

Knowledge Representation

What is knowledge representation?

- Structured knowledge base
- Search and inference algorithms

Example:

- [Wordnet](#)
- [Cyc](#)
- [Openmind Commons](#)

Examples of KR in AI

- **Expert systems** for medical diagnosis
- **Semantic networks, frames** for reasoning about categories
- **Scripts** for story understanding
- **Description logics, ontologies** for web services, e-mail sorting, spam-detection

What's needed in a KR system?

1. A language for representing knowledge, with the following properties

- Expressive enough to represent what is needed for the application
- Unambiguous (e.g., *she runs a company* ≠ *she runs a race*)
- Context independent (the meaning of the representation of "she runs a race" does not change with the context of that representation).
- Compositional: The meaning of a sentence is a function of the meaning of its parts. (e.g. "John loves Mary" = "Mary is loved by John").

Two extremes:

- English
- C++
- Expressive?
- Unambiguous?
- Context independent?
- Compositional?

2. We also need search and inference methods with the following properties:

- Sound (*only* true facts can be derived)
- Complete (*all* true facts can be derived)
- Efficient (a query will result in an answer in reasonable time)

English

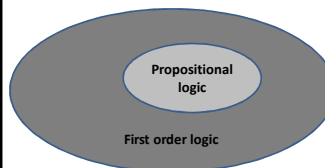
C++

Some major classes of KR “languages” in AI

- Logic
- Semantic networks
- Frames
- Scripts and conceptual dependency
- Description logics
- Ontologies

Propositional logic: AND, OR, NOT, IMPLIES

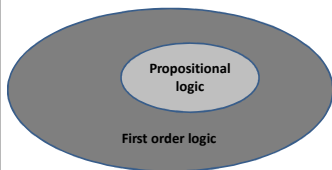
First order logic: add functions (e.g., MotherOf(x)), predicates (e.g., Man(x)), and quantifiers (\exists and \forall)



Propositional logic: AND, OR, NOT, IMPLIES

First order logic: add functions (e.g., MotherOf(x)), predicates (e.g., Man(x)), and quantifiers (\exists and \forall)

Example:
 All men are mortal
 Socrates is a man
 Therefore, Socrates is mortal



Can't do this in propositional logic
 In first order logic, can do:

$\forall x, \text{Man}(x) \rightarrow \text{Mortal}(x)$
 $\text{Man}(\text{Socrates})$

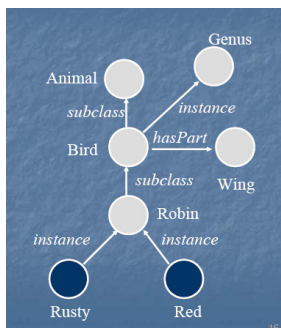
 $\text{Mortal}(\text{Socrates})$

Problems with First Order logic

- Hard to express many concepts
- Hard to express associations
- Hard to keep consistent
- Takes a long time to do inference
- ...

Semantic networks

- Retrieving knowledge = graph search problem
- E.g., “is Rusty an animal?”
- Inheritance: “does Rusty have a wing?”



Example: ConceptNet (Openmind Commonsense)

- Large-scale semantic net mined from OMCS corpus

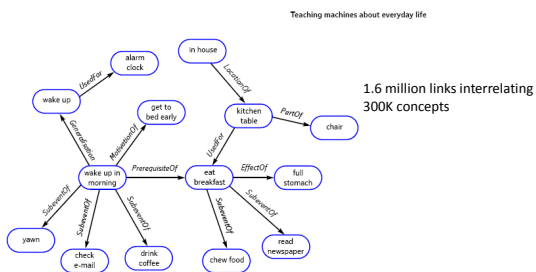


Fig 2 A subset of ConceptNet.

Table 1 ConceptNet's relational ontology of 20 link types.

ConceptuallyRelatedTo	IsA	FirstSubeventOf	DesirousEffectOf
ThematicKLine	MadeOf	SubeventOf	UsedFor
SuperThematicKLine	DefinedAs	LastSubeventOf	LocationOf
CapableOfReceivingAction	CapableOf	PrerequisiteEventOf	MotivationOf
PropertyOf	PartOf	EffectOf	DesireOf

Table 2 Ontology of concept types.

Events	Things	Places	Properties
Eat sandwich	Orange juice	At zoo	Furry
Sell car	Morning coffee	On table	Very expensive
Tell story	Policeman	Near school	Dark
Go to zoo	Leaf blower	Inside oven	Quickly
Type letter	Laptop computer	In closet	Dark

• **Reasoning in ConceptNet** = traversing links (or “spreading activation”)

• **Given an initial set of concepts, can infer:**

- What events might come next
- What might have happened earlier
- What objects might be required to perform an action
- What properties of objects are
- Where object might be found
- Goals of people with respect to events or objects

Example: A story-understanding program reads “He woke up and turned off his alarm clock”, then is asked “Why did he turn off his alarm clock?” “How did he turn off his alarm clock?”

Is your brain a semantic network?

Is your brain a semantic network?

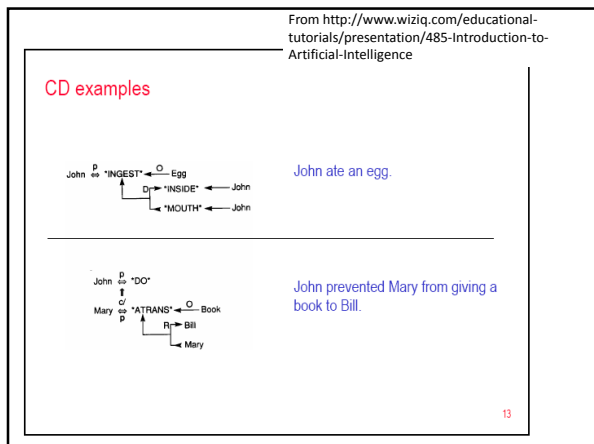
- Does a canary breathe?
- Can a canary fly?
- Can a canary sing?

Problems with semantic networks

- Can they scale?
- How to glom together entire “situations”? (e.g., alarm clock, morning, etc.) and to represent temporal order?
- How to learn the network automatically?

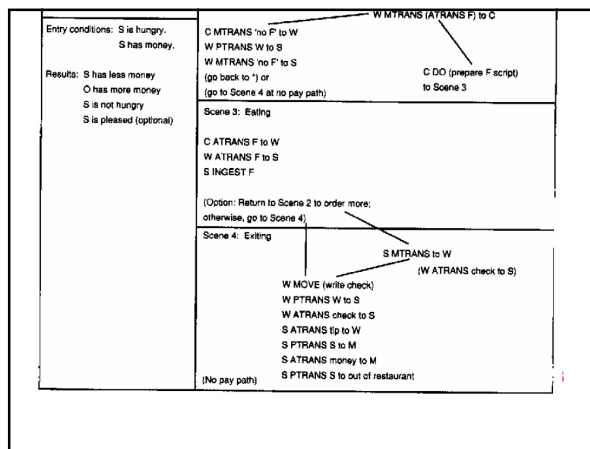
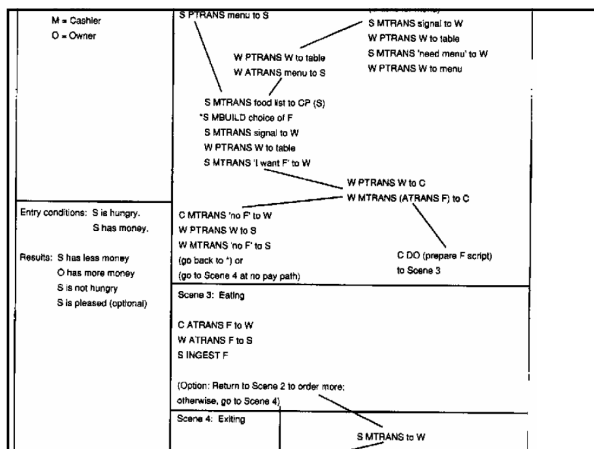
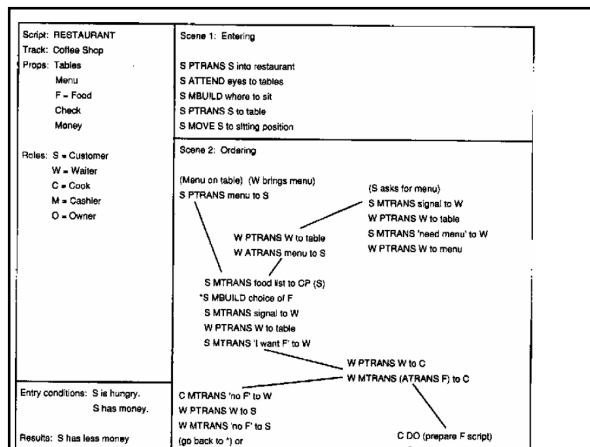
Scripts and Conceptual Dependency (Schank, 1970s-1980s)

- CD is a language that builds up meaning from primitives:
 - ACT action
 - PP objects (picture produces)
 - AA modifiers of actions (action aiders)
 - PA modifiers of objects (picture aiders)
- Primitive actions
 - ATRANS (transfer a relationship)
 - PTRANS (transfer a physical location)
 - MTRANS (transfer mental information)
 - Etc.



- **Scripts:** Stereotyped situations with temporal order, represented in CD.
- **Most famous example:** **Restaurant script**

- **Scene 1: Entering**
S PTRANS S into restaurant, S ATTEND eyes to tables, S MBUILD where to sit, S PTRANS S to table, S MOVE S to sitting position
- **Scene 2: Ordering**
S PTRANS menu to S (menu already on table), S MBUILD choice of food, S MTRANS signal to waiter, waiter PTRANS to table, S MTRANS 'I want food' to waiter, waiter PTRANS to cook
- **Scene 3: Eating**
Cook ATRANS food to waiter, waiter PTRANS food to S, S INGEST food
- **Scene 4: Exiting**
waiter MOVE write check, waiter PTRANS to S, waiter ATRANS check to S, S ATRANS money to waiter, S PTRANS out of restaurant



- **Story:**
 - John went to a restaurant. John ordered a hamburger. When the hamburger came it was cooked perfectly. John was very happy and left a big tip for the waiter.
- **Query:**
 - Did John eat the hamburger?

Problems with scripts

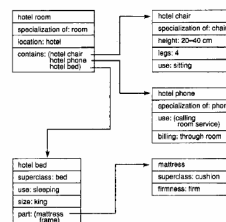
Frames (Minsky, 1970s)

- “When one encounters a new situation (or makes a substantial change in one’s view of a problem one selects from a memory structure called a ‘frame’. This is a remembered framework to be adapted to fit reality by changing details as necessary.”
- (Minsky, 1975)

Frame example

From <http://www.wiziq.com/educational-tutorials/presentation/485-Introduction-to-Artificial-Intelligence>

- a frame is a structured collection of data
- has slots (properties) and fillers (values)
 - fillers can be links to other frames



This work led to the ideas for object-oriented programming!

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Description logics (1990s, 2000s)

- Combination of semantic networks, frames, and first-order logic.
- Allows both structured conceptual representation and logical inference methods.
- Major current application: Language for “ontologies” for semantic web.

Semantic web

- Extension of html, xml for marking up web resources with “semantics”, via “shared ontologies”
- Inference and reasoning algorithms for using this metadata.
- “Intelligent search” versus “intelligent data”

```

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<META HTTP-EQUIV="SHOE" CONTENT="VERSION=1.0">
<TITLE>Prof. James A. Hendler</TITLE>
</HEAD>
<BODY>
<INSTANCE KEY="http://www.cs.umd.edu/users/hendler/">
<USE-ONTOLOGY ID="cs-dept-ontology" VERSION="1.0" PREFIX="cs" URL=
"http://www.cs.umd.edu/projects/plus/SHOE/cs.html" />
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<RELATION NAME="cs.member">
<ARG POS=1 VALUE="http://www.cs.umd.edu/projects/plus/">
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</RELATION>
<RELATION NAME="cs.name">
<ARG POS=2 VALUE="Dr. James Hendler">
</RELATION>
<RELATION NAME="cs.doctoralDegreeFrom">
<ARG POS=1 VALUE="http://www.cs.umd.edu/users/hendler/">
<ARG POS=2 VALUE="http://www.brown.edu">
</RELATION>
<RELATION NAME="cs.emailAddress">
<ARG POS=2 VALUE="hendler@cs.umd.edu">
</RELATION>
<RELATION NAME="cs.head">
<ARG POS=1 VALUE="http://www.cs.umd.edu/projects/plus/">
<ARG POS=2 VALUE="http://www.cs.umd.edu/users/hendler/">
</RELATION>

```

[Markup demo](#)

Ontologies

- “An ontology is a document or file that formally defines the relations among terms.” (Berners-Lee et al., 2001)
- Consists of *taxonomy* and set of inference rules

Ontology examples

- <http://www.schemaweb.info/default.aspx>
- <http://ebiquity.umbc.edu/ontology/event.owl>

- What will the semantic web be good for?
- What kinds of knowledge and reasoning will be necessary?

A few other well-known knowledge representation methods

- Situation calculus
- Neural networks
- Decision trees
- Bayesian networks