Lecture 5: Knowledge Representation

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Contents

1 Introduction to KR

Human Knowledge

- Human knowledge is encoded and communicated in a *natural language* (e.g. English).

  Example 1. Shark is a dangerous fish. Fish live in water. They swim and breath using gills. Fish are animals. Other animals are birds, such as canary and ostrich. Birds have wings.

- Knowledge helps us to solve problems (e.g. finding food, avoid danger).

Question 1. *Is it possible to communicate knowledge to a computer? How should knowledge be represented?*

Why is Knowledge Representation Important?

Problem 2. *A prisoner was attempting to escape from a tower. He found in his cell a rope which was half long enough to permit him to reach the ground safely. He divided the rope in half and tied the two parts together and escaped. How could he have done this?*

(Restle & Davis, 1962)

Remark 1. *It is impossible to solve the problem unless you have the 'right' representation (e.g. of what is a rope).*

2 Types of KR

Knowledge Representation Approaches
Classification due to Mylopoulos & Levesque (1984):

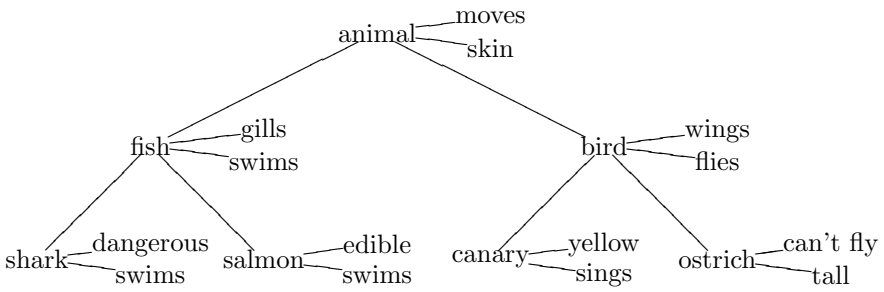
Logical calculus is used, such as first-order predicate calculus, modal, temporal logics.

Procedural or algorithmic representations can encode how to solve particular problems (e.g. rule-based systems).

Networks are used to represent objects and relations (associations) between them (e.g. semantic networks).

Structured data is used to represent classes of objects and relations between them (e.g. frames, ontologies).

Semantic Network



Object Attribute Value (OAV) Triplets

Definition 3 (OAV-triplet)**.** is an association of object $o \in O$ with value $v \in V$ of attribute $a \in A$:

$$\text{object} \xrightarrow{a} \text{value}$$

An attribute $a \in A$ can be seen as a function $a : O \to V$.

Example 4.

*o*bject	*a*ttribute	*v*alue
shark	dangerous	true
shark	locomotion	swims
shark	category	fish
canary	category	bird
canary	dangerous	false

Classification of Objects by Attributes

*o*bject	*a*ttribute	*v*alue
shark	dangerous	true
shark	locomotion	swims
shark	category	fish
canary	category	bird
canary	dangerous	false

Question 2. *What makes one object different from another?*

- Values of attributes can be used to classify objects:

$$\text{Fish} := \{\text{animals} : \text{swim and have gills}\}$$

- Objects are instances of classes (e.g. a shark is an instance of fish).
- Classes of objects can also be organised into hierarchies.

Frames

Definition 5 (Frame)**.** is a set of attributes A used to describe a class of objects. Each object is an instance of a frame (class).

Example 6.

animal	shark	salmon	canary
locomotion	swims	swims	flies
has	gills	gills	wings
colour	gray	gray	yellow
dangerous	true	false	false

Remark 2. *In* ACT–R*, frames are* chunk-types *and objects are* chunks*:*

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(chunk-type animal locomotion has ...)
(fish ISA animal locomotion swims has gills ...)
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3 Knowledge Synthesis and Engineering

Symbolic and Sub-Symbolic Representations

Symbolic representations convey information by discrete units (explicit), usually expressed in formal language (i.e. words, sentences).

Sub-symbolic representations convey information by properties (implicit) of many objects (e.g. data, attribute values, probability distributions, weights in neural networks, etc).

Hybrid systems involve both types of knowledge representation.

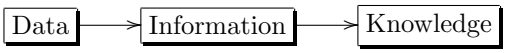
Plane

Train Car

000001100000
000110011000
001100001100
011111111110
110000000011

Knowledge Synthesis

Question 3. *Where does knowledge come from?*



Data — measurements or records about events (prices, temperature, etc). Data can be numerical, alphabetical, images, sounds, etc.

Information — analysed and organised data such that we know its characteristics (average, range, variance, distributions, clusters, etc).

Knowledge — information put into a specific context (e.g. distribution of oil prices, a map of London, etc).

Levels of Abstraction

- Data, Information and Knowledge can be classified by levels of abstraction and quantity.
- Knowledge is the most abstract and exists in the smallest quantity.
- Knowledge itself can have levels of abstraction: concrete (knowledge about the specific problem), domain specific (class of problems) and abstract (many classes of problems).

Knowledge Engineering

The process of designing an ES is called **knowledge engineering**. It consist of three stages:

Knowledge acquisition : the process of obtaining the knowledge from experts (by interviewing and/or observing human experts, reading specific books, etc).

Knowledge representation : selecting the most appropriate structures to represent the knowledge (lists, sets, scripts, decision trees, object-attribute-value triplets, etc).

Knowledge validation : testing that the knowledge of ES is correct and complete.