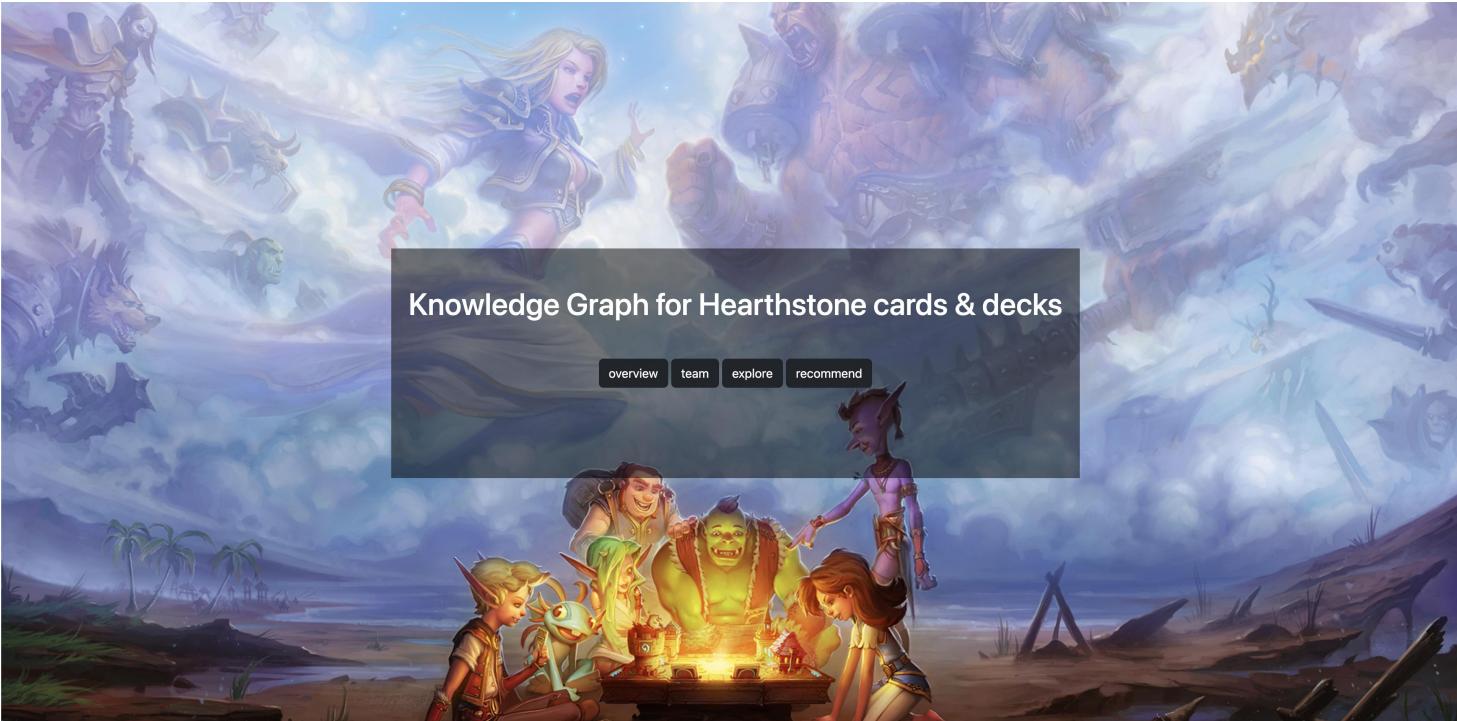


Building Knowledge Graph for Hearthstone cards & decks



Xuyang Wang, Yuqin Chen

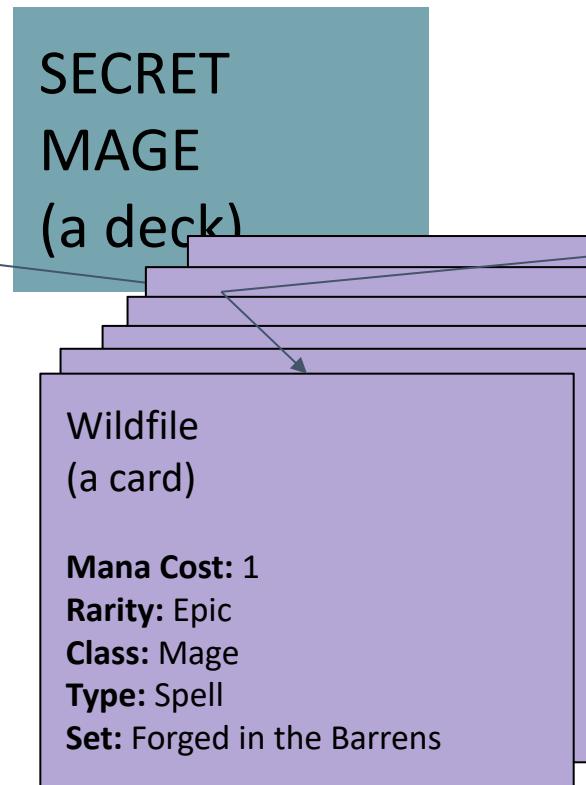
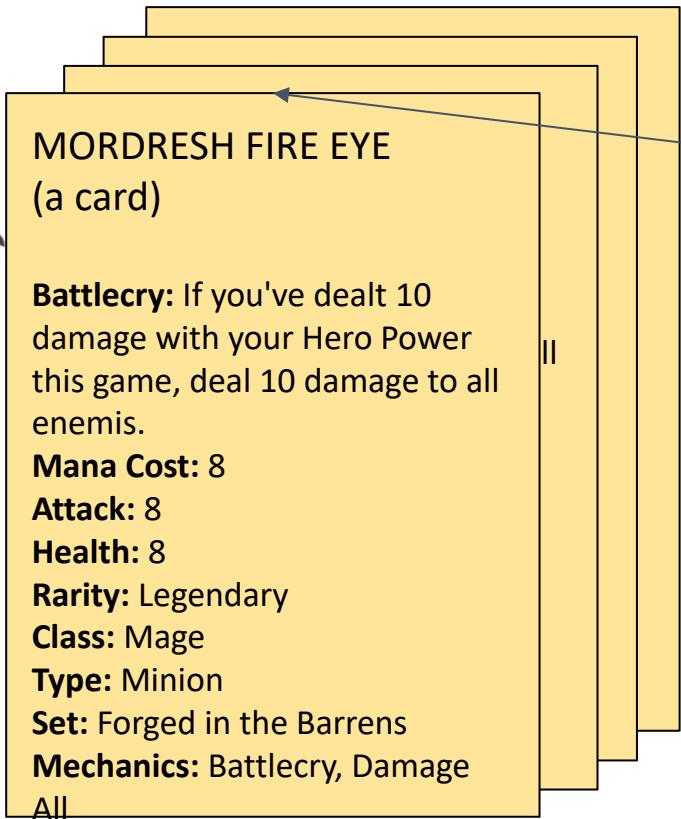
Contents

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- Functionality
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Goal / Objective

Building a knowledge graph about Hearthstone cards & decks

- Players can explore relationship between cards & decks based on KG
- Recommend related cards for player



Data Source

HearthstoneJSON

<https://hearthstone.blizzard.com/en-us/cards>

Card objects
See full card documentation.

Example card:

```
{  
  "id": "EX1_116",  
  "dbfId": 559,  
  "name": "Leeroy Jenkins",  
  "text": "<b>Charge</b>. <b>Battlecry:</b> Summon two 1/1 Whelps for your opponent.",  
  "flavor": "At least he has Angry Chicken.",  
  "artist": "Gabe from Penny Arcade",  
  "attack": 6,  
  "cardClass": "NEUTRAL",  
  "collectible": true,  
  "cost": 5,  
  "elite": true,  
  "faction": "ALLIANCE",  
  "health": 2,  
  "mechanics": [  
    "BATTLECRY",  
    "CHARGE"  
  ],  
  "rarity": "LEGENDARY",  
  "set": "EXPERT1",  
  "type": "MINION"  
}
```

A screenshot of the Leeroy Jenkins card from Hearthstone. The card is a Legendary Neutral Minion with a cost of 5. It has 6 attack and 2 health. The flavor text says "At least he has Angry Chicken.". The card text says "Charge. Battlecry: Summon two 1/1 Whelps for your opponent." The card art shows Leeroy Jenkins in his signature red suit and helmet, standing in front of a large circular frame.

Decks:

<https://hsreplay.net/decks/> Decks:
<https://www.hearthstonetopdecks.com/>

	Similar Decks	Streams	VODs
	Card ▲	Mulligan WR ▼ ?	
0	Aquatic Form	2	▼59.3%
1	Beaming Sidekick	2	▲60.6%
1	Druid of the Reef	2	▼60.2%
1	Irondeep Trogg	2	▲62.2%
1	Living Roots	2	▲60.8%
1	Peasant	2	▲63.3%
1	Planted Evidence	2	▼57.1%
1	Sow the Soil	2	▼58.6%
1	Vicious Slitherspear	2	▼59.5%
2	Crooked Cook	2	▼57.6%
2	Jerry Rig Carpenter	2	▼57.2%
2	Mark of the Wild	2	▼58.4%
2	Thorngrowth Sentries	2	▼58.9%
3	Herald of Nature	2	▲65.7%
4	Pride's Fury	2	▼58.1%

Data extraction

-- How crawler works?

	Deck	Class		Updated	Score
<input type="checkbox"/>	XL Thief Control Priest - #5 Legend (Ryvius) - Knights of Hallow's End Format: hydra - Style: ladder - Season: season-104 - Archetype: Control Priest - Player: Ryvius		17,560	21 hours ago	1
<input type="checkbox"/>	XL Thief Rogue - #85 Legend (Raindet) - Knights of Hallow's End Format: hydra - Style: ladder - Season: season-104 - Archetype: Thief Rogue - Player: Stonekeep		16,120	22 hours ago	1
<input type="checkbox"/>	XL Celestial Ramp Druid - #185 Legend (Karking) - Knights of Hallow's End Format: hydra - Style: ladder - Season: season-104 - Archetype: Celestial Druid - Player: Karking		17,920	22 hours ago	0
<input type="checkbox"/>	Aggro Demon Hunter - #100 Legend (TheHunter) - Knights of Hallow's End Format: hydra - Style: ladder - Season: season-104 - Archetype: Aggro Demon Hunter - Player: Stonekeep		4,800	22 hours ago	1
<input type="checkbox"/>	Hero Power Mage - #229 Legend (vainmglory) - Knights of Hallow's End Format: hydra - Style: ladder - Season: season-104 - Archetype: Hero Power Mage - Player: vainmglory		9,540	22 hours ago	1

<https://www.hearthstonetopdecks.com/decks/>

XL THIEF CONTROL PRIEST - #5 LEGEND (RYVIUS) - KNIGHTS OF HOLLOW'S END

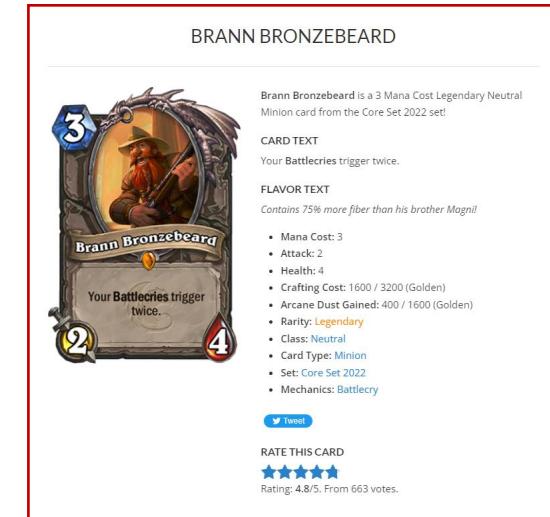
PLAYER: RYVIUS - PUBLISHED: NOVEMBER 24, 2022 - UPDATED: 1 DAY AGO - DUST COST: 17,560 [Tweet](#)

CLASS: PRIEST - FORMAT: HYDRA - TYPE: CONTROL - SEASON: SEASON-104 - STYLE: LADDER - META DECK: CONTROL PRIEST - LINK: SOURCE

EDIT IN DECK BUILDER

Class (35)	Neutral (5)
0 DESPERATE PRAYER	3 BRANN BRONZEBEARD
1 GIFT OF THE NAARU	3 PRINCE RENATHAL
1 PSYCHIC CONJURER	4 SCHOOL TEACHER
1 SHARD OF THE NAARU	5 THEOTAR, THE MAD DUKE
1 THE LIGHT! IT BURNS!	
2 MYSTERIOUS VISITOR	
3 AMULET OF UNDYING	
3 CATHEDRAL OF ATONEMENT	
3 HANDMAIDEN	
3 IDENTITY THEFT	
3 THE HARVESTER OF ENVY	
4 INCRIMINATING PSYCHIC	
4 LIGHTMAW NETHERDRAKE	
4 SHADOW WORD: RUIN	
4 XYRELLA	
5 CLEAN THE SCENE	
6 LIGHTSHOWER ELEMENTAL	
7 ARCHBISHOP BENEDICTUS	
7 BLACKWATER BEHEMOTH	
8 XYRELLA, THE DEVOUT	

<https://www.hearthstonetopdecks.com/decks/xl-thief-control-priest-5-legend-ryvius-knights-of-hallows-end/>

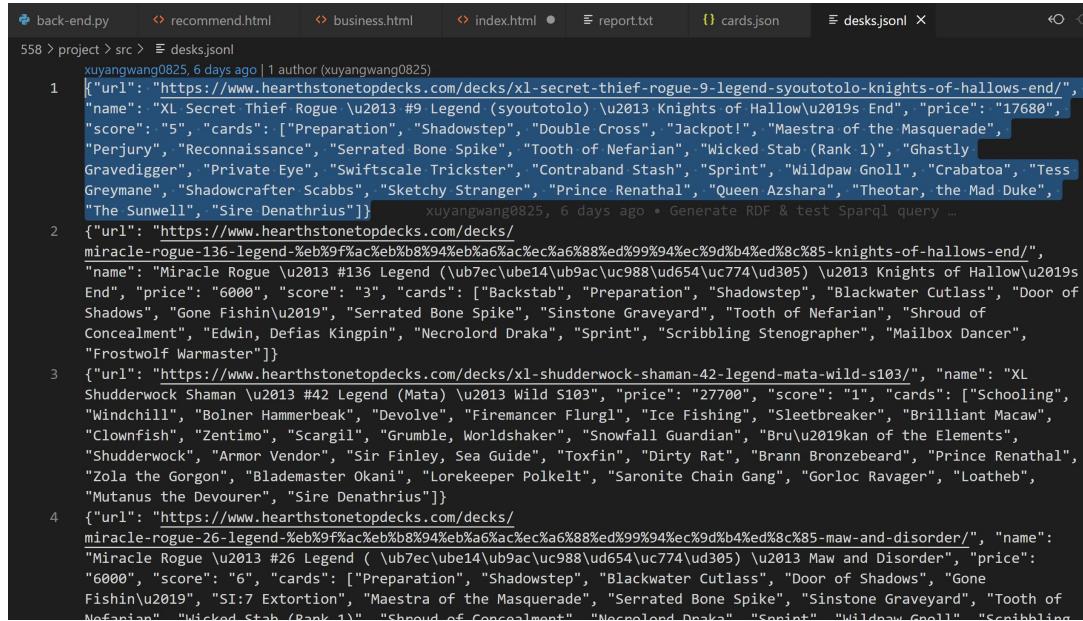


<https://www.hearthstonetopdecks.com/cards/brann-bronzebeard/>

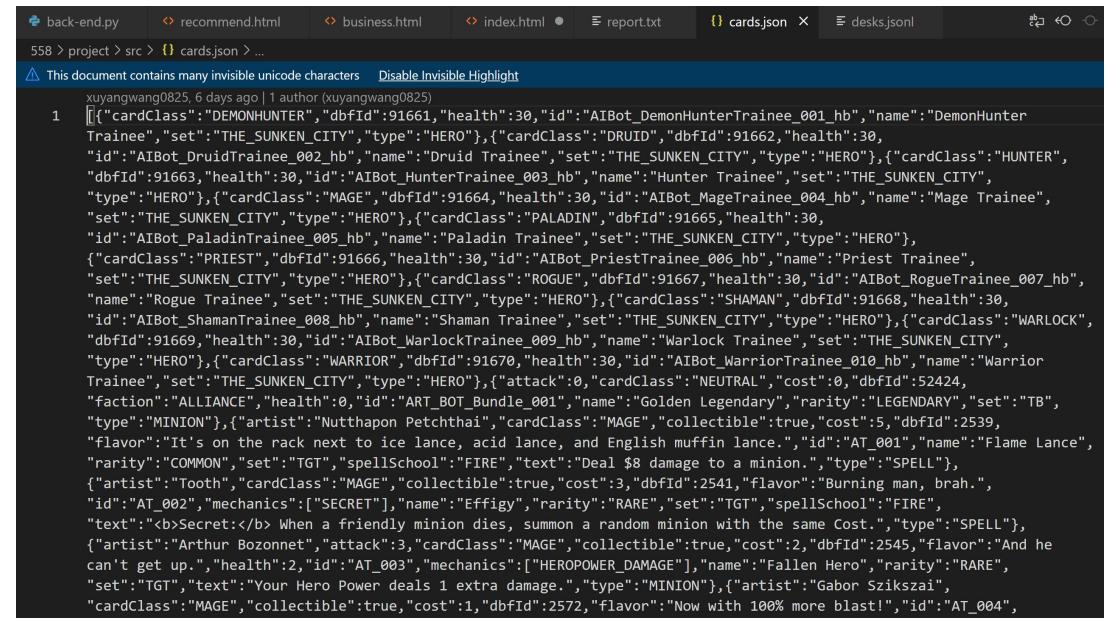
Data extraction

-- How crawler store data?

store data in two json files, then those files will be used for ontology build.



```
xuyangwang0825, 6 days ago | 1 author (xuyangwang0825)
558 > project > src > desks.jsonl
xuyangwang0825, 6 days ago | 1 author (xuyangwang0825)
1 [{"url": "https://www.hearthstonetopdecks.com/decks/xl-secret-thief-rogue-9-legends-youtotolo-knights-of-hallows-end/", "name": "XL Secret Thief Rogue \u2013 #9 Legend (youtotolo) \u2013 Knights of Hallow\u2019s End", "price": "17680", "score": "5", "cards": ["Preparation", "Shadowstep", "Double Cross", "Jackpot!", "Maestra of the Masquerade", "Perjury", "Reconnaissance", "Serrated Bone Spike", "Tooth of Nefarian", "Wicked Stab (Rank 1)", "Ghastly Gravedigger", "Private Eye", "Swiftscale Trickster", "Contraband Stash", "Sprint", "Wildpaw Gnoll", "Crabatoa", "Tess Greymane", "Shadowcrafter Scabs", "Sketchy Stranger", "Prince Renathal", "Queen Azshara", "Theotar, the Mad Duke", "The Sunwell", "Sire Denathrius"]}], xuyangwang0825, 6 days ago • Generate RDF & test Sparql query ...
2 [{"url": "https://www.hearthstonetopdecks.com/decks/miracle-rogue-136-legends-eb%9f%ac%eb%b8%94%eb%a6%ac%ec%a6%88%ed%99%94%ec%9d%b4%ed%8c%85-knights-of-hallows-end/", "name": "Miracle Rogue \u2013 #136 Legend (\ub7ec\ube14\ub9ac\uc988\ud654\uc774\ud305) \u2013 Knights of Hallow\u2019s End", "price": "6000", "score": "3", "cards": ["Backstab", "Preparation", "Shadowstep", "Blackwater Cutlass", "Door of Shadows", "Gone Fishin\u2019", "Serrated Bone Spike", "Sinstone Graveyard", "Tooth of Nefarian", "Shroud of Concealment", "Edwin, Defias Kingpin", "Necrolord Draka", "Sprint", "Scribbling Stenographer", "Mailbox Dancer", "Frostwolf Warmaster"]}], xuyangwang0825, 6 days ago • Generate RDF & test Sparql query ...
3 [{"url": "https://www.hearthstonetopdecks.com/decks/xl-shudderwock-shaman-42-legends-mata-wild-s103/", "name": "XL Shudderwock Shaman \u2013 #42 Legend (Mata) \u2013 Wild S103", "price": "27700", "score": "1", "cards": ["Schooling", "Windchill", "Bolner Hammerbeak", "Devolv", "Firemancer Flurgl", "Ice Fishing", "Sleetbreaker", "Brilliant Macaw", "Clownfish", "Zentimo", "Scargil", "Grumble, Worldshaker", "Snowfall Guardian", "Bru\u2019kan of the Elements", "Shudderwock", "Armor Vendor", "Sir Finley, Sea Guide", "Toxfin", "Dirty Rat", "Brann Bronzebeard", "Prince Renathal", "Zola the Gorgon", "Blademaster Okani", "Lorekeeper Polkelt", "Saronite Chain Gang", "Gorloc Ravager", "Loatheb", "Mutanus the Devourer", "Sire Denathrius"]}], xuyangwang0825, 6 days ago • Generate RDF & test Sparql query ...
4 [{"url": "https://www.hearthstonetopdecks.com/decks/miracle-rogue-26-legends-%eb%9f%ac%eb%b8%94%eb%a6%ac%ec%a6%88%ed%99%94%ec%9d%b4%ed%8c%85-maw-and-disorder/", "name": "Miracle Rogue \u2013 #26 Legend (\ub7ec\ube14\ub9ac\uc988\ud654\uc774\ud305) \u2013 Maw and Disorder", "price": "6000", "score": "6", "cards": ["Preparation", "Shadowstep", "Blackwater Cutlass", "Door of Shadows", "Gone Fishin\u2019", "SI:7 Extortion", "Maestra of the Masquerade", "Serrated Bone Spike", "Sinstone Graveyard", "Tooth of Nefarian", "Wicked Stab (Rank 1)", "Shroud of Concealment", "Necrolord Draka", "Sprint", "Scribbling
```



```
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xuyangwang0825, 6 days ago | 1 author (xuyangwang0825)
1 [{"cardClass": "DEMONHUNTER", "dbfId": 91661, "health": 30, "id": "AIBot_DemonHunterTrainee_001_hb", "name": "DemonHunter Trainee", "set": "THE_SUNKEN_CITY", "type": "HERO"}, {"cardClass": "DRUID", "dbfId": 91662, "health": 30, "id": "AIBot_DruidTrainee_002_hb", "name": "Druid Trainee", "set": "THE_SUNKEN_CITY", "type": "HERO"}, {"cardClass": "HUNTER", "dbfId": 91663, "health": 30, "id": "AIBot_HunterTrainee_003_hb", "name": "Hunter Trainee", "set": "THE_SUNKEN_CITY", "type": "HERO"}, {"cardClass": "MAGE", "dbfId": 91664, "health": 30, "id": "AIBot_MageTrainee_004_hb", "name": "Mage Trainee", "set": "THE_SUNKEN_CITY", "type": "HERO"}, {"cardClass": "PALADIN", "dbfId": 91665, "health": 30, "id": "AIBot_PaladinTrainee_005_hb", "name": "Paladin Trainee", "set": "THE_SUNKEN_CITY", "type": "HERO"}, {"cardClass": "PRIEST", "dbfId": 91666, "health": 30, "id": "AIBot_PriestTrainee_006_hb", "name": "Priest Trainee", "set": "THE_SUNKEN_CITY", "type": "HERO"}, {"cardClass": "ROGUE", "dbfId": 91667, "health": 30, "id": "AIBot_RogueTrainee_007_hb", "name": "Rogue Trainee", "set": "THE_SUNKEN_CITY", "type": "HERO"}, {"cardClass": "SHAMAN", "dbfId": 91668, "health": 30, "id": "AIBot_ShamanTrainee_008_hb", "name": "Shaman Trainee", "set": "THE_SUNKEN_CITY", "type": "HERO"}, {"cardClass": "WARLOCK", "dbfId": 91669, "health": 30, "id": "AIBot_WarlockTrainee_009_hb", "name": "Warlock Trainee", "set": "THE_SUNKEN_CITY", "type": "HERO"}, {"cardClass": "WARRIOR", "dbfId": 91670, "health": 30, "id": "AIBot_WarriorTrainee_010_hb", "name": "Warrior Trainee", "set": "THE_SUNKEN_CITY", "type": "HERO"}, {"attack": 0, "cardClass": "NEUTRAL", "cost": 0, "dbfId": 52424, "faction": "ALLIANCE", "health": 0, "id": "ART_BOT_Bundle_001", "name": "Golden Legendary", "rarity": "LEGENDARY", "set": "TB", "type": "MINION"}, {"artist": "Nutthapon Petchthai", "cardClass": "MAGE", "collectible": true, "cost": 5, "dbfId": 2539, "flavor": "It's on the rack next to ice lance, acid lance, and English muffin lance.", "id": "AT_001", "name": "Flame Lance", "rarity": "COMMON", "set": "TGT", "spellSchool": "FIRE", "text": "Deal $8 damage to a minion.", "type": "SPELL"}, {"artist": "Tooth", "cardClass": "MAGE", "collectible": true, "cost": 3, "dbfId": 2541, "flavor": "Burning man, brah.", "id": "AT_002", "mechanics": ["SECRET"], "name": "Effigy", "rarity": "RARE", "set": "TGT", "spellSchool": "FIRE", "text": "<b>Secret:</b> When a friendly minion dies, summon a random minion with the same Cost.", "type": "SPELL"}, {"artist": "Arthur Bozonnet", "attack": 3, "cardClass": "MAGE", "collectible": true, "cost": 2, "dbfId": 2545, "flavor": "And he can't get up.", "health": 2, "id": "AT_003", "mechanics": ["HEROPOWER_DAMAGE"], "name": "Fallen Hero", "rarity": "RARE", "set": "TGT", "text": "Your Hero Power deals 1 extra damage.", "type": "MINION"}, {"artist": "Gabor Sziksai", "cardClass": "MAGE", "collectible": true, "cost": 1, "dbfId": 2572, "flavor": "Now with 100% more blast!", "id": "AT_004", "name": "Heroic Mage"}]
```

Data extraction

-- Data volume

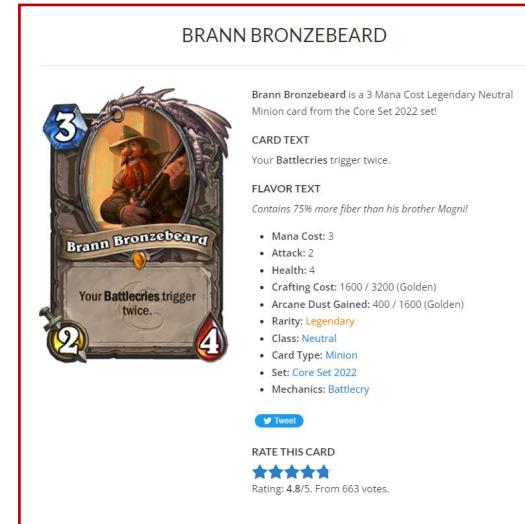
Deck	Class		Updated	Score
XL Thief Control Priest - #5 Legend (Ryvius) - Knights of Hallow's End Format: hydra - Style: ladder - Season: season-104 - Archetype: Control Priest - Player: Ryvius		17,560	21 hours ago	1
XL Thief Rogue - #85 Legend (Raindet) - Knights of Hallow's End Format: hydra - Style: ladder - Season: season-104 - Archetype: Thief Rogue - Player: Stonekeep		16,120	22 hours ago	1
XL Celestial Ramp Druid - #185 Legend (Karking) - Knights of Hallow's End Format: hydra - Style: ladder - Season: season-104 - Archetype: Celestial Druid - Player: Karking		17,920	22 hours ago	0
Aggro Demon Hunter - #100 Legend (TheHunter) - Knights of Hallow's End Format: hydra - Style: ladder - Season: season-104 - Archetype: Aggro Demon Hunter - Player: Stonekeep		4,800	22 hours ago	1
Hero Power Mage - #229 Legend (vainmglory) - Knights of Hallow's End Format: hydra - Style: ladder - Season: season-104 - Archetype: Hero Power Mage - Player: vainmglory		9,540	22 hours ago	1

100 pages of newest decks shared by players

each page contains about 20 decks

CLASS: PRIEST - FORMAT: HYDRA - TYPE: CONTROL - SEASON: SEASON-104 - STYLE: LADDER - META DECK: CONTROL PRIEST - LINK: SOURCE	
EDIT IN DECK BUILDER	
- Class (35)	- Neutral (5)
0 DESPERATE PRAYER	3 BRANN BRONZEBEARD
1 GIFT OF THE NAARU	3 PRINCE RENATHAL
1 PSYCHIC CONJURER	4 SCHOOL TEACHER
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3 AMULET OF UNDYING	
3 CATHEDRAL OF ATONEMENT	
3 HANDMAIDEN	
3 IDENTITY THEFT	
3 THE HARVESTER OF ENVY	
4 INCRIMINATING PSYCHIC	
4 LIGHTMAW NETHERDRAKE	
4 SHADOW WORD: RUIN	
4 XYRELLA	
5 CLEAN THE SCENE	
6 LIGHTSHOWER ELEMENTAL	
7 ARCHBISHOP BENEDICTUS	
7 BLACKWATER BEHEMOTH	
8 XYRELLA, THE DEVOUT	

each deck contains about 20 cards



$$\text{So, } 100 * 20 * 20 = 40,000 !$$

Technical Challenge1: Big data volume

- Problem: How to get so many data without damaging the server or be banned by the server?
- Solution: Set a delay between every two requests.
- Evaluation:
 - request one or two times per second is just like a normal human action, so not damage the server;
 - successfully got all data without any restriction or ban by the website after the program ran several hours.
 - also, randomly selected several decks to check if their information is correct in the json file.

Ontology

Card:

```
@prefix ns1: <http://hskg.org/> .
@prefix ns2: <http://xmlns.com/foaf/0.1/> .
@prefix xsd: <http://www.w3.org/2001/XMLSchema#> .

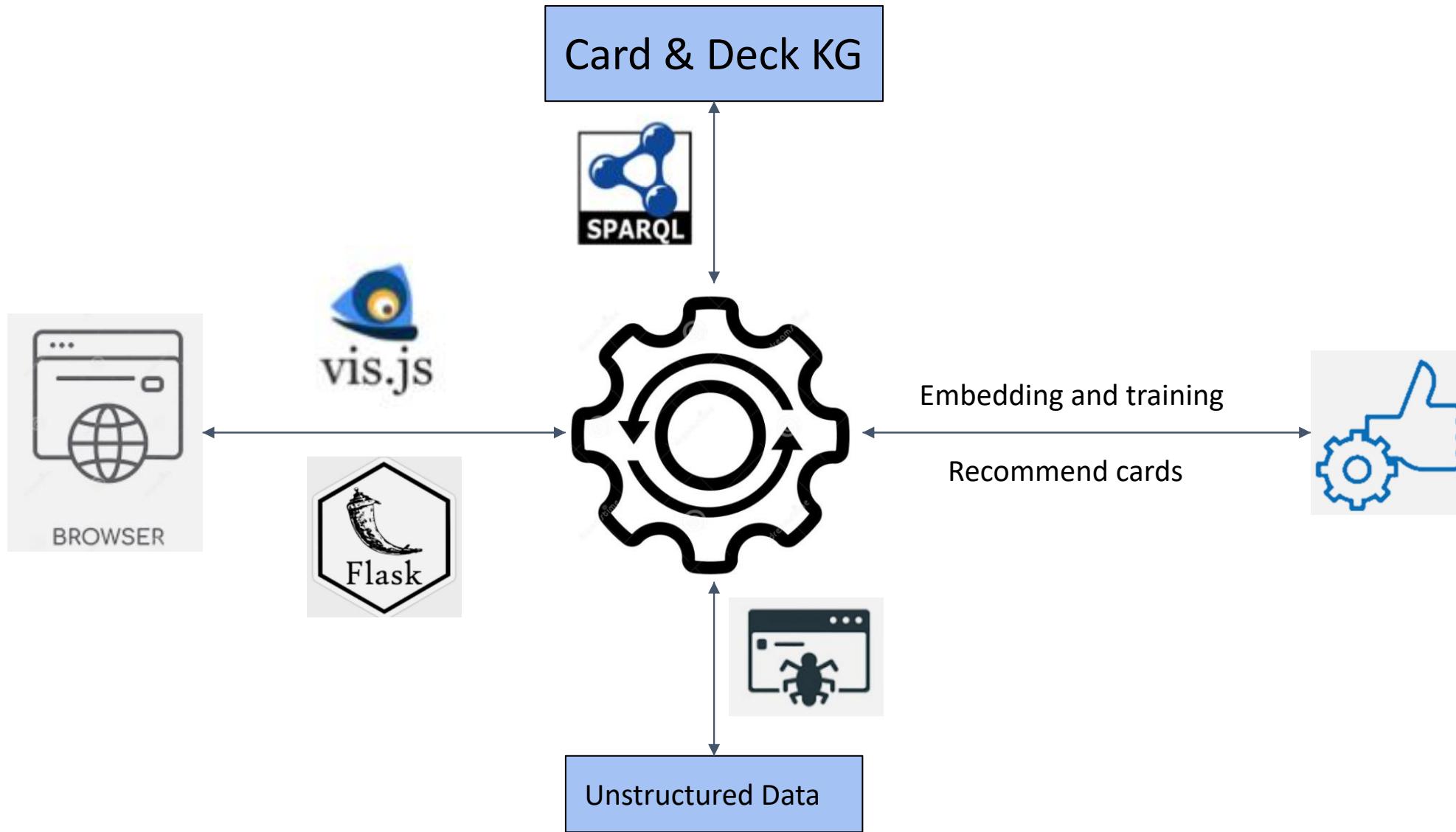
<http://hskg.org/card/100> ns1:attack 4 ;
    ns1:cardClass "HUNTER" ;
    ns1:cost 3 ;
    ns1:dbfId 100 ;
    ns1:health 2 ;
    ns1:id "NEW1_034" ;
    ns1:img_url "https://art.hearthstonejson.com/v1/render/latest/enUS/256x/NEW1_034.png" ;
    ns1:mechanics "['CHARGE']" ;
    ns1:race "BEAST" ;
    ns1:rarity "COMMON" ;
    ns1:set "LEGACY" ;
    ns1:text "<b>Charge</b>" ;
    ns1:type "MINION" ;
    ns2:name "Huffer" .
```

Ontology

Deck:

```
<http://hskg.org/deck/998> ns1:hasCard "Alexstrasza the Life-Binder",
    "Brann Bronzebeard",
    "Brawl",
    "Forged in Flame",
    "From the Depths",
    "Frozen Buckler",
    "Heavy Plate",
    "Igneous Lavagorger",
    "Mutanus the Devourer",
    "Nellie, the Great Thresher",
    "Outrider's Axe",
    "Raid Boss Onyxia",
    "Rokara, the Valorous",
    "Rustrot Viper",
    "School Teacher",
    "Shield Block",
    "Shield Shatter",
    "Shield Slam",
    "Sir Finley, Sea Guide",
    "Tidal Revenant" ;
ns1:price "15000" ;
ns1:score "9" ;
ns1:url "https://www.hearthstonetopdecks.com/decks/control-warrior-9-legend-ichi-throne-of-tides/" ;
ns2:name "Control Warrior – #9 Legend (ichi) – Throne of Tides" .
```

System Architecture



Technical Challenge2: Explore Card & Deck

- Problem: How to give player a easy way to explore the card they want?
- Example: A player want to find a replacement of a card in mage class and cost 7+.
- Solution:
 - Build KG for cards
 - Use sparql to search and filter the entitys
 - Return result as a graph to help player find the card they want.
- Evaluation:
 - That's very precise. Player can modify the parameter of filter to get the result space as a graph.

Explore Card

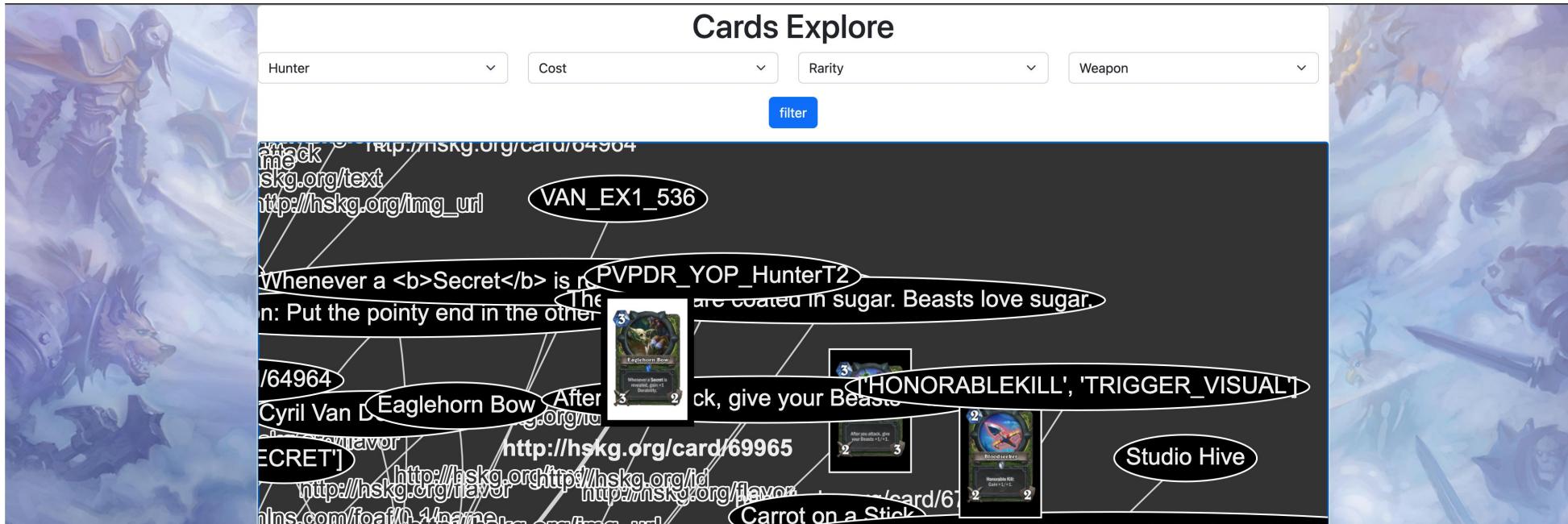
Parameters:

Class : [Mage, Hunter...] 12classes

Cost: [0 ~ 6, 7+]

Rarity: [Free, Common, Rare, Epic, Legendary]

Type: [Minion, Weapon, Spell...] 7 types

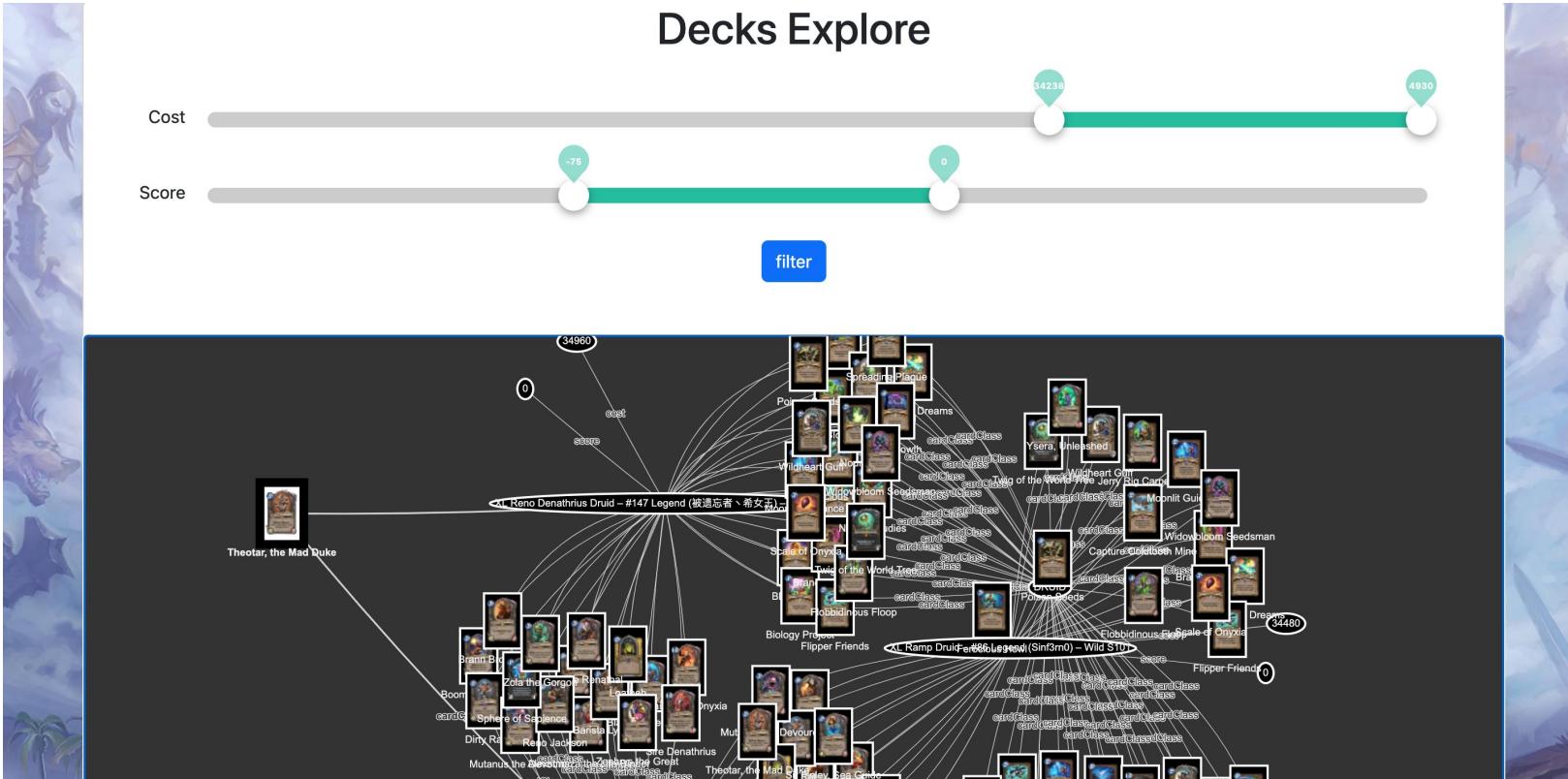


Explore Deck

Parameters:

Score: [-150, 150]

Cost: [0~50000] Arcane Dust



Sparql Example - Deck

```
@app.route('/filter/desk', methods=['GET'])
def filter_desk():
    score_min = request.args.get("score_min")
    score_max = request.args.get("score_max")
    cost_min = request.args.get("cost_min")
    cost_max = request.args.get("cost_max")
    q = """
        PREFIX xsd: <http://www.w3.org/2001/XMLSchema#>
        SELECT * WHERE {
            ?desk ns2:name ?deskName .
            ?desk ns1:price ?deskPrice .
            ?desk ns1:score ?deskScore .
            Filter(xsd:integer(?deskScore) >= scoreMin && xsd:integer(?deskScore) <= scoreMax) .
            Filter(xsd:integer(?deskPrice) >= costMin && xsd:integer(?deskPrice) <= costMax) .
        } ORDER BY DESC(?deskScore) (?deskPrice)
    """
    q = q.replace('scoreMin', score_min).replace('scoreMax', score_max).replace('costMin', cost_min).replace('costMax', cost_max)

    nodes, edges = [], []
    id = 1
    class_dic = {} # className: id
    for r in g.query(q):
        nodes.append({'id': id, 'label': r.deskName.toPython()})
        nodes.append({'id': id+1, 'label': r.deskPrice.toPython()})
        nodes.append({'id': id+2, 'label': r.deskScore.toPython()})
        edges.append({'from': id, 'to': id+1, 'label': 'cost'})
        edges.append({'from': id, 'to': id+2, 'label': 'score'})
        id += 3
    id, nodes, edges, class_dic = sub_search_desk(r.deskName.toPython(), id, nodes, edges, class_dic)
    if len(nodes) > 300: break

return {'nodes': nodes, 'edges': edges}
```

- Call API in front-end
- Back-end get parameters:
 - Score & Cost
- Sparql query
- Generate Graph
 - Use Vis.JS
 - Generate nodes
 - Generate edges
- Return result
- Show graph in front-end

Technical Challenge3: Recommender System

- Problem: How to recommend more cards for a existing deck?
- Solution: Build a TransE model. (More details in report)
- Evaluation: Randomly hide 20% data in the triples (deck-hasCard->card) as test dataset, got a 0.09 MRR.

Recommend card for a deck

Recommend more cards for your desk!

Step1: find desk by name: Reno Paladin – RegisKillbin

Reno Paladin – RegisKillbin – Sunken City Queen Azshara

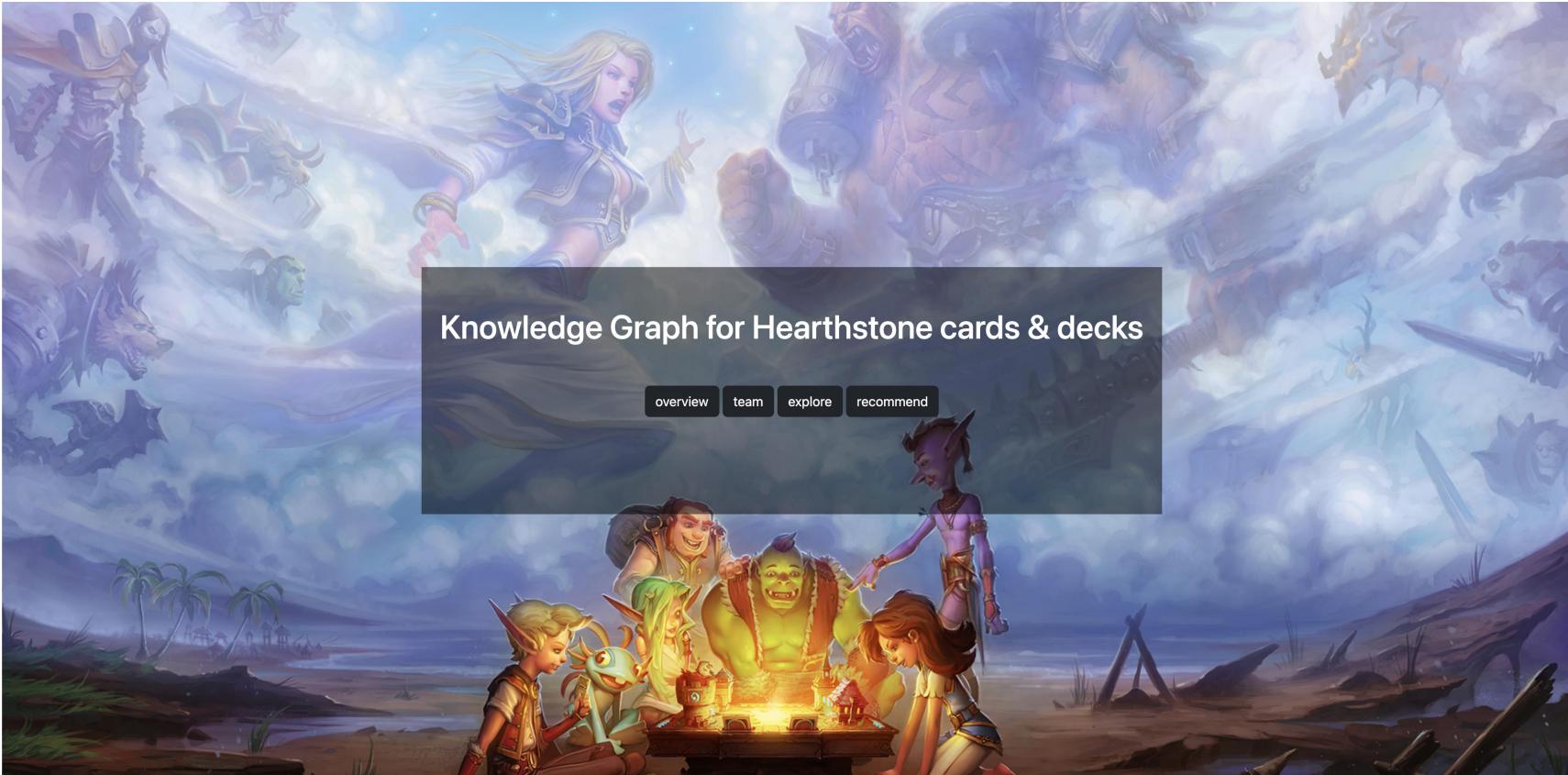
Step2: get top-5 recommend card for this desk:

ranking	card name
1	The Garden's Grace
2	Hand of A'dal
3	Lightbringer's Hammer
4	Za'cui

KG Quality

- Intrinsic
 - Accuracy: All cards and decks free of error & correctly describing facts
 - Objectivity: Decks are from different players, so it's free of bias & impartial.
Cards' information are official.
 - Consistency: Card's properties and deck's properties are consistent.
- Contextual
 - Card data is up to date
 - Deck data is required to update periodically by crawler
- Representational
 - Data can be interpreted by machine and human without ambiguity

UI Design

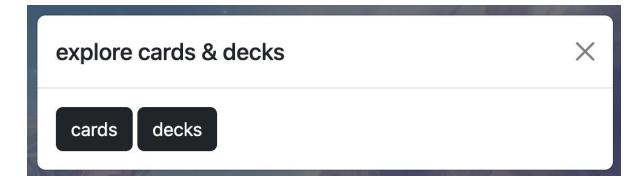


Home Page

Overview:
Introduction of our system

Team:
Introduction of team members

Explore
Explore card & deck



Recommend
Recommend card based on deck

Future works

- support users upload their own decks;
- get more data to better train the model:
 - more accuracy score of each decks in KG
 - more attributes of each decks like the win-lose rate
 - expand the KG with competition data
- more data visualizations to better analyze data