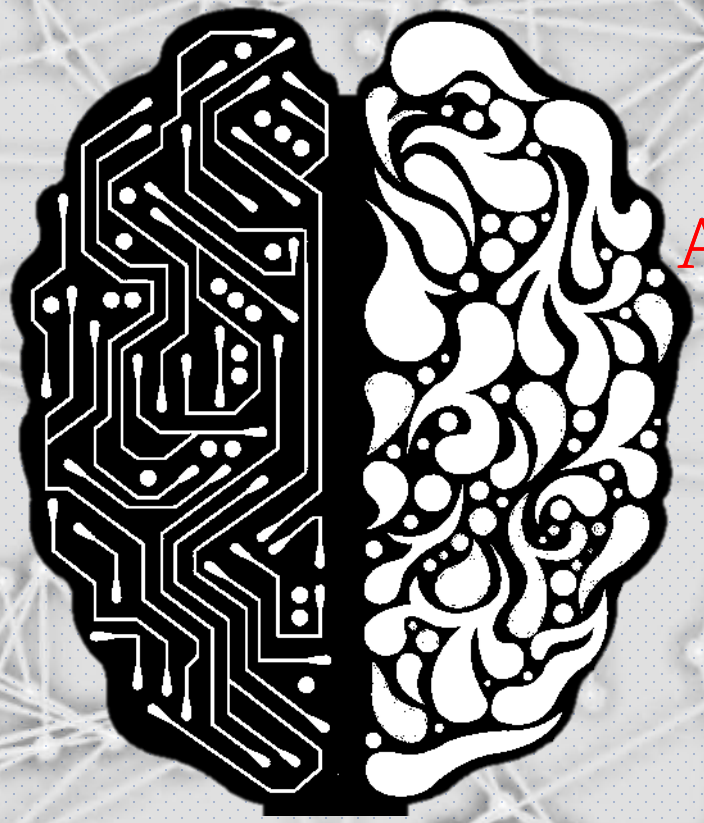

Multi-Agent Systems

Lecture 11

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- School of Computer Science
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Shout out to…

Lecture II Learning Objectives

- To understand the elements of an Expert System (ES):
- To understand Inference principles of an ES;
- To understand the principles Distributed AI;
- To understand the definition of Agent
- To understand the differences of Agency

Anatomy of an Expert System

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Expert systems start with some **initial state** relating to a problem domain which they combine with **general rules** about how **additional state** information can be derived from the current state.

Anatomy of An Expert System

Expert systems start with some initial state relating to a problem domain which they combine with general rules about how additional state information can be derived from the current state.

The data base holds the initial state, typically in the form of **facts** about the problem domain:

e.g. for a weather system, this might be:

LOW_PRESSURE
CLOUDY
COLD

Anatomy of An Expert System

Expert systems start with some **initial state** relating to a problem domain which they combine with **general rules** (represent the expertise knowledge as data or rules) about how **additional state** information can be derived from the current state.

The rule base describes how additional state can be derived from existing state.

e.g. for a weather system, this might be:

IF LOW_PRESSURE & CLOUDY
THEN RAIN_LIKELY

IF HIGH_PRESSURE & NOT CLOUDY
THEN RAIN_UNLIKELY

Anatomy of An Expert System

Expert systems start with some **initial state** relating to a problem domain which they combine with **general rules** (represent the expertise knowledge as data or rules) about how **additional state** information can be derived from the current state.

Rules are known as **production rules**.

ANTECEDENT >------> CONSEQUENT

e.g.

HOT & SUNNY >------> GOOD DAY

The rule base is typically **ordered**.

Anatomy of An Expert System

Expert systems start with some **initial state** relating to a problem domain which they combine with **general rules** (represent the expertise knowledge as data or rules) about how **additional state** information can be derived from the current state.

Some systems include **certainty factors:**

ANTECEDENT >---X---> CONSEQUENT

e.g.

HOT & SUNNY >--0.8--> GOOD DAY

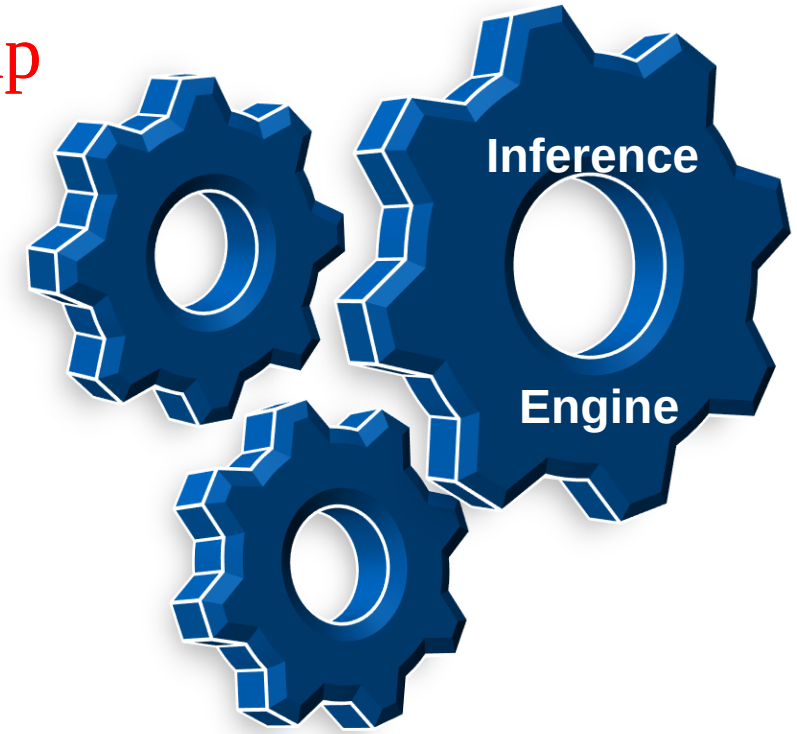
It is 80% certain that it will be a good day if it is hot and sunny.

Anatomy of An Expert System

Expert systems start with some **initial state** relating to a problem domain which they combine with **general rules** about how **additional state** information can be derived from the current state.

The inference engine is the procedural part that actually applies the rules to generate additional state:

1) **Forwards Chaining** inference engines generate all the consequences of the initial state.
2) **Backwards Chaining** inference engines are query oriented – i.e. based on the initial state and rule base, is the following fact true?



Anatomy of An Expert System

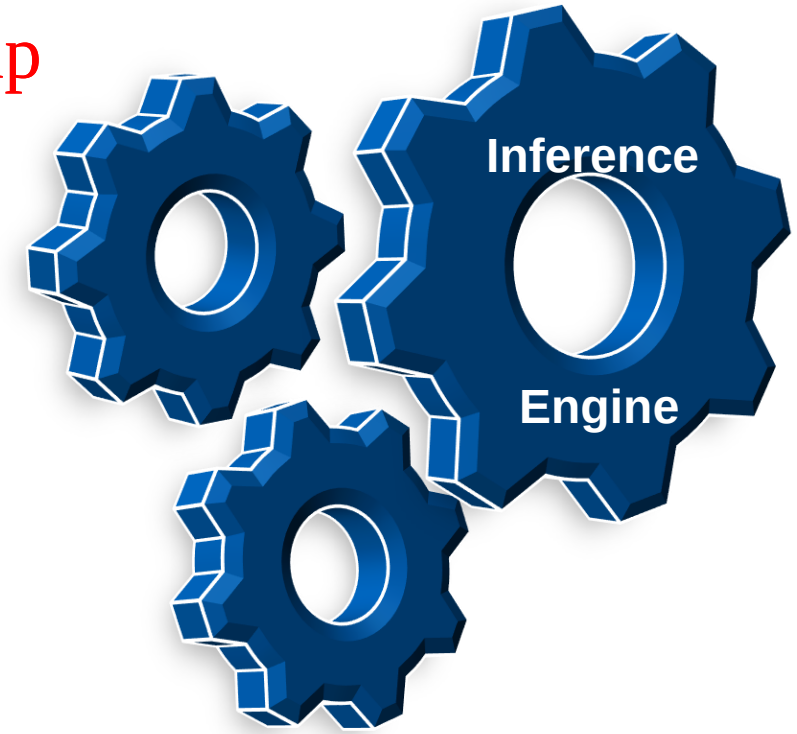
- Expert systems start with some **initial state** relating to a problem domain which they combine with **general rules** about how **additional state** information can be derived from the current state.

Forwards Chaining:

The inference engine repeatedly *selects* a rule and *updates* the database.

If the update does not add new state, the rule is ignored until an update occurs.

If none of the rules add new state, then the inference engine terminates.



Anatomy of An Expert System

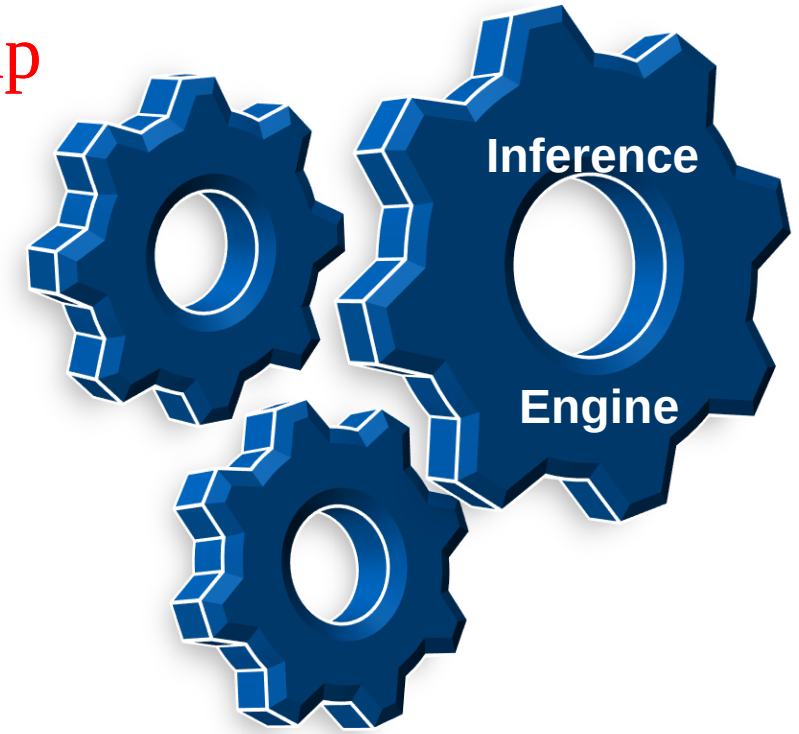
- Expert systems start with some **initial state** relating to a problem domain which they combine with **general rules** about how **additional state** information can be derived from the current state.

Forwards Chaining:

LOW_PRESSURE
CLOUDY
COLD
RAIN_LIKELY

IF LOW_PRESSURE & CLOUDY
THEN RAIN_LIKELY

IF HIGH_PRESSURE & NOT CLOUDY
THEN RAIN_UNLIKELY



Anatomy of An Expert System

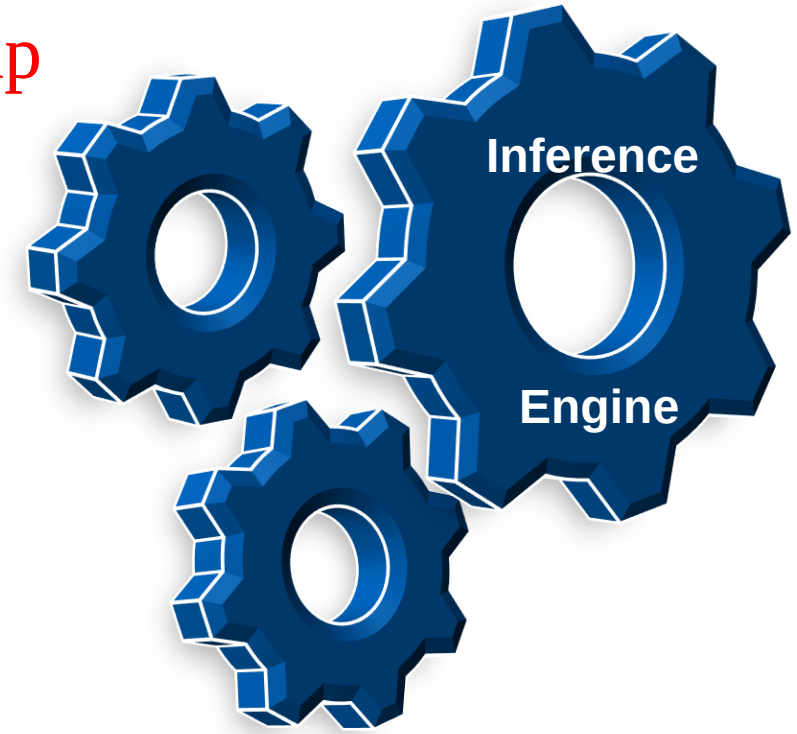
Backwards Chaining:

Start with a question – given the initial state and the rules, is the X true?

Check the data base – if X is there then it is true.

Check for a rule R where X is a consequent – if there is no R then X is false.

Recursively check is the antecedents of R are true.



Anatomy of An Expert System

Backwards Chaining:

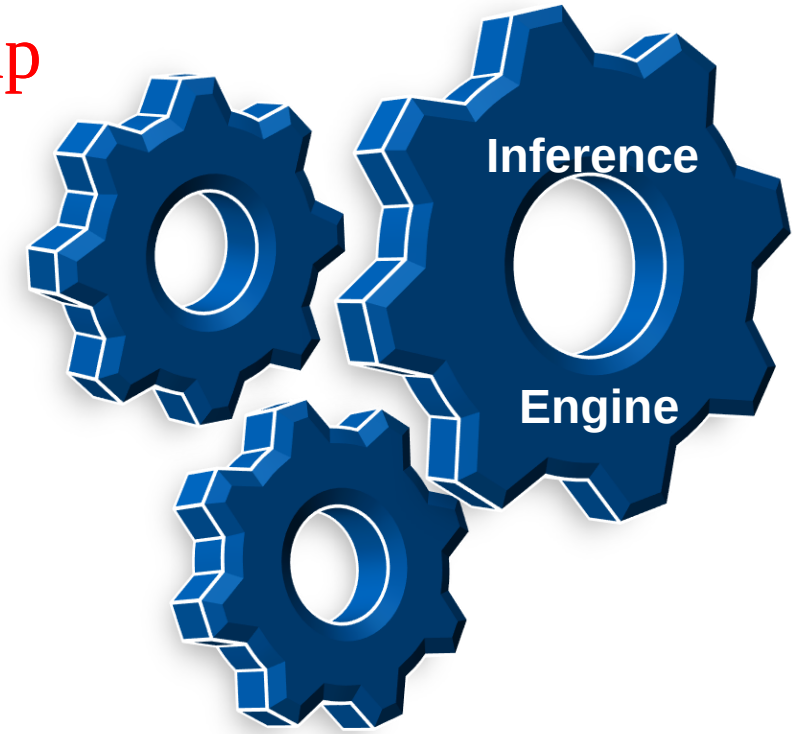
- .

LOW_PRESSURE
CLOUDY
COLD

IF LOW_PRESSURE & CLOUDY
THEN RAIN_LIKELY

IF HIGH_PRESSURE & NOT CLOUDY
THEN RAIN_UNLIKELY

Is RAIN_LIKELY true?



Anatomy of An Expert System

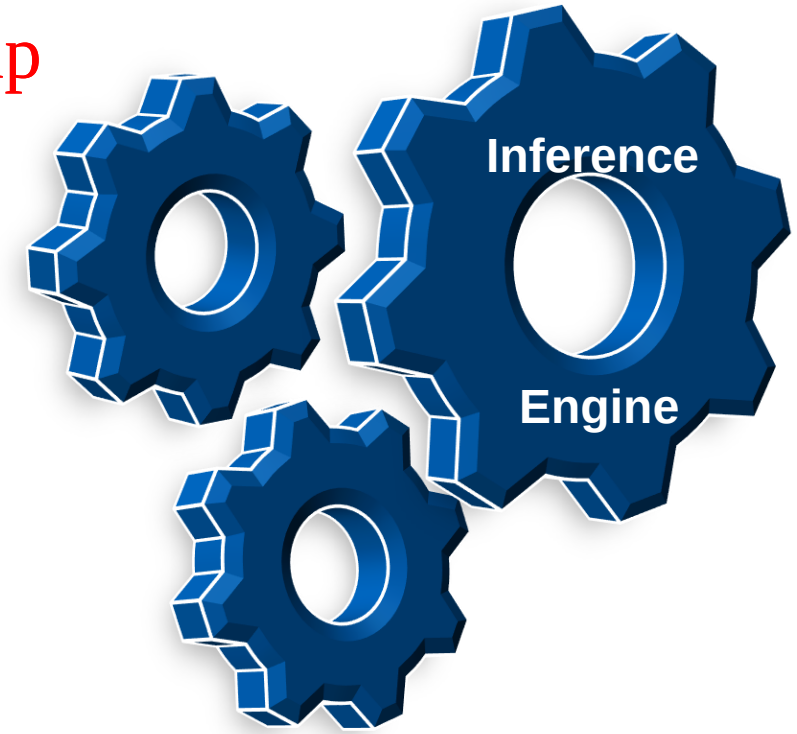
Backwards Chaining:

LOW_PRESSURE
CLOUDY
COLD

IF LOW_PRESSURE & CLOUDY
THEN RAIN_LIKELY

IF HIGH_PRESSURE & NOT CLOUDY
THEN RAIN_UNLIKELY

Is LOW_PRESSURE & CLOUDY true?



Anatomy of An Expert System

Backwards Chaining:

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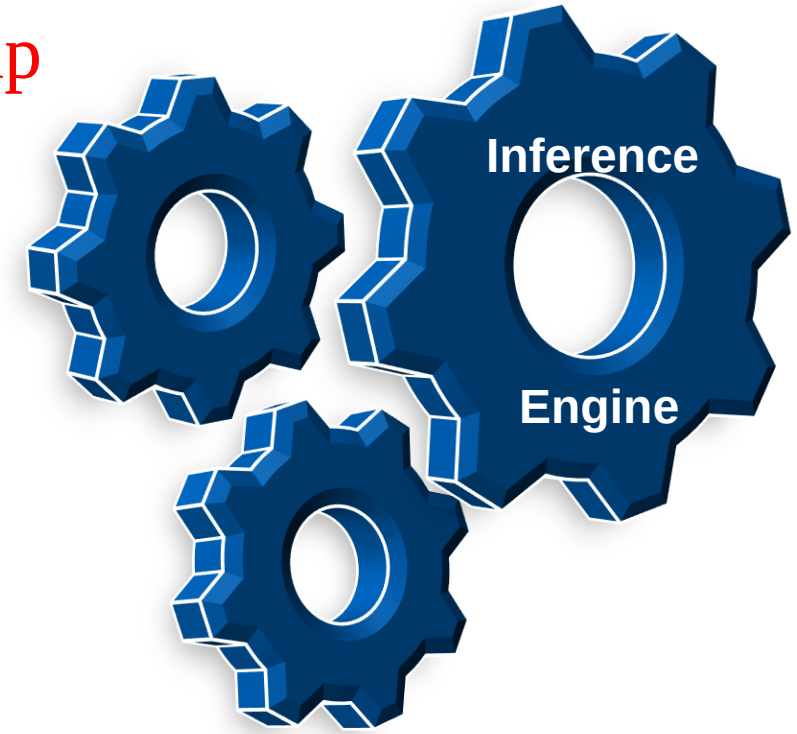
It then follows that RAIN_LIKELY is true!



Example Expert System

- The *rule base*:

1 SALTY AND FRIED--> GOOD
2 MEATY AND NO_VEGGIE--> YUMMY
3 MEATY AND VEGGIE AND NOT SALTY --> HEALTHY
4 COLD AND NOT MEATY --> YUCKY
5 NOT FRIED OR MEATY-->BAD

Forwards Chaining

- Benefits:
  - Good for query intensive applications:
  - Once you have derived all possible facts, querying is low cost (you can check the database many times).
  - Works well with dynamic environments:
  - Rules can be added to ensure that the database can be easily updated due to changes in the system state.

- Drawbacks:
  - Excessive overheads:
    Large rule base = lots of derived facts (very slow)
  - Wasted computations:
    Only a small subset of the derived facts may be required for the queries that are made.

Backwards Chaining

Benefits:

- On-demand inference:
  Derived facts are generated when necessary.
- Optimised Performance:
  Only the pertinent facts are derived.

Drawbacks:

- Replication of reasoning:
  Sometimes the same fact may be derived many times for the same state (can be alleviated through caching)
- Loss of intermediate facts:
  Often, any fact derived which checking a query is thrown away once the query is complete.

Beyond Propositional Symbols…

Experts systems can be extended to first-order logic:

- **Facts**: predicates
- **Rules**: Inferences
- **Inference Engine**: modus ponens (forward chaining) or resolution (backward chaining).

Example:

- Facts:
  - Is(greg, man), is(man, human)
  - Is(caroline, woman), is(woman, human)
- Rules:
  - is(X, Y) and is(Y, Z) => is(X, Z)
  - is(X, Z) and is(Y, Z) => same(X, Y)