CS 5/7320
Artificial Intelligence

Making Simple Decisions
AIMA Chapter 16

Introduction slides by Michael Hahsler

Decision network slides by Dan Klein and Pieter Abbeel

What is a simple decision?

- The environment most likely is **stochastic** with non-deterministic actions. It may also only be **partially observable**. Otherwise, making a decision would be trivial.
- We make the same decision frequently + making it once does not affect future decisions. This means we have an **episodic environment**.

- Decision theory formalizes making optimal simple decisions under uncertainty.

Decision theory =
Probability theory (evidence & belief)
+
Utility theory (want)

Decision-theoretic Agents (=Utility-based Agent)

Logical agents

Cannot deal with:
- Uncertainty
- Conflicting goals

Goal-based agents

- Can only assign goal/not goal to states and find goal states.

Utility-based agents

- Assign a utility value to each state.
- A rational agent optimizes the expected utility (i.e., is utility-based).
- Utility is related to the external performance measure (see PEAS).

Utility

- A utility function $U(s)$ expresses the desirability of being in state s.
- Utility functions are derived from preferences:

$$U(A) > U(B) \Leftrightarrow A \succ B$$

and

$$U(A) = U(B) \Leftrightarrow A \sim B$$

- It is often enough to know a **ordinal utility function** representing a **ranking** of states to make decisions.

Expected Utility of an Action Under Uncertainty

We need:

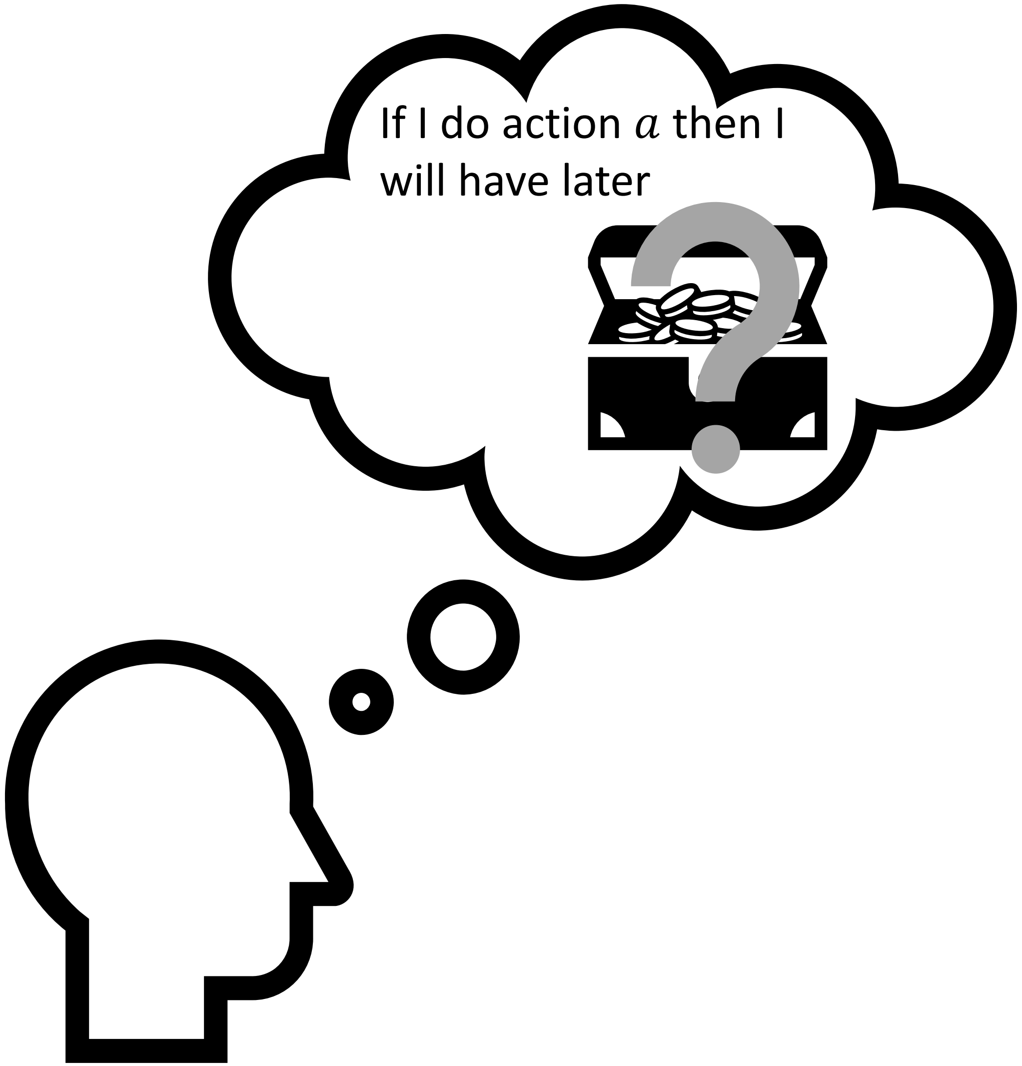
- A **cardinal utility** function $U(s)$ where the number represents levels of absolute satisfaction.
- The probability $P(s)$, that the current state is s.
- Transition probabilities $P(s'|s,a)$.

The probability that action a will get us to a future state s'

$$P(Result(a) = s') = \sum_{s} P(s)\, P(s'|s,a)$$

The expected utility of action a over all possible states is

$$EU(a) = \sum_{s'} P(Result(a) = s')\, U(s')$$



Principle of Maximum Expected Utility (MEU)

Given the expected utility of an action

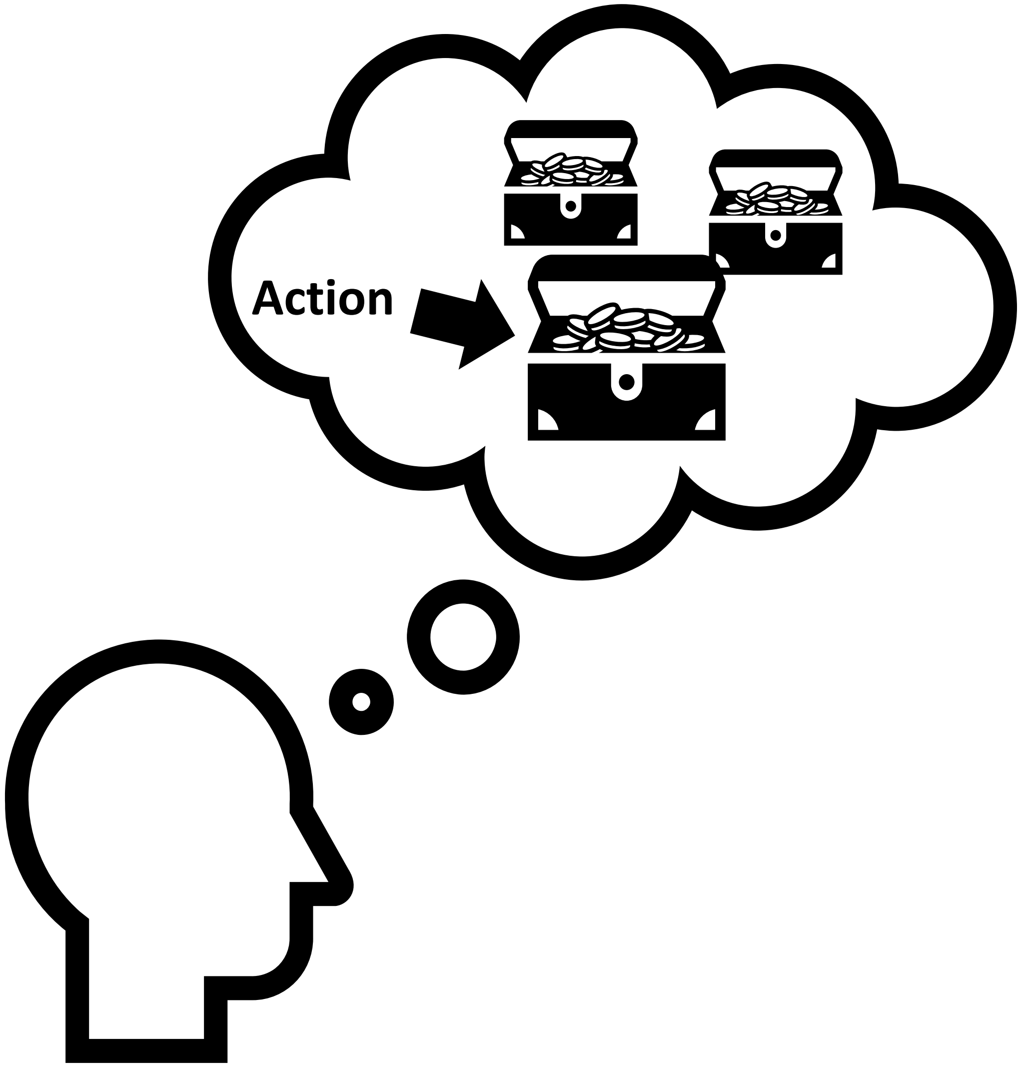
$$EU(a) = \sum_{s'} P(Result(a) = s')\, U(s')$$

choose action that maximizes the expected utility:

$$a^* = \text{argmax}_a\, EU(a)$$

Issues:

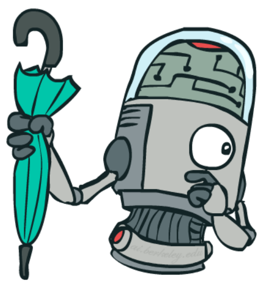
- $P(Result(a) = s') = \sum_s P(s)\, P(s'|s, a)$ may be a very large table.
- $U(s)$ may be hard to estimate. It may depend on what states we can get to from s.



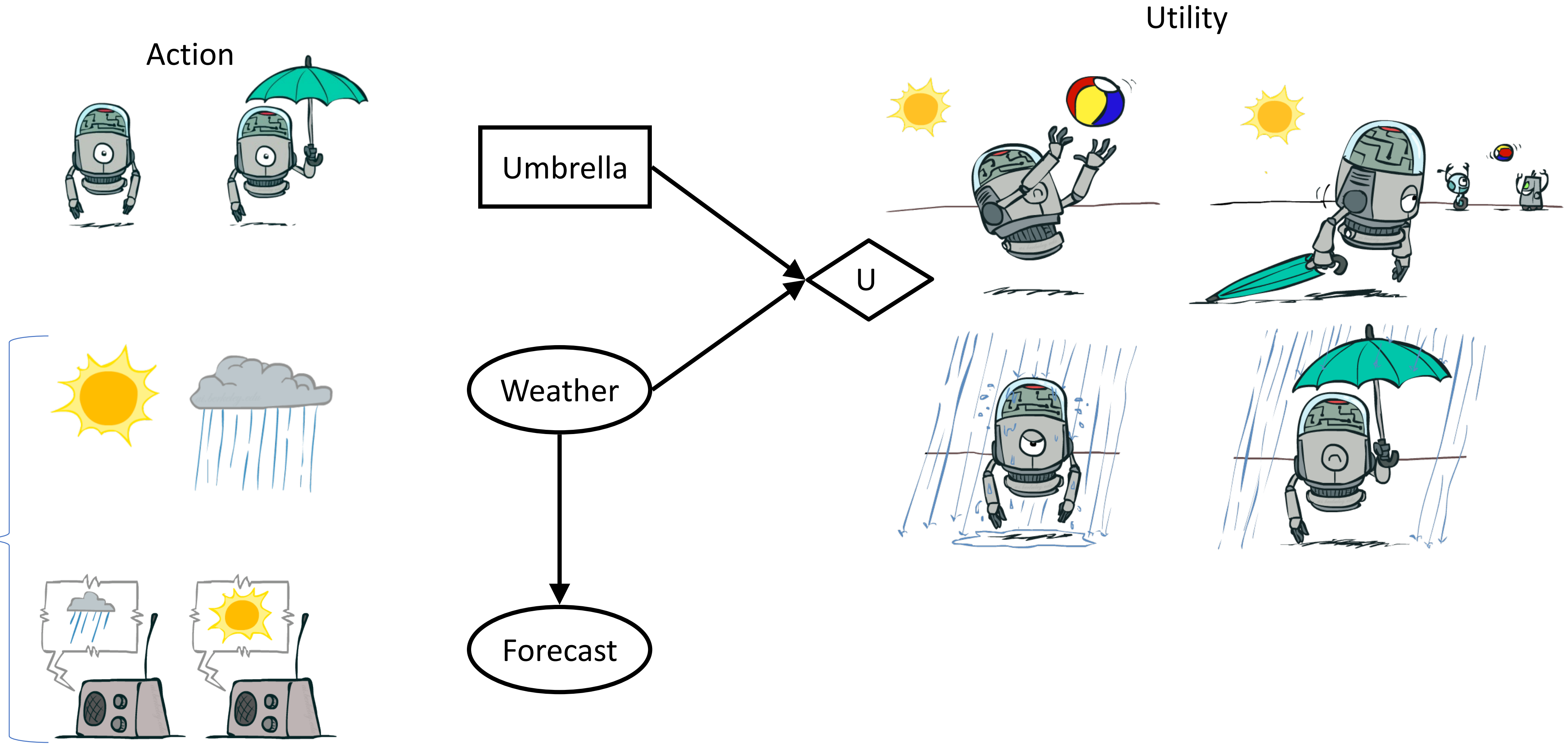
Decision Networks

Using Bayes Nets to calculate the Expected Utility of Actions.

These slides were created by Dan Klein, Pieter Abbeel, Sergey Levine, with some materials from A. Farhadi. All CS188 materials are at http://ai.berkeley.edu



Decision Networks



Random Events

Decision Networks

Decision networks

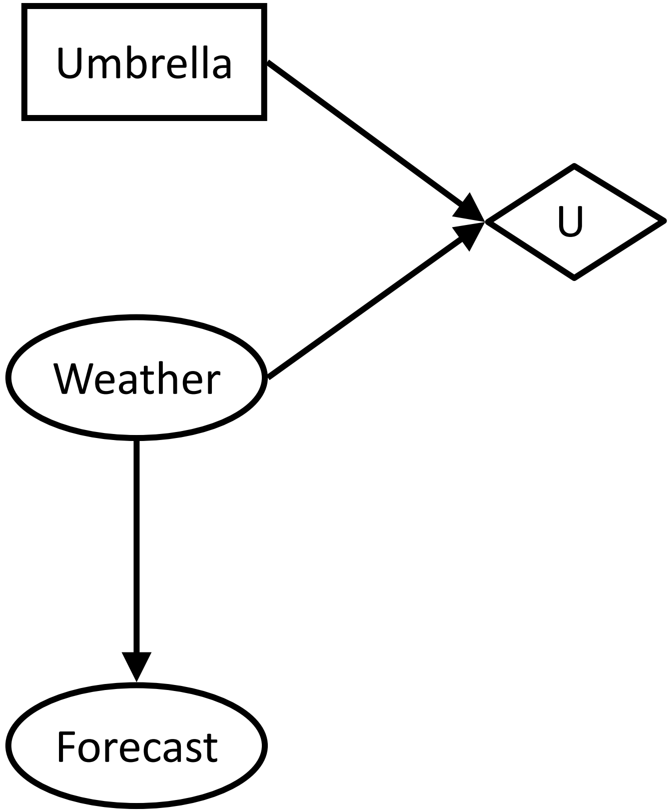
- Bayes nets with additional nodes for utility and actions.
- Allows to specify the joint probability in a compact way using independence.
- Calculate the expected utility for each possible action and choose the best.

Node types

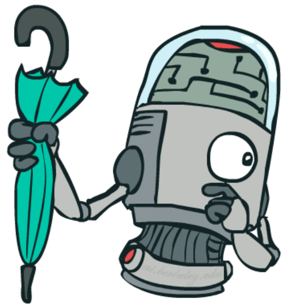
Chance nodes: Random variables in BNs

Action nodes: Cannot have parents, act as observed evidence

Utility node: Depends on action and chance nodes



Decision Network without Forecast



Action: Umbrella = leave

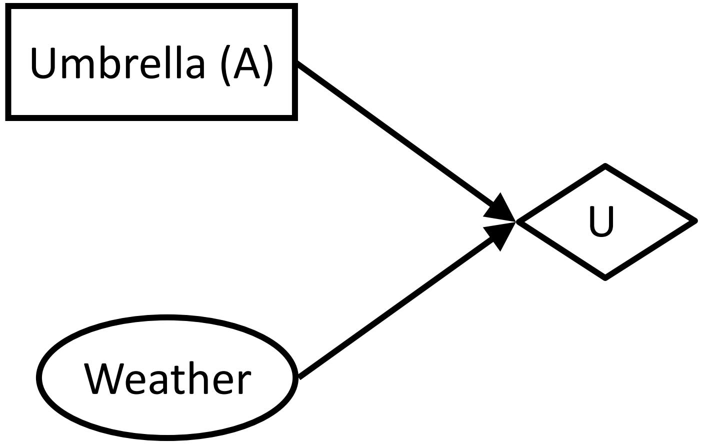
$$\text{EU}(\text{leave}) = \sum_{w} P(w)U(\text{leave}, w)$$
$$= 0.7 \cdot 100 + 0.3 \cdot 0 = 70$$

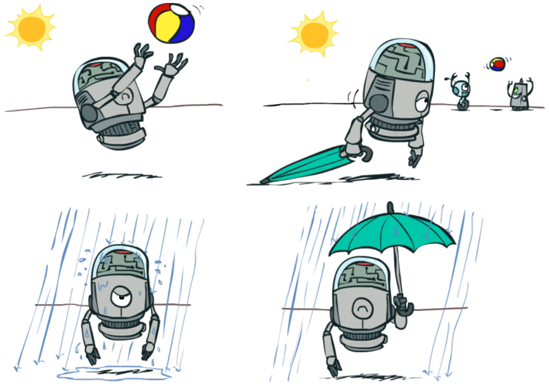
Action: Umbrella = take

$$\text{EU}(\text{take}) = \sum_{w} P(w)U(\text{take}, w)$$
$$= 0.7 \cdot 20 + 0.3 \cdot 70 = 35$$

Optimal decision a^* = leave

$$\text{MEU}(\emptyset) = \max_{a} \text{EU}(a) = 70$$

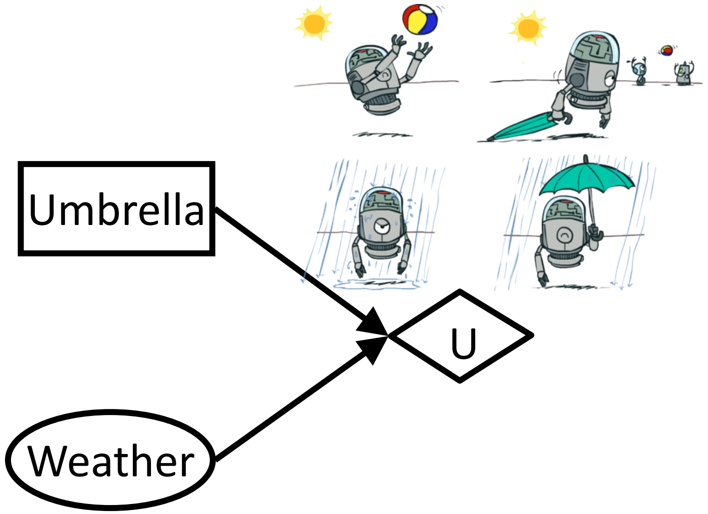


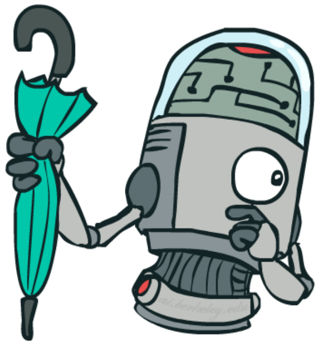


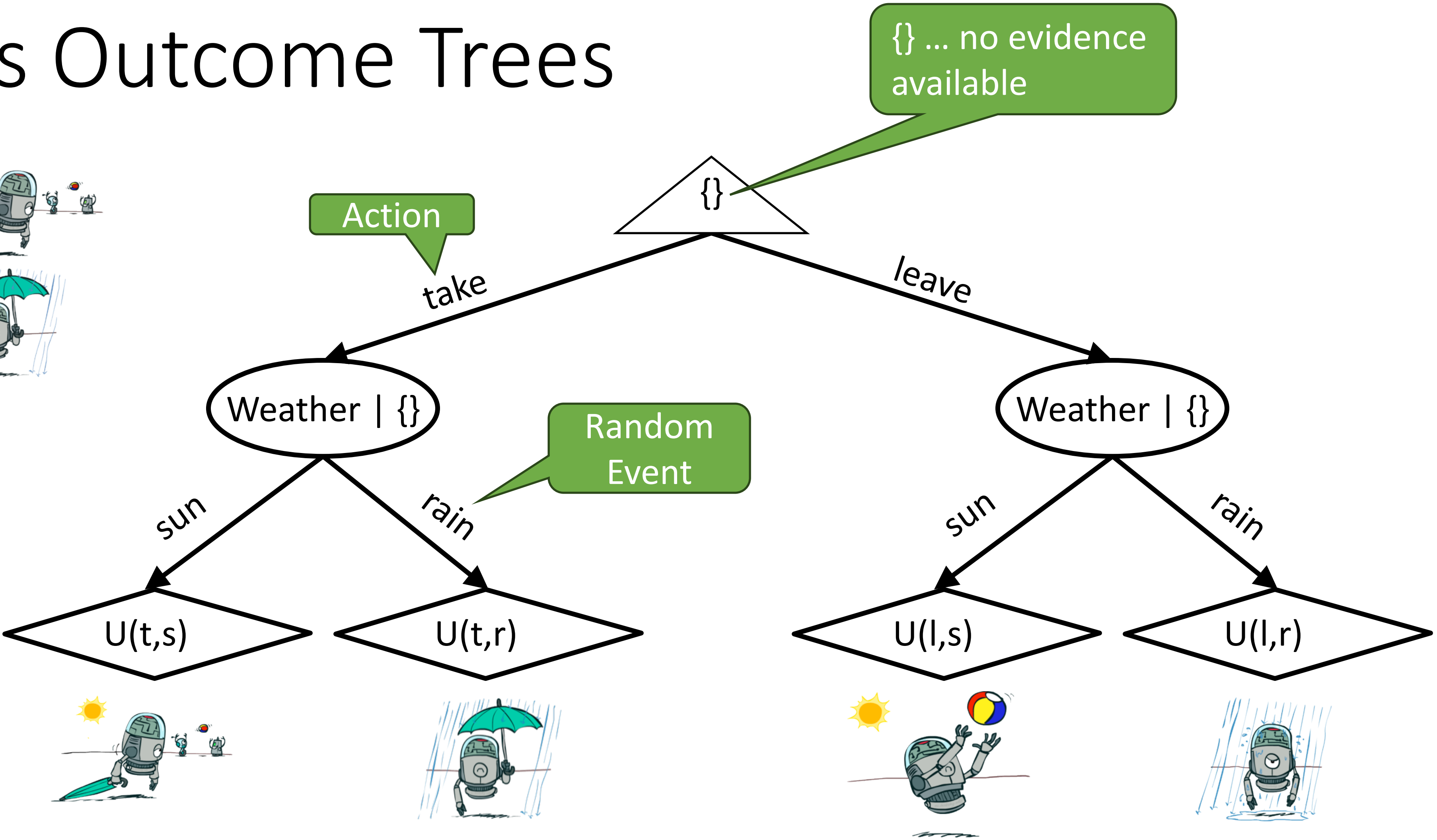
W	$P(W)$
sun	0.7
rain	0.3

A	W	$U(A,W)$
leave	sun	100
leave	rain	0
take	sun	20
take	rain	70

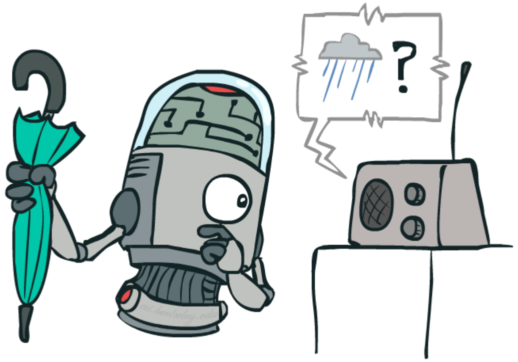
Decisions as Outcome Trees







Decision Network with Bad Forecast



Action: Umbrella = leave

$$\mathrm{EU}(\mathrm{leave}|\mathrm{bad}) = \sum_w P(w|\mathrm{bad})U(\mathrm{leave}, w)$$

$$= 0.34 \cdot 100 + 0.66 \cdot 0 = 34$$

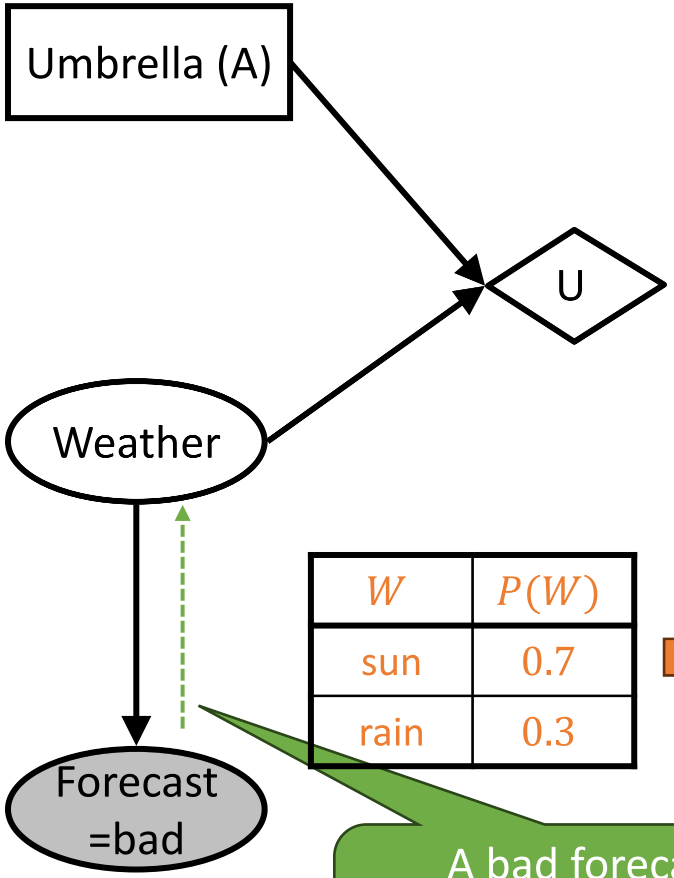
Action: Umbrella = take

$$\mathrm{EU}(\mathrm{take}|\mathrm{bad}) = \sum_w P(w|\mathrm{bad})U(\mathrm{take}, w)$$

$$= 0.34 \cdot 20 + 0.66 \cdot 70 = 53$$

Optimal decision = take

$$\mathrm{MEU}(F = \mathrm{bad}) = \max_a \mathrm{EU}(a|\mathrm{bad}) = 53$$



A	W	$U(A,W)$
leave	sun	100
leave	rain	0
take	sun	20
take	rain	70

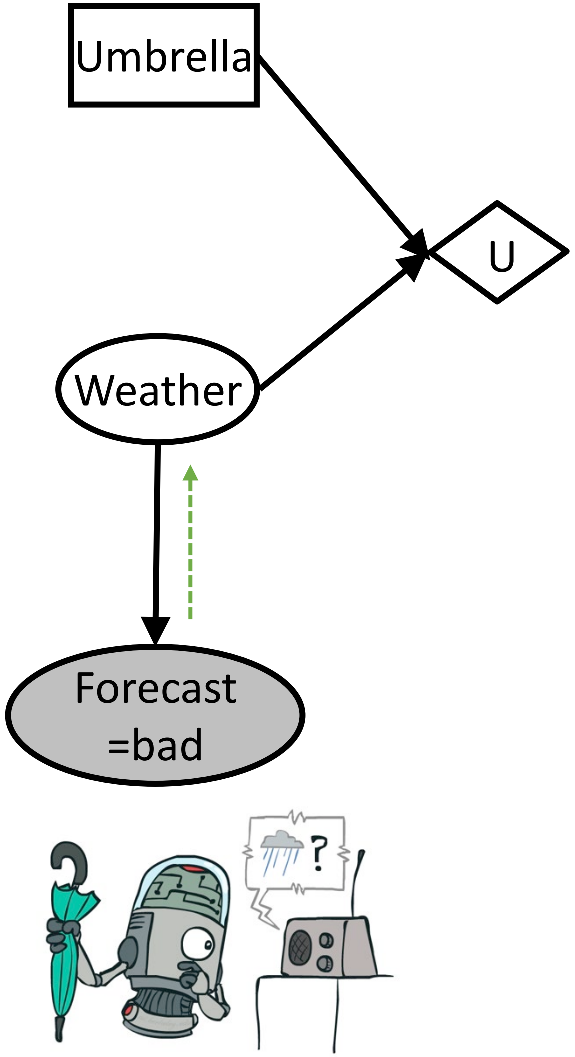
W	$P(W)$
sun	0.7
rain	0.3

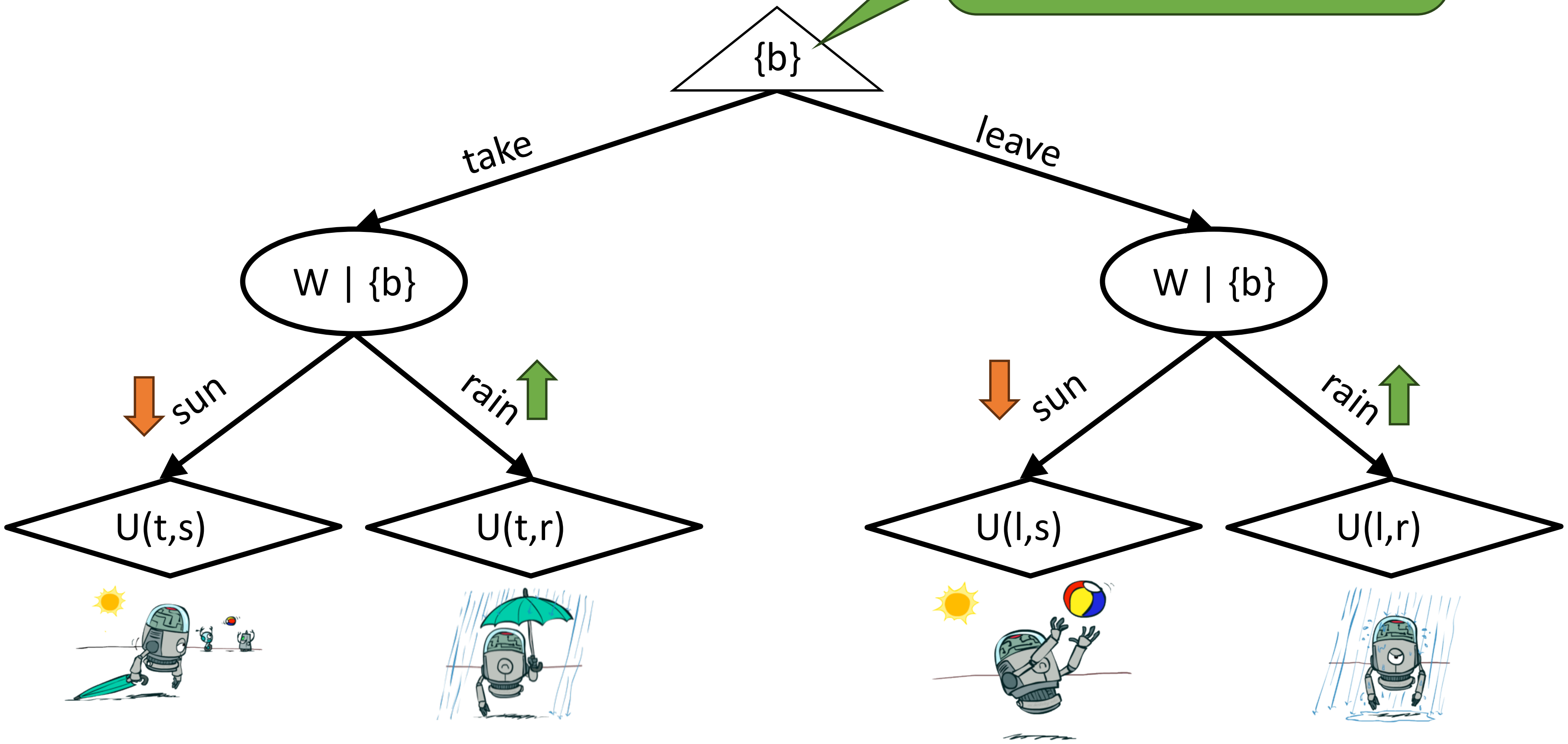
W	$P(W\|F = bad)$
sun	0.34
rain	0.66

A bad forecast increases the probability of rain!

Decisions as Outcome Trees

{b} … evidence is bad weather forecast increases the probability of rain





Conclusion

Decision networks are an extension of Bayes nets that add actions and utility to compactly specify the joint probability.

The network is used to calculate the expected utility of actions.

Decision networks can be used to make simple repeated decisions in a stochastic, partially observable, and episodic environment.

Sequential decision-making deals with decisions that influence each other and are made over time. This is a more complex decision problem and needs different methods like **Markov Decision Processes.**