Elective Course
Course Code: CS4103
Autumn 2025-26

Lecture #22

Artificial Intelligence for Data Science

Week-6:

Introduction to Genetic Algorithm (GA) [Part-III]
Introduction to Knowledge Representation and Logic [Part-I]

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TSP – Crossover operator

Partially Mapped Crossover (PMX)

C_1	A	G	D	F	O	H	K	M	B	J	N	E	L	I	C
P_1	O	D	G	L	A	H	K	M	B	J	F	C	N	I	E
P_2	H	G	M	F	O	A	D	K	I	C	N	E	L	B	J

Likewise for cities I and C

Remember that city K is already in C_1…

Copy the remaining cities directly from P_2

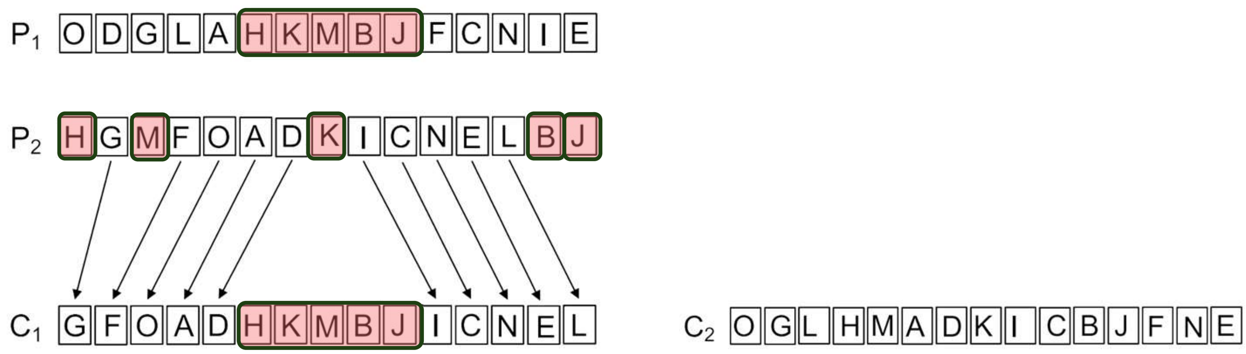
C_2	O	M	G	L	H	A	D	K	I	C	F	J	N	B	E

The second child C_2 is constructed in a similar manner, first copying the subtour from P_2

Adapted from NPTEL Course: Prof. Deepak Khemani, IIT Madras

TSP – Crossover operator

Order Crossover



Copy a subtour from P_1 into C_1 and the remaining from P_2 in the order they occur in P_2.

The second child C_2 is constructed in a similar manner, first copying the subtour from P_2

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TSP – Mutation Operators

- **Exchange Mutation Operator (EM)**
  - Randomly select two nodes and interchange their positions.
  - (1 2 3 4 5 6) can become (1 2 6 4 5 3)
- **Displacement Mutation Operator (DM)**
  - Select a random sub-tour, remove and insert it in a different location.
  - (1 2 [3 4 5] 6) becomes (1 2 6 3 4 5)

Why crossover and mutation?

- Crossover
  - Produces new solutions while ‘remembering’ the characteristics of old solutions
  - Partially preserves distribution of strings across schemas
- Mutation
  - Randomly generates new solutions which cannot be produced from existing population
  - Avoids local optimum

When to use GA

- Non-analytical problems.
- Non-linear models.
- Uncertainty.
- Large state spaces.

When not to use GA!

- Constrained mathematical optimization problems especially when there are few solutions.
- Constraints are difficult to incorporate into a GA.
- Guided domain search is possible and efficient.

Introduction to Knowledge Representation and Logic

Data, Information, and Knowledge

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- **Data**
  - Raw material/sensation
- **Information**
  - Categorized data
  - Data with meaning that may change knowledge
- **Knowledge**
  - Actionable information
  - Information that can be reasoned to be either true or false

Knowledge

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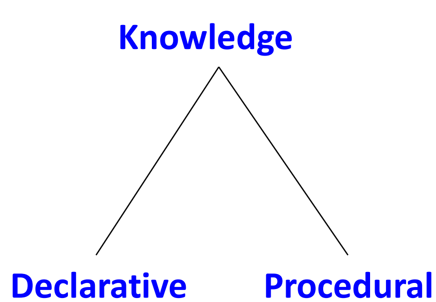

- Declarative knowledge deals with factoid questions
- Procedural knowledge deals with "How"

Knowledge Representation

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- A subarea of AI concerned with understanding, designing, and implementing ways of representing information in computers so that programs (agents) can use this information

Representation
- Should be able to represent everything in scope (expressive power)
- Correct
- Efficient

Knowledge
- Structured
- Semi-structured
- Unstructured

Simple Relational Knowledge

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Planet	Star system	Radius	Moons
Mercury	Sun	2440 km	0
Venus	Sun	6052 km	0
Earth	Sun	6371 km	1
Mars	Sun	3389 km	2
Kepler-438b	Kepler-438	7135 km	?

- Database table in relational database

Other knowledge representation schemes

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1. Semantic net
2. Frames
3. Propositional calculus
4. Predicate calculus

Semantic Net

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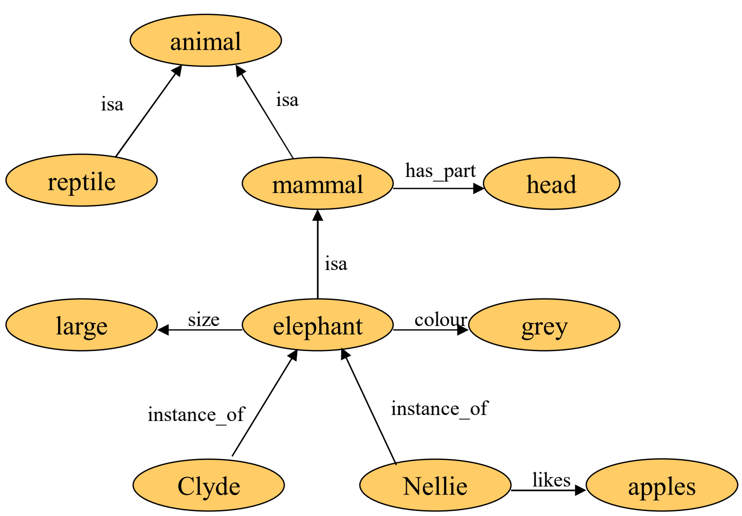

Ontologies

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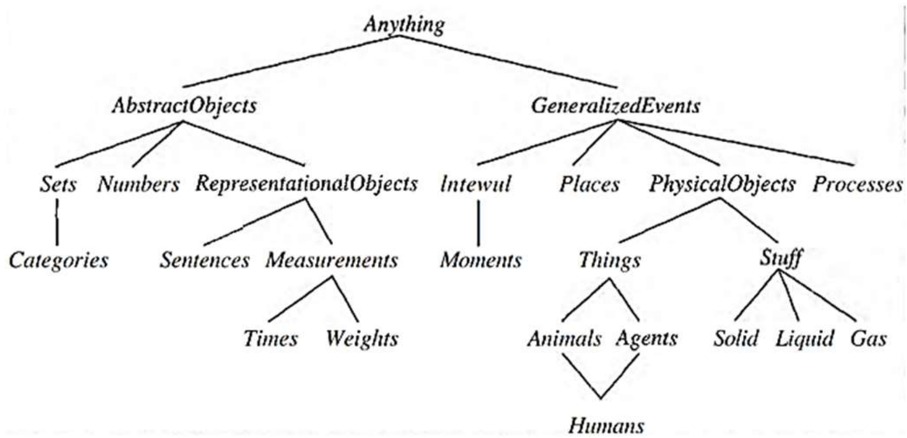
- Organize knowledge about everything in a single taxonomy



Frames

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- A frame is a collection of attributes or slots and associated values that describe some real-world entity
- Each frame represents
  - a class, or
  - an instance (an element of a class)

Frames: Example

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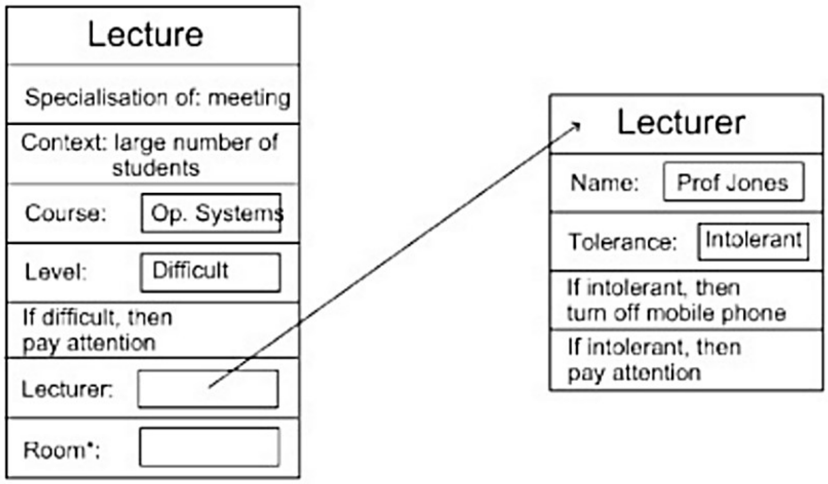

Reasoning

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- Deriving information that is implied by the information already present
- Knowledge representation schemes are useless without the ability to reason with them.

(Knowledge-based) Reasoning Agents

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- Know about the world. They maintain a collection of facts (statements) about the world, their **Knowledge Base**, expressed in some **formal language**
- Reason about the world. They are able to derive new facts from those in the KB using some **inference mechanism**
- Act upon the world. They map percepts to actions by **querying** and **updating** the KB

Knowledge Representation Languages

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- Why don't we use natural language (e.g., English) to represent knowledge?
  - Natural language is certainly **expressive** enough!
  - But it is also **too ambiguous** for automated reasoning

    Ex: I saw the person on the hill with the telescope
- Why don't we use programming languages?
  - They are **well-defined and unambiguous**
  - But they are **not expressive** enough

Knowledge Representation and Logic

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- The field of Mathematical Logic provides powerful, formal knowledge representation languages and inference systems to build reasoning agents
- We will consider two languages, and associated inference systems, from mathematical logic:
  - Propositional Logic
  - First-order Logic

Parts of the Study/Specification of a Logic

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- **Syntax:** The atomic symbols of the logical language, and the rules for constructing well-formed, nonatomic expressions (symbol structures) of the logic.
- **Semantics:** The meanings of the atomic symbols of the logic, and the rules for determining the meanings of nonatomic expressions of the logic.
- **Proof Theory:** The rules for determining a subset of logical expressions, called theorems of the logic.

Logic

A logic is a triple $\langle \mathcal{L}, \mathcal{S}, \mathcal{R} \rangle$ where

- $\mathcal{L}$, the logic's language, is a class of sentences described by a formal grammar
- $\mathcal{S}$, the logic's semantics is a formal specification of how to assign *meaning* in the "real world" to the elements of $\mathcal{L}$
- $\mathcal{R}$, the logic's inference system, is a set of formal derivation *rules* over $\mathcal{L}$

There are several logics: propositional, first-order, higher-order, modal, temporal, intuitionistic, linear, equational, non-monotonic, fuzzy, ...

We will concentrate on propositional logic and first-order logic

Questions?

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