

Agency modeling in Hearthstone

What is hearthstone?



What we've done



Thank you!



Questions!

AI discussion



Demo video



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Demo video



What is hearthstone?



TH



Weapon

Opponent

History

Enemy Minions

END TURN

Your Minion

Your Deck

Hero Power

Player

Mana

Your Hand

1/3

What is hearthstone?



TH

What we've done

u!



Actuator



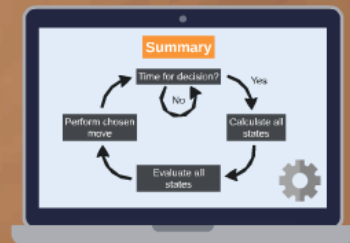
Perception



Intelligence



Agent



Standard Agent Design

Actuator

How do we perform moves inside the game?

We made a robot-class that can perform "moves" in the game-client.



There are 19 possible moves, some examples of moves are:

```
playMinionFromHandToIndex  
(int indexInHand, int indexOnBoard)  
  
attackAction  
(int friendlyIndex, int enemyIndex)  
  
endTurn()
```

It also interpolates the cursor between points instead of teleporting it.
It makes the mouse-movement look more human-like.



Percept

How do we know what happens in the game?

Hearthstone has no API to fetch data from the game.

But we found out that we can access the game state on logging in the client.

The log outputs a lot of data, so we needed to establish a schema for the data we needed to reconstruct our state.



How do we perform moves inside the game?

We made a robot-class that can perform "moves" in the game-client.



The robot knows where on the board minions are and where in the hand cards are.



There are 19 possible moves,
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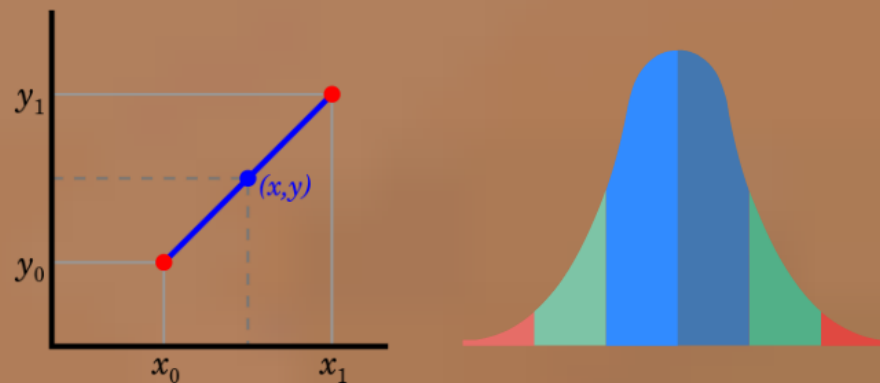
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Perception

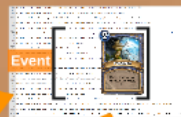
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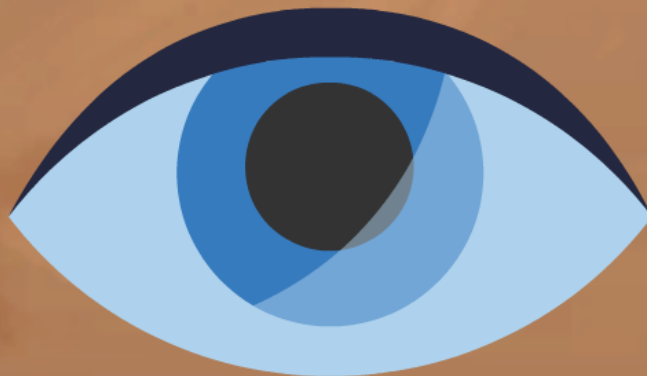
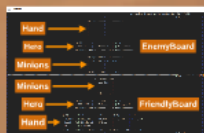
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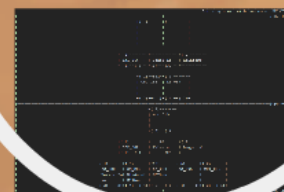


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How do we play the game well?

Our approach is to make informed evaluation of BoardStates with advanced Heuristic functions.



Example

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Therefore the `heroHealth` weight returns a greater value, making the parameter more impactful.



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```
5116 (Filename: C:/buildslave/unity/build/artifacts/generated/common/runtime/UnityEngineDebugBindings.gen.cpp Line: 65)
5117
5118 [Power] GameState.DebugPrintPower() - TAG_CHANGE Entity=AlphaStone tag=MULLIGAN_STATE value=DEALING
5119
5120 (Filename: C:/buildslave/unity/build/artifacts/generated/common/runtime/UnityEngineDebugBindings.gen.cpp Line: 65)
5121
5122 [Power] GameState.DebugPrintPower() - BLOCK_START BlockType=TRIGGER Entity=AlphaStone EffectCardId= EffectIndex=6 Target=0
5123
5124 (Filename: C:/buildslave/unity/build/artifacts/generated/common/runtime/UnityEngineDebugBindings.gen.cpp Line: 65)
5125
5126 [Power] GameState.DebugPrintPower() - SHOW_ENTITY - Updating Entity=[id=7 cardId= type=INVALID zone=DECK zonePos=0 player=1] CardID=CS2_024
5127
5128 (Filename: C:/buildslave/unity/build/artifacts/generated/common/runtime/UnityEngineDebugBindings.gen.cpp Line: 65)
5129
5130 [Power] GameState.DebugPrintPower() - tag=COST value=2
5131
5132 (Filename: C:/buildslave/unity/build/artifacts/generated/common/runtime/UnityEngineDebugBindings.gen.cpp Line: 65)
5133
5134 [Power] GameState.DebugPrintPower() - tag=ZONE value=HAND
5135
5136 (Filename: C:/buildslave/unity/build/artifacts/generated/common/runtime/UnityEngineDebugBindings.gen.cpp Line: 65)
5137
5138 [Power] GameState.DebugPrintPower() - tag=FACTION value=NEUTRAL
5139
5140 (Filename: C:/buildslave/unity/build/artifacts/generated/common/runtime/UnityEngineDebugBindings.gen.cpp Line: 65)
5141
5142 [Power] GameState.DebugPrintPower() - tag=CARDTYPE value=SPELL
5143
5144 (Filename: C:/buildslave/unity/build/artifacts/generated/common/runtime/UnityEngineDebugBindings.gen.cpp Line: 65)
5145
5146 [Power] GameState.DebugPrintPower() - tag=RARITY value=COMMON
5147
5148 (Filename: C:/buildslave/unity/build/artifacts/generated/common/runtime/UnityEngineDebugBindings.gen.cpp Line: 65)
5149
5150 [Power] GameState.DebugPrintPower() - tag=FREEZE value=1
5151
5152 (Filename: C:/buildslave/unity/build/artifacts/generated/common/runtime/UnityEngineDebugBindings.gen.cpp Line: 65)
5153
5154 [Power] GameState.DebugPrintPower() - TAG_CHANGE Entity=[id=32 cardId= type=INVALID zone=DECK zonePos=0 player=1] tag=ZONE_POSITION value=3
5155
5156 (Filename: C:/buildslave/unity/build/artifacts/generated/common/runtime/UnityEngineDebugBindings.gen.cpp Line: 65)
5157
5158 [Power] GameState.DebugPrintPower() - HIDE_ENTITY - Entity=[name=Azure Drake id=33 zone=HAND zonePos=3 cardId=EX1_284 player=1] tag=ZONE value=DECK
5159
```

Event



- SHOW_ENTITY - Updating Entity=[id=?] Pos=0

d/artifacts/generated/common/runtime/Unity

- tag=COST value=2

d/artifacts/generated/common/runtime/Unity

- tag=ZONE value=HAND

d/artifacts/generated/common/runtime/Unity

- tag=FACTION value=NEUTRAL

d/artifacts/generated/common/runtime/Unity

- tag=CARDTYPE value=SPELL

d/artifacts/generated/common/runtime/Unity

- tag=RARITY value=COMMON

d/artifacts/generated/common/runtime/Unity

- tag=FREEZE value=1



Action

Action

```

[ation] C:\Program Files\Java\jre1.8.0_25\bin\javaw.exe (21 maj 2016 21:58:05)
EVENT #40 ACT_ID:28 -PLAY BLOCK_START BlockType=PLAY Entity=[name=Unearthed Raptor id=28 zone=HAND zonePos=2 cardId=LOE_019 player=1] Effect
CHANGE ENT_ID:2 #40 ACT_ID:28 -PLAY TAG_CHANGE Entity=Molk tag=RESOURCES_USED value=3
CHANGE ENT_ID:2 #40 ACT_ID:28 -PLAY TAG_CHANGE Entity=Molk tag=NUM_RESOURCES_SPENT_THIS_GAME value=5
CHANGE ENT_ID:2 #40 ACT_ID:28 -PLAY TAG_CHANGE Entity=Molk tag=NUM_CARDS_PLAYED_THIS_TURN value=1
CHANGE ENT_ID:17 #40 ACT_ID:28 -PLAY TAG_CHANGE Entity=Molk tag=NUM_MINIONS_PLAYED_THIS_TURN value=1
CHANGE ENT_ID:30 #40 ACT_ID:28 -PLAY TAG_CHANGE Entity=[name=Azure Drake id=17 zone=HAND zonePos=6 cardId=EX1_284 player=1] tag=ZONE_POSITION value=5
CHANGE ENT_ID:14 #40 ACT_ID:28 -PLAY TAG_CHANGE Entity=[name=Southsea Squidface id=30 zone=HAND zonePos=5 cardId=OG_267 player=1] tag=ZONE_POSITION value=3
CHANGE ENT_ID:31 #40 ACT_ID:28 -PLAY TAG_CHANGE Entity=[name=Sap id=14 zone=HAND zonePos=4 cardId=EX1_581 player=1] tag=ZONE_POSITION value=3
CHANGE ENT_ID:28 #40 ACT_ID:28 -PLAY TAG_CHANGE Entity=[name=Shadow Strike id=31 zone=HAND zonePos=3 cardId=OG_176 player=1] tag=ZONE_POSITION value=2
CHANGE ENT_ID:28 #40 ACT_ID:28 -PLAY TAG_CHANGE Entity=[name=Unearthed Raptor id=28 zone=HAND zonePos=2 cardId=LOE_019 player=1] tag=ZONE value=PLAY
CHANGE ENT_ID:28 #40 ACT_ID:28 -PLAY TAG_CHANGE Entity=[name=Unearthed Raptor id=28 zone=HAND zonePos=2 cardId=LOE_019 player=1] tag=ZONE_POSITION value=1
CHANGE ENT_ID:28 #40 ACT_ID:28 -PLAY TAG_CHANGE Entity=[name=Unearthed Raptor id=28 zone=HAND zonePos=2 cardId=LOE_019 player=1] tag=EXHAUSTED value=1
CHANGE ENT_ID:28 #40 ACT_ID:28 -PLAY TAG_CHANGE Entity=[name=Unearthed Raptor id=28 zone=HAND zonePos=2 cardId=LOE_019 player=1] tag=JUST_PLAYED value=1
CHANGE ENT_ID:2 #40 ACT_ID:28 -PLAY TAG_CHANGE Entity=Molk tag=LAST_CARD_PLAYED value=28
EVENT #40 ACT_ID:28 -POWER BLOCK_START BlockType=POWER Entity=[name=Unearthed Raptor id=28 zone=PLAY zonePos=1 cardId=LOE_019 player=1] Effect
EVENT #40 ACT_ID:28 -PLAY BLOCK_END
CHANGE ENT_ID:2 #40 ACT_ID:28 -PLAY TAG_CHANGE Entity=Molk tag=COMBO_ACTIVE value=1
CHANGE ENT_ID:2 #40 ACT_ID:28 -PLAY TAG_CHANGE Entity=Molk tag=NUM_OPTIONS_PLAYED_THIS_TURN value=1
EVENT #40 NO_ACTION BLOCK_END
EVENT #41 ACT_ID:64 -ATTACK BLOCK_START BlockType=ATTACK Entity=[name=Valeera Sanguinar id=64 zone=PLAY zonePos=0 cardId=HERO_03 player=1] Effect
CHANGE ENT_ID:1 #41 ACT_ID:64 -ATTACK TAG_CHANGE Entity=GameEntity tag=PROPOSED_ATTACKER value=64
CHANGE ENT_ID:1 #41 ACT_ID:64 -ATTACK TAG_CHANGE Entity=GameEntity tag=PROPOSED_DEFENDER value=45
CHANGE ENT_ID:64 #41 ACT_ID:64 -ATTACK TAG_CHANGE Entity=[name=Valeera Sanguinar id=64 zone=PLAY zonePos=0 cardId=HERO_03 player=1] tag=ATTACKING value=1
CHANGE ENT_ID:1 #41 ACT_ID:64 -ATTACK TAG_CHANGE Entity=GameEntity tag=NEXT_STEP value=MAIN_ACTION
CHANGE ENT_ID:1 #41 ACT_ID:64 -ATTACK TAG_CHANGE Entity=GameEntity tag=STEP value=MAIN_COMBAT
CHANGE ENT_ID:2 #41 ACT_ID:64 -ATTACK TAG_CHANGE Entity=Molk tag=NUM_OPTIONS_PLAYED_THIS_TURN value=2
CHANGE ENT_ID:45 #41 ACT_ID:64 -ATTACK TAG_CHANGE Entity=[name=Loot Hoarder id=45 zone=PLAY zonePos=1 cardId=EX1_096 player=2] tag=DEFENDING value=1
CHANGE ENT_ID:45 #41 ACT_ID:64 -ATTACK TAG_CHANGE Entity=[name=Loot Hoarder id=45 zone=PLAY zonePos=1 cardId=EX1_096 player=2] tag=PREDAMAGE value=1
CHANGE ENT_ID:45 #41 ACT_ID:64 -ATTACK TAG_CHANGE Entity=[name=Loot Hoarder id=45 zone=PLAY zonePos=1 cardId=EX1_096 player=2] tag=PREDAMAGE value=0
EVENT #41 ACT_ID:64 -ATTACK META_DATA - Meta=DAMAGE Data=1 Info=1
EVENT #41 ACT_ID:64 -ATTACK Info[0] = [name=Loot Hoarder id=45 zone=PLAY zonePos=1 cardId=EX1_096 player=2]
CHANGE ENT_ID:45 #41 ACT_ID:64 -ATTACK TAG_CHANGE Entity=[name=Loot Hoarder id=45 zone=PLAY zonePos=1 cardId=EX1_096 player=2] tag=LAST_AFFECTED_BY value=1
CHANGE ENT_ID:45 #41 ACT_ID:64 -ATTACK TAG_CHANGE Entity=[name=Loot Hoarder id=45 zone=PLAY zonePos=1 cardId=EX1_096 player=2] tag=DAMAGE value=1
CHANGE ENT_ID:64 #41 ACT_ID:64 -ATTACK TAG_CHANGE Entity=[name=Valeera Sanguinar id=64 zone=PLAY zonePos=0 cardId=HERO_03 player=1] tag=PREDAMAGE value=1
CHANGE ENT_ID:64 #41 ACT_ID:64 -ATTACK TAG_CHANGE Entity=[name=Valeera Sanguinar id=64 zone=PLAY zonePos=0 cardId=HERO_03 player=1] tag=PREDAMAGE value=0
EVENT #41 ACT_ID:64 -ATTACK META_DATA - Meta=DAMAGE Data=2 Info=1
EVENT #41 ACT_ID:64 -ATTACK Info[0] = [name=Valeera Sanguinar id=64 zone=PLAY zonePos=0 cardId=HERO_03 player=1]
CHANGE ENT_ID:64 #41 ACT_ID:64 -ATTACK TAG_CHANGE Entity=[name=Valeera Sanguinar id=64 zone=PLAY zonePos=0 cardId=HERO_03 player=1] tag=LAST_AFFECTED_BY value=1
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CHANGE ENT_ID:64 #41 ACT_ID:64 -ATTACK TAG_CHANGE Entity=[name=Valeera Sanguinar id=64 zone=PLAY zonePos=0 cardId=HERO_03 player=1] tag=EXHAUSTED value=1
EVENT #41 ACT_ID:2 -TRIGGER BLOCK_START BlockType=TRIGGER Entity=Molk EffectCardId= EffectIndex=3 Target=0
CHANGE ENT_ID:69 #41 ACT_ID:2 -TRIGGER TAG_CHANGE Entity=[name=Wicked Knife id=69 zone=PLAY zonePos=0 cardId=CS2_082 player=1] tag=PREDAMAGE value=1
CHANGE ENT_ID:69 #41 ACT_ID:2 -TRIGGER TAG_CHANGE Entity=[name=Wicked Knife id=69 zone=PLAY zonePos=0 cardId=CS2_082 player=1] tag=PREDAMAGE value=0
EVENT #41 ACT_ID:2 -TRIGGER META_DATA - Meta=DAMAGE Data=1 Info=1
EVENT #41 ACT_ID:2 -TRIGGER Info[0] = [name=Wicked Knife id=69 zone=PLAY zonePos=0 cardId=CS2_082 player=1]
CHANGE ENT_ID:69 #41 ACT_ID:2 -TRIGGER TAG_CHANGE Entity=[name=Wicked Knife id=69 zone=PLAY zonePos=0 cardId=CS2_082 player=1] tag=LAST_AFFECTED_BY value=1

```

We learned that all things in the game are treated as **entities**.

An **entity** is built up by unique tags that are set to values. We chose to represent an **entity** with a:

HashMap<String, String> tags

A **boardstate** is built up by 70 **entities** from the start but as the game progresses more are added.

We chose to represent a **boardstate** with a:

HashMap<String, Entity> entities

Printing board with hashcode -829771274

(0 / 4)

Hand



```
+ ( ) -----+ ( ) -----+
|
|
|
+-----+-----+
```

Hero



```
+ ( 3 ) -----+ +-----+ + ( 2 ) -----+
| EX1_366 | | Uther Li | | Reinforc |
+ ( 1 ) -- ( 4 ) + + ( 1 ) -- ( 30 ) + +-----+
```

EnemyBoard

Minions



```
+ ( 1 ) --zZZ--+ ( 3 ) -----+
| CS2_188 | | AT_087 |
|
|
+ ( 2 ) -- ( 1 ) + ( 4 ) -- ( 1 ) +
```

[Opponents turn]

Minions



```
+ ( 3 ) --zZZ--+
| LOE_019 |
|
|
+ ( 3 ) -- ( 4 ) +
```

Hero



```
+ ( 1 ) -----+ +---zZZ-----+ + ( 2 ) -----+
| CS2_082 | | Valeera | | Dagger M |
+ ( 1 ) -- ( 1 ) + +----- ( 23 ) + +-----+
```

FriendlyBoard

Hand



```
+ ( 4 ) -----+ ( 9 ) -----+ ( 10 ) -----+ ( 5 ) -----+ ( 2 ) -----+
| OG_080 | | OG_282 | | OG_280 | | OG_295 | | EX1_096 |
| Xaril, Po| | Blade of | | C'Thun | | | |
| is | | C'Thun | | | |
+ ( 3 ) -- ( 2 ) + ( 4 ) -- ( 4 ) + ( 6 ) -- ( 6 ) + ( 4 ) -- ( 4 ) + ( 2 ) -- ( 1 ) +
```

(0 / 3)

ator

Perception

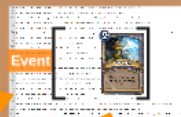
Intelli

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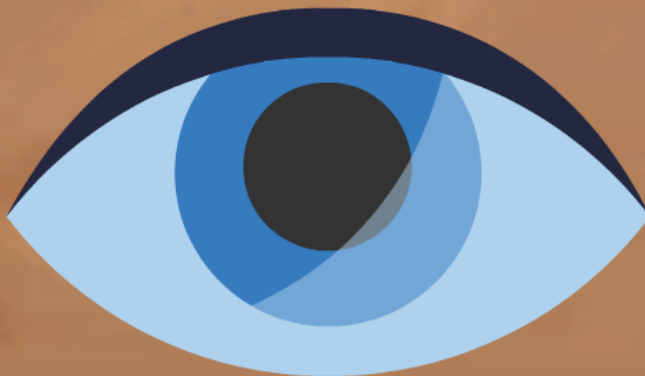
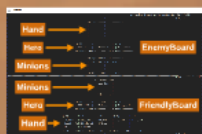
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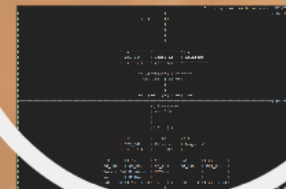


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How do we play the game well?

Our approach is to make informed evaluation of BoardStates with advanced Heuristic functions.



Example

The `heroHealth` parameter becomes more important when one of the heroes are close to dying.

Therefore the `heroHealth` weight returns a greater value, making the parameter more impactful.



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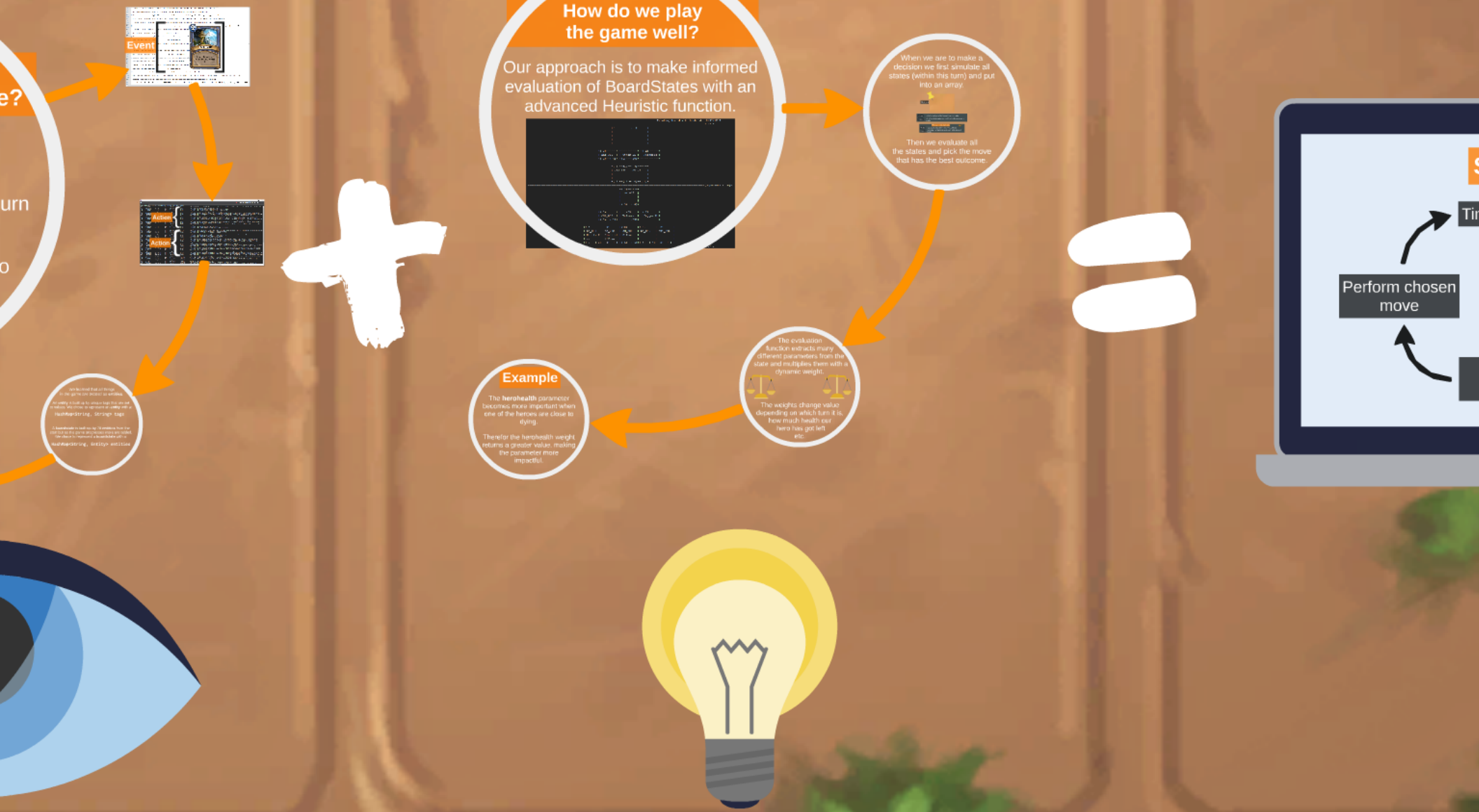
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Intelligence

Ag

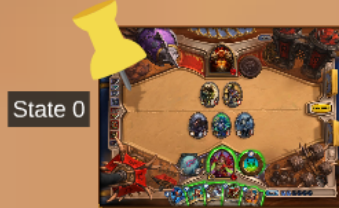


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```
Printing board with hashcode -829771274
----- ( 0 / 4) -----
+ ( ) -----+ ( ) -----+
|   |   |   |   |
+-----+-----+-----+
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+-----+-----+-----+
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| LOE_019 |
|   |   |   |
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+ ( 3) -- ( 2) + ( 4) -- ( 4) + ( 6) -- ( 6) + ( 4) -- ( 4) + ( 2) -- ( 1) +
----- ( 0 / 3) -----
```

When we are to make a decision we first simulate all states (within this turn) and put into an array.



| | |
|--------|---|
| Moves | Calculate all possible "moves" we can make |
| States | Simulate what states we could be in after a move is made. |

| | |
|--------------------------|---|
| For each simulated state | |
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Then we evaluate all the states and pick the move that has the best outcome.

State 0



Moves

Calculate all possible "moves" we can make

States

Simulate what states we could be in after a move is made.

For each simulated state

Moves

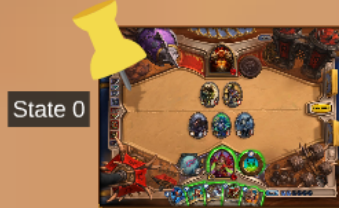
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States

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| Moves | Calculate all possible "moves" we can make |
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Then we evaluate all the states and pick the move that has the best outcome.

The evaluation function extracts many different parameters from the state and multiplies them with a dynamic weight.



The weights change value depending on which turn it is, how much health our hero has got left etc.

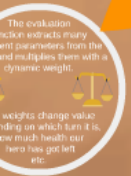
Example

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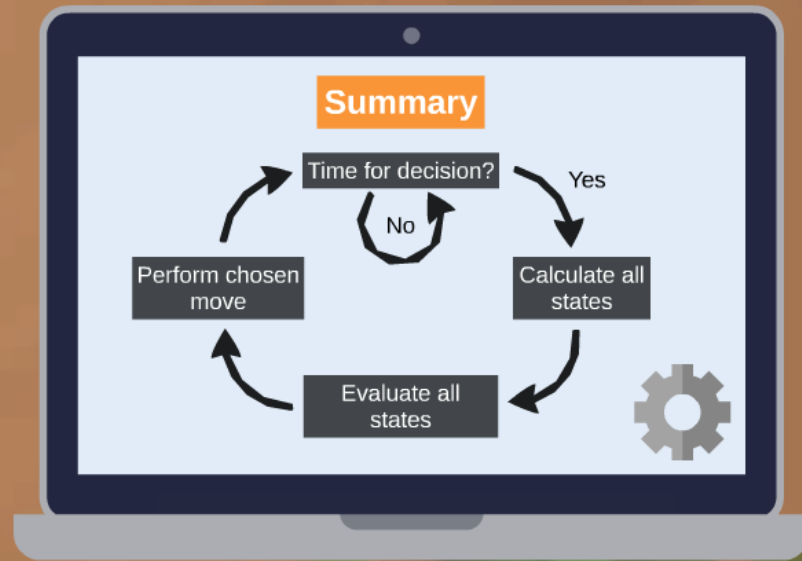
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gience

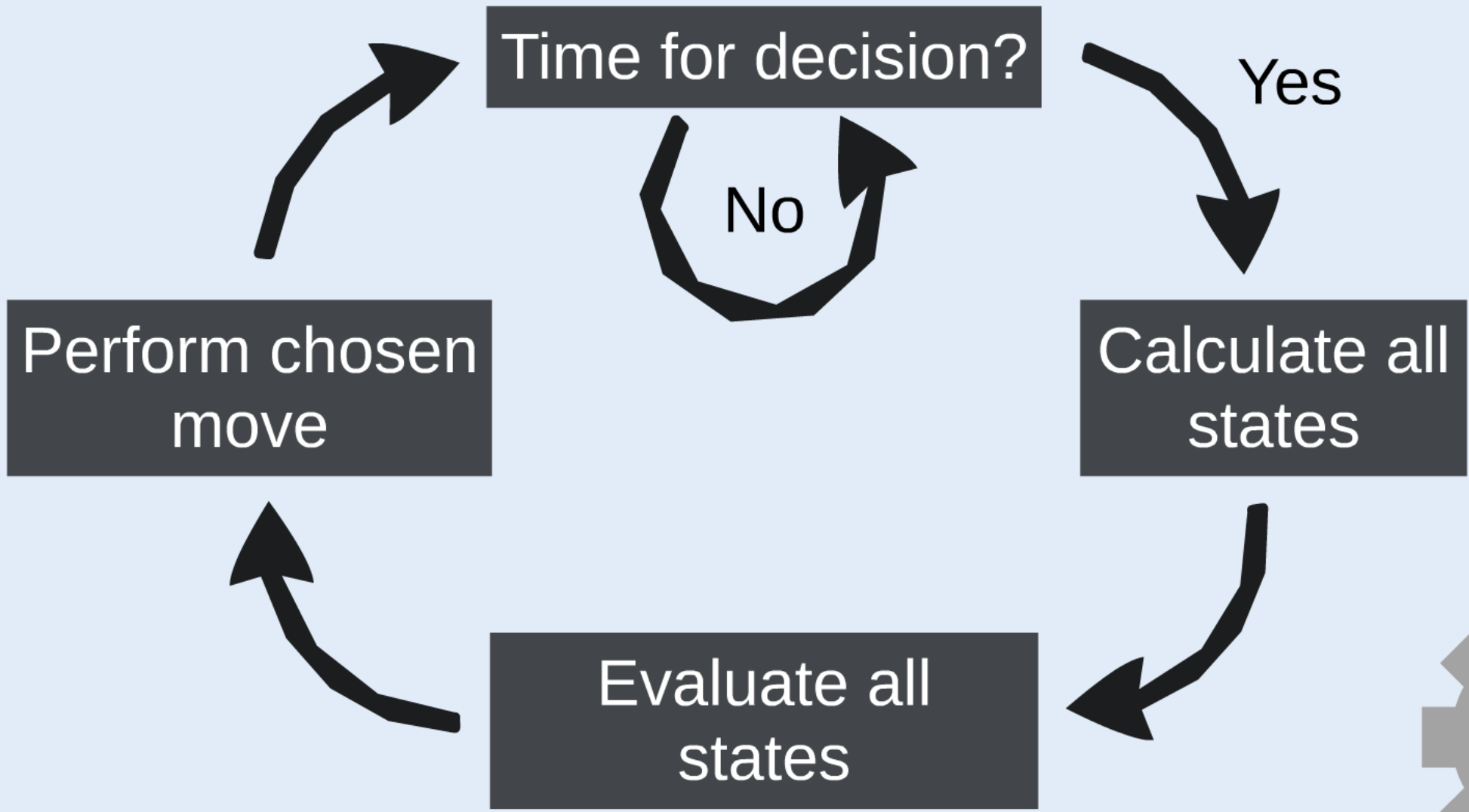
Agent



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Summary



What we've done

u!



AI discussion



Why not use a planning algorithm?

There are over 2000 cards in the game, how could we reason about what the opponent might do?



...Even if we could reason effectively, we would not have time to implement all the cards

Why not a machine learning algorithm?

A game commonly take between 5-15 minutes



It would take too long for us to play enough games

Our approach

There are a lot of knowledge about good tactics and what to strive for in Hearthstone

A heuristic function was a way to implement some of that knowledge into the AI



A future approach

If we were to continue our work

We would try to use machine learning to tune the weights and improve the heuristic function



Why not use a planning algorithm



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how could we reason about what the
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There are a lot of knowledge about good tactics and what to strive for in Hearthstone

A heuristic function was a way to implement some of that knowledge into the AI



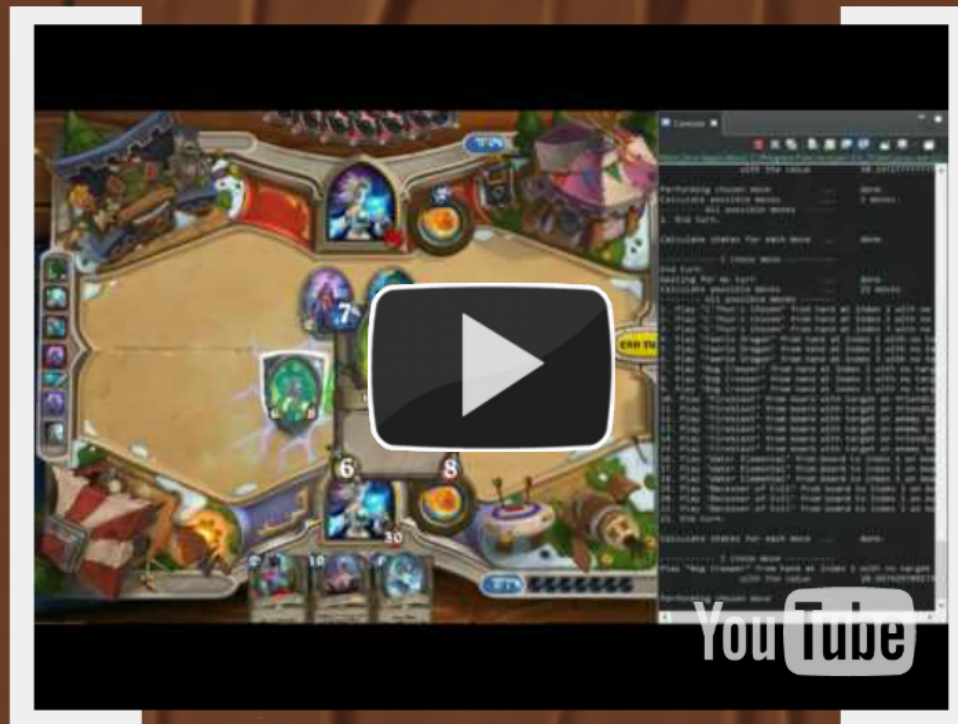
A future approach

If we were to continue our work

We would try to use machine learning
to tune the weights and improve the
heuristic function



Demo video





```

[Turn 7]
Cost: 0
7/11
Calculating possible moves ... Done
----- All possible moves -----
1. Big Game

Calculating costs for each move ... Done
----- 1 move move -----
End Turn
COINING FOR NO COST
Calculating possible moves ... Done
----- All possible moves -----
Play "Water Elemental" from hand at index 1 with no
Play "Water Elemental" from hand at index 2 with no
Play "Water Elemental" from hand at index 3 with no
Play "Water Elemental" from hand at index 4 with no
Play "Water Elemental" from hand at index 5 with no
Play "Water Elemental" from hand at index 6 with no
Play "Water Elemental" from hand at index 7 with no
Play "Water Elemental" from hand at index 8 with no
Play "Water Elemental" from hand at index 9 with no
Play "Water Elemental" from hand at index 10 with no
Play "Water Elemental" from hand at index 11 with no
Play "Water Elemental" from hand at index 12 with no
Play "Water Elemental" from hand at index 13 with no
Play "Water Elemental" from hand at index 14 with no
Play "Water Elemental" from hand at index 15 with no
Play "Water Elemental" from hand at index 16 with no
Play "Water Elemental" from hand at index 17 with no
Play "Water Elemental" from hand at index 18 with no
Play "Water Elemental" from hand at index 19 with no
Play "Water Elemental" from hand at index 20 with no
Play "Water Elemental" from hand at index 21 with no
Play "Water Elemental" from hand at index 22 with no
Play "Water Elemental" from hand at index 23 with no
Play "Water Elemental" from hand at index 24 with no
Play "Water Elemental" from hand at index 25 with no
Play "Water Elemental" from hand at index 26 with no
Play "Water Elemental" from hand at index 27 with no
Play "Water Elemental" from hand at index 28 with no
Play "Water Elemental" from hand at index 29 with no
Play "Water Elemental" from hand at index 30 with no
Play "Water Elemental" from hand at index 31 with no
Play "Water Elemental" from hand at index 32 with no
Play "Water Elemental" from hand at index 33 with no
Play "Water Elemental" from hand at index 34 with no
Play "Water Elemental" from hand at index 35 with no
Play "Water Elemental" from hand at index 36 with no
Play "Water Elemental" from hand at index 37 with no
Play "Water Elemental" from hand at index 38 with no
Play "Water Elemental" from hand at index 39 with no
Play "Water Elemental" from hand at index 40 with no
The turn.
Calculating costs for each move ... Done
----- 1 move move -----
Play "Big Game" from hand at index 1 with no target
with the value 26 90146919027
Performing chosen move:

```

YouTube

Agency modeling in Hearthstone

What is hearthstone?



What we've done



Thank you!



Questions!

AI discussion



Demo video



Thank you!



Session

Dem

Questions!

