Artificial Intelligence

Tom: You want to do a lecture on AI?

Kevin: Yeah, I think artificial intelligence is great!

Tom: Yeah, I think your intelligence is artificial.

Two Types of AI

- Symbolic AI actually tries to encode knowledge as it is
  - I should play a lightning bolt when a creature with toughness 3 or less attacks
- Statistical AI
  - I should play a lightning bolt when my position is quantitatively better than it would be if I didn’t play it

Symbolic AI

- Most approaches rely upon logic
  - Usually, first-order logic
- As we've seen, magic can be stated largely as a series of logical statements

Logical Knowledge Representation

- Also known as KR
- Uses normal logical deduction to "learn" things
- ∀c∀p∀t (Attacking(c,p) & ~Blocked(c) -> Life (p,t+1) = Life(p,t) – 3)
    - Subtraction is actually a fn here, not a legal logical operator

How does this become valuable?

- KR allows us to understand situations more completely through inference
- Magic has many inferred concepts and aspects
  - Grizzly Bears that didn't attack when it is the strongest is probably going to block
- Need to use a bunch of predicates to make our language more expressive

Predicates for our example

- attack(c, t) – creature, turn
- tapped(c, t, p) – creature, turn, phase
- after(x, y) – phase, phase
- For us, all lower-case letters are variables
- Things in quotes will be our contants, though not really

Example truth

- $\forall c \forall t \forall p\ ((\text{attack}(c, t) \wedge \text{after}(p, \text{“combat”})) \rightarrow \text{tapped}(c, t, p))$
- $\forall c \forall t \forall p\ ($
- $(\text{attack}(c, t) \wedge \text{after}(p, \text{“combat”}))$
- $\rightarrow \text{tapped}(c, t, p))$
- Generally true, and probably an axiom
- Why would this not be true?
- How would we fix that?

How does that help us?

- Assume attack("RagingGoblin","1")
- If we assert $\forall c \forall t \forall p\ ((\text{attack}(c,t) \wedge \text{after}(p, \text{"combat"})) \rightarrow \text{tapped}(c,t,p))$
- and after("end","combat")
- we know tapped("RagingGoblin", "1", "end")

The drawbacks to Logic

- Very large predicate and axiom requirements
  - Though not necessarily larger than human knowledge
- Quantitative knowledge is also hard
  - Had to cheat to get subtraction
- Frame problem: Hard to know if unrelated predicates are changing
  - Not so much in magic, but it exists

Why KR is still cool

- It can do a lot of stuff
  - There was a point in which mathematical facts were being generated by computers
- Can learn a lot from very small examples
- More powerful with inconsistent systems
  - Extensible into ML
- It actually makes sense

The next step

- KR is cool, but it doesn’t give us a Magic playing AI
- What more do we need for that?

Cognitive Architectures

- Basic environment or state
- KR or equivalent logical system to find truths in state
- Goals to shoot for
- Actions to achieve goals

Icarus

- One of many existing cognitive architectures
  - Soar, ACT-R, Prodigy
- Began by Pat Langley, now maintained by his lab
- Written entirely in Lisp

Basic flow

- Define environment and goal
- For each cycle
  - Recognize percepts from environment
  - Apply concepts to determine beliefs
  - If goal isn't satisfied
    - Go to appropriate skill and execute action or subgoals

Cognitive Architecture Recap

- Often requires a lot of hand-coded domain knowledge
- Big goal is to demonstrate cross-domain knowledge

Master Decoy
1
Summon Soldier
, : Tap target creature.
"A skilled decoy can throw your enemies off your trail. A master decoy can survive to do it again."
—Gerrard of the Weatherlight
Illus. Phil Foglio
©1997 Wizards of the Coast, Inc.
1/2

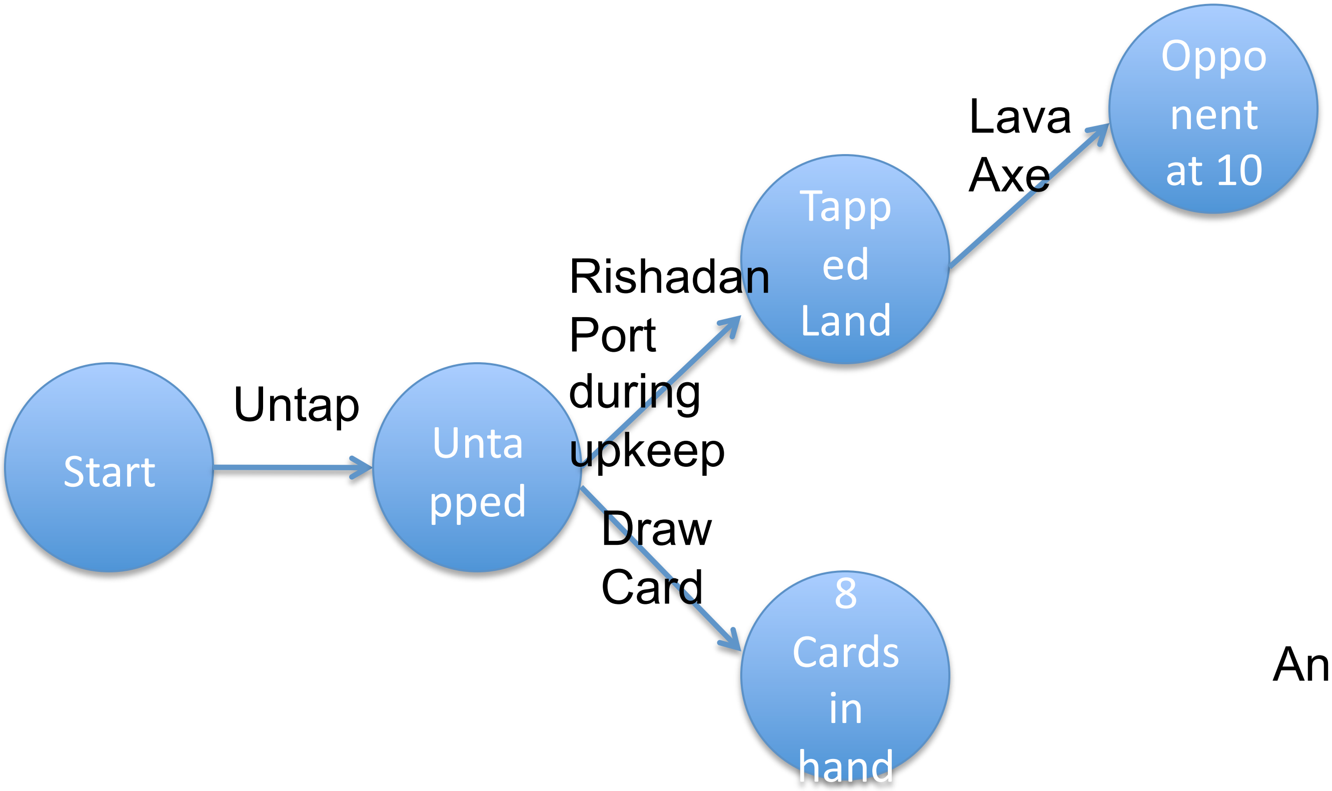
Let’s go statistical

- Look at an example of a statistical approach
- Built upon game theory, graph theory, and computation

Game Trees

- Game trees are directed graphs representing entire games
- Nodes are complete descriptions of positions
  - Includes creatures in play, cards in hand, library arrangement, etc
- Edges are various actions that change the position
  - Drawing a card, attacking

Example tree



And so on

For some perspective…

- Rubik's cube is a good way to think about the tree
- Each configuration of the cube is a different position
- Each spin, twist, pull, twirl, bop is an action
- Total position size?

So back to total positions

- According to Wikipedia, 3x3 cube has 43,252,00 ions
- About 900 ce right now
  - For 60 ca 55 decks
  - 10^80 at
  - Most of
- Magic is t not really

So what's next?

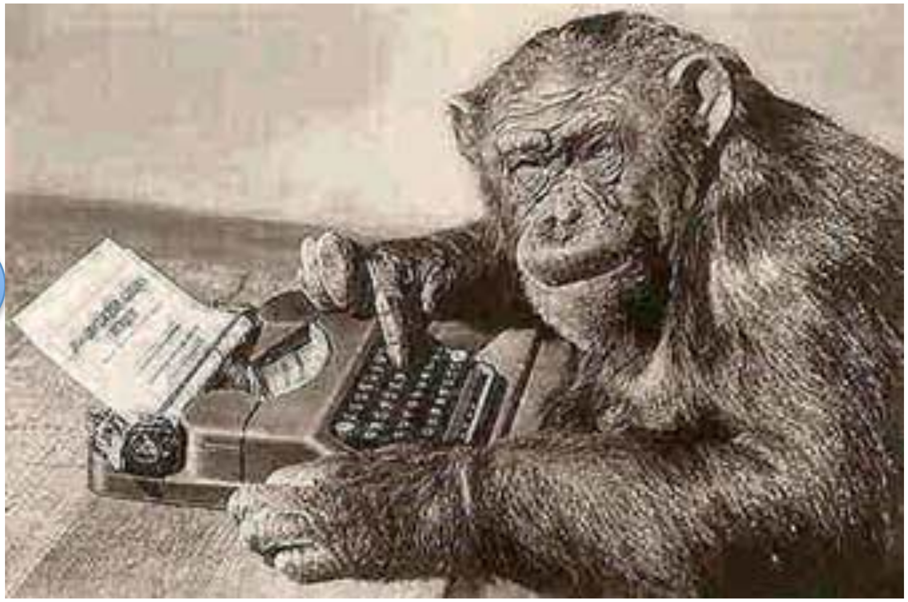
- Game tree is analogous to KR
  - Gives us a way to understand the game, but not a way to play
- How do we turn this into a Magic player?
- Search!
- Really looking for a path from current position to winning position
  - Use your favorite old-fashioned search algo with logic for following edges

Do you chump?

Canyon Minotaur
3
Creature — Minotaur Warrior
"We'll scale these cliffs, traverse Brittle Bridge, and then fight our way down the volcanic slopes on the other side."
"Isn't the shortest route through the canyon?"
"Yes."
"So shouldn't we—"
"No."
Steve Prescott
3/3

Grizzly Bears
1
Creature — Bear
"We cannot forget that among all of Dominaria's wonders, a system of life exists, with prey and predators that will never fight wars nor vie for ancient power."
—Jolrael, empress of beasts
D. J. Cleland-Hura
2/2

I'm not optimistic about this



What about in finite time?

- Need to use heuristics
- Can look a certain depth away instead of all the way down
- Use an evaluation function to compare the "goodness" of various positions

If we do block…

2 * 0 (for having no grizzly bears)
+ .1 * 20 (for having 20 life)
+ .01 * 44 (cards in library)
+ -.1 * 18 (opponent's life)
+ 4 * 3 (cards in hand)
+ -3 * 2 (cards in opponent's hand)
+ 1 * 1 (open forests)
+ .5 * 2 (open mountains)
+ .1 * 2 (cards in graveyard)
+ 1000 * 1 (because psychic battle isn't in play)
+ -2 * 0 (for number of poison counters on you)
+ S * 3 (for the change in entropy)
+ avagadro's number * 4
+ number of episodes in Avatar: the Last Airbender

+…. =

Something less than 5

If we don’t block…

2 * 1 (for having 1 grizzly bear)
+ .1 * 18 (for having 18 life)
+ .01 * 44 (cards in library)
+ -.1 * 18 (opponent’s life)
+ 4 * 3 (cards in hand)
+ -3 * 2 (cards in opponent’s hand)
+ 1 * 1 (open forests)
+ .5 * 2 (open mountains)
+ .1 * 1 (cards in graveyard)
+ 1000 * 1 (because psychic battle isn’t in play)
+ -2 * 0 (for number of poison counters on you)
+ S * 3 (for the change in entropy)
+ avagadro’s number * 4
+ number of episodes in Avatar: the Last Airbender

+…. =

Something more than 5

Minimax

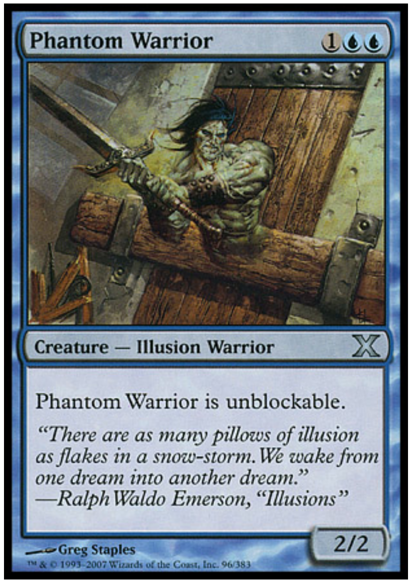
- So it's helpful to do this to the deepest level possible
- Trickier because you need to alternate levels with your opponent
  - Assume opponent picks best move for them each time, and propagate that value upwards
- Can push a value up to your current position
- This is minimax

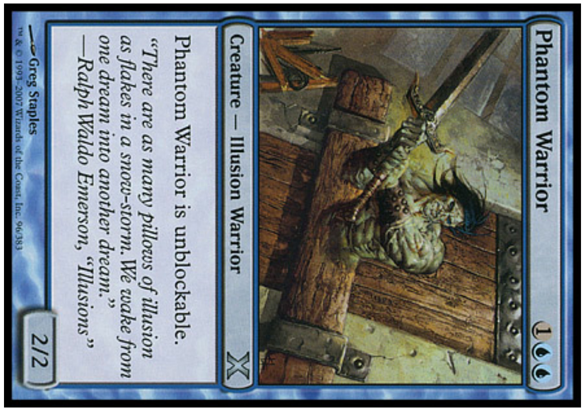
Minimax in action

- http://www.ocf.berkeley.edu/~yosenl/extras/alphabeta/alphabeta.html

Scenario

TOM
4 Life
0 Cards in hand


Phantom Warrior
Creature — Illusion Warrior
Phantom Warrior is unblockable.
"There are as many pillows of illusion as flakes in a snow-storm. We wake from one dream into another dream."
—Ralph Waldo Emerson, "Illusions"
2/2
Greg Staples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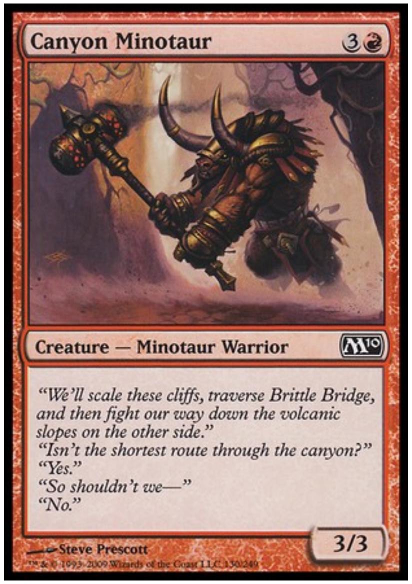
2/2
Greg Staples

ME
2 Life
0 Cards in hand


Canyon Minotaur
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3/3
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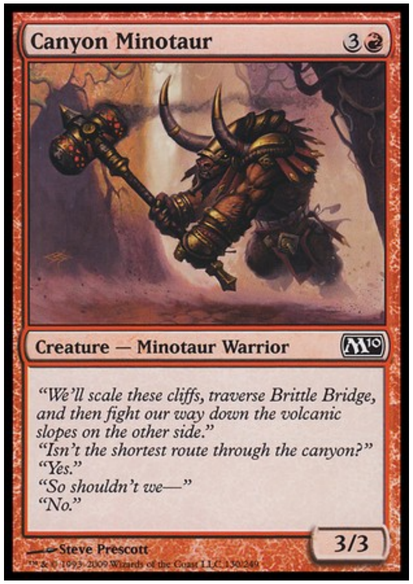
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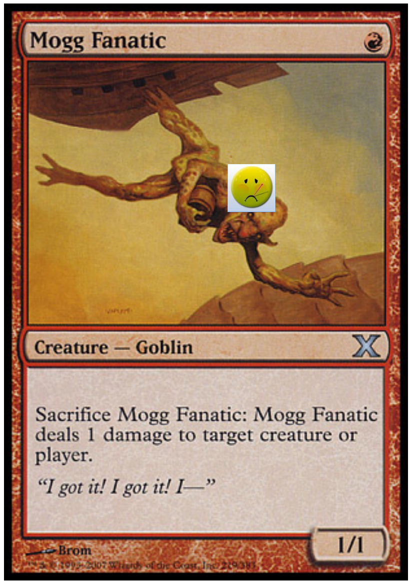
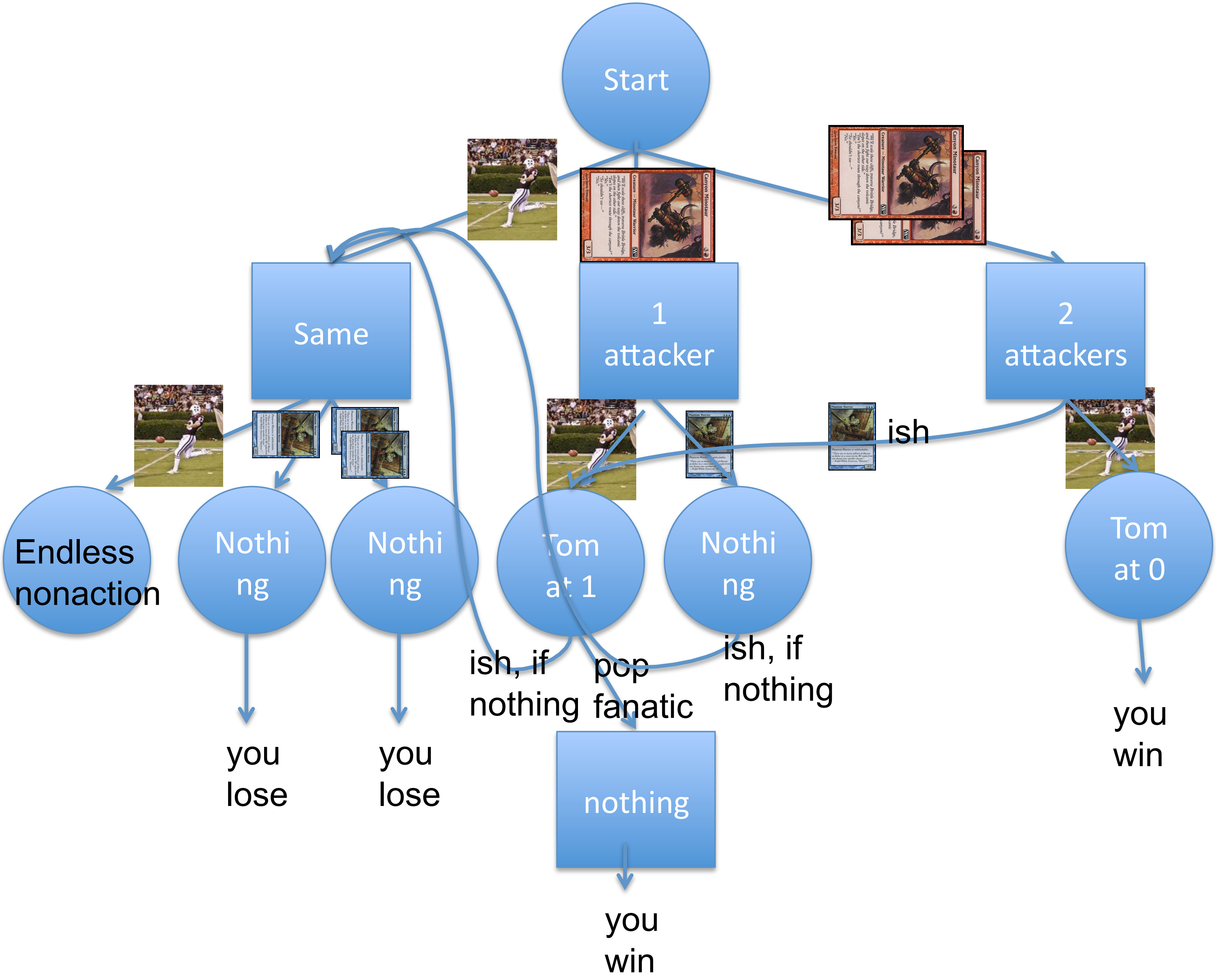

Mogg Fanatic
Creature — Goblin
Sacrifice Mogg Fanatic: Mogg Fanatic deals 1 damage to target creature or player.
"I got it! I got it! I—"
1/1
Brom

What should I do?


Start
Same
1 attacker
2 attackers
Endless nonaction
Nothing
Nothing
Tom at 1
Nothing
Tom at 0
ish
ish, if nothing
pop fanatic
ish, if nothing
nothing
you lose
you lose
you win
you win

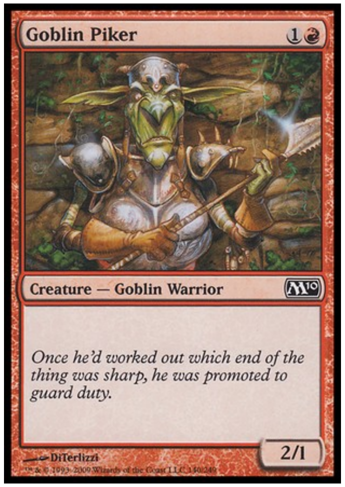
Minimax properties

- Designed for 2 player, 0 sum games
  - Your loss is my victory, vice versa
  - Alternating actions for 2 people
- Complete
  - ie slow as balls
  - What to do?

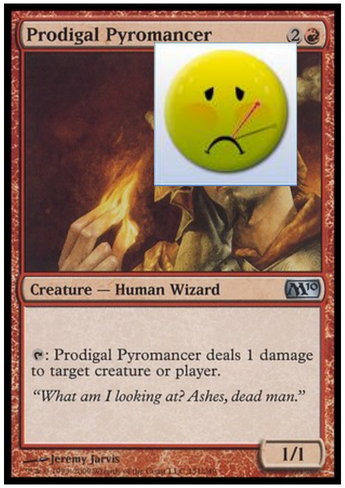
Alpha-Beta Pruning

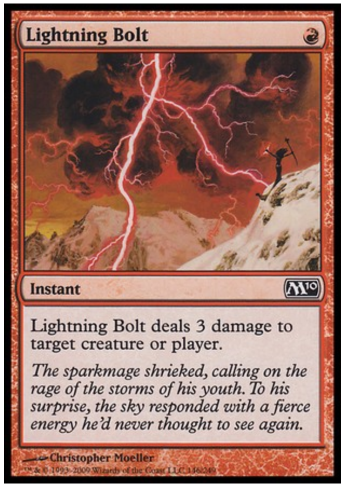
- Reduces total search by ignoring unimportant subtrees
- Which subtrees are unimportant?
  - The ones that are worse than ones you’ve already seen

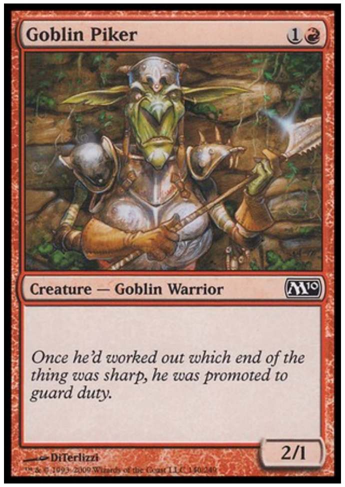
Example


Goblin Piker
Creature — Goblin Warrior
Once he'd worked out which end of the thing was sharp, he was promoted to guard duty.
2/1

TOM
6 Life
0 Cards in Hand
Piker on top


Prodigal Pyromancer
Creature — Human Wizard
: Prodigal Pyromancer deals 1 damage to target creature or player.
"What am I looking at? Ashes, dead man."
1/1


Lightning Bolt
Instant
Lightning Bolt deals 3 damage to target creature or player.
The sparkmage shrieked, calling on the rage of the storms of his youth. To his surprise, the sky responded with a fierce energy he'd never thought to see again.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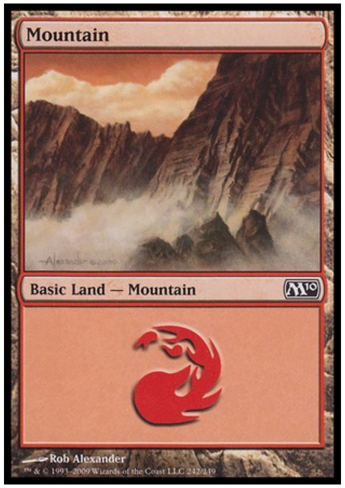
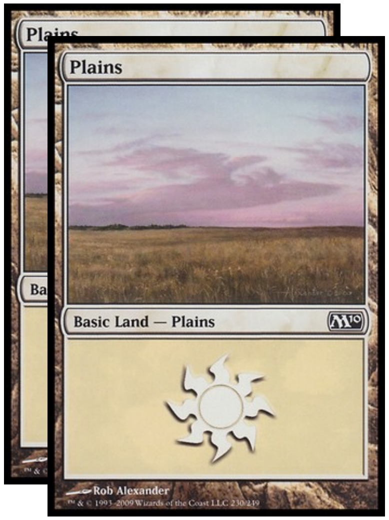
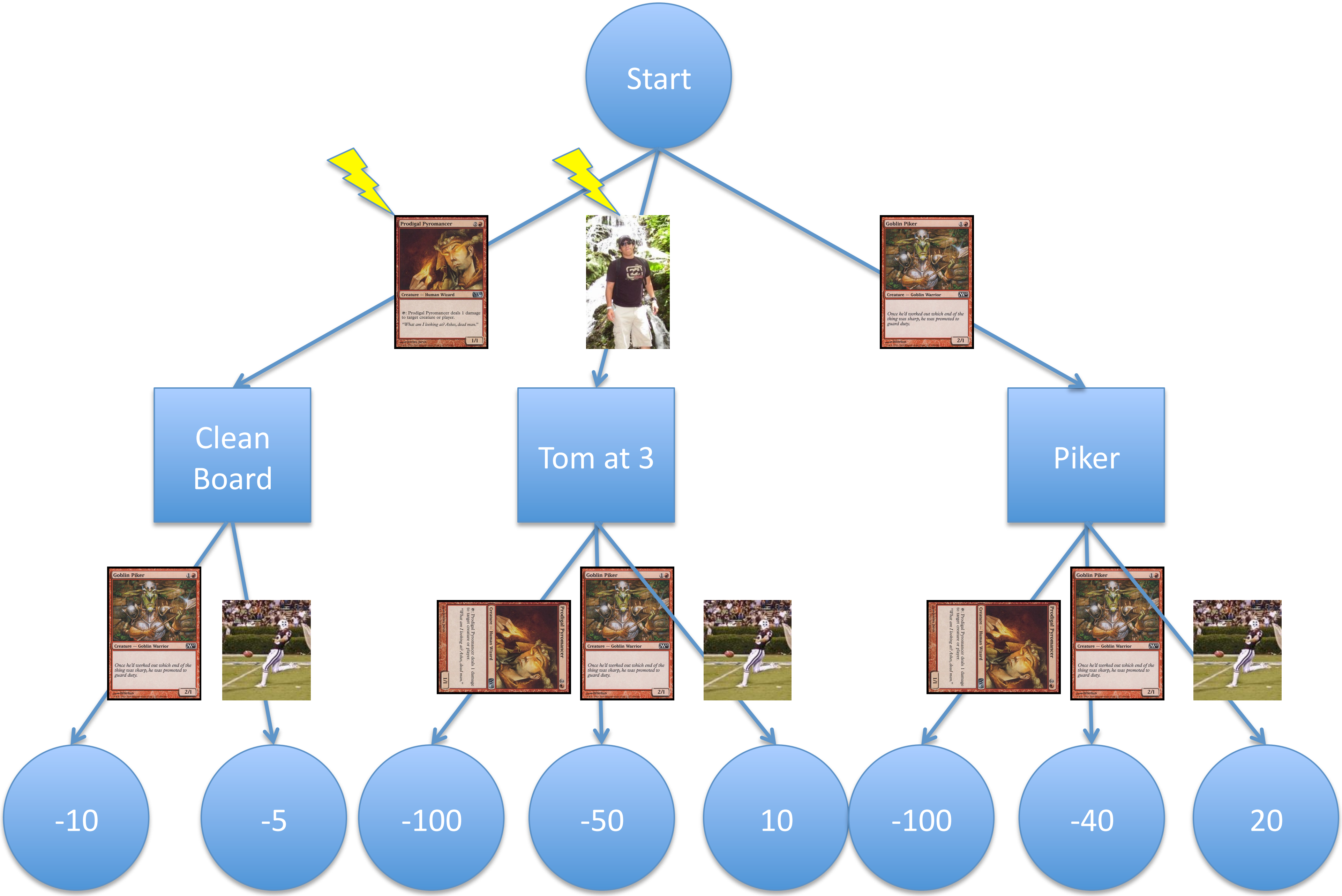
2/1

ME
1 Life







Start

Clean Board

Tom at 3

Piker

-10

-5

-100

-50

10

-100

-40

20

How are you a better player?

- Ignore situations that you know your opponent can play around
- Isolate important vars to determine if a position is better than another
- Think about Magic like a tree of actions

Want more?

- Gavin Verhey mentions that good players keep options open for later
  - Equivalent to picking paths that have multiple, high evaluation nodes
- Perhaps equivalent to constraint-satisfaction problems
  - Forward-checking and least-constraining vars
- General heuristics