INTRODUCTION TO KNOWLEDGE ENGINEERING

TOPIC 1

Agenda

- What is knowledge?
- Types of knowledge
- Knowledge engineering
- Knowledge representation and reasoning
- KE vs. KM

All men by nature desire to know.

- Aristotle

Philosophical Basis

- Traditional questions that have been analyzed by philosophers, psychologists, and linguists:
  - What is knowledge?
  - What do people have inside their head when they know something?
  - Is knowledge expressed in words?
  - If so, how could one know things that are easier to do than to say, like tying a shoestring or hitting a baseball?
  - If knowledge is not expressed in words, how can it be transmitted in language?
  - How is knowledge related to the world?
  - What are the relationships between the external world, knowledge in the head, and the language used to express knowledge about the world?

Philosophical Basis

- With the advent of computers, the questions addressed by the field of artificial intelligence (AI) are:
  - Can knowledge be programmed in a digital computer?
  - Can computers encode and decode that knowledge in ordinary language?
  - Can they use it to interact with people and with other computer systems in a more flexible or helpful way?

Information Processing Views of Knowledge

- Hierarchical view: data → information → knowledge
  - Information is the input or raw material of new knowledge
  - Knowledge is authenticated/personalized information

- Reversed hierarchical view: knowledge → information → data
  - Knowledge must exist before information can be formulated and before data can be collected

- Non-hierarchical view: data → information

  knowledge
  - Knowledge is needed in converting data into information
  - Knowledge is the accumulation of experiences vs. knowledge is created through conjectures and refutations.

Alternative Perspectives on Knowledge

- Knowledge can be defined as a justified belief that increases an entity's capacity for effective action.
- It may be viewed from several perspectives:
  - (1) a state of mind – knowledge is the state of knowing and understanding
  - (2) an object – knowledge is an object to be stored and manipulated
  - (3) a process – knowledge is a process of applying expertise
  - (4) a condition – knowledge is organized access to and retrieval of content
  - (5) a capability – knowledge is the potential to influence action

Taxonomies of Knowledge

- Tacit vs. Explicit
  - Explicit knowledge refers to knowledge that is transmittable in formal, systematic language
  - Tacit knowledge is deeply rooted in actions, experience, and involvement in a specific context. It consists of cognitive element (mental models) and technical element (know-how and skills applicable to specific work).
- Individual vs. Social
  - Individual knowledge is created by and exists in the individual whereas social knowledge is created by and exists in the collective actions of a group.

Taxonomies of Knowledge

- Five Types of Knowledge
  - Declarative knowledge
    - Know-about
  - Procedural knowledge
    - Know-how
  - Causal knowledge
    - Know-why
  - Conditional knowledge
    - Know-when
  - Relational knowledge
    - Know-with
- Meta-knowledge
  - Knowledge about knowledge

Four Modes of Knowledge Conversion (Nonaka 1994)

From \ *To*	Tacit knowledge	Explicit knowledge
Tacit knowledge	Socialization	Externalization
Explicit knowledge	Internalization	Combination

Knowledge Engineering

- "Knowledge engineering refers to all technical, scientific and social aspects involved in building, maintaining and using knowledge-based systems." (From *https://en.wikipedia.org/wiki/Knowledge_engineering*)
- It normally involves five distinct steps in transferring human knowledge into some form of knowledge based systems (KBS)

Five Steps of Knowledge Engineering

- Knowledge acquisition
- Knowledge validation
- Knowledge representation
- Inferencing
- Explanation and justification

Knowledge Elicitation Techniques

- Interview
- Protocol analysis
- Laddering
- Concept sorting
- Repertory grids
- Structural assessment

Knowledge Representation and Reasoning

- Knowledge representation and reasoning are concerned with how to use a symbol system to represent a domain of knowledge with functions that allow inference (formalized reasoning) about the objects within the domain.

Common Knowledge Representation Methods

- Logic
  - First-order logic
- Rules
  - Production rules
- Frames
- Semantic networks

First-Order Logic Syntax

- **Symbols**
  - Variable symbols: x, y, z, …
  - Function symbols: f, g, h, bestFriend, f(x), g(x,y), …
  - Predicate symbols: P, Q, R, OlderThan, P(x), Q(x,y), …
  - Logic symbols: “¬”, “∧”, “∨”, “∃”, “∀”, “=”, “→”
  - Punctuation symbols: “(“, “)”, and “.”

∧and	
∨ or	
¬not	
→	by implication
↔	is equivalent to
∀	for all
∃	there exists

First-order Logic Examples

- Likes (John, icecream)
- Loves (John, Alice) $\wedge$ Loves (John, Emily)

- $\neg$Cloudy $\rightarrow$ Take_Sunglasses

- $\forall$x (Likes (Slither, x) $\rightarrow$ eats (Slither, x))

- People(Aristotle)
- $\forall$x (People(x) $\rightarrow$ die)

Properties of Quantifiers

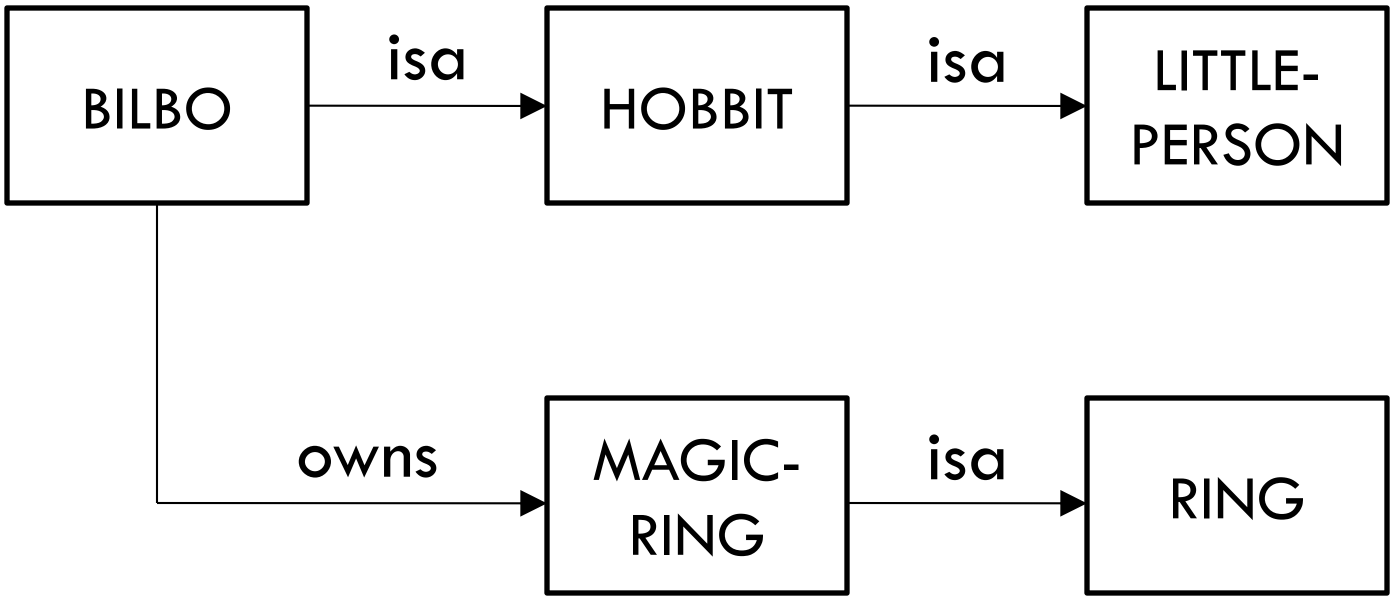
- $\forall x\ \forall y$ is the same as $\forall y\ \forall x$
- $\exists x\ \exists y$ is the same as $\exists y\ \exists x$
- $\exists x\ \forall y$ is not the same as $\forall y\ \exists x$
- $\exists x\ \forall y$ Loves(x,y)
  - "There is a person who loves everyone in the world"
- $\forall y\ \exists x$ Loves(x,y)
  - "Everyone in the world is loved by at least one person"
- Quantifier duality: Each can be expressed using the other
  - $\forall x$ Likes(x, icecream) $\qquad \neg\exists x\ \neg$Likes(x, iceCream)
  - $\exists x$ Likes(x, broccoli) $\qquad \neg\forall x\ \neg$Likes(x, broccoli)

Representing Procedural/Relational Knowledge

- Production Rules
  - If <premise>, then <conclusion>
  - If <condition>, then <action>
  - Rules permit the generation of new knowledge in the form of facts that are not initially available but that can be deduced from other knowledge parts. These facts are generated as the conclusions of the rules are applied.
- Semantic Networks
  - Graphical descriptions of knowledge composed of nodes and links that carry semantic information about the relationships between the nodes.
- Frames
  - Organizes knowledge typically according to cause-and-effect relationships. The slots of a frame contains items like rules, facts, references, and so on.

Semantic Knowledge Representation Example

- Tolkien's Hobbit World



Reasoning: Forward Chaining

- In order to prove X where X has the form $A \rightarrow C$, find an axiom or theorem of the form $A \rightarrow B$ and transform the problem to the problem of proving $B \rightarrow C$.
- Starts with some facts and applies rules to find all possible conclusions (data-driven)
- steps
  1. Consider the initial facts and store them in working memory of the knowledge base.
  2. Check the antecedent part of the rules.
  3. If all the conditions are matched, fire the rule.
  4. If there is only one rule, do the following:
     a. Perform necessary actions
     b. Modify working memory and update facts.
     c. Check for new conditions
  5. If more than one rule is selected, use the conflict resolution strategy to select the most appropriate rule and go to Step 4
  6. Continue until an appropriate rule is found and executed.

Reasoning: Backward Chaining

- In order to prove X where X has the form A → C, find an axiom or theorem of the form B → C and transform the problem to the problem of proving A → B.
- Starts with the desired conclusion(s) and works backward to find supporting facts (goal-driven)
- steps
  1. Start with a possible hypothesis, H.
  2. Store the hypothesis H in working memory, along with the available facts.
  3. If H is in the initial facts, the hypothesis is proven. Go to Step 7.
  4. If H is not in the initial facts, find a rule R that has a descendent (action) part mentioning the hypothesis.
  5. Store R in the working memory.
  6. Check conditions of R and match with the existing facts.
  7. If matched, then fire the rule R and stop. Otherwise, continue to Step 4.

Reasoning Example

- R1: if (nasal congestion and virosis), then diagnose (influenza) exit
- R2: if (runny nose), then assert (nasal congestion)
- R3: if (body aches), then assert (itchiness)
- R4: if (temp > 100), then assert (fever)
- R5: if (headache), then assert (itchiness)
- R6: if (fever and itchness and cough), then assert (virosis)

Knowledge Engineering (KE) vs. Knowledge Management (KM)

- KE is primarily concerned with constructing a knowledge-bases system while KM is primarily concerned with identifying and leveraging knowledge to the organization's benefit.
- KE and KM activities are inherently interrelated.
- Knowledge engineers are interested in what technologies are needed to meet the enterprise's KM needs.