Adversarial Search - II

CS5491: Artificial Intelligence
ZHICHAO LU

Content Credits: **Prof. Wei**'s CS4486 Course and **Prof. Boddeti**'s AI Course

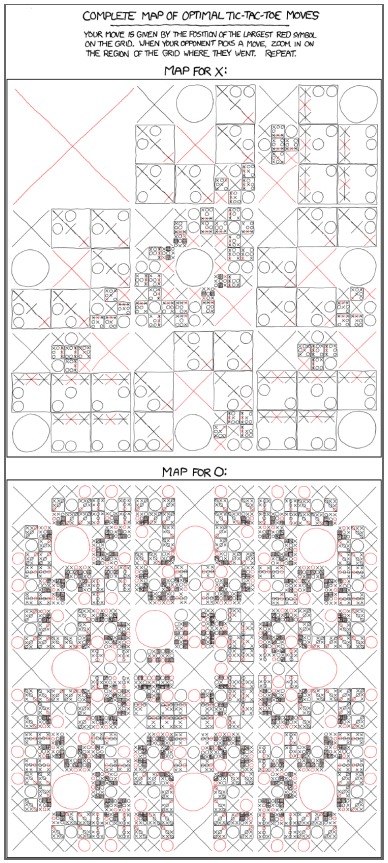
TODAY

Expectimax Games

Utilities

Reading

- Today's Lecture: RN Chapters 16.1-16.3



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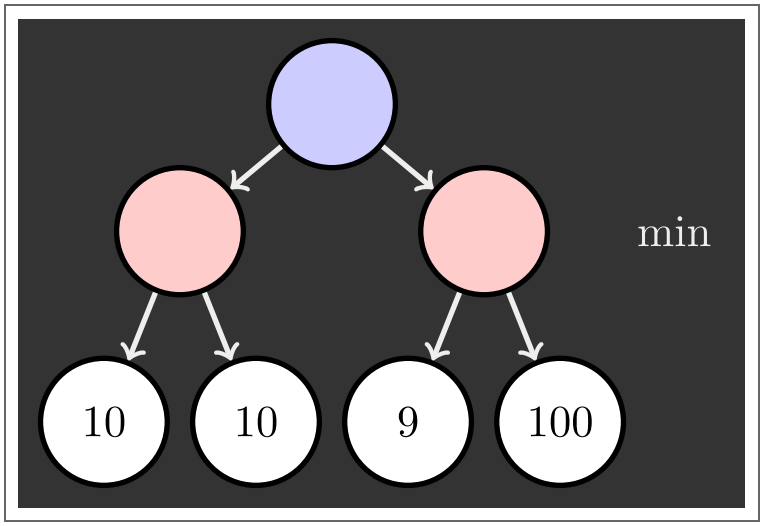
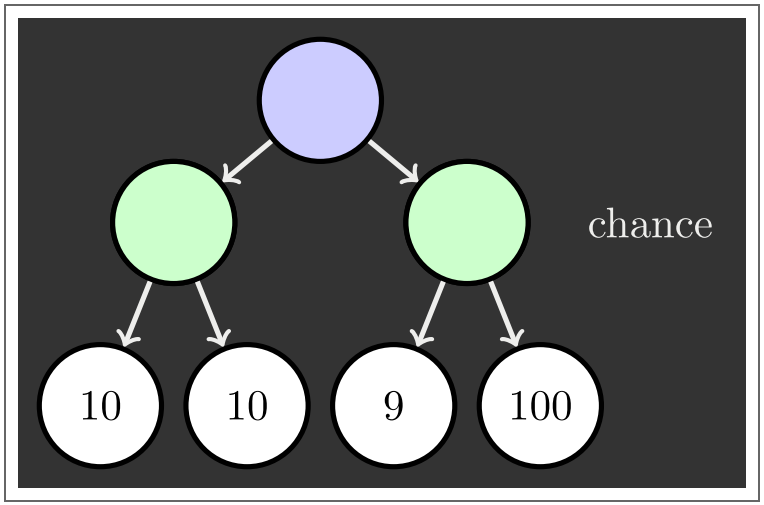
UNCERTAIN OUTCOMES

WORST CASE VS AVERAGE CASE





Idea: Uncertain outcomes controlled by chance, not an adversary.

STOCHASTIC GAMES

Why would we not know what the result of an action will be?

- Explicit randomness: rolling dice
- Unpredictable opponents: the ghosts respond randomly
- Actions can fail: when moving a robot, wheels might slip

Values should now reflect average-case (expectimax) outcomes, not worst-case (minimax) outcomes

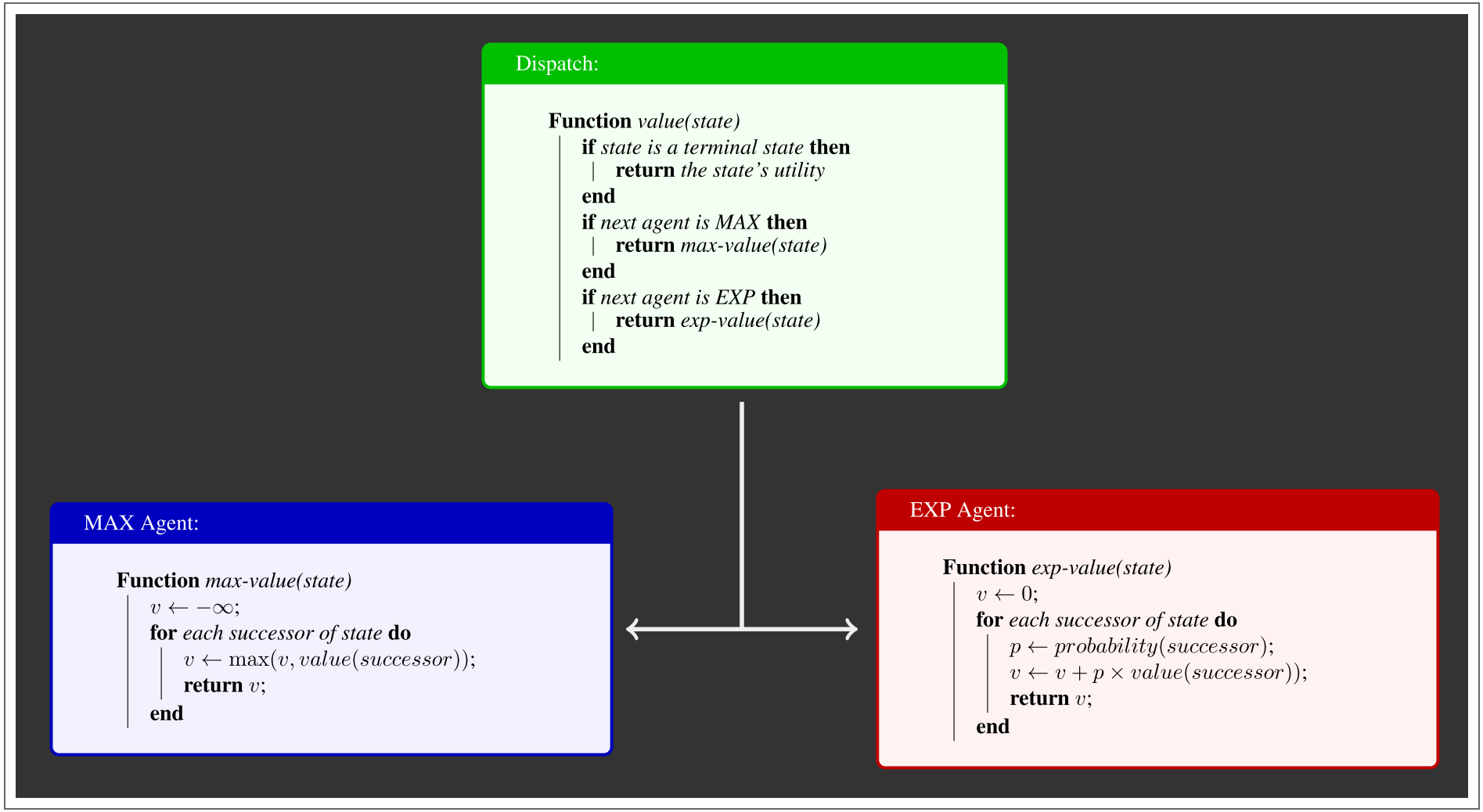
EXPECTIMAX SEARCH

Expectimax search: compute the average score under optimal play

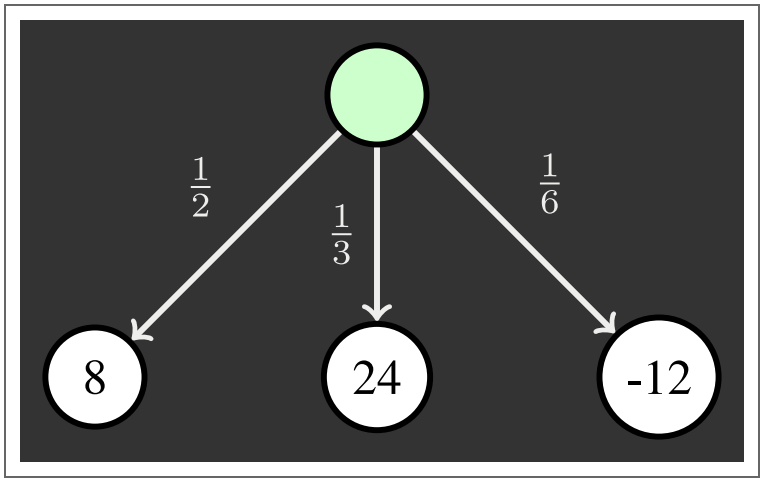
- Max nodes as in minimax search
- Chance nodes are like min nodes but the outcome is uncertain
- Calculate their expected utilities
- i.e., take weighted average (expectation) of children

Later, we will learn how to formalize the underlying uncertain-result problems as Markov Decision Processes

EXPECTIMAX IMPLEMENTATION



EXPECTIMAX IMPLEMENTATION

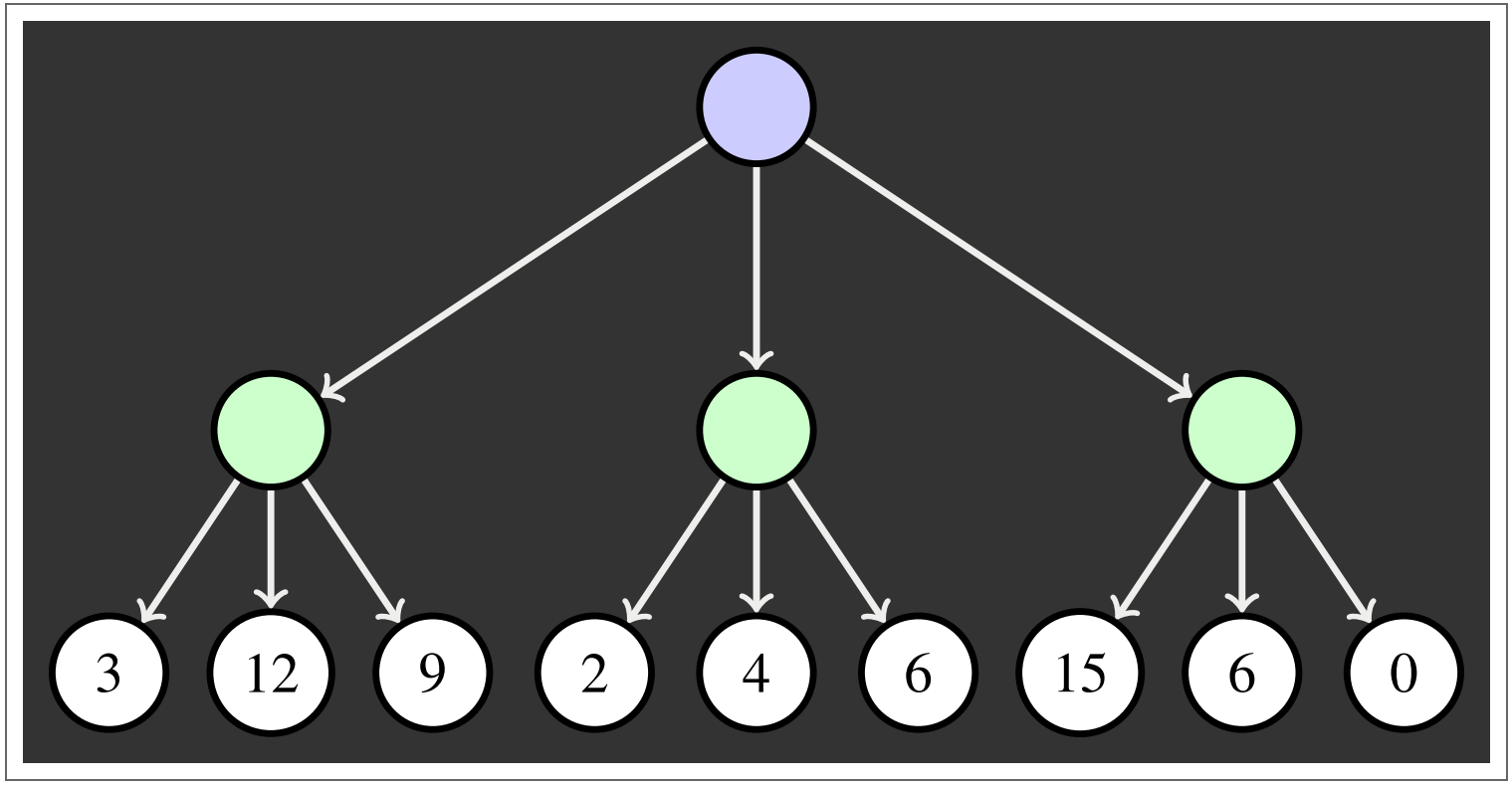


EXP Agent:

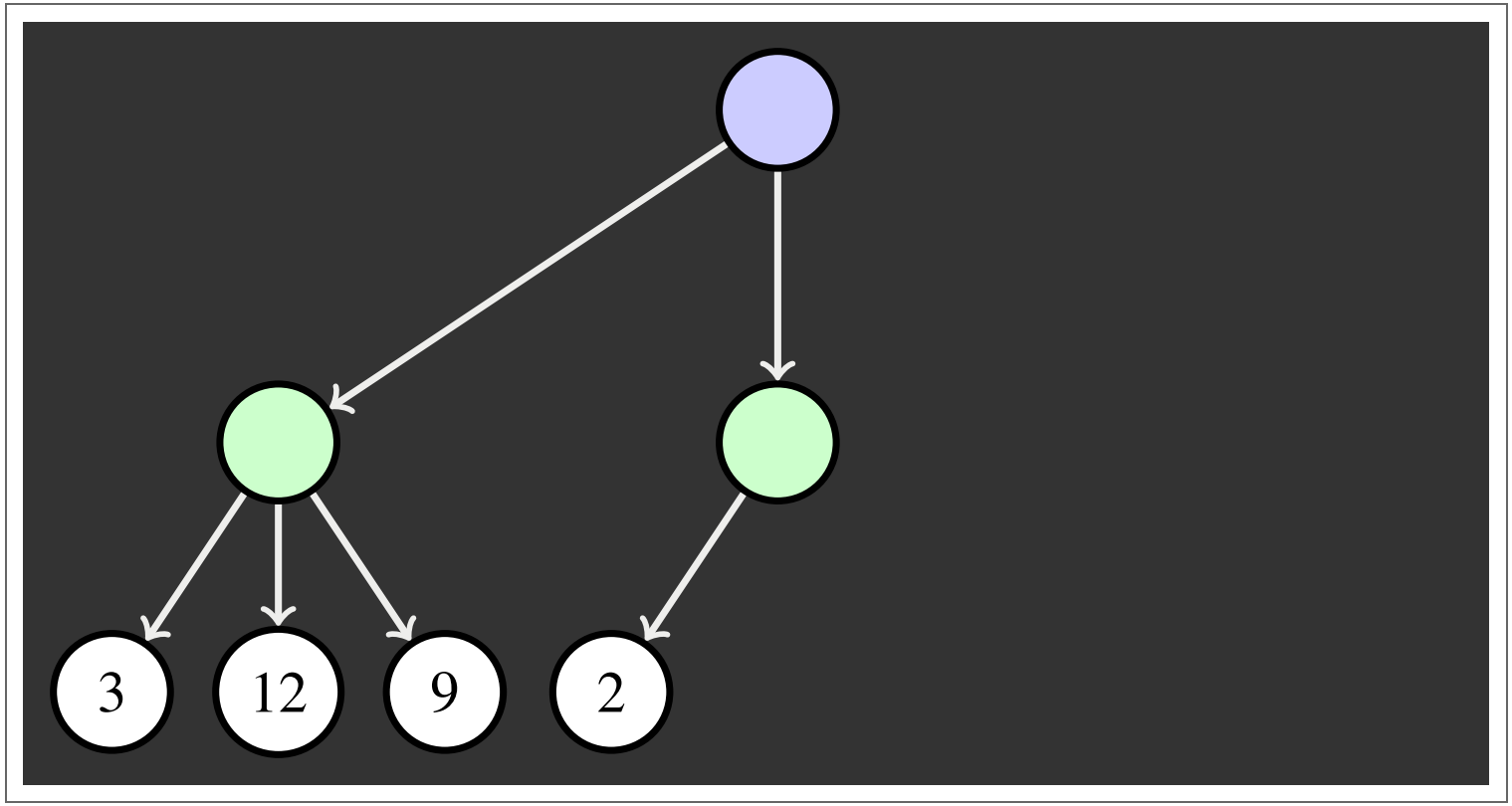
Function *exp-value(state)*
  $v \leftarrow 0$;
  for *each successor of state* **do**
    $p \leftarrow probability(successor)$;
    $v \leftarrow v + p \times value(successor))$;
    return v;
  end

$$v = \frac{1}{2} * 8 + \frac{1}{3} * 24 - \frac{1}{6} * 12 = 10 \quad (1)$$

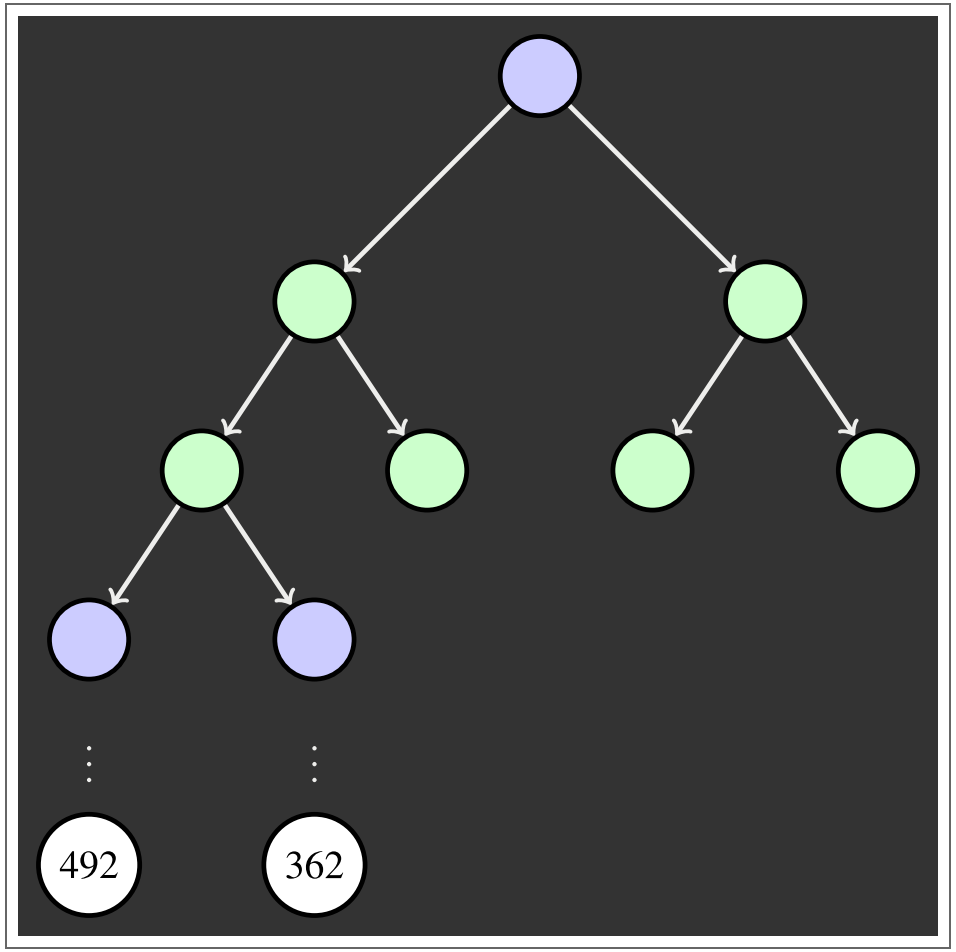
EXPECTIMAX EXAMPLE

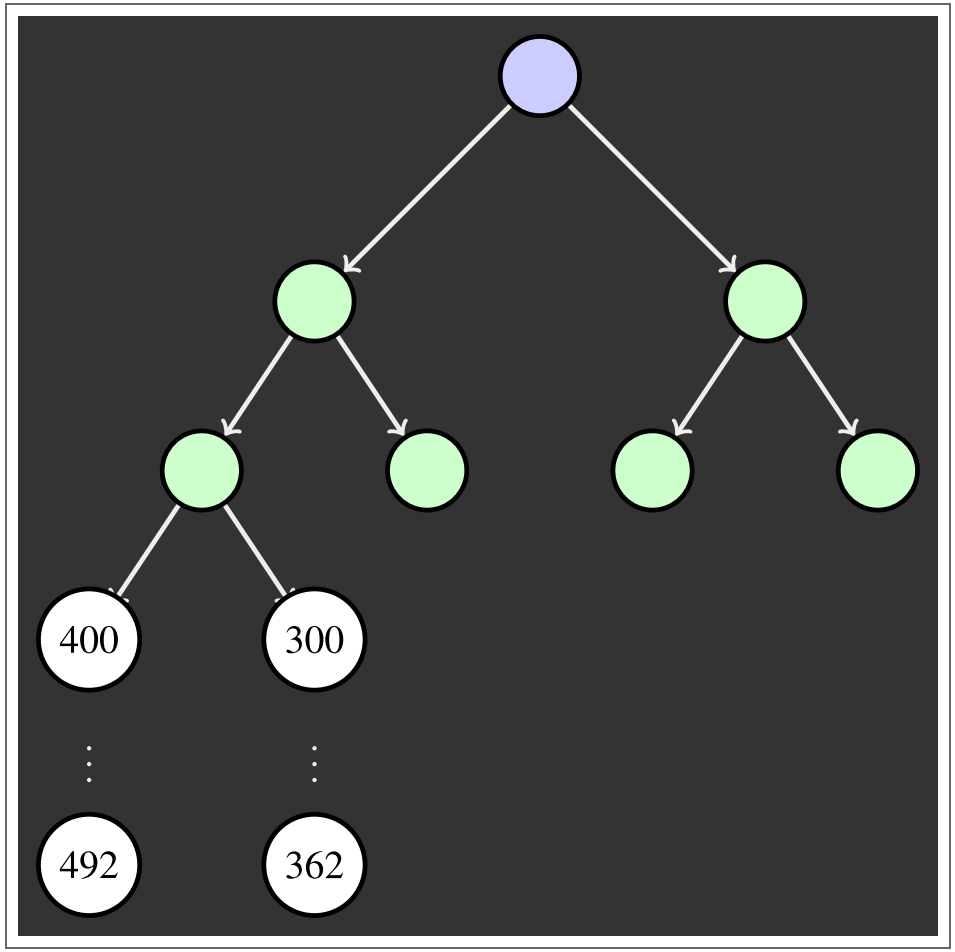


EXPECTIMAX PRUNING



DEPTH-LIMITED EXPECTIMAX




400
300
492
362

PROBABILITIES

PRIMER: PROBABILITIES

A random variable represents an event whose outcome is unknown.

A probability distribution is an assignment of weights to outcomes

Example: Traffic on freeway

- Random variable: $T = \text{ whether there is traffic}$
- Outcomes: $T \in \{none, mild, heavy\}$
- Distribution: $P(T = none) = 0.25$, $P(T = mild) = 0.50$, $P(T = heavy) = 0.25$

PRIMER: PROBABILITIES...

Some laws of probability (more later):

- Probabilities are always non-negative
- Probabilities over all possible outcomes sum to one

As we get more evidence, probabilities may change:

- $P(T = heavy) = 0.25, P(T = heavy \mid Hour = 8am) = 0.60$
- We will talk about methods for reasoning and updating probabilities later

PRIMER: EXPECTATIONS

The expected value of a function of a random variable is the average, weighted by the probability distribution over outcomes

Example: How long to get to the airport?

	$None$	$mild$	$heavy$
Time:	20	30	60
Probability:	0.25	0.50	0.25

	$None$		$mild$		$heavy$		
Time:	20		30		60		
	$\times$	+	$\times$	+	$\times$	=	35
Probability:	0.25		0.50		0.25		

WHAT PROBABILITIES TO USE?

In expectimax search, we have a probabilistic model of how the opponent (or environment) will behave in any state

- Model could be a simple uniform distribution (roll a die)
- Model could be sophisticated and require a great deal of computation
- We have a chance node for any outcome out of our control: opponent or environment
- The model might say that adversarial actions are likely.

For now, assume each chance node magically comes along with probabilities that specify the distribution over its outcomes

QUIZ: INFORMED PROBABILITIES

Let us say you know that your opponent is actually running a depth 2 minimax, using the result 80% of the time, and moving randomly otherwise.

Question: What tree search should you use?

Answer: Expectimax

- To figure out EACH chance node's probabilities, you have to run a simulation of your opponent
- This kind of thing gets very slow very quickly
- Even worse if you have to simulate your opponent simulating you
- Except for minimax, which has the nice property that it all collapses into one game tree

MODELING ASSUMPTIONS

THE DANGERS OF OPTIMISM AND PESSIMISM

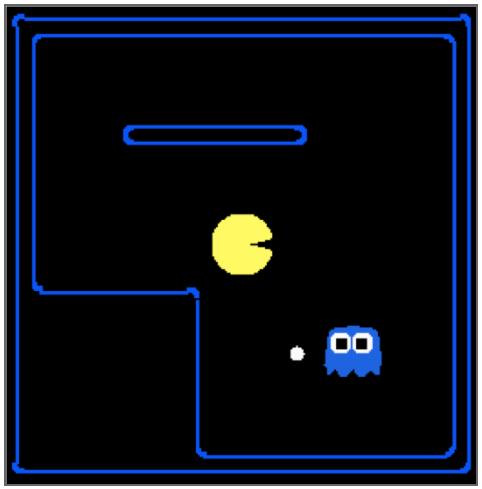
Dangerous Optimism

- Assuming chance when the world is adversarial

Dangerous Pessimism

- Assuming the worst case when it is not likely

ASSUMPTIONS VS REALITY

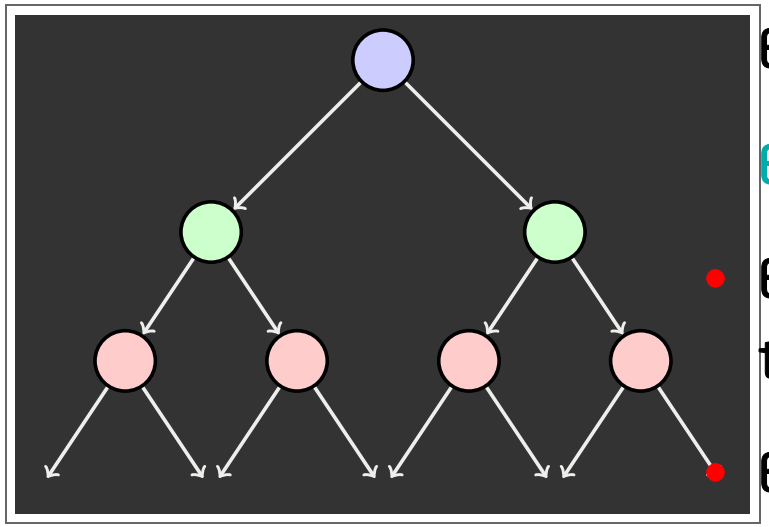


Pacman used depth 4 search with an eval function that avoids trouble

Ghost used depth 2 search with an eval function that seeks Pacman

	Adversarial Ghost	Random Ghost
Minimax Pacman	Won 5/5 Avg. Score: 483	Won 5/5 Avg. Score: 493
Expectimax Pacman	Won 1/5 Avg. Score: -303	Won 5/5 Avg. Score: 503

MIXED AGENT GAMES



E.g. Backgammon

Expectiminimax

Environment is an extra "random agent" player that moves after each min/max agent

Each node computes the appropriate combination of its children

MIXED AGENT GAMES: BACKGAMMON

Dice rolls increase b: 21 possible rolls with 2 dice

- $\approx$ 20 legal moves
- Depth $2 = 20 \times (21 \times 20)^3 = 1.2 \times 10^9$

As depth increases, probability of reaching a given search node shrinks

- So usefulness of search is diminished
- So limiting depth is less damaging
- But pruning is trickier

Historic AI: TDGammon uses depth-2 search + very good evaluation function + reinforcement learning: world-champion level play

1st AI world champion in any game !!

UTILITIES

MAXIMUM EXPECTED UTILITY

Why should we average utilities? Why not minimax?

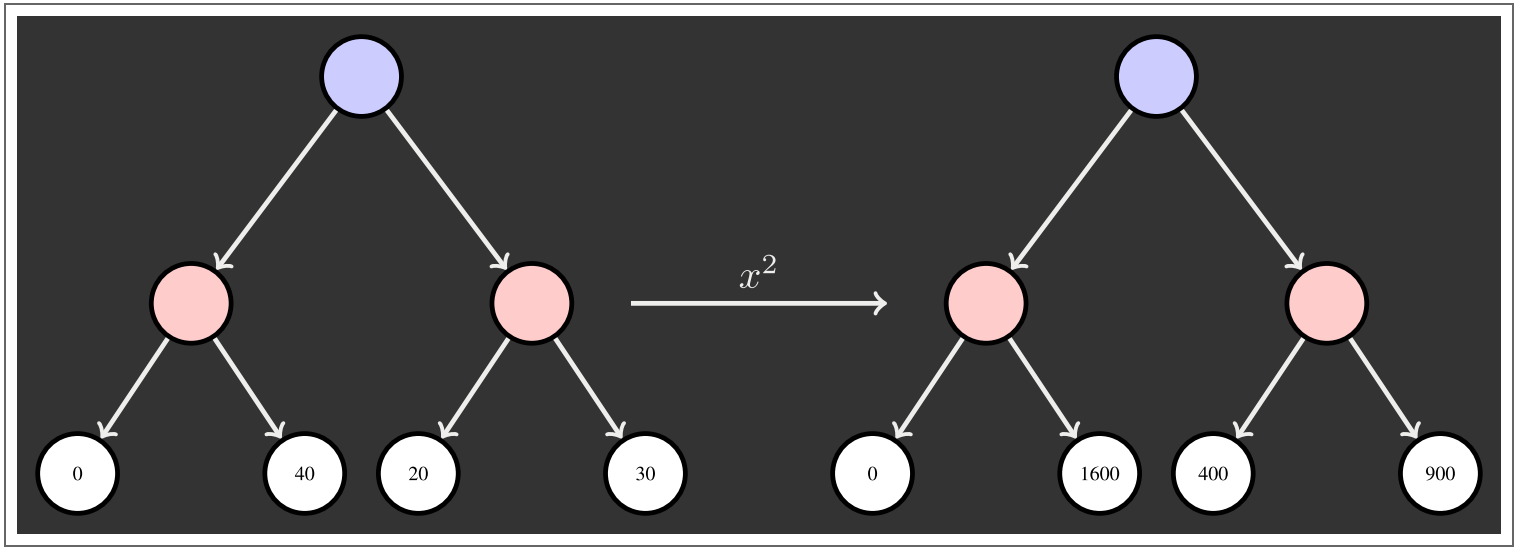
Principle of maximum expected utility:

- A rational agent should chose the action that maximizes its expected utility, given its knowledge

Questions:

- Where do utilities come from?
- How do we know such utilities even exist?
- How do we know that averaging even makes sense?
- What if our behavior (preferences) cannot be described by utilities?

WHAT UTILITIES TO USE?



For worst-case minimax reasoning, terminal function scale does not matter

- We just want better states to have higher evaluations (get the ordering right)
- We call this insensitivity to monotonic transformations.

For average-case expectimax reasoning, we need magnitudes to be meaningful

UTILITIES

Utilities are functions from outcomes (states of the world) to real numbers that describe an agent's preferences

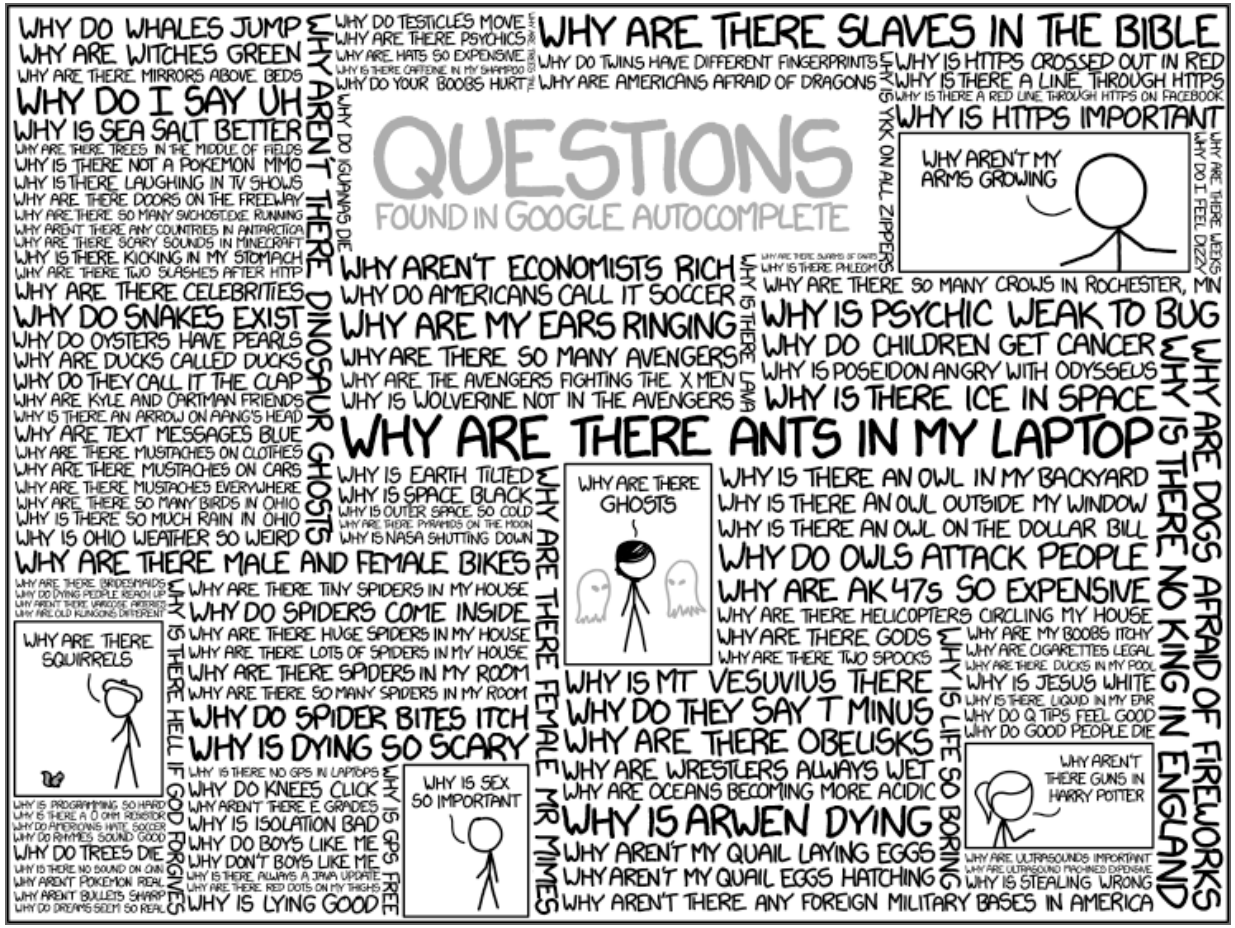
Where do utilities come from?

- In a game, may be simple $(+1/-1)$
- Utilities summarize the agent's goals
- Theorem: any "rational" preferences can be summarized as a utility function

We hard-wire utilities and let behaviors emerge

- Why don't we let agents pick utilities?
- Why don't we prescribe behaviors?

Q & A


QUESTIONS
FOUND IN GOOGLE AUTOCOMPLETE
WHY ARE THERE SLAVES IN THE BIBLE
WHY DO WHALES JUMP
WHY ARE WITCHES GREEN
WHY ARE THERE MIRRORS ABOVE BEDS
WHY DO I SAY UH
WHY IS SEA SALT BETTER
WHY ARE THERE TREES IN THE MIDDLE OF FIELDS
WHY IS THERE NOT A POKEMON MMO
WHY IS THERE LAUGHING IN TV SHOWS
WHY ARE THERE DOORS ON THE FREEWAY
WHY ARE THERE SO MANY SVCHOST.EXE RUNNING
WHY AREN'T THERE ANY COUNTRIES IN ANTARCTICA
WHY ARE THERE SCARY SOUNDS IN MINECRAFT
WHY IS THERE KICKING IN MY STOMACH
WHY ARE THERE TWO SLASHES AFTER HTTP
WHY ARE THERE CELEBRITIES
WHY DO SNAKES EXIST
WHY DO OYSTERS HAVE PEARLS
WHY ARE DUCKS CALLED DUCKS
WHY DO THEY CALL IT THE CLAP
WHY ARE KYLE AND CARTMAN FRIENDS
WHY IS THERE AN ARROW ON AANG'S HEAD
WHY ARE TEXT MESSAGES BLUE
WHY ARE THERE MUSTACHES ON CLOTHES
WHY ARE THERE MUSTACHES ON CARS
WHY ARE THERE MUSTACHES EVERYWHERE
WHY ARE THERE SO MANY BIRDS IN OHIO
WHY IS THERE SO MUCH RAIN IN OHIO
WHY IS OHIO WEATHER SO WEIRD
WHY ARE THERE MALE AND FEMALE BIKES
WHY ARE THERE BRIDESMAIDS
WHY DO DYING PEOPLE REACH UP
WHY AREN'T THERE VARICOSE ARTERIES
WHY ARE OLD KINGDOMS DIFFERENT
WHY ARE THERE SQUIRRELS
WHY IS PROGRAMMING SO HARD
WHY IS THERE A 0 OHM RESISTOR
WHY DO APERONYMS HATE SOCCER
WHY DO RHYMES SOUND GOOD
WHY DO TREES DIE
WHY IS THERE NO BOUND ON PI
WHY AREN'T POKEMON REAL
WHY AREN'T BULLETS SHARP
WHY DO DREAMS SEEM SO REAL
WHY DO TESTICLES MOVE
WHY ARE THERE PSYCHICS
WHY ARE HATS SO EXPENSIVE
WHY IS THERE CAFFEINE IN MY SHAMPOO
WHY DO YOUR BOOBS HURT
WHY DO TWINS HAVE DIFFERENT FINGERPRINTS
WHY ARE AMERICANS AFRAID OF DRAGONS
WHY DO IGUANAS DIE
WHY IS YKK ON ALL ZIPPERS
WHY IS HTTPS CROSSED OUT IN RED
WHY IS THERE A LINE THROUGH HTTPS
WHY IS THERE A RED LINE THROUGH HTTPS ON FACEBOOK
WHY IS HTTPS IMPORTANT
WHY AREN'T MY ARMS GROWING
WHY ARE THERE WEEKS
WHY DO I FEEL DIZZY
WHY AREN'T ECONOMISTS RICH
WHY DO AMERICANS CALL IT SOCCER
WHY ARE MY EARS RINGING
WHY ARE THERE SO MANY AVENGERS
WHY ARE THE AVENGERS FIGHTING THE X MEN
WHY IS WOLVERINE NOT IN THE AVENGERS
WHY ARE THERE SWARMS OF GNATS
WHY IS THERE PHLEGM
WHY ARE THERE SO MANY CROWS IN ROCHESTER, MN
WHY IS PSYCHIC WEAK TO BUG
WHY DO CHILDREN GET CANCER
WHY IS POSEIDON ANGRY WITH ODYSSEUS
WHY IS THERE ICE IN SPACE
WHY IS THERE LAVA
WHY ARE THERE ANTS IN MY LAPTOP
WHY ARE DOGS AFRAID OF FIREWORKS
WHY IS THERE NO KING IN ENGLAND
WHY IS EARTH TILTED
WHY IS SPACE BLACK
WHY IS OUTER SPACE SO COLD
WHY ARE THERE PYRAMIDS ON THE MOON
WHY IS NASA SHUTTING DOWN
WHY ARE THERE GHOSTS
WHY IS THERE AN OWL IN MY BACKYARD
WHY IS THERE AN OWL OUTSIDE MY WINDOW
WHY IS THERE AN OWL ON THE DOLLAR BILL
WHY DO OWLS ATTACK PEOPLE
WHY ARE AK 47s SO EXPENSIVE
WHY ARE THERE HELICOPTERS CIRCLING MY HOUSE
WHY ARE THERE GODS
WHY ARE THERE TWO SPOOKS
WHY ARE MY BOOBS ITCHY
WHY ARE CIGARETTES LEGAL
WHY ARE THERE DUCKS IN MY POOL
WHY IS JESUS WHITE
WHY IS THERE LIQUID IN MY EAR
WHY DO Q TIPS FEEL GOOD
WHY DO GOOD PEOPLE DIE
WHY AREN'T THERE GUNS IN HARRY POTTER
WHY ARE ULTRASOUNDS IMPORTANT
WHY ARE ULTRASOUND MACHINES EXPENSIVE
WHY IS STEALING WRONG
WHY AREN'T THERE ANY FOREIGN MILITARY BASES IN AMERICA
WHY ARE THERE TINY SPIDERS IN MY HOUSE
WHY DO SPIDERS COME INSIDE
WHY ARE THERE HUGE SPIDERS IN MY HOUSE
WHY ARE THERE LOTS OF SPIDERS IN MY HOUSE
WHY ARE THERE SPIDERS IN MY ROOM
WHY ARE THERE SO MANY SPIDERS IN MY ROOM
WHY DO SPIDER BITES ITCH
WHY IS DYING SO SCARY
WHY IS THERE NO GPS IN LAPTOPS
WHY DO KNEES CLICK
WHY AREN'T THERE E GRADES
WHY IS ISOLATION BAD
WHY DO BOYS LIKE ME
WHY DON'T BOYS LIKE ME
WHY IS THERE ALWAYS A JAVA UPDATE
WHY ARE THERE RED DOTS ON MY THIGHS
WHY IS LYING GOOD
WHY IS SEX SO IMPORTANT
WHY IS MT VESUVIUS THERE
WHY DO THEY SAY T MINUS
WHY ARE THERE OBELISKS
WHY ARE WRESTLERS ALWAYS WET
WHY ARE OCEANS BECOMING MORE ACIDIC
WHY IS ARWEN DYING
WHY AREN'T MY QUAIL LAYING EGGS
WHY AREN'T MY QUAIL EGGS HATCHING
WHY IS LIFE SO BORING
WHY IS THERE HELL IF GOD FORGIVES
WHY IS GPS FREE
WHY ARE THERE FEMALE MR MIMES

XKCD

Speaker notes

Q & A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