Smart Tech in Hearthstone

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Who am I?

- Lead Data Scientist **@Blizzard**
  - Doing Math / Machine Learning stuff for *Hearthstone*

- Ph.D. in Mathematics **@UT Austin**

- Gamer
  - Legend rank in *Hearthstone* every season
  - Master rank in *Starcraft II*
  - 2nd Place *Netrunner* Store Championship @Houston, TX
  - …and casually play many other games…

Outline

- Introduction

- Smart Tech
  - Smart Deck Builder for Constructed
  - Smart Loot Buckets for Duels
  - Auto Balance for Arena

- Final Notes

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What is Hearthstone?

- Digital collectible card game (PC/mobile)
  - 100M+ Players
  - One of the largest card games in the market

since 2014

since 2014   since 2019   since 2020   ...

Deck Building

- Essential to Hearthstone, but not simple

- Different modes have different ways to build a deck
  - Build from collection (Constructed & Duels)
  - Dungeon-run style (Duels)
  - Drafting style (Arena)

Deck Building

- Build from collection

Deck Building

- Dungeon-run style

Deck Building

- Drafting style

ML/DS in Hearthstone

- In-game features
- Game balance
- Meta analysis
- Rating/Matchmaking systems
- Simulations
- Recommendations
- Predictive modeling
- AI for PvE mode
- Etc.

today's talk

What is Smart Tech?

- Smart / Auto - </item> is a product that utilizes data and rules to automatically achieve various goals during the deck building phase

  - Build a *Hunter* deck with *Trampling Rhino* x2 for *SkyGALA*

  - Provide a 3-card *Mage* bucket given the current deck

  - Adjust card appearance rates of *Druid* in deck drafting

Motivations

- **Gameplay first** is always our #1 core value

- Before we made the products, we want to achieve certain goals that **improve the gameplay experience**

How Can Smart Tech Improve Gameplay?

- Help to easily build a good constructed deck
  - Any player, any deck, any collection, any time

- Provide choice varieties on top of human inputs to dungeon-style deck building

- Balance class win-rates in drafting mode

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Deck Building

- Build from collection

Why are We Doing This?

- Deck building is a big challenge for many players

- Legacy (simple "rule-based") in-game deck builder was sub-optimal

- When players ask us to build a deck, we need a smart deck builder to build a GOOD deck for them!
  - Cards picked are all in their collection
  - "Good" = competitive

Benefits

- Help our players (esp. new and returning players):
  - Learn the game
  - Develop interests
  - Increase win-rate to improve player experience

- Better deck building experience
  - Especially on Mobile platforms
  - Test decks with "interesting" cards

I can't express enough my excitement for this kind of feature.

This is cool. Can't wait to have HS build dragon paladin for me!

Now I can netdeck without leaving the game

This might bring me back to the game. I'm crap at building decks

That's really cool. Most of my decks are, "Oh I just opened a <new legendary>", let's try to make a deck with it. Going to try 1 card decks + autofill and see how they turn out.

I think this is an incredible addition to the game, for new players and veteran players alike. sure, netdecking will still be a thing but it'll be interesting to see what decks the game makes for you with this new deck builder and to see how well they work out.

As Simple As One Click

Post-launch Sentiments

The new autocomplete is INSANE! First one was made from scratch, second I only put in Togwaggle, and for the third one I only put in Mecha'Thun.

That is an **amazing** feature. Like, mind-blowingly amazing. More people need to know about this.

THAT COMPLETE MY DECK FEATURE IS THE BEST THING IN HEARTHSTONE IN 5 YEARS

Discussion

Holy fuck!

I'm casual player enjoying my rank 20-10 play since beta. And this feature is so awesome! I'm playing all night long (its 4 AM i'm from Siberia) and EVERY DECK IS DIFFERENT. No more same net decks. People just enjoy good decks with cards they can afford. Now its really free to play and MUCH MUCH MORE FUN. Thank you Blizzard!

Why the new deck completion system is sneakily the biggest change in years

Discussion

IMO, the new deck-completion system is low-key the biggest change to Hearthstone in years.

As someone into statistics and Machine Learning, I'd love to see how you guys do this behind the scenes! I can't imagine it's simple, considering some of these bugs.

Glad to see Hearthstone implementing this technology in their game, it definitely isn't the usual test case.
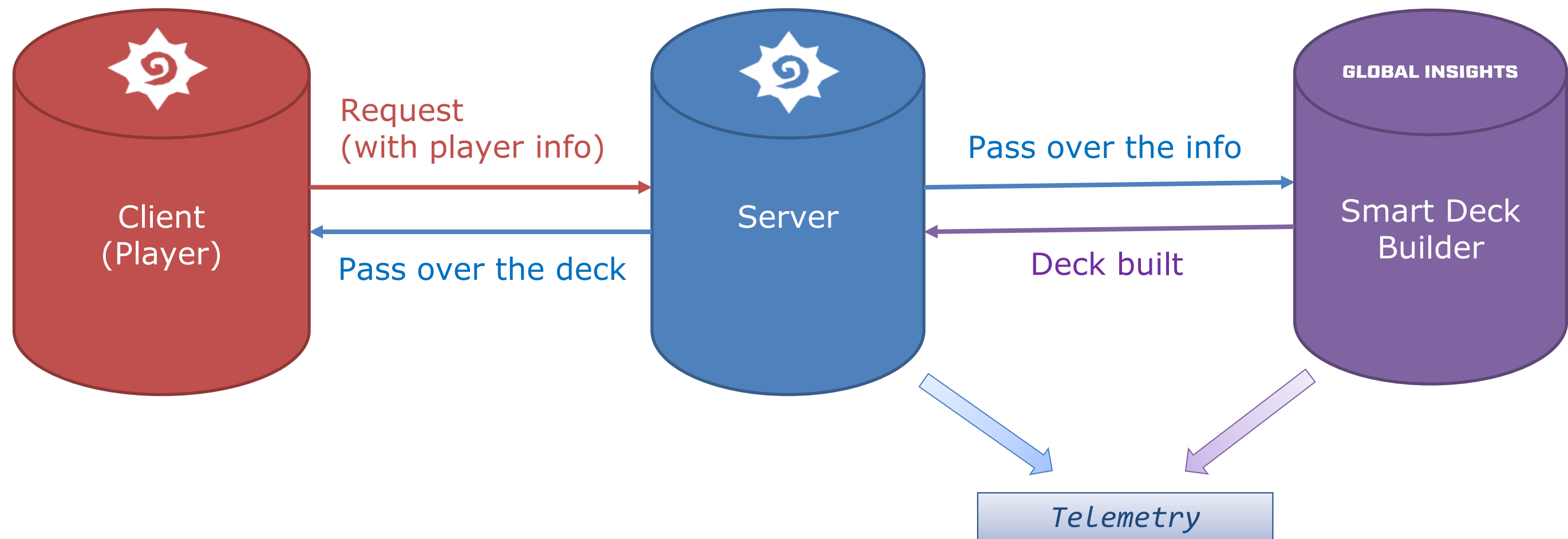
Some Notes

- Launch on patch 13.4 (Mar 2019)

- Algorithm has been updated many times since then

- Currently support standard and wild constructed mode

- Average response time is ~3ms

System Workflow

Smart Deck Builder

Auto built deck

Unfinished deck by player

Layer 1 (meta)

Rules | Cool down

enough cards?

Yes

No

Layer 2 (backfill)

Rules

Backfilled deck

Custom Mage
- 4 Fireball
- 7 Flamestrike
- Complete My Deck

Custom Mage
- 1 Brain Freeze — 2
- 1 Devolving Missiles — 2
- 1 Font of Power — 2
- 1 Primordial Studies — 2
- 1 Shooting Star
- 2 Cram Session — 2
- 2 Incanter's Flow — 2
- 2 Runed Orb — 2
- 3 Arcane Intellect — 2
- 3 Combustion
- 4 Deck of Lunacy — ★
- 4 Fireball — 2
- 4 Refreshing Spring Water — 2
- 4 Ring Toss — 2
- 5 Apexis Blast — 2
- 7 Flamestrike
- 7 Mask of C'Thun — 2

Layer 1

Smart Deck Builder

Layer 1 (meta)

What is Hearthstone Meta?

- Short for the "metagame"
- Meta describes the trends of deck/class choices currently seen in Hearthstone

Class % Breakdown by Games

Druid 14.36%
Warrior 22.61%
Hunter 8.04%
Mage 6.83%
Paladin 2.59%
Priest 2.09%
Rogue 31.39%
Shaman 4.99%
Warlock 7.10%

Combo Druid 1.81%
Token Druid 92.85%
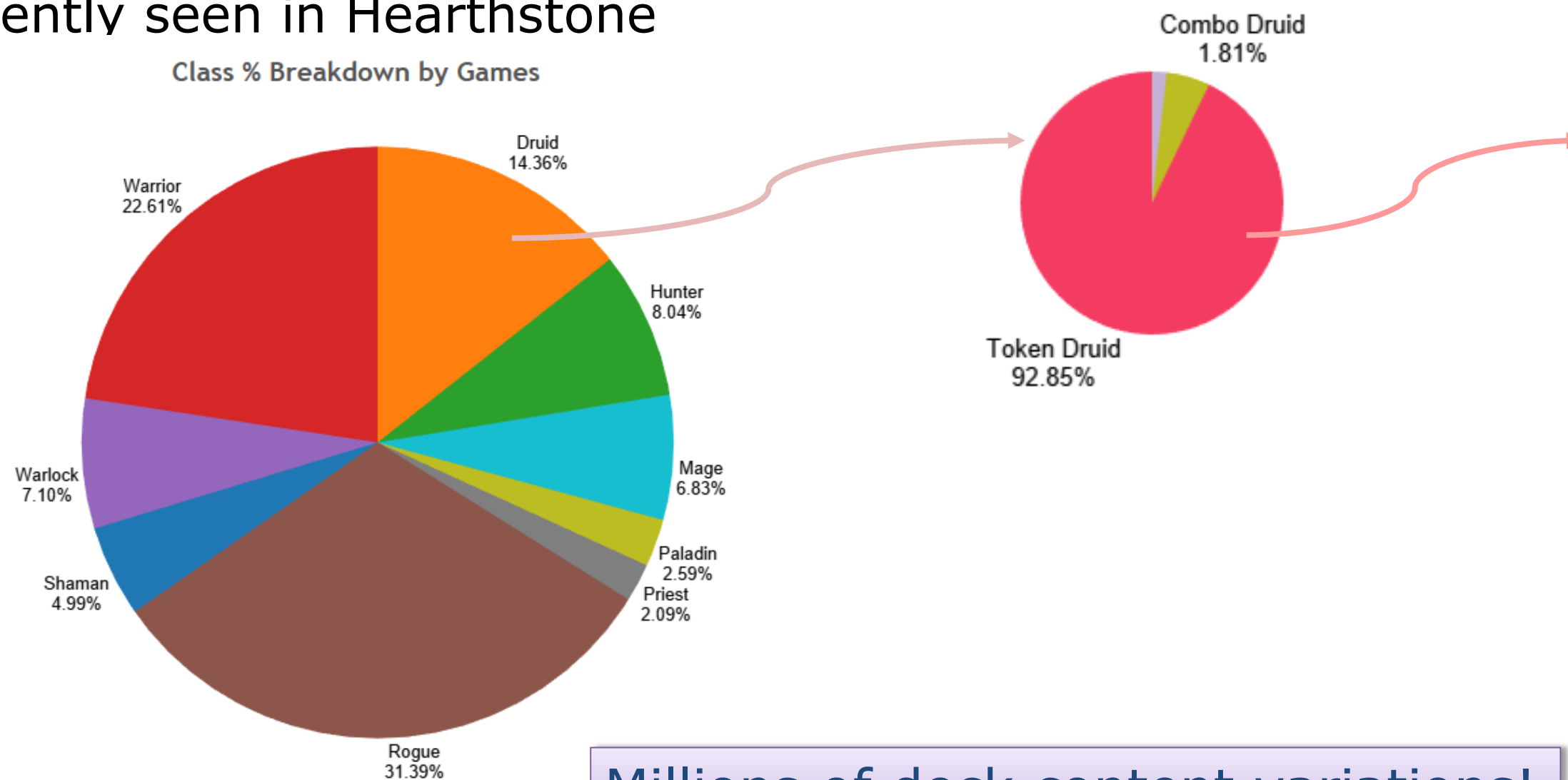
token
Standard — Druid

1	Acornbearer	2
2	Crystalsong Portal	2
2	Dreamway Guardians	2
2	EVIL Cable Rat	2
2	Keeper Stalladris	★
2	Power of the Wild	2
2	Wrath	2
3	Blessing of the Ancients	2
3	Landscaping	2
3	Savage Roar	2
4	Archmage Vargoth	★
4	Mark of the Loa	2
4	Soul of the Forest	2
4	Swipe	2
4	Wispering Woods	2
8	The Forest's Aid	2

Millions of deck content variations!

Meta Is Evolving

Mid-range Hunter Win-rate Over Time
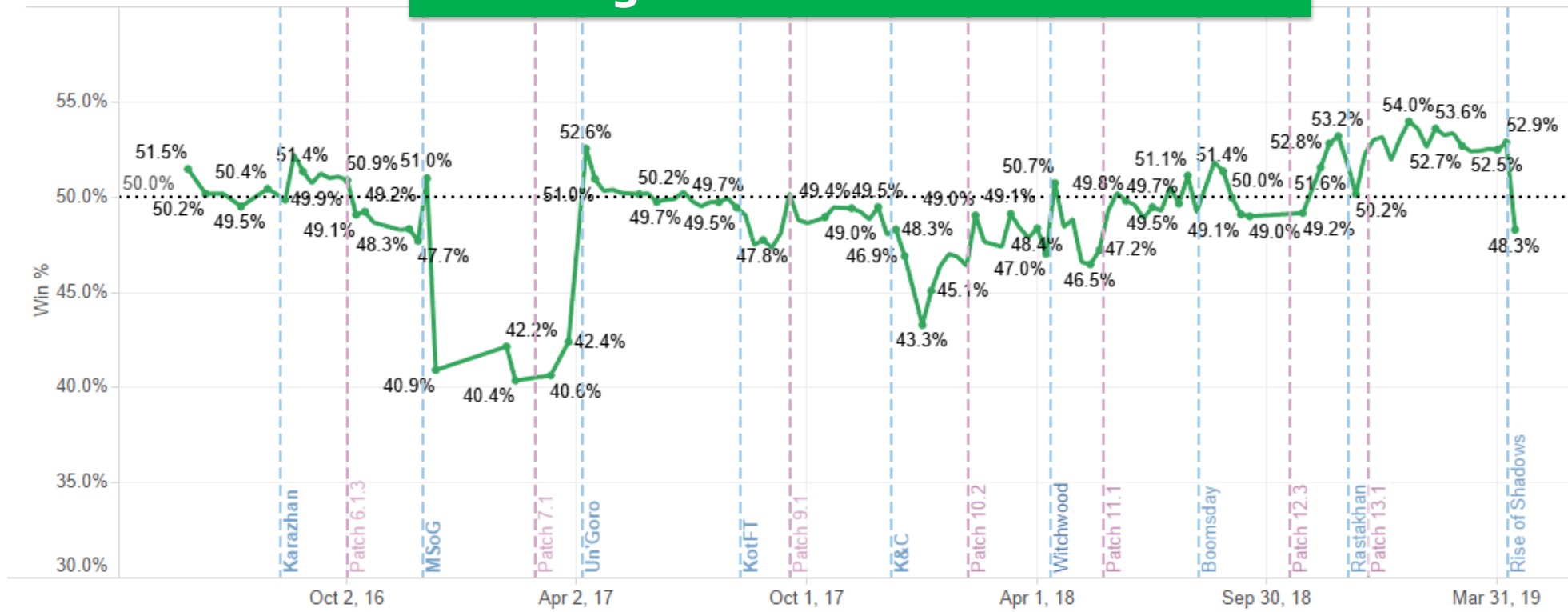
Each Deck as a Data Point

2 x Demon Companion

1 x Tracking

2 x Quick Shot

2 x Trampling Rhino

...

Deck vector

...	Demon Companion	Tracking	Snake Trap	Deadly Shot	...	Quick Shot	Trampling Rhino	...
...	2	1	0	0	...	2	2	...

About 400 columns

Meta Clusters: Data Points in a Hundreds of Dimension of Space
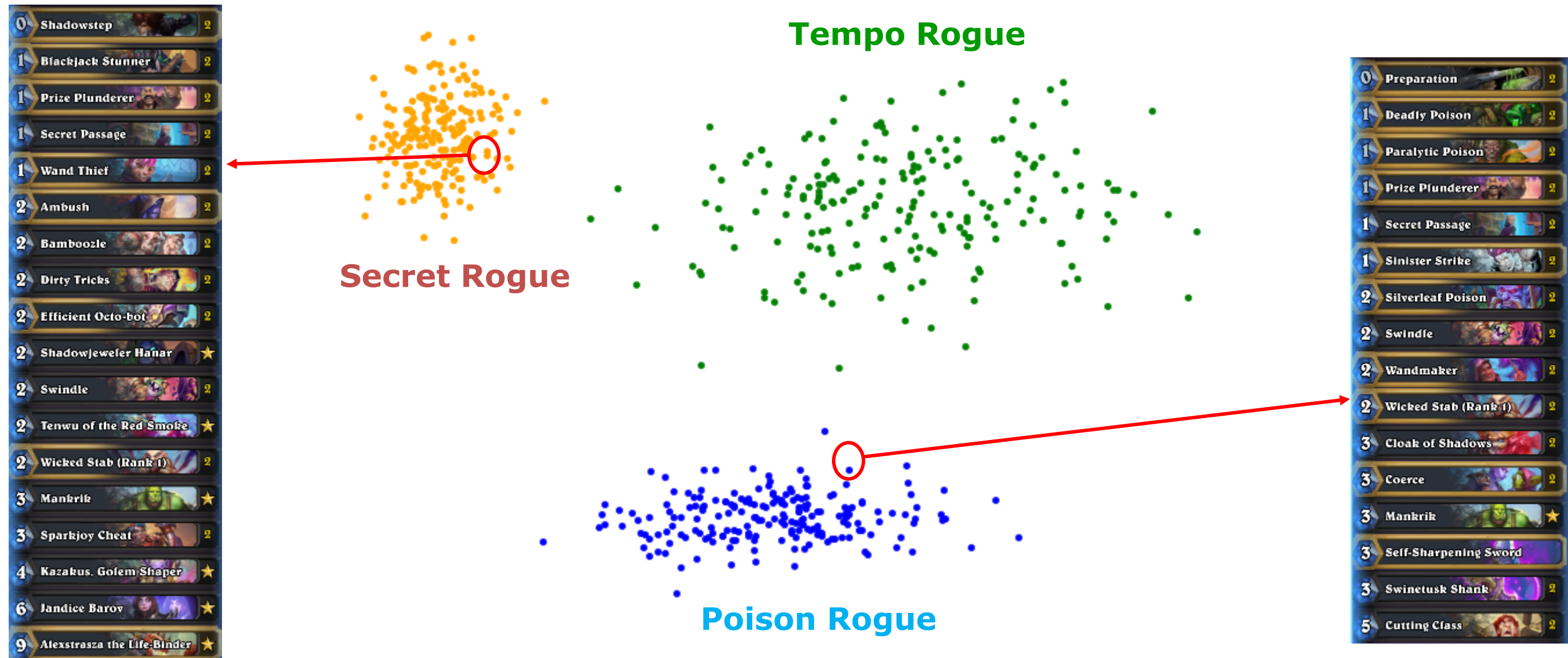
Notes for Layer 1

- Basic steps
    1. Prototype-based clustering to get centroids
    2. Apply some mathematical iterative process

- Meta is generally not the same across different ranks, player skills, etc.
    - Different sub-layers for this meta-deck filling

- Meta pipeline updates daily

Layer 2

Layer 1 (meta)

enough cards?

No
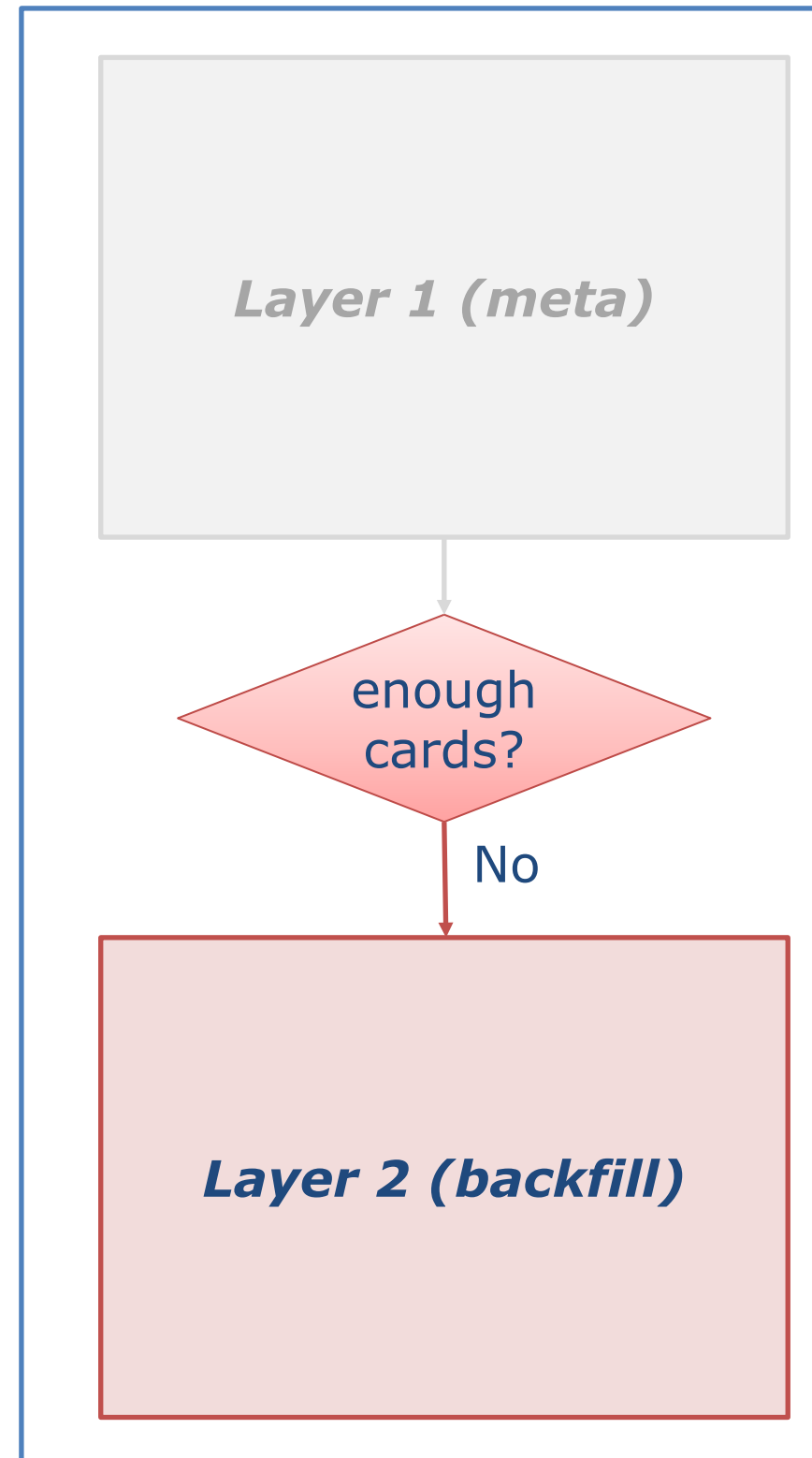
Layer 2 (backfill)

Backfill Algorithm

- Revert what Layer 1 did if necessary

- Synergy part is gone

- Fill the deck "dynamically" by "card power"

Card Power I

- Game Impact: How much a card contributes to a deck's win rate?

Card Power II

- Mana Cost Bucket: A collection of cards with the same mana cost
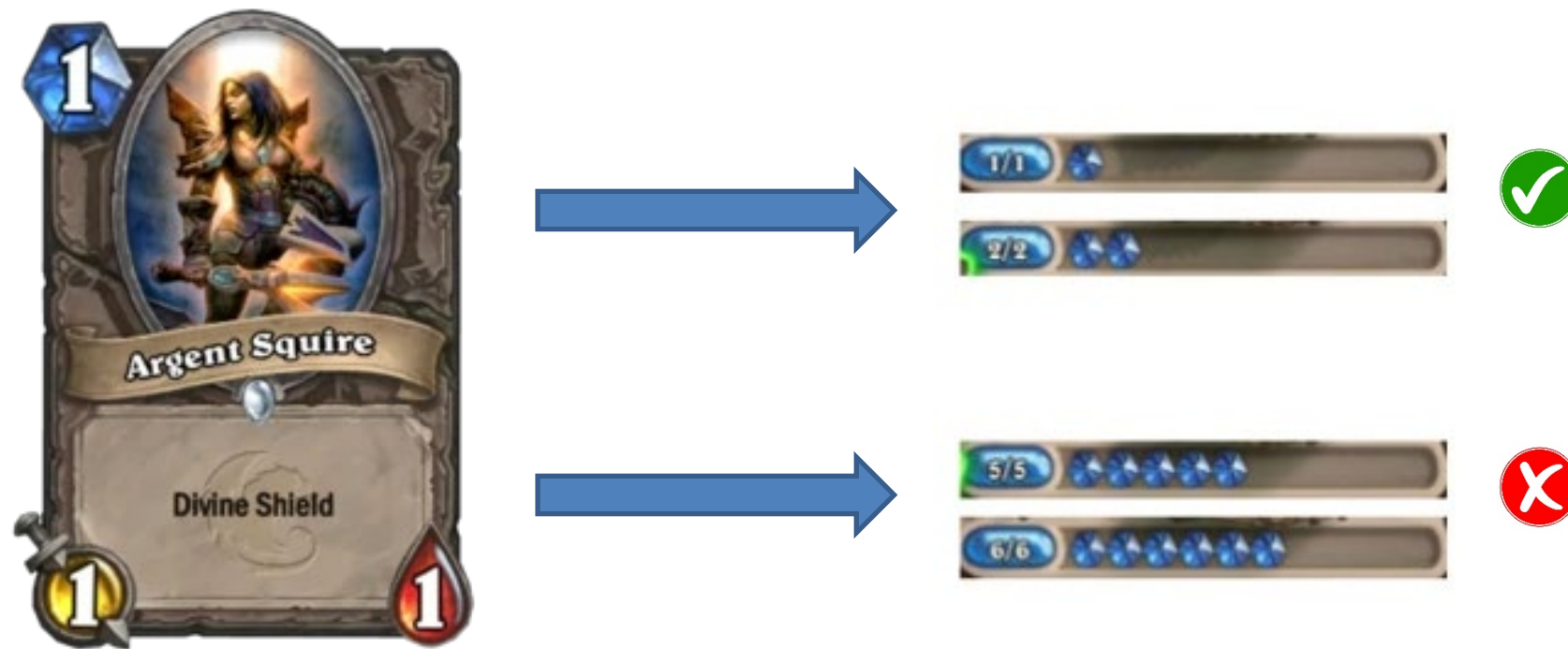
Card Power III

- Avoiding Overfilling a Mana Bucket

Rules

Layer 1 (meta)

Rules

enough cards?

No

Layer 2 (backfill)
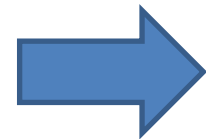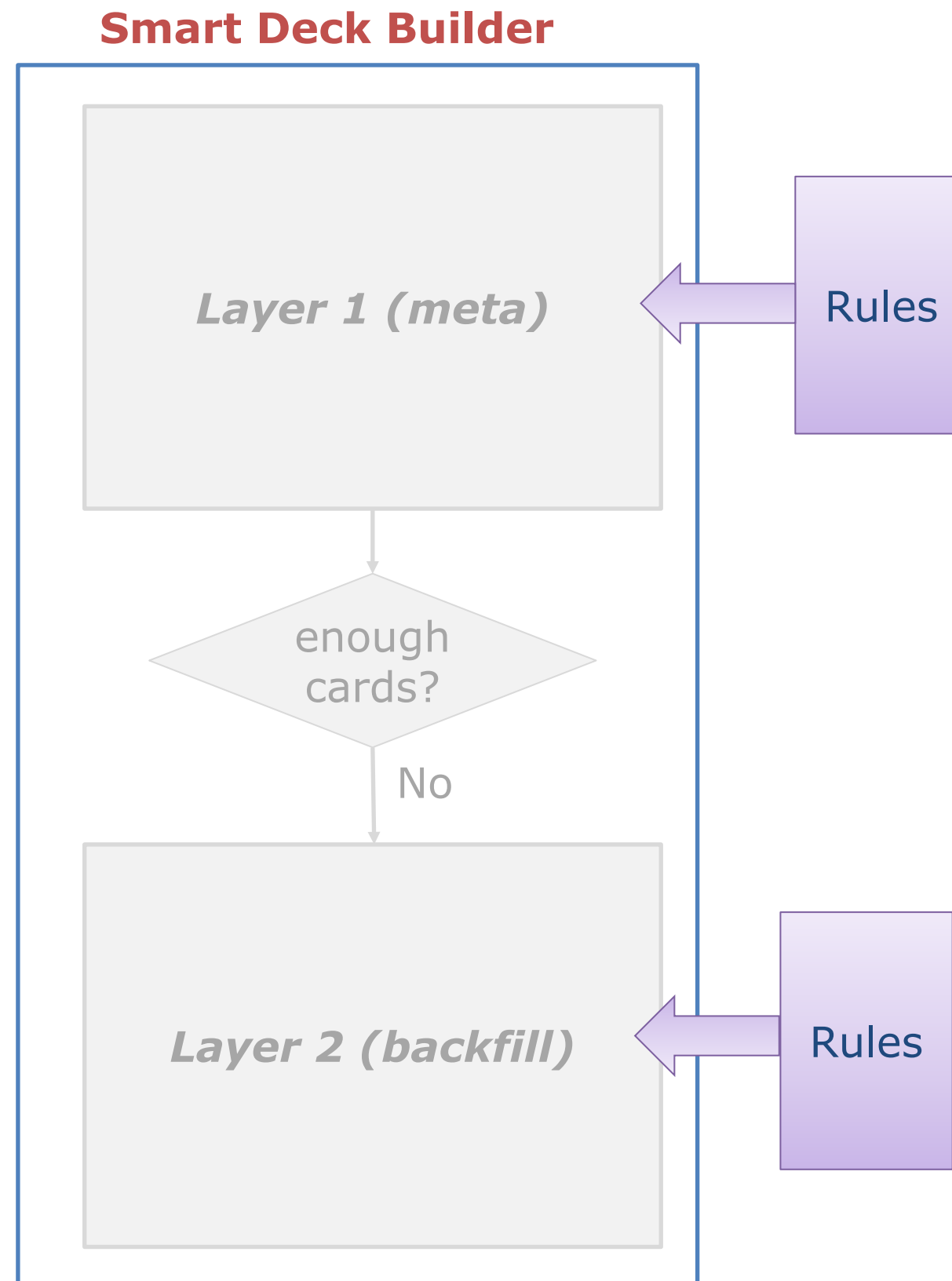
Rules

Hard Rules, Soft Rules

- Card constraints in the partially-filled deck, or cards in the partially-filled deck indicate such constraints should be met later

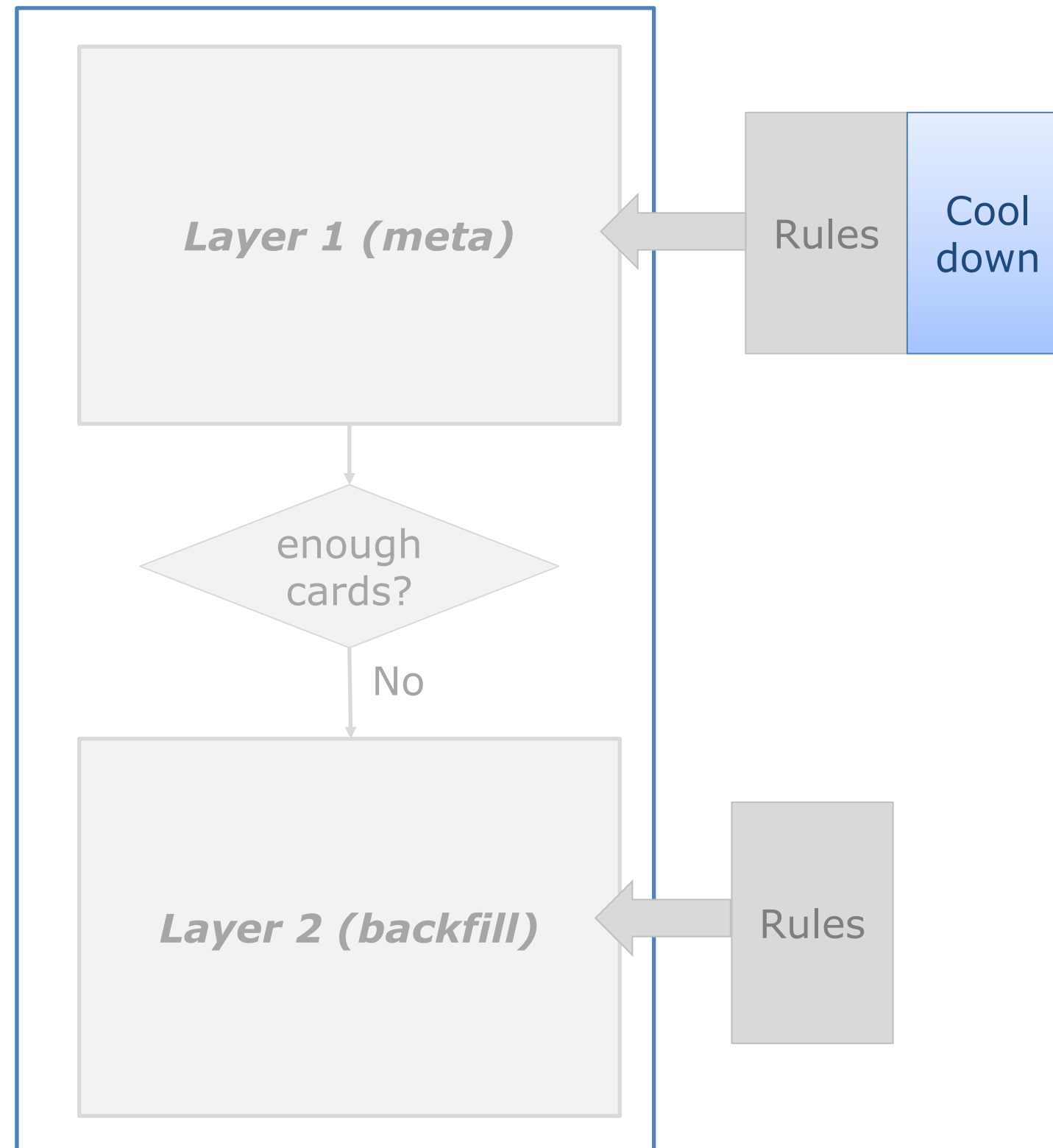- Certain cards need to be "scaled down/up" from game design's perspective

Cooldown

Layer 1 (meta)

Rules

Cool down

enough cards?

No

Layer 2 (backfill)

Rules

Cooldown

- Provides variety in the deck recommendation

- Helper
  - In-memory data structure store
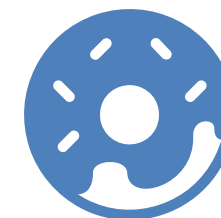
     redis

 Deck 1

 Deck 2

 Deck 3

Outline

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  - **Smart Loot Buckets for Duels**
  - Auto Balance for Arena

- Final Notes

Deck Building

- Dungeon-run style

Smart Loot Bucket

- "Group Learning"
  - Fits the "Scholomance Academy" theme

- Recommend card bucket that synergizes well with the current deck

- Launch on Oct. 2020

Power Word: Synergy

- Learning from gameplay data

- Synergy Score
  - How were cards played in each game?
  - Which stage of the game and what turns were these cards played?
  - What is the end-game impact (i.e. win/loss) after the card pair was played?

Pairwise Synergy Score

- Efficient to compute

- Extensible to arbitrary number of cards

- Works naturally for both generation and recommendation algorithms

- Normalized for fair comparison

Example

- Compute the pairwise scores under different "weight bases"

22.34

2.57

Generate Buckets

- Bucket synergy score = an aggregation of the pairwise scores

- Dedupe + additional filters

- "Reversed soft-minimum" aggregation

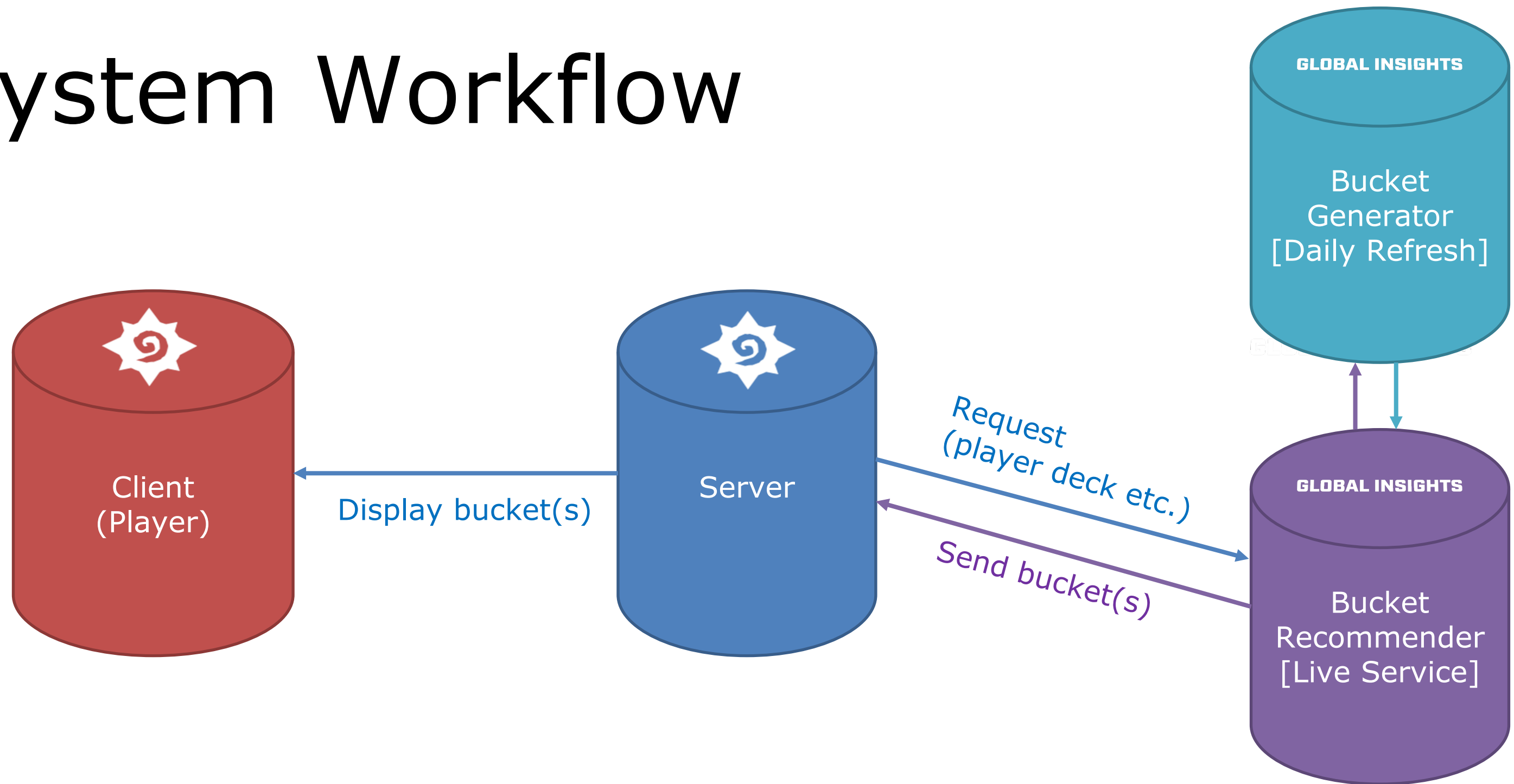Bucket score: 2.74

Recommend Bucket(s)

- Apply some math adjustments to raw information

- Adjust scores for mana curve

- Apply card multi-appearance penalties ("redux" factor)

- Weighted sampling: "controlled randomness"

System Workflow

Bucket Generator [Daily Refresh]

Client (Player)

Server

Bucket Recommender [Live Service]

Display bucket(s)

Request (player deck etc.)

Send bucket(s)

GLOBAL INSIGHTS

Design Iterations

- "Brawl blocks"

- Eliminate duplicate cards from the same buckets

- Encourage card diversity

- Increase the chance of certain cards that we want to promote

- "Group learning" buckets + designer bucket

Outline

Deck Building

- Drafting style

Background & Goal

- Need win-rate across all classes -- as close to 50% as possible

- Achieve the balance by tuning the weights associated with each card
  - Weight is a number that represents the relative likelihood that a card appears in a draft

- "Micro-adjustments"

Sources

- Gameplay data
  - Card actions
  - Player skill ratings
  - Game impacts of each card
- Card information (e.g. Spell, Minion, which expansion etc.)
- Card offer rate
- Card pick rate
- Current Arena draft tree structure

Methodology

- Three steps
    1. Build a model
    2. Solve constrained optimization problems
    3. Calculate the weights

Step 1: Build a Model

- Win probability impact: "Draw *The Lich King*" > "Draw *Snowflipper Penguin*"

- Build a predictive model to predict win probability given a "card draw state"

Step 2: Constrained Optimization

Tuning the "knobs"
(each "knob" represents a card)

Constraints
(e.g. card tiers, zero sum, no
"drastic changes" etc.)

find the best
solution from all
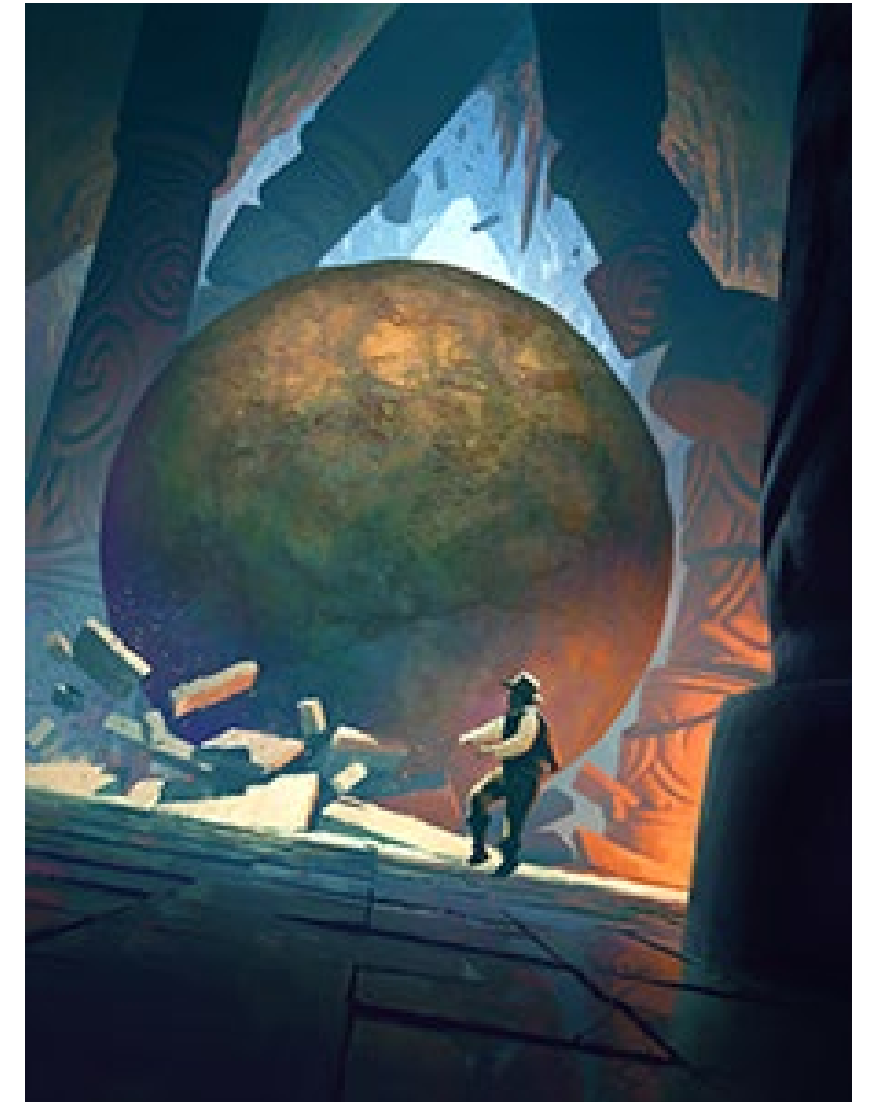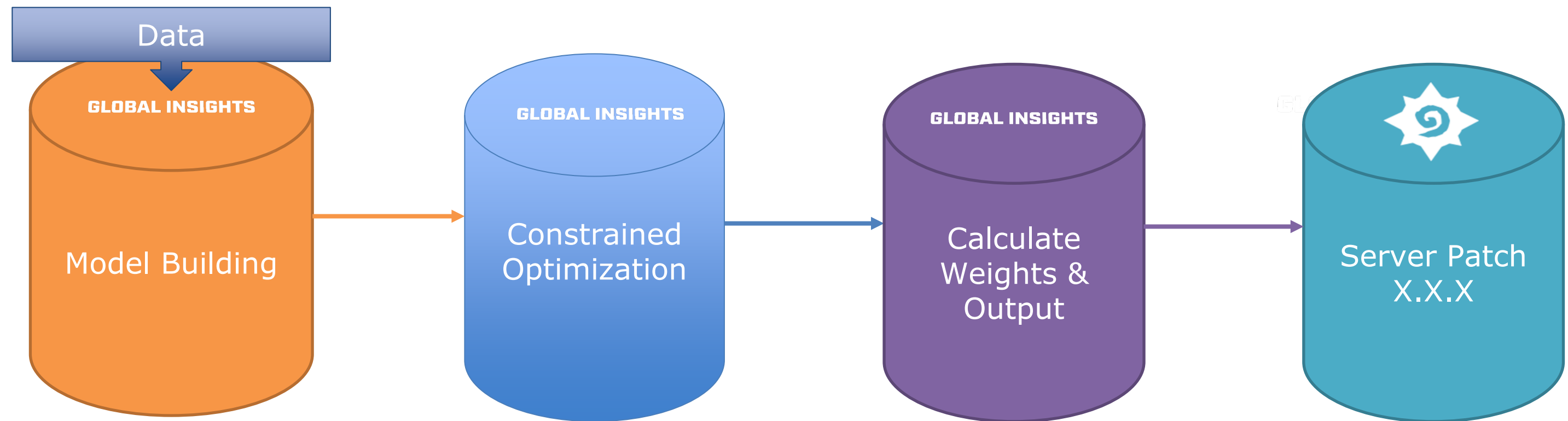feasible solutions

Class win-rate
close to 50%

Step 3: Calculate the Weights

- Adjust the weights assigned to each card
  - Based on what we learned from step 1 & 2
  - Which "knobs" to tune and how much to tune these "knobs"
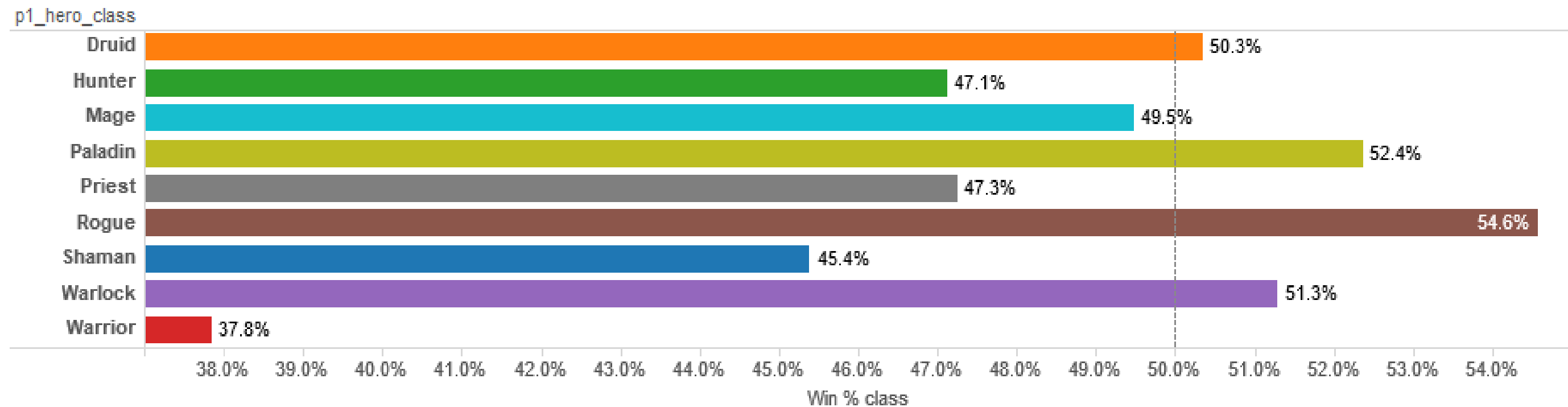 - Link each "knob" to the probability of each card showing up in a draft

System Workflow

Data

GLOBAL INSIGHTS

Model Building

GLOBAL INSIGHTS

Constrained Optimization

GLOBAL INSIGHTS

Calculate Weights & Output

Server Patch X.X.X

Results

Before Patch 9.2 (10/14 – 10/15/17)

p1_hero_class

Class	Win %
Druid	50.3%
Hunter	47.1%
Mage	49.5%
Paladin	52.4%
Priest	47.3%
Rogue	54.6%
Shaman	45.4%
Warlock	51.3%
Warrior	37.8%

Win % class

Results

After Patch 9.2 (11/7 – 11/8/17)
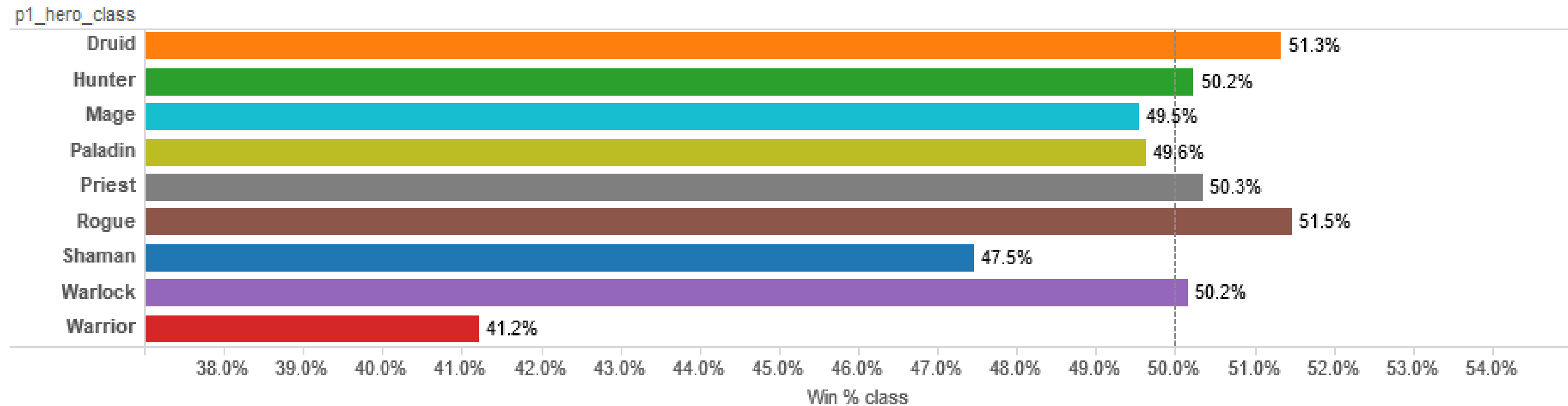
Results

Before (server hotfix) patch 10.0.3 (12/18 – 12/19/17)

p1_hero_class

Class	Win %
Druid	45.5%
Hunter	59.0%
Mage	44.6%
Paladin	50.0%
Priest	52.2%
Rogue	45.2%
Shaman	45.4%
Warlock	50.8%
Warrior	40.0%

Win % class
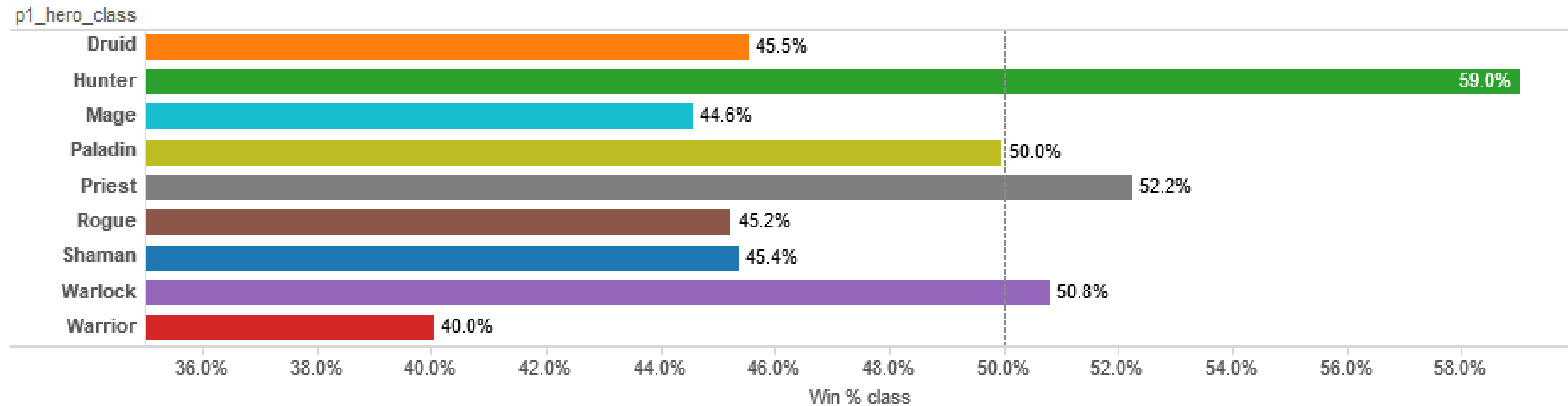
Results

After (server hotfix) patch 10.0.3 (1/1 – 1/3/18)
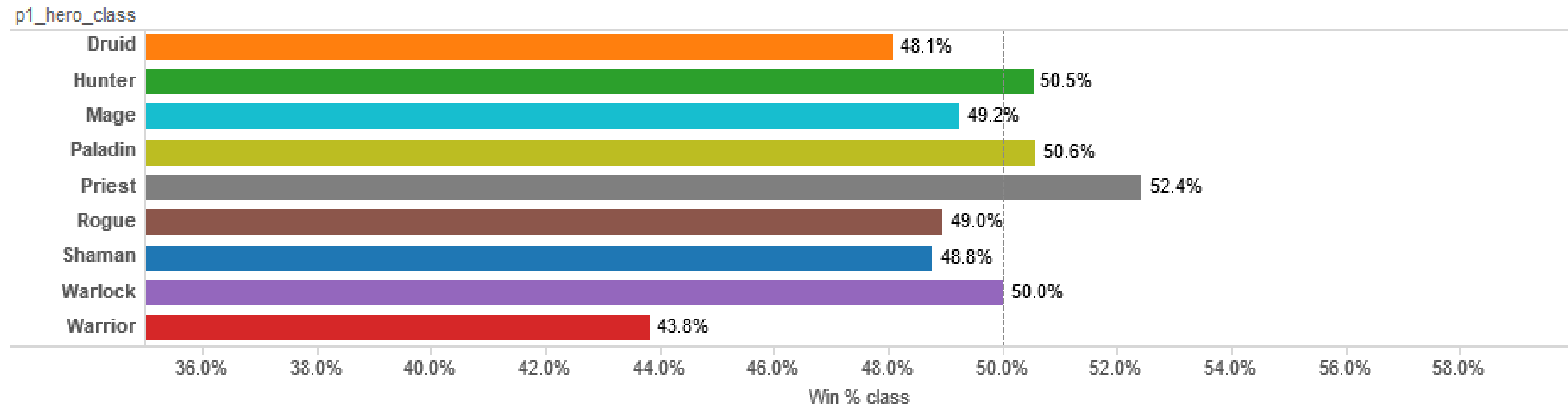
p1_hero_class

Class	Win % class
Druid	48.1%
Hunter	50.5%
Mage	49.2%
Paladin	50.6%
Priest	52.4%
Rogue	49.0%
Shaman	48.8%
Warlock	50.0%
Warrior	43.8%

Win % class

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The Golden Triangle
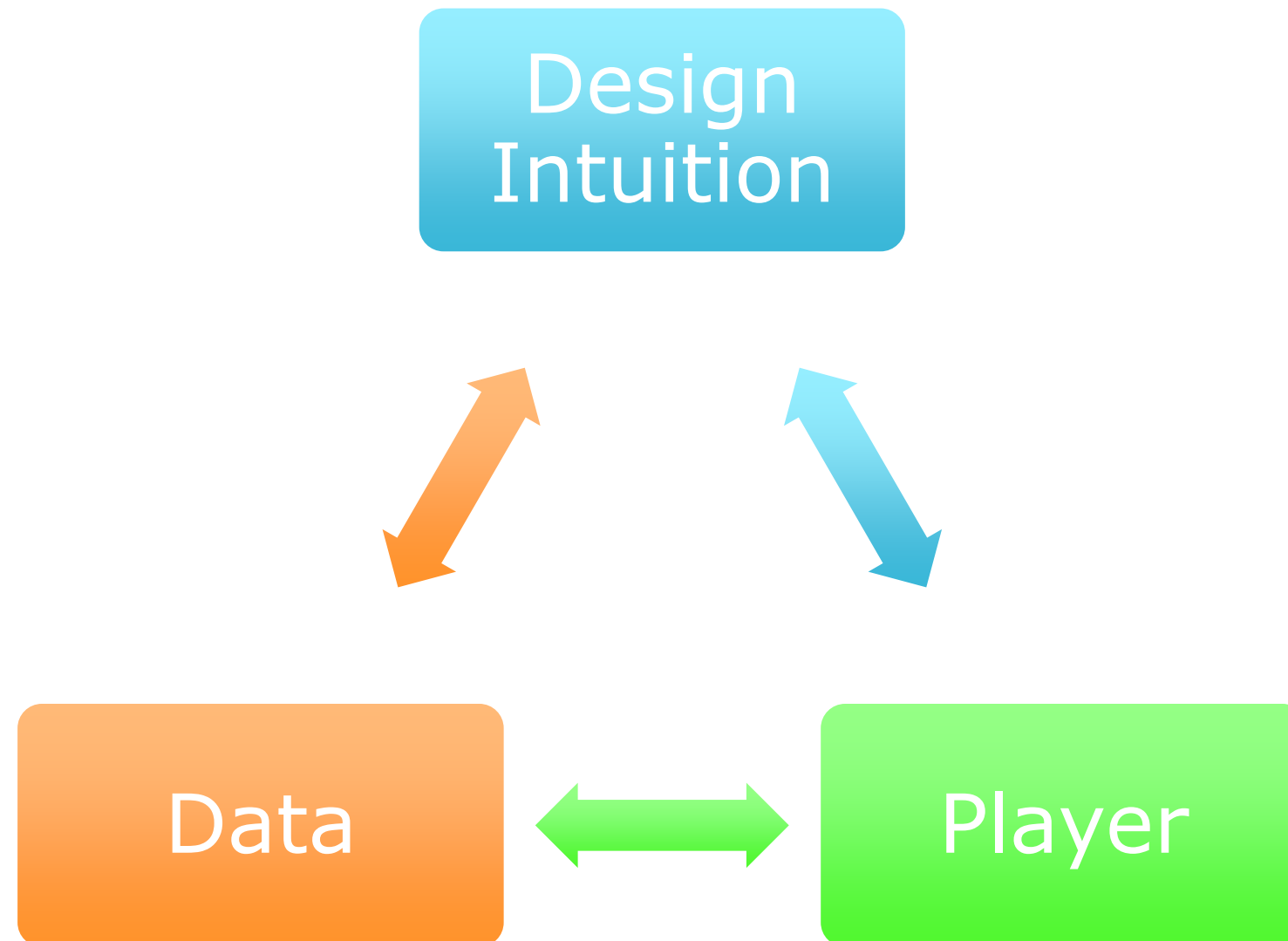
Extensibility and Automation

- Smart tech has been designed to be scalable for future changes

- Reduce manual work or find solutions can't be solved manually

- Output evolves as game evolves

Tech Choices For Smart Tech

- Scala / Apache Spark

- Java

- python / Airflow

Reference

- Developer Insights Blogs
  - Smart Deck Builder (https://news.blizzard.com/en-us/hearthstone/22938500/developer-insights-smart-deck-builder)
  - Smart Loot Buckets (https://playhearthstone.com/en-us/news/23558960/dev-insights-treasure-pools-and-smart-loot-buckets-in-duels)
  - Arena Balance Through Science (https://playhearthstone.com/en-us/news/22788308)

Thank you!

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