LU29-Acting under Uncertainty

LU Objectives	
To handle uncertain knowledge and take rational decisions	
LU Outcomes	CO : 3
Ability to handle uncertain knowledge and take rational decisions	

Uncertainty - Introduction

What we have already learnt ?

- Under Problem Solving
  - Searching technique
  - Heuristic searching
- In all this environment, agent knows enough facts about its environment
- i.e The Environment gives enough information to the Agent to do actions towards the goal

What we are going to learn now ?

- Study about the uncertain environment of an agent.
- Here the agent will not get clear information
- So making decisions are difficult under unclear environment
- i.e. Identifying the truth of particular fact is difficult

UNCERTAIN KNOWLEDGE AND REASONING

- Uncertainty
- Review of probability
- Probabilistic Reasoning
- Bayesian networks
- Inferences in Bayesian networks
- ~~Temporal models~~
- ~~Hidden Markov models~~

Uncertainty

- When an agent knows enough facts about its environment, the logical plans and actions produces a guaranteed work.
- Unfortunately, *agents never have access to the whole truth about their environment.* Agents act under **uncertainty.**

CAR

- Example: Seeing the front elevation of the car. There are 2 tyres. (Automatically assume that there are another 2 tyres at the back)

NEXT

CAR

- Example: Seeing the front elevation of the car. There are 2 tyres. (Automatically assume that there are another 2 tyres at the back)
- But in rare cases, any of the back tire may be punctured or stolen out which we do not know if we are in the front side.
- Without the full knowledge about the environment, taking decisions are difficult or it may go around.

Nature of Uncertain Knowledge

- The Diagnosis : medicine, automobile repair, or whatever-is a task that almost always involves uncertainty

- Analyzing or judgementing something
- This may occur in
  - MEDICINE for a particular DISEASE
  - Identifying Automobile repair …

Nature of Uncertain Knowledge

- The Diagnosis : medicine, automobile repair, or whatever-is a task that almost always involves uncertainty
- Let us try to write rules for dental diagnosis using first-order logic, so that we can see how the logical approach breaks down. Consider the following rule:

  antecedent consequent

  - $\forall p \; \mathit{Symptom}(p, \mathit{Toothache}) \Rightarrow \mathit{Disease}(p, \mathit{Cavity})$.
- The problem is that this rule is wrong.
- Not all patients with toothaches have cavities; some of them have gum disease, swelling, or one of several other problems
  - $\forall p \; \mathit{Symptom}(p, \mathit{Toothache}) \Rightarrow \mathit{Disease}(p, \mathit{Cavity}) \vee \mathit{Disease}(p, \mathit{GumDisease}) \vee \mathit{Disease}(p, \mathit{Swelling}) \ldots$

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Nature of Uncertain Knowledge…

- to make the rule true, we have to add almost unlimited list of possible causes.
- We could try a causal rule:
  - $\forall p$ *Disease(p, Cavity)* $\Rightarrow$ *Symptom(p, Toothache)*.
- But this rule is also not right either; not all cavities cause pain
- Toothache and a Cavity are unconnected, so the judgement may go wrong.

Nature of Uncertain Knowledge...

- This is a type of the medical domain, as well as most other judgmental domains: law, business, design, automobile repair, gardening, dating, and so on.
- The agent take action, only a **degree of belief** in the relevant sentences.
- Our main tool for dealing with degrees of belief will be **probability theory**
- **The Probability** assigns to each sentence a numerical degree of belief between 0 and 1.

Uncertainty – Introduction
Theory Slides

Uncertainty - Introduction

- Agents may need to handle **uncertainty, whether due to partial observability, nondeterminism,** or a combination of the two.
- An agent may never know for certain what state it’s in or where it will end up after a sequence of actions.

Uncertainty - Introduction

- Problem-solving agents and logical agents handle uncertainty by **keeping track of a belief state** (It is the set of all possible world states that it might be in) and generating a contingency plan that handles every possible eventuality that its sensors may report during execution.
- **Drawbacks of this method**:
  - When interpreting partial sensor information, a logical agent must consider every logically possible explanation for the observations, no matter how unlikely. This leads to impossible large and complex belief-state representations.
  - A correct contingent plan that handles every eventuality can grow arbitrarily large and must consider arbitrarily unlikely contingencies.
  - Sometimes there is no plan that is guaranteed to achieve the goal—yet the agent must act.

Uncertainty - Introduction

- For example: A_{90} – Leaving to airport 90 minutes earlier to catch the flight avoiding the long waiting time in the airport
- Many **subjective factors** are involved and None of the conditions could be deduced and hence the plan success could not be inferred

- Even though the airport is only about 5 miles away, a logical taxi agent will not be able to conclude with certainty that "Plan A90 will get us to the airport in time."
- **Factors**: Instead, it reaches the weaker conclusion "Plan A90 will get us to the airport in time, as long as the car doesn't break down or run out of gas, and I don't get into an accident, and there are no accidents on the bridge, and the plane doesn't leave early, and no meteorite hits the car, and . . . ."
- None of these conditions can be deduced for sure, so the plan's success cannot be inferred.

Uncertainty - Introduction

- For example: A_{90} – Leaving to airport 90 minutes earlier to catch the flight avoiding the long waiting time in the airport
- Many subjective factors are involved and None of the conditions could be deduced and hence the plan success could not be inferred
- This is an example for the **qualification problem**

- A90 is expected to **maximize the agent's performance measure** (where the expectation is relative to the agent's knowledge about the environment).
- The performance measure includes **getting to the airport in time** for the flight, **avoiding a long, unproductive wait** at the airport, and **avoiding speeding tickets** along the way.
- The agent's knowledge **cannot guarantee any of these outcomes for A_{90}**, but it can provide some degree of belief that they will be achieved.

Uncertainty - Introduction

- For example: A_{90} – Leaving to airport 90 minutes earlier to catch the flight avoiding the long waiting time in the airport
- Many subjective factors are involved and None of the conditions could be deduced and hence the plan success could not be inferred
- This is an example for the **qualification problem**
- Hence conditional planning can be deployed provided enough information is available through sensing mechanism and no too many contingencies are available
- The information may not guarantee the achievement of the A_{90} (A_{120})

Uncertainty – Introduction …contd

The right thing to do is take the rational decision which depends on the relative importance of the various **goals** and the **likelihood** that and **degree** to which, they will be achieved.

Handling the uncertain knowledge
Uncertain Reasoning

antecedent **consequent**

For all p,
Symptom(p, Toothache} => Disease(p, Cavity) .. Not true in all cases

For all *p*,
Symptom(p, Toothache) =>
Disease(p, Cavity) V Disease(p, GumDisease) V Disease(p, ImpactedWisdom)...

We could try turning the rule into a causal rule
For all p,
Disease(p, Cavity) => Symptom(p, Toothache)

But this rule is not right either; not all cavities cause pain

Handling the uncertain knowledge …contd

Trying to use first-order logic to cope with a domain like medical diagnosis thus fails for three main reasons:

1. **Laziness**: It is too much work to list the complete set of antecedents or consequents needed to ensure an exceptionless rule, and too hard to use the enormous rules that result.
2. **Theoretical ignorance:** Medical science has no complete theory for the domain.
3. **Practical ignorance**: Even if we know all the rules, we may be uncertain about a particular patient because all the necessary tests have not or cannot be run

Uncertainty and rational decisions

- The connection between toothaches and cavities is just not a logical consequence in either direction.
- This is typical of the medical domain, as well as most other judgmental domains: law, business, design, automobile repair, gardening, dating, and so on.
- Hence the agent's knowledge can at best provide only a **degree of belief** in the relevant sentences.
- The main tool for dealing with degrees of belief will be **probability theory,** which assigns a numerical degree of belief between 0 and 1 to sentences

Uncertainty and rational decisions

- Probability provides a way **of summarizing** the uncertainty that comes from our laziness and ignorance
- Belief could be derived from statistical data—80% of the toothache patients seen so far have had cavities—or from some general dental knowledge, or from a combination of evidence sources.
- But there is no uncertainty in the actual world: the patient either has a cavity or doesn’t. So what does it mean to say the probability of a cavity is 0.8? Shouldn’t it be either 0 or 1?
- Probability statements are made with respect to a knowledge state, not with respect to the real world.

Uncertainty and rational decisions

- A sentence such as “the probability that the patient has a cavity is 0.8” is about the agent’s belief not directly about the world
- The belief depends on the percepts the agent has received to date
- Prior or unconditional probability and the conditional or posterior probability are subjects of studies dealing with them

Uncertainty and rational decisions…contd

- In Airport reaching problem, **A1440**, a plan that involves leaving home 24 hours in advance, can it be used?
- In most circumstances, this is not a good choice, because although it almost guarantees getting there on time, it involves an intolerable wait—not to mention a possibly unpleasant diet of airport food.
- An agent must first have **preferences between the different possible outcomes of the various plans**.
- An outcome is a completely specified state, including such factors as whether the agent arrives on time and the length of the wait at the airport.
- We use utility theory to represent and reason with preferences.
- Utility theory says that every state has a degree of usefulness, or utility, to an agent and that the agent will prefer states with higher utility.

Uncertainty and rational decisions…contd

Utility theory related to the preferences and outcomes of the various plan (The utility of a state is relative to an agent)

Hence

Decision theory = probability theory + utility theory

The fundamental idea of decision theory is that an agent is rational if and only if it chooses the action that yields the highest expected utility, averaged over all the possible outcomes of the action. This is called the principle of **maximum expected utility (MEU).**

Here expected means the "average," or "statistical mean" of the outcomes, weighted by the probability of the outcome.

Design for a decision-theoretic agent

function DT-AGENT(*percept)* **returns** an *action*

static: belief state a set probabilistic beliefs about the state of the world

action – the agent's action

1. **update** belief state based on the action and percept
2. **calculate** outcome probabilities for actions, given action descriptions and probabilities of current states
3. **select *action*** with highest expected utility given probabilities of outcomes and utility information

return *action*

The primary difference between an ordinary agent and decision – theoretic agent is that the decision-theoretic agent's belief state represents not just the *possibilities for world* states but also their *probabilities.*

Assessment questions

Define uncertainty.	**2**	**K1**
Why rational decision is important in uncertainty?	2	K1
Why first order logic fails in uncertainty?	4	K2
What do you mean by degree of belief?	2	K1
Define uncertain knowledge, prior probability and conditional probability.	4	K1

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