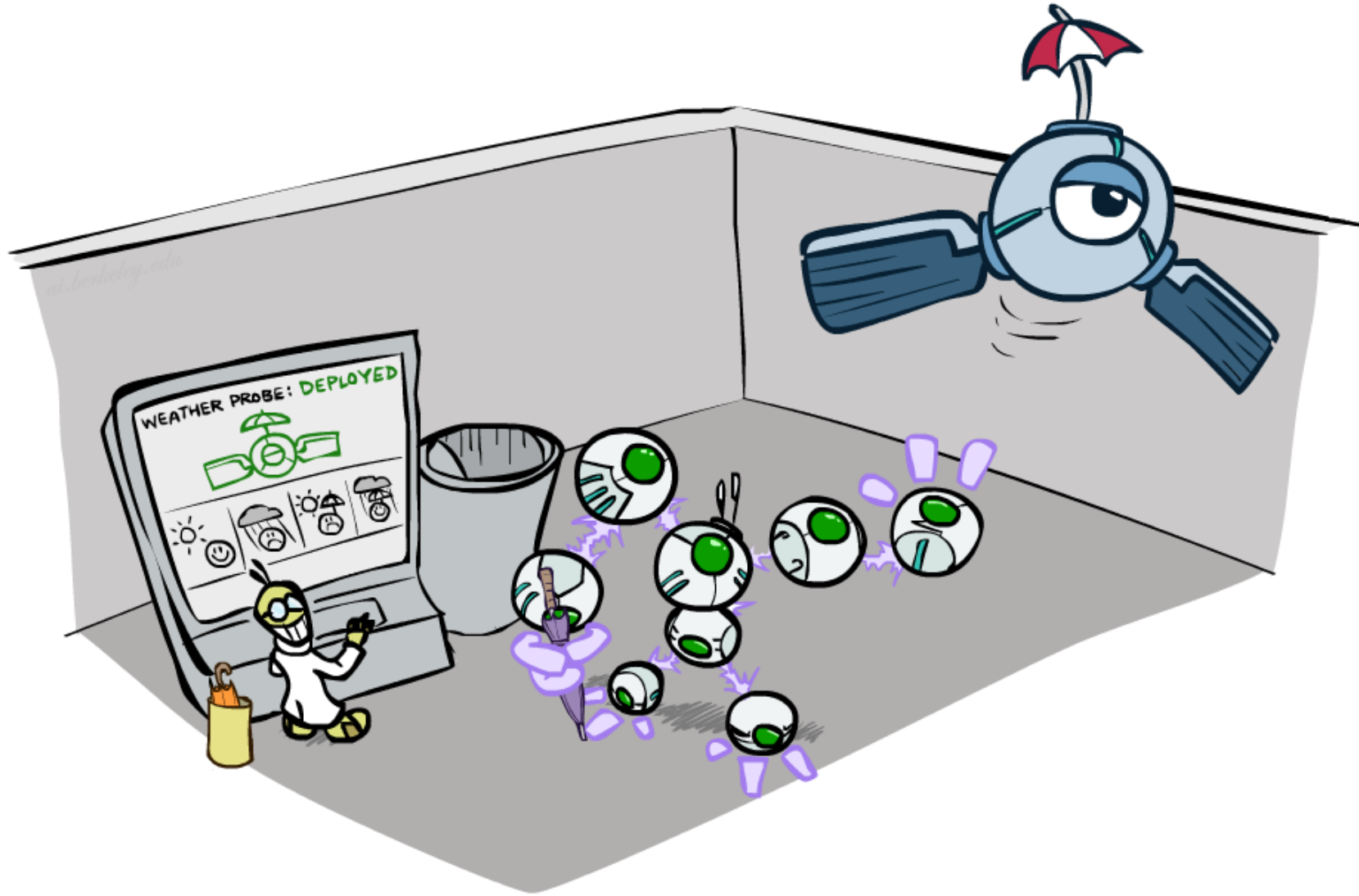
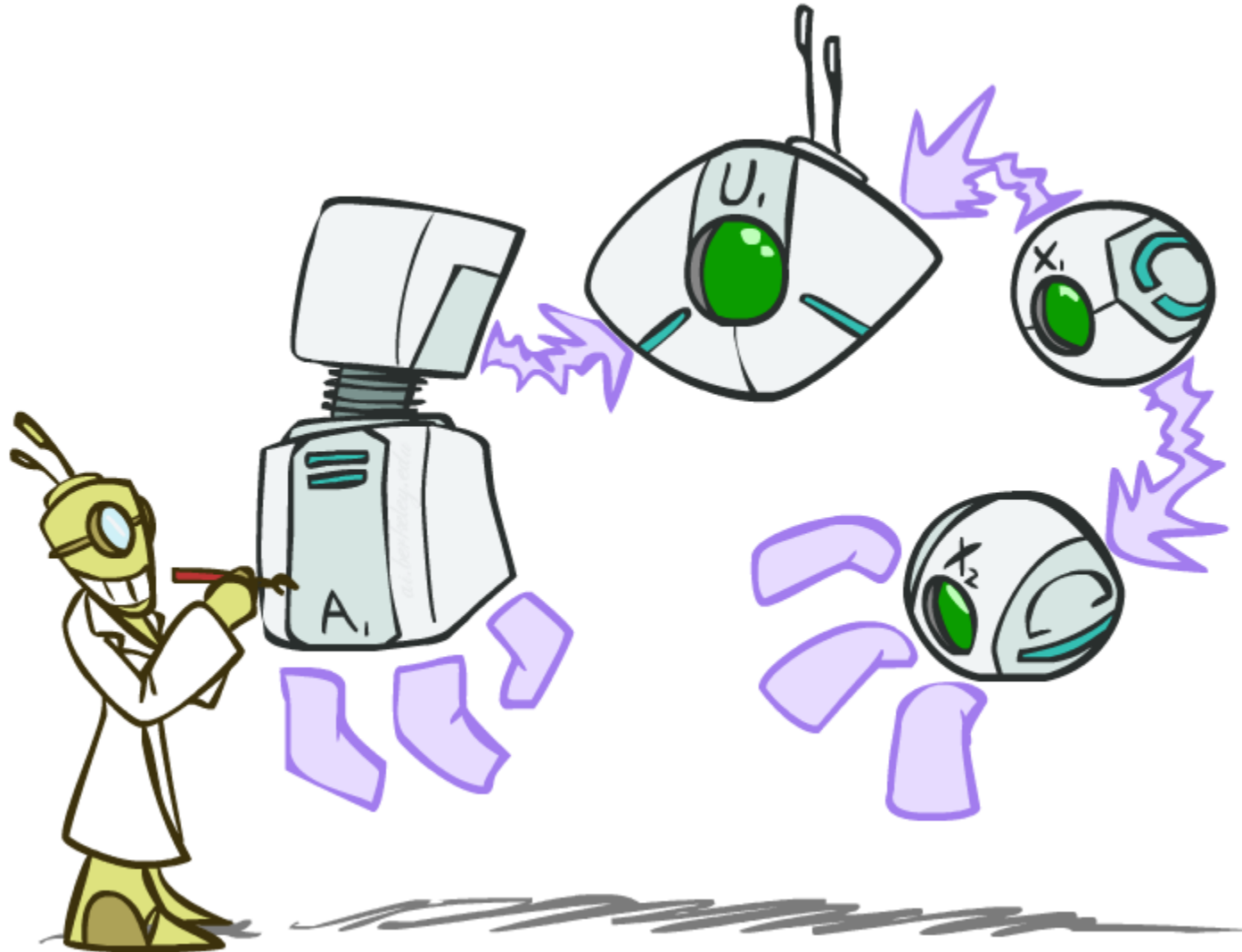


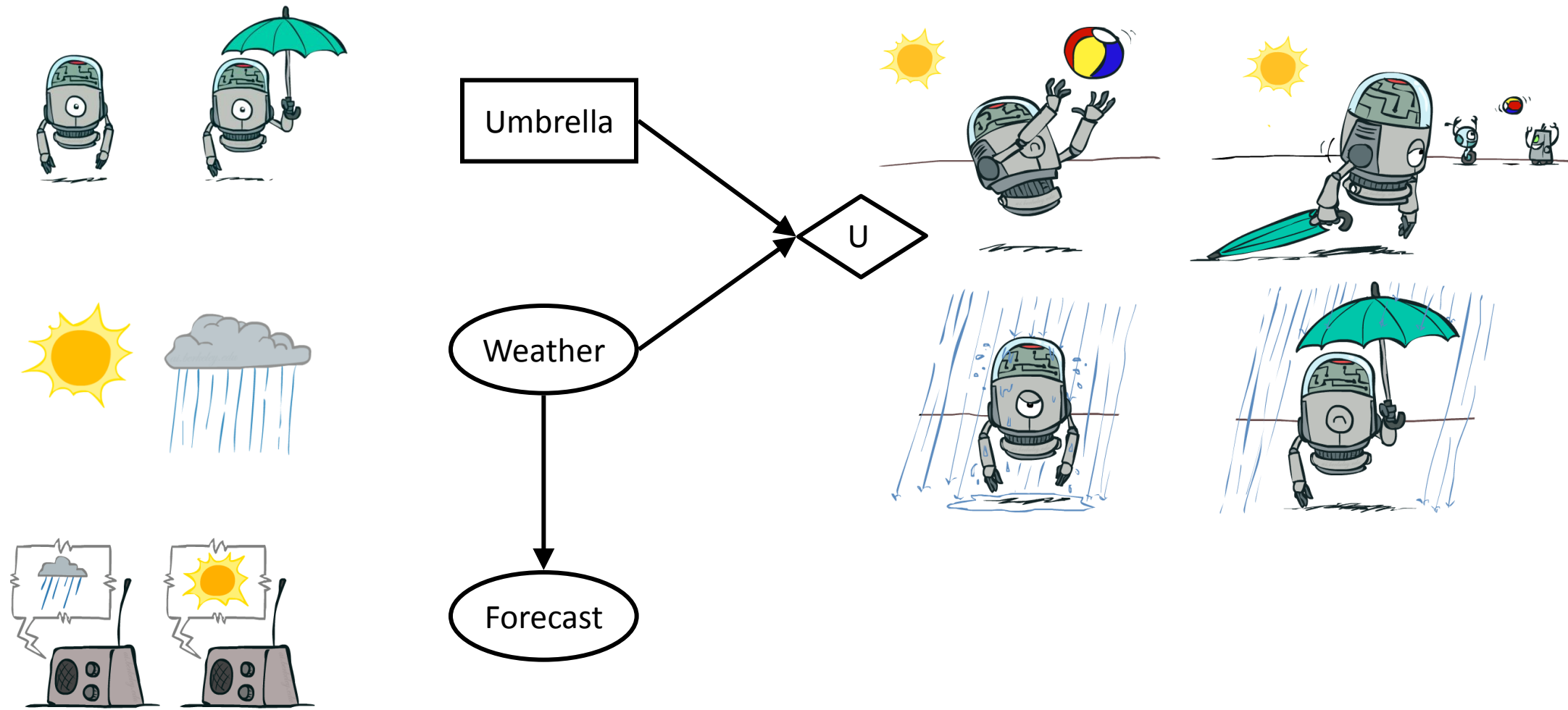
Decision Networks and Value of Perfect Information



Decision Networks



Decision Networks



Decision Networks

- **MEU: choose the action which maximizes the expected utility given the evidence**

- Can directly operationalize this with decision networks

- Bayes nets with nodes for utility and actions
- Lets us calculate the expected utility for each action

- New node types:



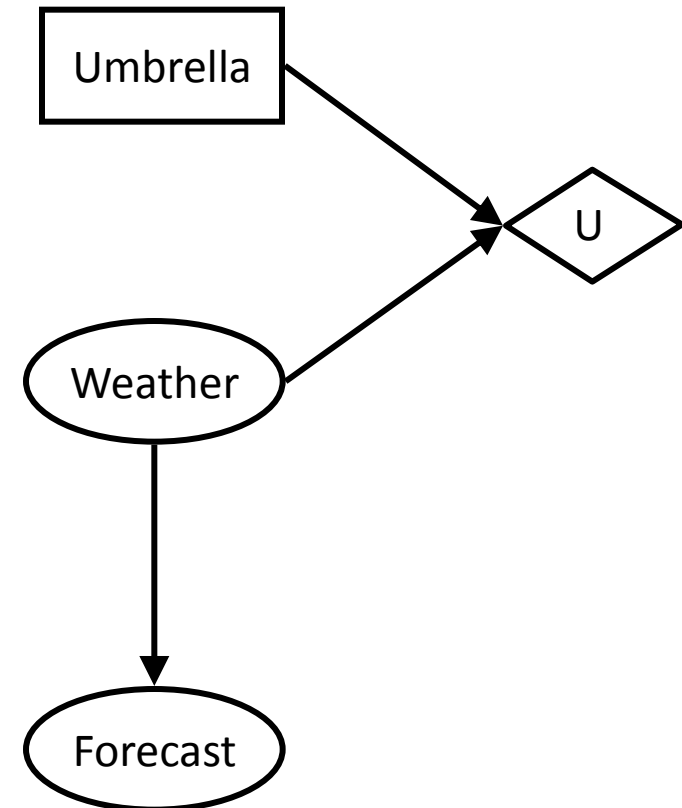
- Chance nodes (just like BNs)



- Actions (rectangles, cannot have parents, act as observed evidence)

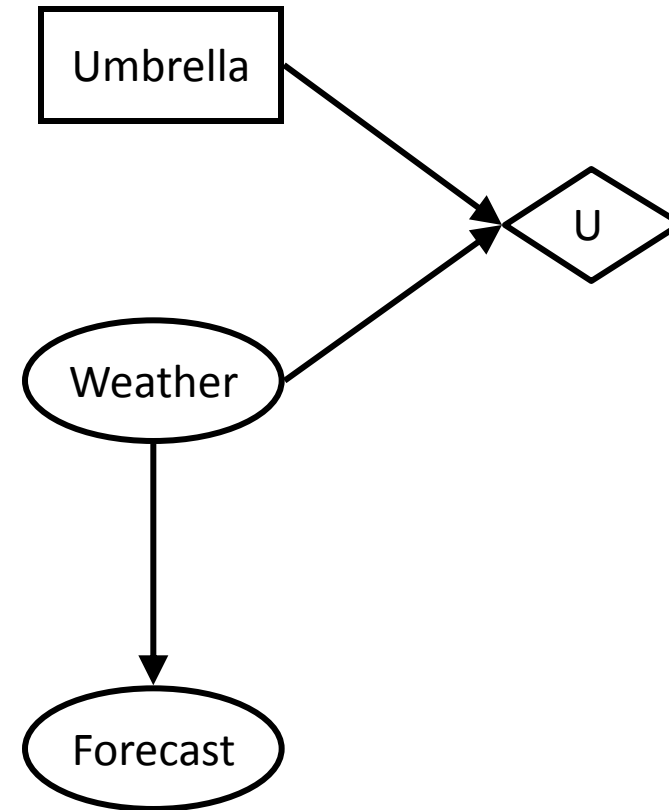


- Utility node (diamond, depends on action and chance nodes)



Decision Networks

- Action selection
 - Instantiate all evidence
 - Set action node(s) each possible way
 - Calculate posterior for all parents of utility node, given the evidence
 - Calculate expected utility for each action
 - Choose maximizing action



Decision Networks

Umbrella = leave

$$EU(\text{leave}) = \sum_w P(w)U(\text{leave}, w)$$

$$= 0.7 \cdot 100 + 0.3 \cdot 0 = 70$$

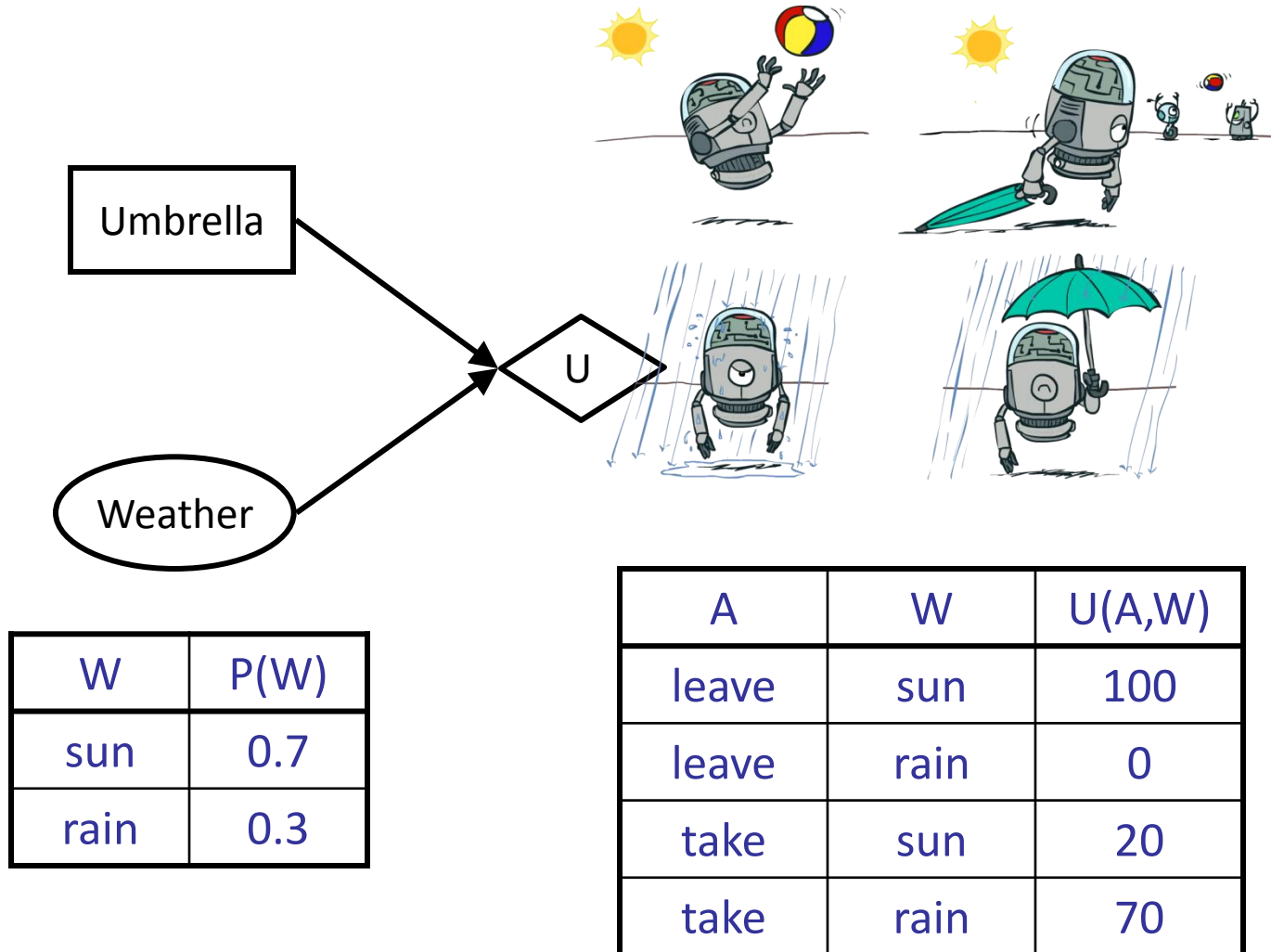
Umbrella = take

$$EU(\text{take}) = \sum_w P(w)U(\text{take}, w)$$

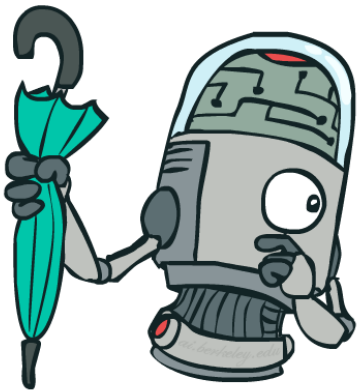
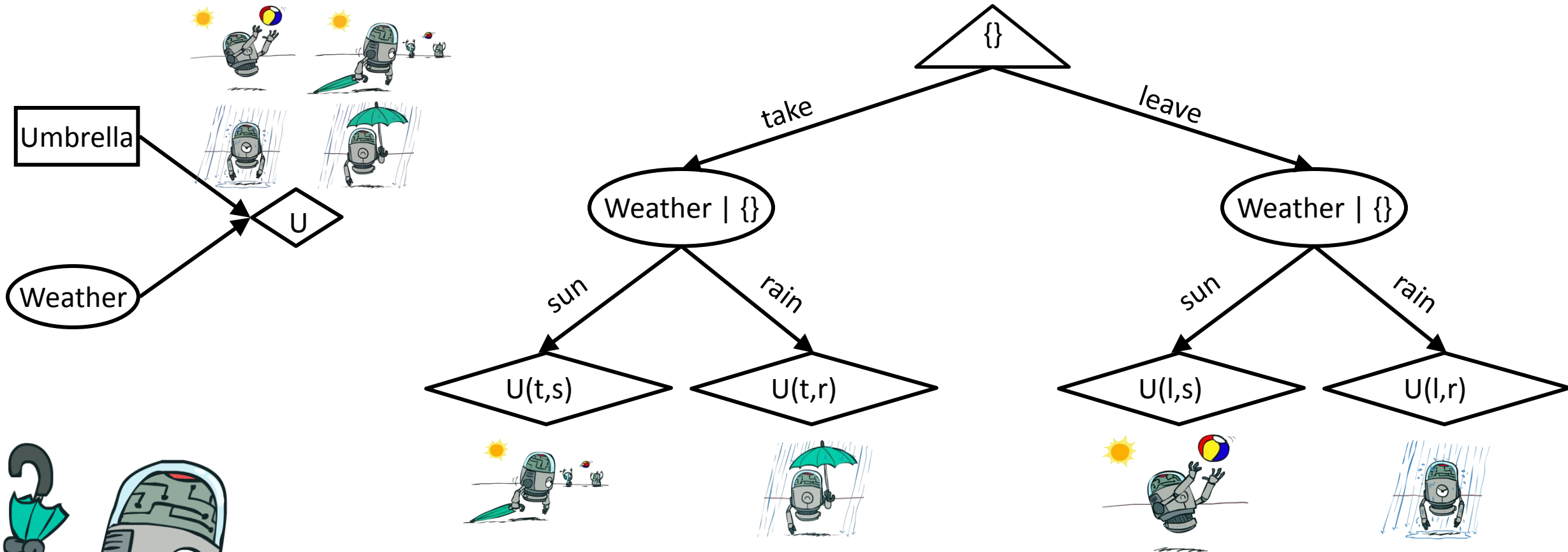
$$= 0.7 \cdot 20 + 0.3 \cdot 70 = 35$$

Optimal decision = leave

$$MEU(\emptyset) = \max_a EU(a) = 70$$



Decisions as Outcome Trees



- Almost exactly like expectimax / MDPs
- What's changed?

Example: Decision Networks

Umbrella = leave

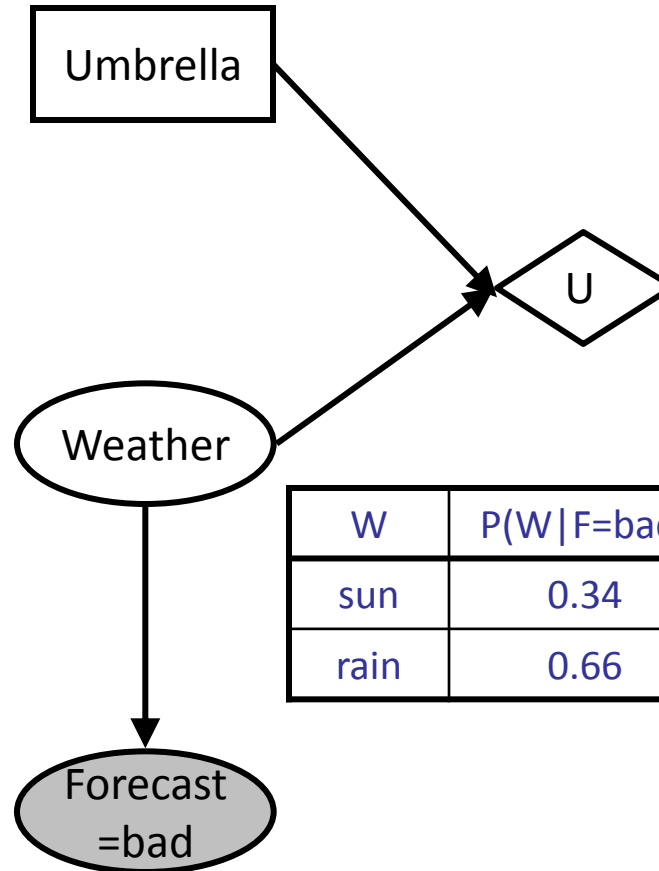
$$\begin{aligned} EU(\text{leave}|\text{bad}) &= \sum_w P(w|\text{bad})U(\text{leave}, w) \\ &= 0.34 \cdot 100 + 0.66 \cdot 0 = 34 \end{aligned}$$

Umbrella = take

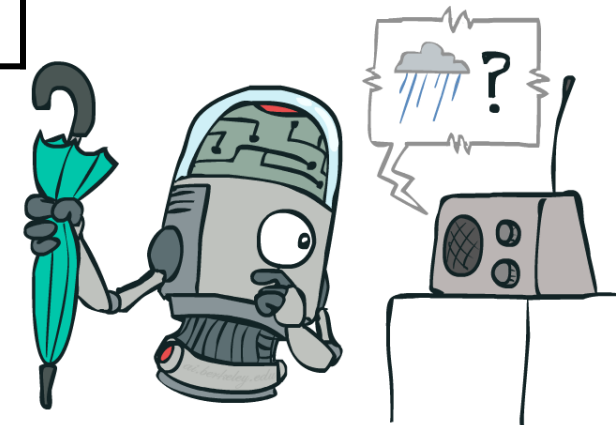
$$\begin{aligned} EU(\text{take}|\text{bad}) &= \sum_w P(w|\text{bad})U(\text{take}, w) \\ &= 0.34 \cdot 20 + 0.66 \cdot 70 = 53 \end{aligned}$$

Optimal decision = take

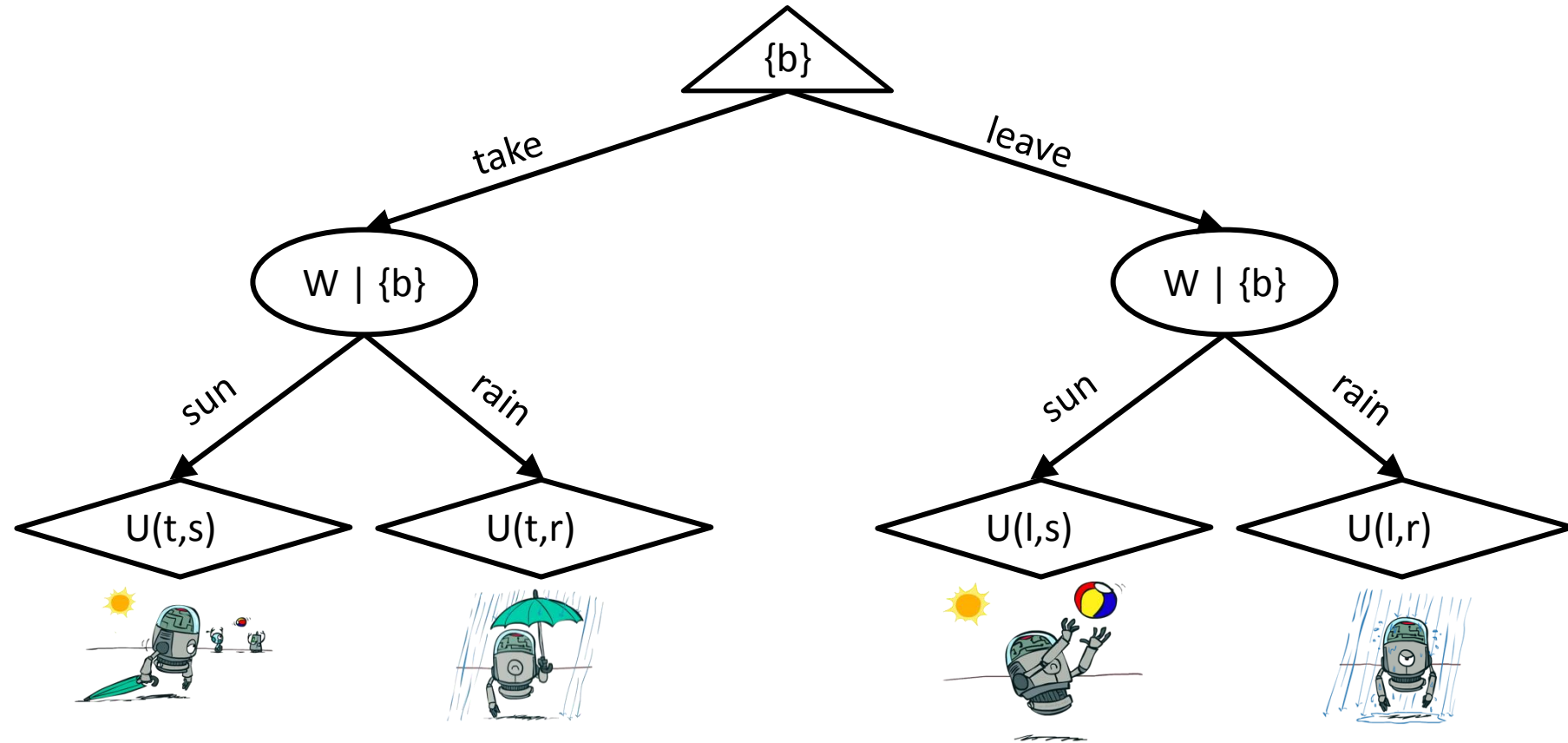
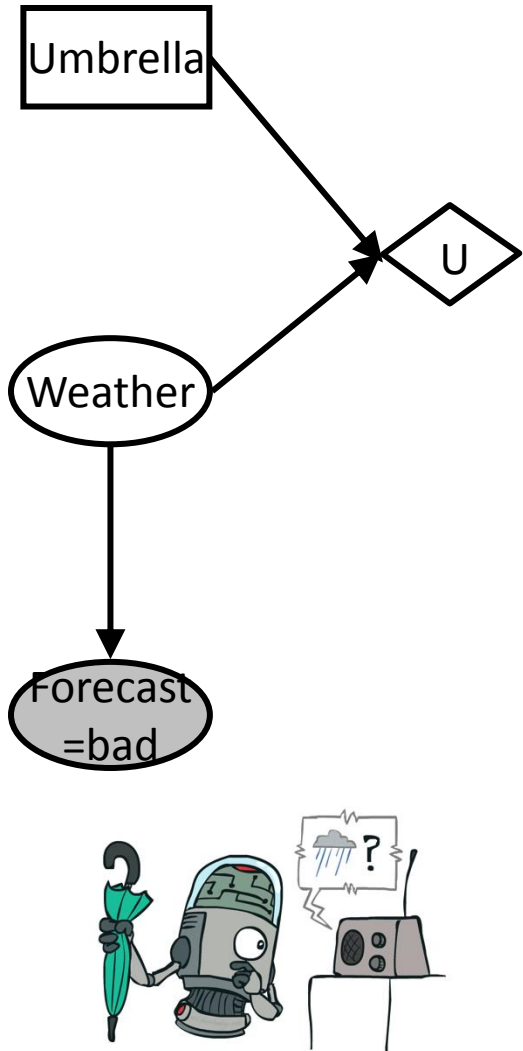
$$MEU(F = \text{bad}) = \max_a EU(a|\text{bad}) = 53$$



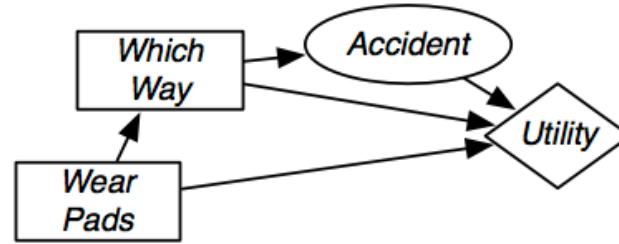
| A | W | U(A,W) |
|-------|------|--------|
| leave | sun | 100 |
| leave | rain | 0 |
| take | sun | 20 |
| take | rain | 70 |



Decisions as Outcome Trees



Single-Stage Decision

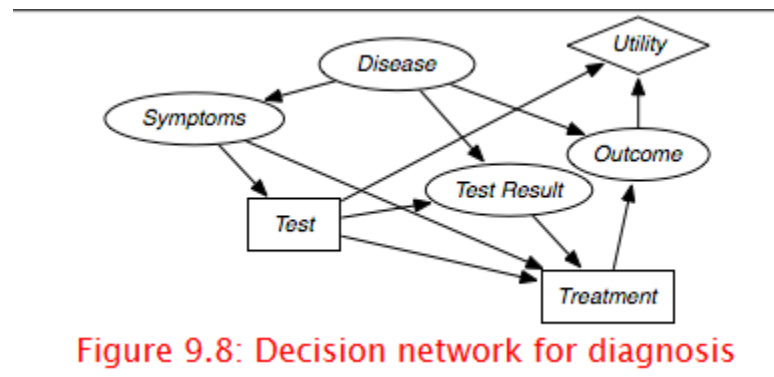


| <i>Which Way</i> | <i>Accident</i> | Value |
|------------------|-----------------|-------|
| short | true | 0.2 |
| short | false | 0.8 |
| long | true | 0.01 |
| long | false | 0.99 |

| <i>Wear Pads</i> | <i>Which Way</i> | <i>Accident</i> | Utility |
|------------------|------------------|-----------------|---------|
| true | short | true | 35 |
| true | short | false | 95 |
| true | long | true | 30 |
| true | long | false | 75 |
| false | short | true | 3 |
| false | short | false | 100 |
| false | long | true | 0 |
| false | long | false | 80 |

Figure 9.5: Single-stage decision network for the delivery robot

Diagnosis Decision Network



Markov Decision Process (MDP)

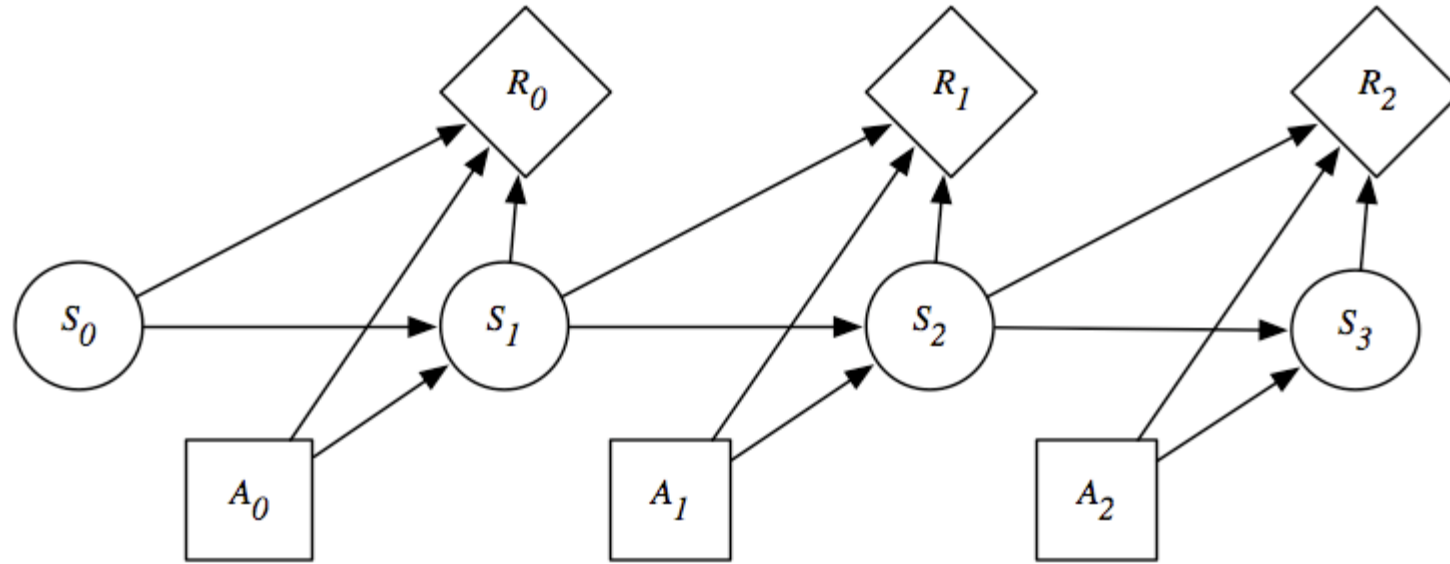
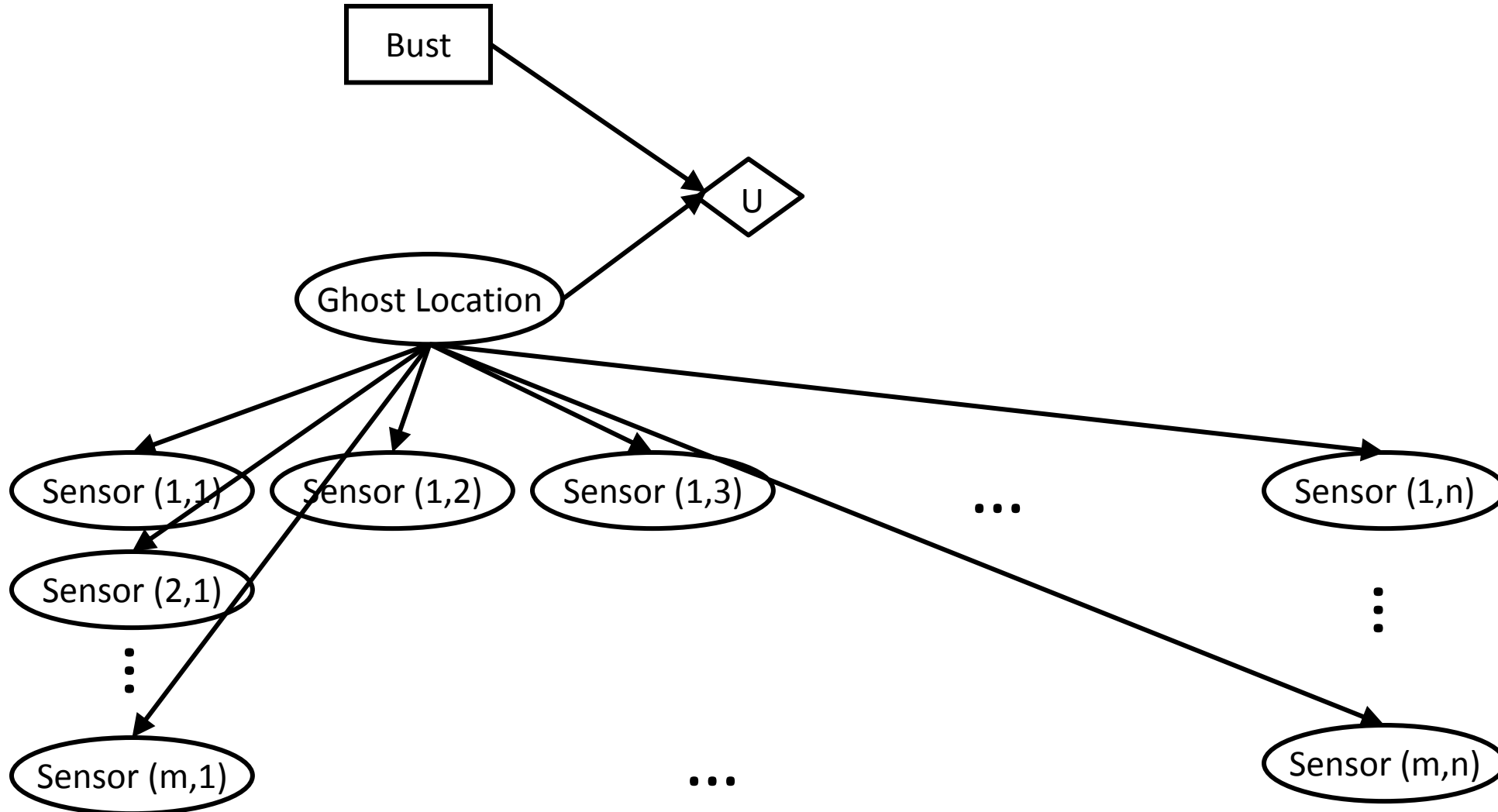


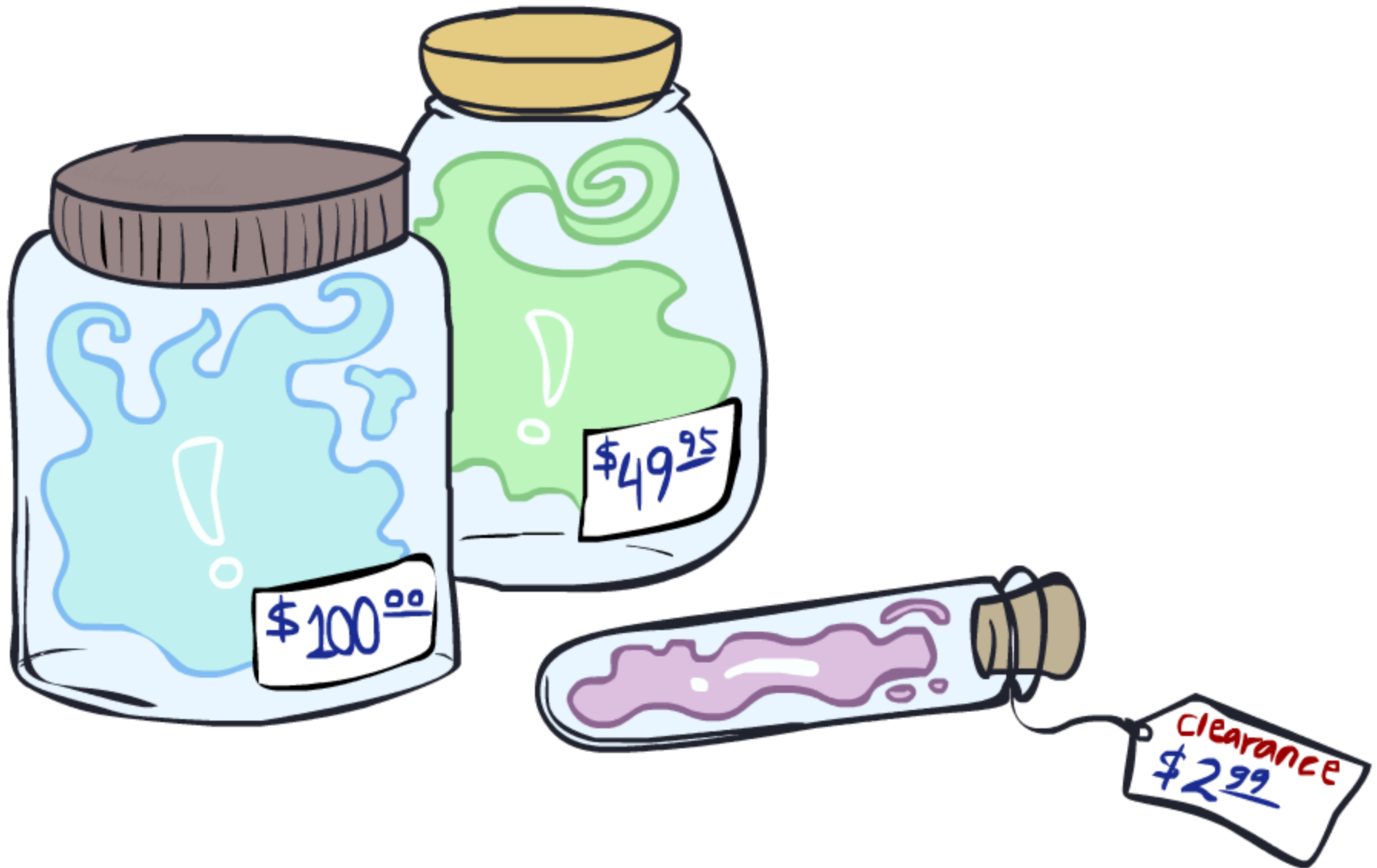
Figure 9.12: Decision network representing a finite part of an MDP

Ghostbusters Decision Network

Demo: Ghostbusters with probability

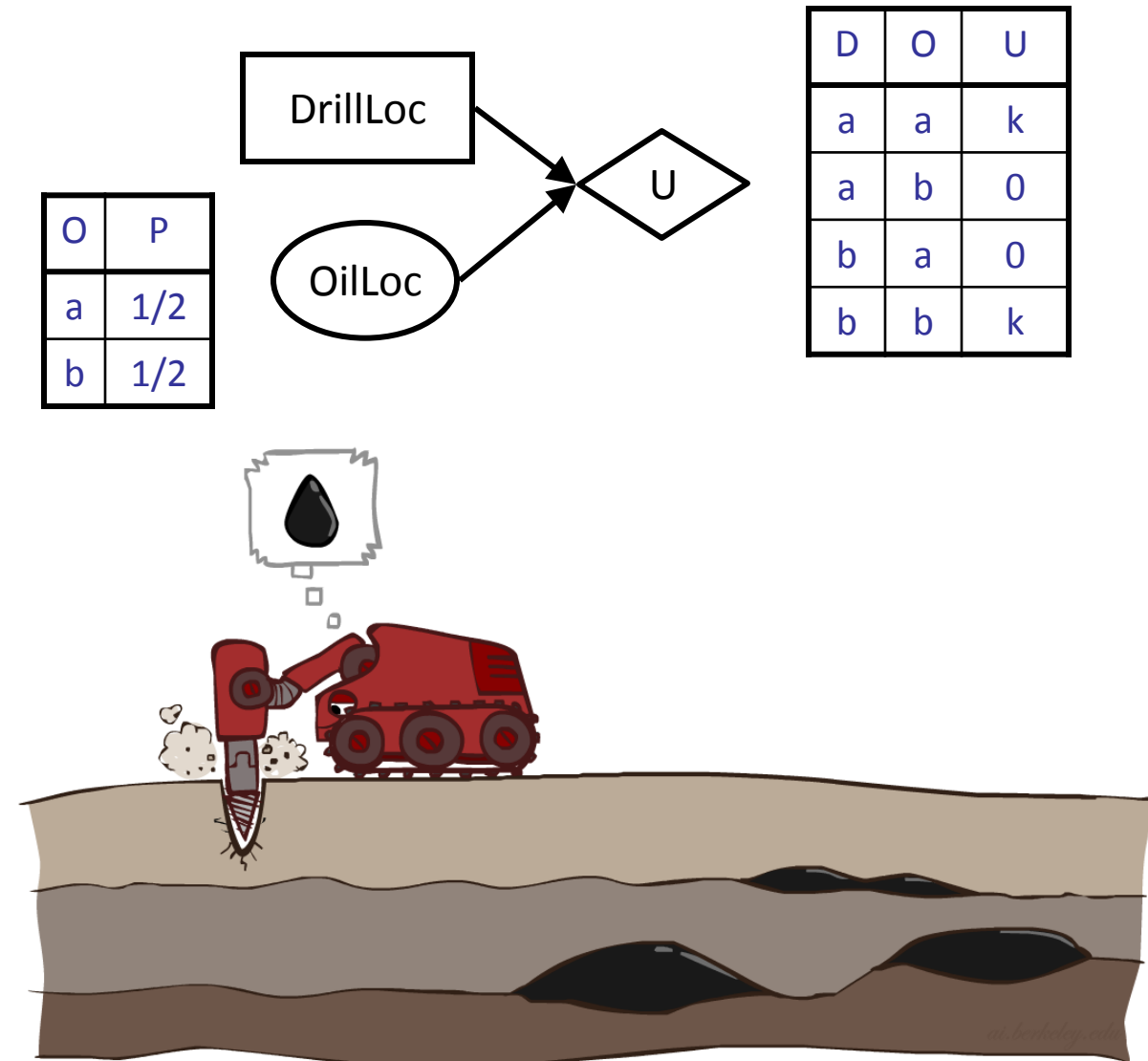


Value of Information



Value of Information

- Idea: compute value of acquiring evidence
 - Can be done directly from decision network
- Example: buying oil drilling rights
 - Two blocks A and B, exactly one has oil, worth k
 - You can drill in one location
 - Prior probabilities 0.5 each, & mutually exclusive
 - Drilling in either A or B has $EU = k/2$, $MEU = k/2$
- Question: what's the value of information of O ?
 - Value of knowing which of A or B has oil
 - Value is expected gain in MEU from new info
 - Survey may say "oil in a" or "oil in b," prob 0.5 each
 - If we know OilLoc, MEU is k (either way)
 - Gain in MEU from knowing OilLoc?
 - $VPI(OilLoc) = k/2$
 - Fair price of information: $k/2$



VPI Example: Weather

MEU with no evidence

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

MEU if forecast is bad

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

MEU if forecast is good

$$\text{MEU}(F = \text{good}) = \max_a \text{EU}(a|\text{good}) = 95$$

Forecast distribution

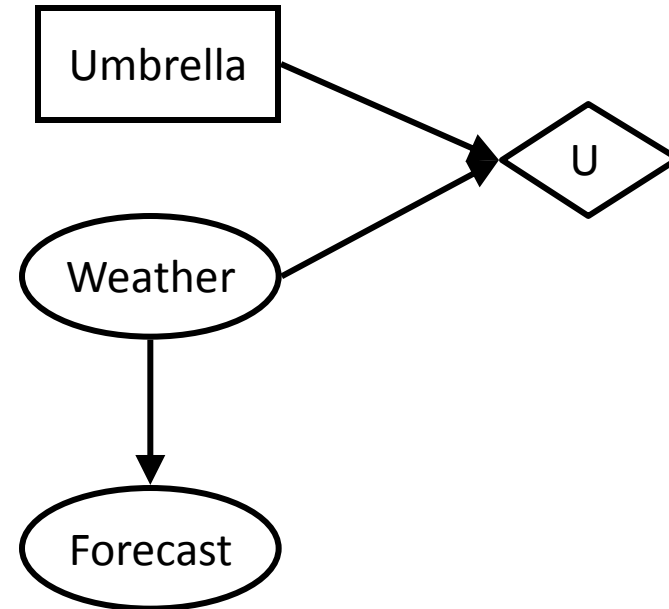
| F | P(F) |
|------|------|
| good | 0.59 |
| bad | 0.41 |



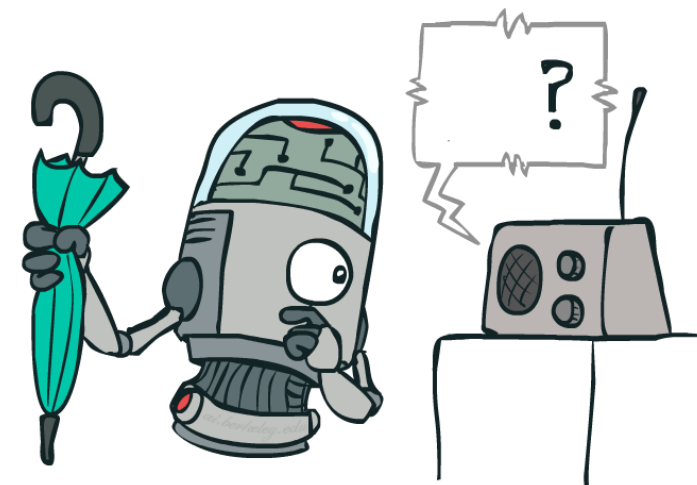
$$0.59 \cdot (95) + 0.41 \cdot (53) - 70$$

$$77.8 - 70 = 7.8$$

$$\text{VPI}(E'|e) = \left(\sum_{e'} P(e'|e) \text{MEU}(e, e') \right) - \text{MEU}(e)$$



| A | W | U |
|-------|------|-----|
| leave | sun | 100 |
| leave | rain | 0 |
| take | sun | 20 |
| take | rain | 70 |



Value of Information

- Assume we have evidence $E=e$. Value if we act now:

$$MEU(e) = \max_a \sum_s P(s|e) U(s, a)$$

- Assume we see that $E' = e'$. Value if we act then:

$$MEU(e, e') = \max_a \sum_s P(s|e, e') U(s, a)$$

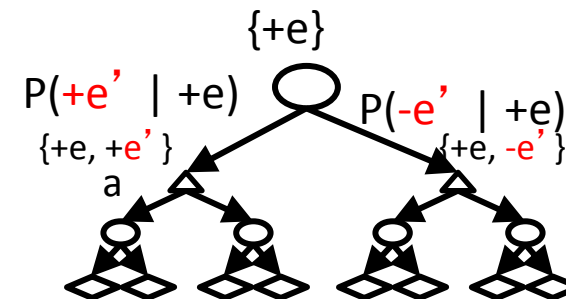
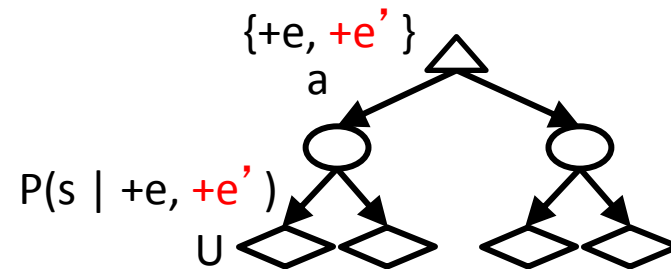
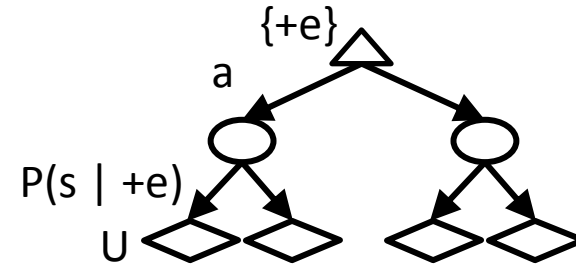
- BUT E' is a random variable whose value is unknown, so we don't know what e' will be

- Expected value if E' is revealed and then we act:

$$MEU(e, E') = \sum_{e'} P(e'|e) MEU(e, e')$$

- Value of information: how much MEU goes up by revealing E' first then acting, over acting now:

$$VPI(E'|e) = MEU(e, E') - MEU(e)$$



VPI Properties

- Nonnegative

$$\forall E', e : \text{VPI}(E'|e) \geq 0$$



- Nonadditive

(think of observing E_j twice)

$$\text{VPI}(E_j, E_k|e) \neq \text{VPI}(E_j|e) + \text{VPI}(E_k|e)$$



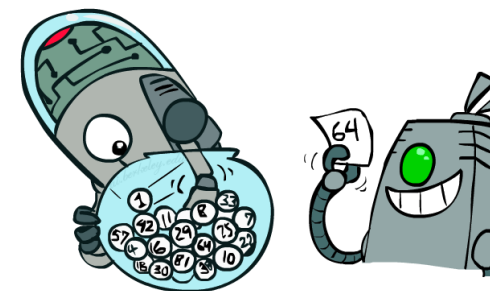
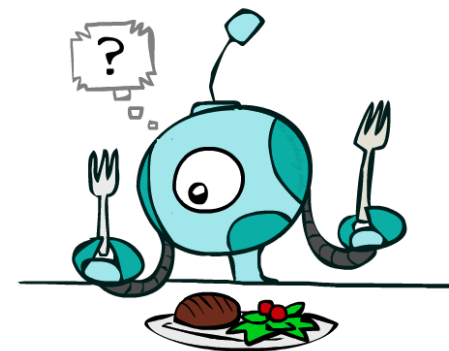
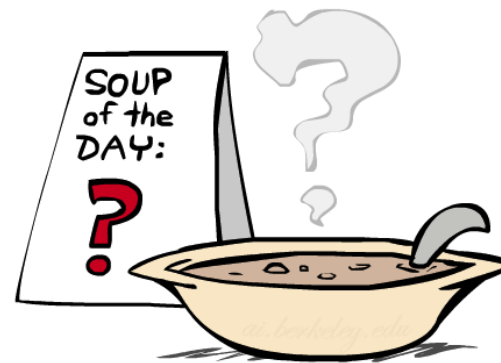
- Order-independent

$$\begin{aligned} \text{VPI}(E_j, E_k|e) &= \text{VPI}(E_j|e) + \text{VPI}(E_k|e, E_j) \\ &= \text{VPI}(E_k|e) + \text{VPI}(E_j|e, E_k) \end{aligned}$$



Quick VPI Questions

- The soup of the day is either clam chowder or split pea, but you wouldn't order either one. What's the value of knowing which it is?
- There are two kinds of plastic forks at a picnic. One kind is slightly sturdier. What's the value of knowing which?
- You're playing the lottery. The prize will be \$0 or \$100. You can play any number between 1 and 100 (chance of winning is 1%). What is the value of knowing the winning number?



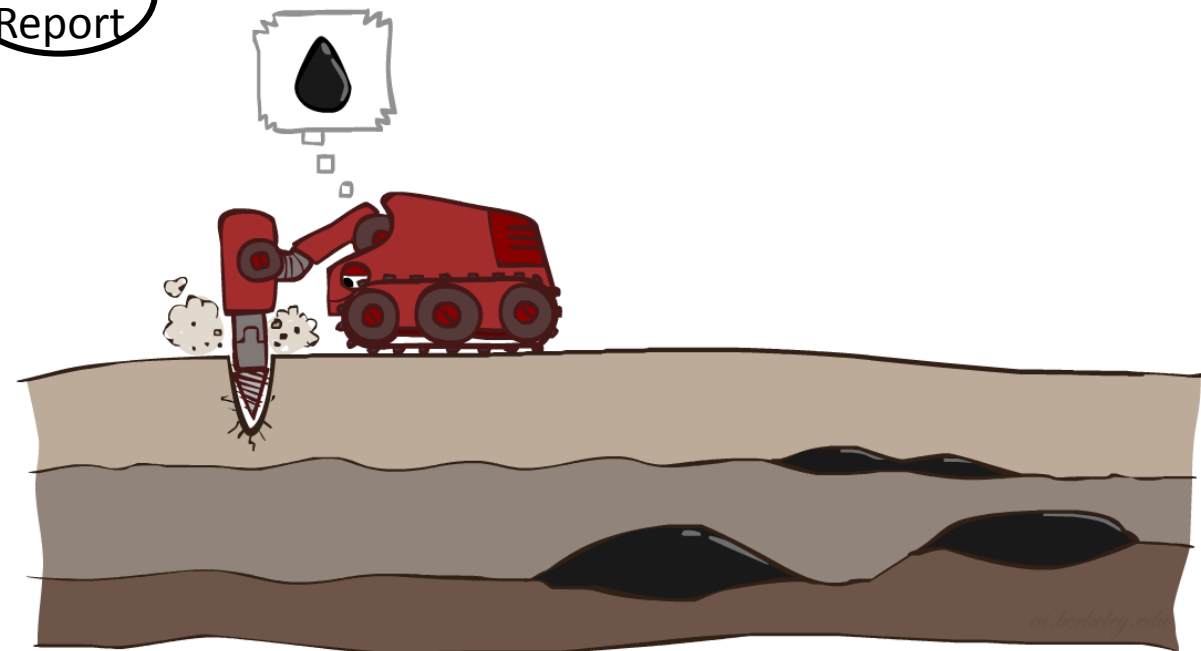
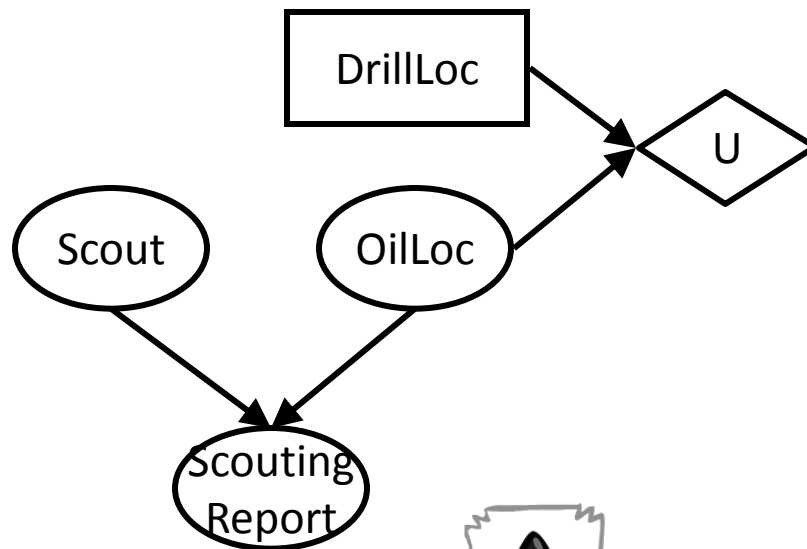
Value of Imperfect Information?



- No such thing
- Information corresponds to the observation of a node in the decision network
- If data is “noisy” that just means we don’t observe the original variable, but another variable which is a noisy version of the original one

VPI Question

- VPI(OilLoc) ?
- VPI(ScoutingReport) ?
- VPI(Scout) ?
- VPI(Scout | ScoutingReport) ?



- Generally:
If $\text{Parents}(U) \perp\!\!\!\perp Z \mid \text{CurrentEvidence}$
Then $\text{VPI}(Z \mid \text{CurrentEvidence}) = 0$