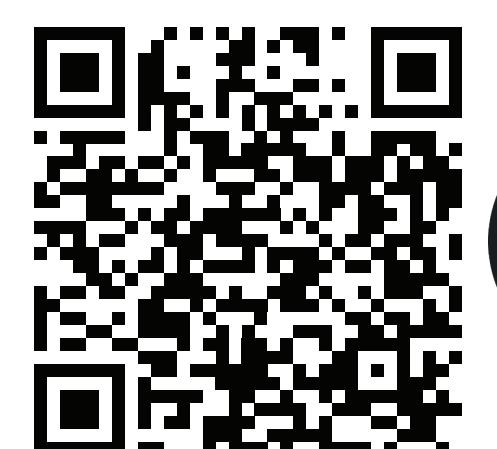
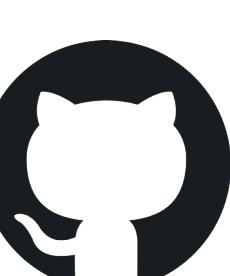


Big Data Reduction: Lessons Learned From Analyzing One Billion Dota2 Matches

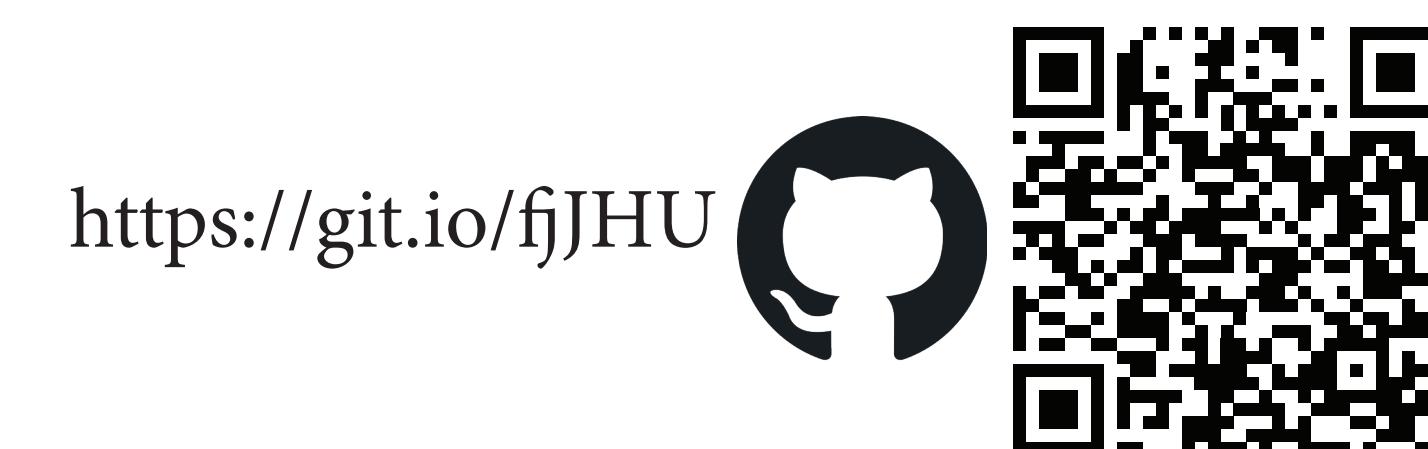


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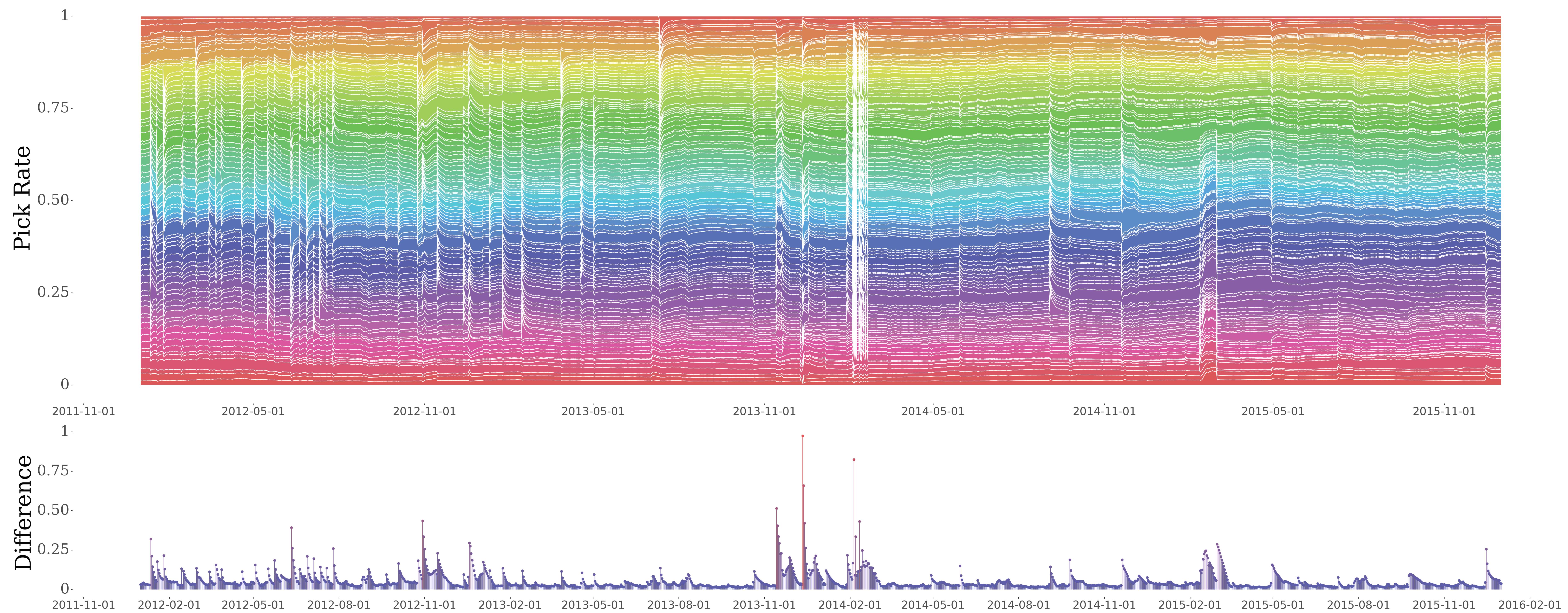
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Heroes Pick Rates (2011-11-22 - 2016-04-23)



Abaddon	to	Rubick
Alchemist	Jakiro	Sand King
Ancient Apparition	Juggernaut	Shadow Demon
Anti-Mage	Keeper of the Light	Shadow Fiend
Arc Warden	Kunkka	Shadow Shaman
Axe	Legion Commander	Silencer
Bane	Leshrac	Skywrath Mage
Batrider	Lich	Slardar
Beastmaster	Lifestealer	Stark
Bloodseeker	Lina	Sniper
Bounty Hunter	Lion	Spectre
Brewmaster	Lone Drift	Spirit Breaker
Bristleback	Luna	Storm Spirit
Broodmother	Lycan	Sven
Centaur Warrunner	Magnus	Techies
Chaos Knight	Medusa	Templar Assassin
Chen	Meepo	Terrorblade
Clinkz	Mirana	Timbersaw
Clockwerk	Morphling	Tinker
Crystal Maiden	Naga Siren	Tiny
Dark Seer	Nature's Prophet	Treant Protector
Dazzle	Necrophos	Troll Warlord
Death Prophet	Night Stalker	Nyx Assassin
Disruptor	Ogre Magi	Omniknight
Doom	Phantom Assassin	Oracle
Dragon Knight	Phantom Lancer	Outworld Devourer
Drow Ranger	Phoenix	Phantom Assassin
Earth Spirit	Puck	Phantom Lancer
Earthshaker	Pudge	Phoenix
Elder Titan	Pugna	Phantom Assassin
Ember Spirit	Queen of Pain	Phantom Lancer
Enchantress	Razor	Phoenix
Enigma	Riki	Phantom Assassin
Faceless Void	Gyrocopter	Phantom Lancer
Gyrocopter	Huskar	Phoenix
Huskar	Invoker	Phoenix
Invoker		Phoenix

Why Study DOTA2?

Why study a Video Game? The availability of large datasets of player choices in popular online computer games presents an opportunity to identify sudden changes in choice patterns and explore what factors may contribute to such changes. We were particularly interested in the challenges posed by the scale of such large datasets (we attempted to obtain another >1TB dataset as well).

What is DOTA2? DOTA2 is a popular MOBA (Multiplayer Online Battle Arena) videogame. The core gameplay revolves around teams of five players choosing from a character pool of over 100 characters and facing off against another five-person team in a race to destroy a large structure located in the enemy's base called The Ancient. The game is also known for its large prizepool annual tournament, The International, whose prize pool ranges in the millions of dollars (\$25 million for 2018).

Why study DOTA2? Neither of the authors has significant experience with the game, and we had initially explored the availability of datasets for a wide gamut of games with which we have more experience with. However, DOTA2 is unique in having a long-running community project to collect data on the game which is periodically released for use in research. The OpenDota (formerly YASP) project's most recent "data dump" covers >1 billion matches from March 2011 to March 2016 [1] and clearly boosts the appeal of DOTA2 as subject of study.

Research Objectives

- To detect metagame shifts from hero pick ratios, that is to attempt to recognize significant changes in players' propensity for picking certain heroes that would be caused by external events (patches to the game, major tournaments, etc.)
- To attempt to "tame" the dataset's enormity using the simplest tools possible, and using only the resource of a normal machine as may be available to an average researcher without extensive funding

Big Data Reduction

The Dataset. The dataset ranges from March 2011 to April 2016 and contains data on 1,191,768,403 (>1 billion) matches that were played during that time [1]. This data is publicly available as a gunzipped CSV file (151GB zipped, 1.2TB unzipped). At our disposal was only a personal machine with good but not outstanding performance that could not possibly handle the data in its original format. As such, we had to use for Big Data Reduction techniques.

Dimensionality reduction. The curse of dimensionality is a well-known problem where the high number of dimensions present in the dataset cause increasingly high computational burdens [2]. In our case, we have over 50 dimensions in the dataset. We established that only 22 dimensions were needed to achieve our objectives and processed our dataset accordingly. We calculated that on an average day in the dataset, this could have reduced the space needed as much as from 671 MB to 99MB (a 6.7x reduction).

Locality reduction or optimization. We also established that for our purposes of detecting points where the metagame shifted, we need not possess extremely granular data. After all, we are interested in the day or few days when this shift occurs rather than the minute. Thus, we can afford a much coarser locality than what is present in the dataset – we do not need per-match data, just per-day or per-week summaries of what heroes were picked. A sum of the daily picks (and wins/losses) for each hero was what we sought to produce. Condensing the data in this manner produced extraordinary space savings as expected: the potential reduction could be as great as from 99MB to 3KB (35,545x reduction).

Locality reduction or optimization. These are theoretical results for simulated data; however in our actual implementation, we observed the original dataset of 1.2TB being reduced to 3MB or a 396,514x compression. The increased performance in the real-world application is likely a result of JSON compression and some level of data sparsity that was not present in the hand-crafted test case.

Poor Man's Solution

Java 8 Streams (Bad idea! Keep it simpler!). With such a large amount of data to be processed, it is not viable to load the data in memory, and it is necessary to process it iteratively. Initially, we sought to use Java 8 Streams to do so to avoid having to decompress it ahead of time. However, we quickly discovered that Streams add significant overhead and quickly exhaust a consumer computer's memory. A simple for-loop (well, an iterator really) was much more performant!

CSV Parsers (They matter!). Key to the performance of iterating through such a large dataset. We originally attempted to use the fastest CSV parser available, uniVocity-parsers [3]. However, memory usage from this parser was extremely substantial and would slow down after ~400,000 and crash at ~450,000 records. We fell back to one of the most common and well supported parsers, opencsv; however we found its performance insufficient (around 2,000 lines/s). We found that the second-fastest parser, SimpleFlatMapper, has negligible performance loss but maintains a constant low memory profile. The entire processing could be done with a few hundred megabytes of RAM!

JSON Parsers (Take your pick). As each row contains a JSON field that needs to be parsed, a JSON parser must be employed. We did not see any significant differences in the parsers we briefly auditioned and were able to make our choice by and large based on intuitiveness. We found Jsoniter to be perfectly serviceable.

HashMap Optimization (Doesn't matter). We were concerned about the memory usage by the HashMap/Dictionary we intended to store the condensed data in while it was processed, and selected a high-performance library, Trove4j. This library from Palantir stores a THashMap using only (8 * CAPACITY) bytes compared to Java's HashMap that uses (32 * SIZE + 4 * CAPACITY) bytes [4]. However, it became evident that the HashMap's memory utilization was not a significant concern because of the coarseness of the locality.

```
FileReader fileReader = new FileReader(input);
Iterator<String[]> cReader = CsvParser.iterator(fileReader);
while (cReader.hasNext()) parseRow(cReader.next(), onlyCount);
```

Metagame Shifts

The "diversity" graph records the difference between a day's hero picks and the average of the previous 14 days of picks. This is computed using a simple Manhattan distance where each hero's pick rate represents a dimension in the vector.

We sought to match the more prominent peaks to external events that might influence player behavior such as game patches [5] and major tournaments.

2012-01-12 Major rebalancing of heroes & item changes

2012-06-11 Chaos Knight, Phantom Assassin, Gyrocopter released

2012-07-26 Nyx Assassin, Keeper of the Light, Visage released

2012-10-30 Recently released Centaur Warrunner is nerfed

2012-12-19 Major rebalance of most/all champions

2013-11-14 Three Spirits Patch, significant out-of-game & economy changes

2013-12-12 Skeleton King removed shortly before, Legion Commander added, Wraith King added shortly after

2014-01-29 Terrorblade, Phoenix released

2014-02-05 Year Beast Brawl (special game mode)

2015-02-18 Year Beast Brawl (special game mode)

2015-05-03 No major changes, but The Summit 3 Tournament tickets released

2015-12-16 Arc Warden released

No major spikes were detected that could be attributed to The International, the major tournament which is normally held yearly in August (with a few exceptions in July and May).

We believe our approach as largely been proven to work, even if some major spikes such as that of 2015-05-03 remain unexplained. We intend on seeking the assistance of subject matter experts in interpreting at least that particular spike.

Future Work

We have identified several promising venues for extension of the work which we hope to pursue, in addition to overdue cleanup of the codebase which is already in progress. Exploring further metrics that are available from the underlying data, chiefly the wins-losses ratio for each hero which we currently export but do not explore may be a significant metric which can lead to metagame shift detection.

Another possible avenue for improved detection we have identified is to explore pick ratios not in term of individual heroes but in term of the role these heroes fill.

Lastly, the high dimensionality of the dataset means that using as simple a distance function as Manhattan or Euclidean distance is likely not the best idea, and that a more meaningful dissimilarity measure might be more effective.

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- [3] uniVocity Software Pty Ltd, "Comparisons among all Java-based CSV parsers in existence: uniVocity-parsers-comparison, univocity, 2018.
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