Uncertainty

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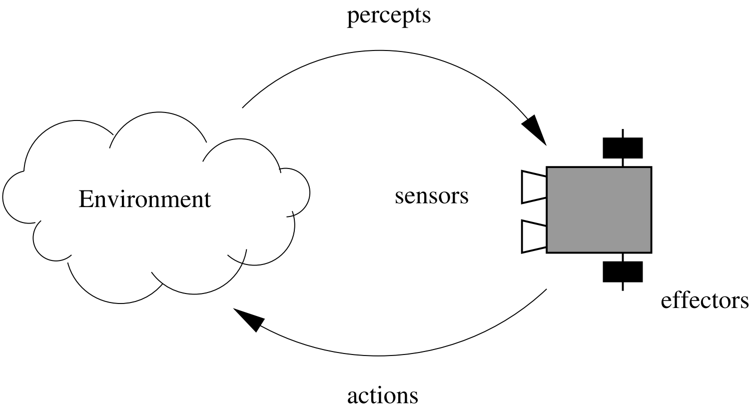
Today

- Introduction
- Probabilistic Reasoning
- Sequential Decision Making
- Game Theory
- (A peek at) Machine Learning
- Argumentation
- AI & Ethics

Recap



- AI Systems operate in environments

Recap

- Environments are:
  - Acessible or not.
  - Deterministic / stochastic / non-deterministic
  - Static or Dynamic
  - Sequential or Episodic
  - Discrete or continuous
  - Observable / Fully observable / partially observable.

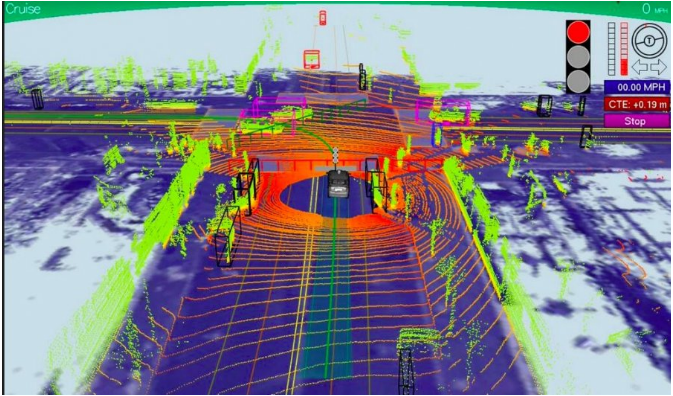
Partial observability

- Full observability: Chess, Go, Ur
- Partial observability: Poker, Starcraft, Fornite, 0AD ...

Real world: Partially observable environment

(mystorybook.com/books/42485)

Real world: Partially observable environment



(Sebastian Thrun & Chris Urmson/Google)

Partial observability

- Partial observability can arise for many reasons.
  - World structure $vs.$ sensor ability.
  - Sensor noise.
  - Computational complexity.
- Partial observability → uncertainty. This will allow us to derive abstract models.

Uncertainty

- Say you're at the Strand campus and you have to catch a flight at Heathrow Airport
- When do you leave?
- Let action A_t: you leave for airport t minutes before the flight
- Example: A_{60}: you leave one hour before
- Will A_t get me there on time?
- Problems:
  1. partial observability (tube state, other travelers' plans, etc.)
  2. noisy sensors (Google Maps' traffic updates)
  3. uncertainty in action outcomes (strike, too many leaves, issues with the signalling, etc.)
  4. immense complexity of modelling and predicting traffic

Example: Modelling Uncertainty

- Making statements based on partial observations is tricky
    1. risks falsehood: "A_{90} will get me there on time"
    2. leads to conclusions that are too weak for decision making:
       "A_{90} will get me there on time if there are fewer than 300 people at the the first two stops, and there is no strike and the signalling remains intact etc."

(bbc.co.uk) *(Getty Images)*

Uncertainty

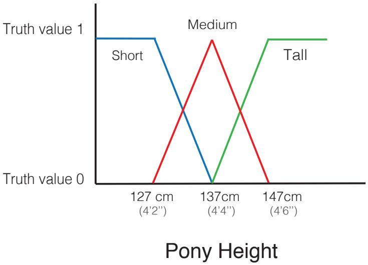
- Play safe: A_{1440} might reasonably be said to get me there on time but you'd have to stay overnight in the airport . . .
- Can we do something better?

Methods for handling uncertainty

- Use probability
  - Given the available evidence,
    A_{25} will get me there on time with probability 0.04
- Probabilistic assertions summarize effects of
  - laziness: failure to enumerate exceptions, qualifications, etc.
  - ignorance: lack of relevant facts, initial conditions, etc.
- Even with probabilistic assumptions there are still issues: Computational complexity, obtaining values, semantics.
  - We will consider the computational issues in some detail.

Aside

- Fuzzy logic handles degree of truth NOT uncertainty
  - Given a 142cm-tall pony we have
  - $ShortPony$ is true to degree 0
  - $MediumPony$ is true to degree 0.5
  - $TallPony$ is true to degree 0.5



Probability

- Subjective or Bayesian probability:
  - Probabilities relate propositions to one's own state of knowledge
  - $P(A_{25}) = 0.04$. Knowing that no traffic issues was reported (say in the morning), makes it more likely

$$P(A_{25}|\text{no reported traffic issues}) = 0.06$$

- Probabilities of propositions change with new evidence:

$$P(A_{25}|\text{no reported traffic issues, leaving at 5 a.m.}) = 0.15$$

$$P(A_{25}|\text{no reported traffic issues, leaving at 9 a.m.}) = 0.03$$

Making decisions under uncertainty

- Suppose I believe the following:

$$\begin{aligned}
P(A_{25} \text{ gets me there on time} | \ldots) &= 0.04 \\
P(A_{90} \text{ gets me there on time} | \ldots) &= 0.70 \\
P(A_{120} \text{ gets me there on time} | \ldots) &= 0.95 \\
P(A_{1440} \text{ gets me there on time} | \ldots) &= 0.9999
\end{aligned}$$

Which action to choose?

Methods for handling uncertainty

- Depends on our preferences for missing flight vs. airport cuisine, sleeping on a bench, and so on.
- Utility theory is used to represent and infer preferences
- Decision theory = utility theory + probability theory
- We will come back to decision theory in a few weeks.

Summary

- There is a lot of uncertainty
- Uncertainty can be modelled very well by using probabilities