindi

Danke

German

多谢

Simplified Chinese

நன்றி

Tamil

Tamil

ありがとうございました

Japanese

감사합니다

Korean