A Network Science Approach to Balancing MOBA Games

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Abstract

This work explores the use of network analysis in analyzing the strengths of the heroes in Dota 2. By creating a network of hero win rates and looking at degree centrality and eigenvector centrality, we are able to pinpoint the strongest heroes based on the advantages they demonstrate against other heroes. This technique can be used by developers to make the game more balanced or if they want to introduce new elements in the game.

1 Introduction

1.1 The Video Game Industry Then vs Now

Before the 1990s, all video game companies had a Pay to Play (P2P) business model. Players had to pay first before they could play the game (e.g. arcades and consoles). During this time, all the games were played offline and simply offered a player-vs-enemy (PvE) experience where player(s) just compete against a computer (e.g. Galaga, Pacman and Dongkey Kong). The few games that did offer a player-vs-player (PvP) experience (e.g. Bomber Man, Battle City Tanks, Contra), did so by creating "mirror matches." Different players had nearly identical "loadouts" (selection of characters, items and or abilities) to ensure that all players had equal chances of winning. Back then, it was impossible for game developers to provide post release support for their games. There was no way of correcting any issues such as bugs and imbalances, nor was there a way to build upon a video game other than releasing a sequel.

The internet age had huge impact on the video gaming industry because it created a shift in mindset. For one, it made the Free-to-Play business model feasible because companies now have an alternative source of revenue in the form of in-game ads, pay wall subscriptions and/or microtransactions. In particular, microtransactions have been very effective with some games generating more than $1.5 billion dollars in revenue just for the sale of in-game unlockables, like special characters, items and abilities (Makuch, 2019). In addition, most video games now require some degree of internet connectivity, as it allows developers to provide post release support in the form of patch updates. These updates could be aimed at fixing bugs, adding features and/or "balancing" the game. Now, companies can earn by building on and improving games after release.

1.2 Rise of Online Multiplayer

Another big shift in the gaming industry is the increasing demand for online multiplayer capability. These games are designed to be played by multiple players on a global scale. Players either collaborate, compete or both (e.g. team A vs. team B) to achieve a certain objective.

Contrary to how developers used to implement mirror matches for PvP, most online games nowadays offer some form of customizations that may or may not directly affect the game's mechanics. For First Person Shooter (FPS) games, these are the guns that have varying attributes (e.g. damage, range, accuracy). For Massive Multiplayer Online Role-Playing Games (MMORPG), these are the in-game item collectibles (e.g. unique upgradable weapons and armor pieces). For Multiplayer Online Battle Arena (MOBA) games, these are the characters with different spells (e.g. nuke, stun, illusion).

Note that while customizable features add variety, it also introduces imbalance. Players will eventually develop certain preferences, playing styles, and strategies that capitalize on these imbalances. In gaming terms, this is what is known as the "meta," which is a trend where players just choose whatever increases their chances of winning. This phenomenon is best explained by the concept of game theory, where competing players formulate their strategies by also accounting for what their competitors are most likely to do.

1.3 Imbalance and Microtransactions

Several companies have deliberately introduced imbalance in their video games in order to increase their microtransaction sales (Crunch, 2019). This is done by creating a Pay 2 Win (P2W) environment where players are influenced to avail of microtransactions in order to increase their chances of winning, like Clash of Clans, Maple Story, or Destiny ("The Best and Worst Pay to Win Games", 2020). This practice has been heavily criticized over the years, with law makers comparing it to "gambling targeted at children" (Webb, 2019). In fact, as of 2018, Belgium has deemed microtransactions illegal (Gerken, 2018). A balanced video game ensures that companies are not able to exploit players through microtransactions. While law makers are addressing this problem on the side of business, gamers are addressing this on the side of game development.

The gaming community is very vocal in their feedback when it comes to balance in video games. In fact, there exist websites (that record statistics) and forums dedicated to improving the balance of different video games. These provide developers insights on how a game is evolving especially in the context of multiplayer matches. This enables developers to change certain aspects of the game to meet the demand of the gaming community.

Balancing is easier said than done, as video games tend to be very complex. Statistics alone won't be able to capture the complex interactions between different elements while feedback from players is prone to biases. None embodies this complexity more so than MOBA games.

1.4 Multiplayer Online Battle Arena

Multiplayer online battle arena (MOBA) is a type of video game where each player controls a single character as part of a team competing against another team of players and battling it out to occupy the opposing team's base or some other victory condition (Wikipedia contributors, 2020b). Among the most popular MOBA games include Heroes of the Storm, Dota 2, and League of Legends (Ziegler, 2019). In this work, we take a closer look at Dota 2 due to its popularity and the availability of data for analysis. Dota 2 is a free-to-play MOBA game that was created by Valve (Wikipedia contributors, 2020a). It has a highly competitive esports scene, with Valve hosting an annual tournament for professional players (with cash prizes reaching more than US$30 million). It has also been used in machine learning experiments, and there is already an AI (OpenAI Five) that can defeat professional players ("OpenAI Five", n.d.).

1.5 Dota 2

To play Dota 2, ten players are divided into two teams and each team occupies and defends their base on the map. The goal of the game is to destroy the other team's "Ancient", a large structure located in a team's base. Each player controls their chosen character (called a "hero") who has unique abilities and attributes. Players select (or ban) a hero during the drafting phase at the start of a game. Once selected (or banned), heroes are removed from the drafting pool and become unavailable to all other players in the game. Heroes start at level 1 and max out at level 25 (30 as per the most recent patch). As the game progresses, players gain gold and experience. This allows each player to buy items and level up certain abilities for their hero which they can then use as leverage against the opposing team.

1.6 Balancing

The developers of Dota 2 releases a new patch every year. This patch contains gameplay changes that are based on the feedback and statistics gained from several sites like Dotabuff ("Heroes - All Heroes - DOTABUFF - Dota 2 Stats", 2020), DOTAFire ("DOTAFire :: DotA 2 Builds & Guides for Hero Strategy", n.d.), and Steam Community ("Steam Community :: Dota 2", n.d.). In addition, test servers are also made available for very experienced players to try different versions of the game. This approach is tedious, inefficient and prone to biases. It also fails to capture the interactions between different heroes of the game.

In this paper, we will explore the use of network analysis to compare the heroes of Dota 2. We will use eigenvector centrality to determine if the heroes are more or less balanced, or if there are overpowered heroes in the game.

2 Data and Methodology

Information on the heroes of Dota 2 were obtained from Dotabuff ("Heroes - All Heroes - DOTABUFF - Dota 2 Stats", 2020) via web scraping, spanning from the release of patch 7.19 until February 2, 2020 (patch 7.24) as of this writing. Information on the average win rate of one hero against another hero can be obtained per patch, across all the games registered in the site. Refer to Figure 1 for a sample information displayed on Dotabuff.

Figure 1: Dotabuff screenshot on Rubick, a playable hero for Dota 2.

For this analysis, only the average across all player skill brackets were considered. We also note that the win rate values for the latest patch (7.24) are still changing since people are currently playing this patch, so this analysis is valid for the data obtained up to February 2, 2020.

2.1 Creation of the Network

A win rate network will be made for the latest patch (patch 7.24) of Dota 2. This is a weighted directed network where the nodes are the heroes and the directed edges are weighted by the win rate of one hero over another hero. The direction of the network will be drawn from the hero with the lower win rate to the hero with the higher win rate. We only consider the win rates that are strictly above 50% to indicate who wins in a hero match-up. We then subtract 50% from the win rate to get the edge weight, since we are only interested with how much advantage a hero has over another hero. This is illustrated in Figure 2.

To Illustrate the creation of this network, we refer to the statistics of the hero Rubick in Figure 1. Looking at the "Hero Win Rate" column, the network we can generate is displayed in Figure 3. Note that we only selected a few heroes in the figure for illustration purposes.

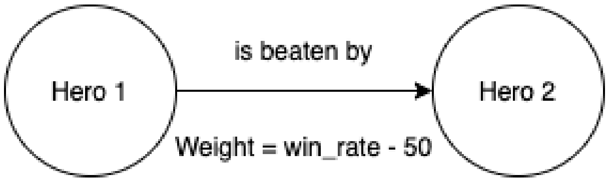

Figure 2: Creation of the network of Dota 2 heroes. The direction of the edge is from the hero with the lower win rate to the hero with the higher win rate. The weight of the edge is equal to the win rate of the stronger hero subtracted by 50.

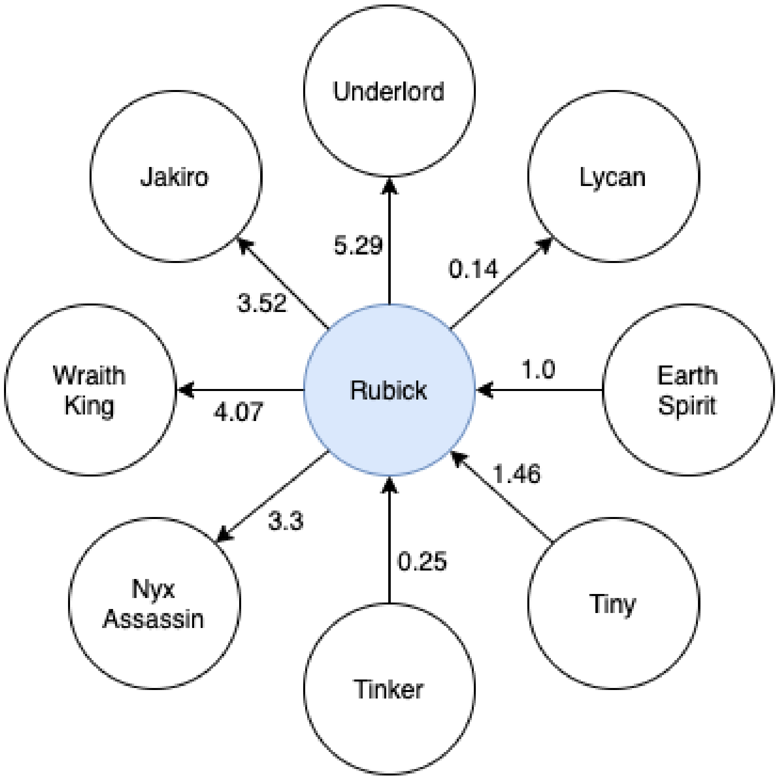

Figure 3: Win rate network of Rubick. He has a higher win rate over Earth Spirit, Tinker, and Tiny, but is defeated by the other heroes.

When two heroes are equally matched (with 50% win rate), we will not draw an edge connecting these two heroes. This will give rise to a network where every node is connected to almost every other node. With these rules, we end up with a network having 119 nodes and 7017 edges. See Figure 4 for the win rate network of patch 7.24.

2.2 Centrality Analysis

We look at two different graph centrality measures to determine which of the Dota 2 heroes are powerful: the in-degree centrality and the eigenvector centrality. Refer to the discussion of Newman (Newman, 2018) and the NetworkX documentation (NetworkX Developers, n.d.) on centrality measures of a network.

The in-degree centrality for a node in a directed network is the fraction of nodes its incoming edges are connected to. In the context of the Dota 2 win rate network, the in-degree centrality is higher for heroes who can beat a lot of heroes when pitted against each other. The weights are not taken into account with this centrality measure, only the number of incoming edges. This means that we measure the strength of a hero based on the number of other heroes it can beat in battle.

Eigenvector centrality in a directed network gives higher scores to nodes that are being referred to (or pointed at) by other high scoring nodes. In addition, the edge weights also affect the eigenvector centrality score. The larger the weight, the larger the eigenvector centrality score.

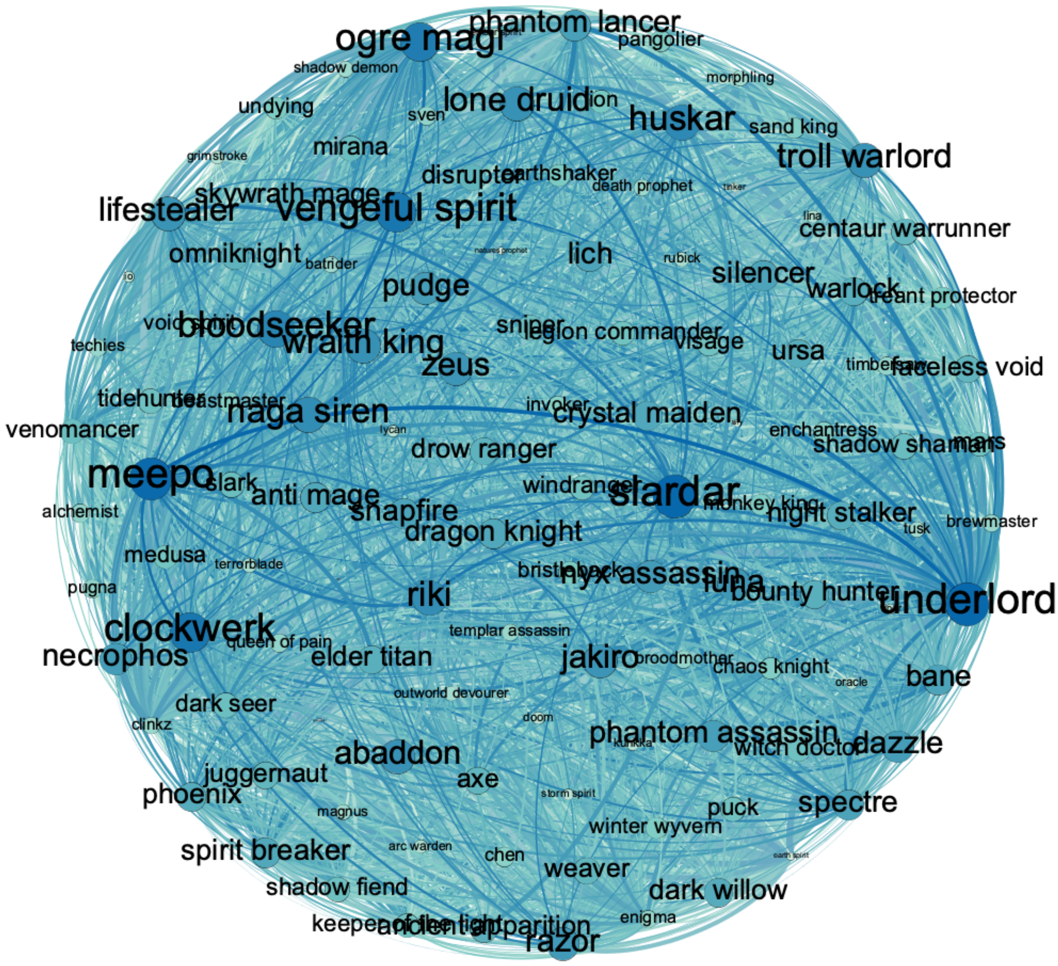

Figure 4: Win rate network for Dota 2 (patch 7.24). The nodes highlighted in this network are the ones with the high win rates.

Eigenvector centrality allows for a more holistic view of balance because we are able to account for directionality. For instance, consider a hard counter hero (a hero that is extremely effective versus a select few of heroes). The hard counter may have lower win rates against the majority of heroes but this can be offset by high win rates against the popular heroes. Looking at just the average win rates would result into thinking that the hard counter hero is underpowered when it isn't. By looking at the eigenvector centrality of each hero, developers are able to account for the following:

- For a selected hero, who are the other heroes that it can beat?
- How strong are those heroes that it can beat?
- By how much can the selected hero beat those heroes?

3 Results

Figure 5 shows the histogram of eigenvector centralities across the 6 patches. It can be seen that the distributions are exponential in nature. Wherein for each patch there are usually 30-40 heroes (35% of the maximum hero pool) that are underpowered. On the other hand, for each patch, there exist a small group of strong heroes that dominate the meta. The implications of this is that, in theory, if a player wants to increase his/her chances of winning the game then he/she should focus on the top tier heroes whilst avoiding the 30-40 low tier heroes.

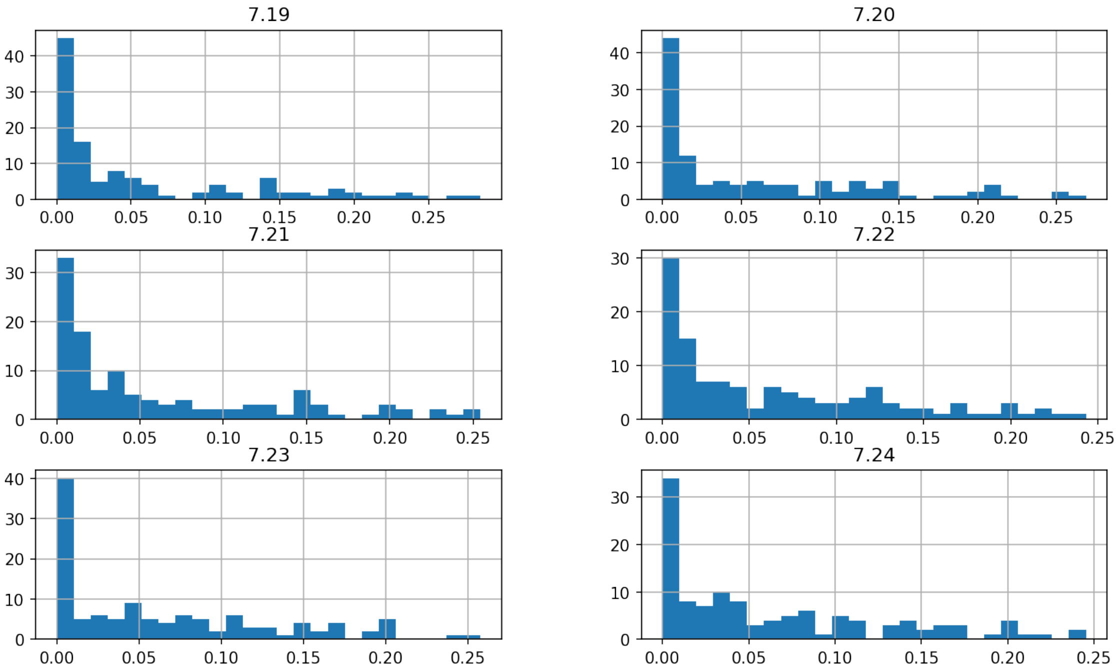

Figure 5: Histogram of eigenvector centralities across 6 patches.

Looking at the trends though across patches, it can be seen that the number of underpowered heroes is actually going down. In patch 7.19 there's around 45 heroes that are underpowered, however by patch 7.24 its just around 35.

Figure 6 shows the trend for the maximum eigenvector centrality score, wherein it can clearly be seen that the max values tend to decrease with each new patch. This means that the overpowered heroes of each new patch tend to be weaker in comparison to the overpowered heroes of the previous patches. This has 2 main positive implications. First is that dealing with a "meta hero" is not as difficult as it was before. Second is that developers are getting better at "capping" the strengths of heroes.

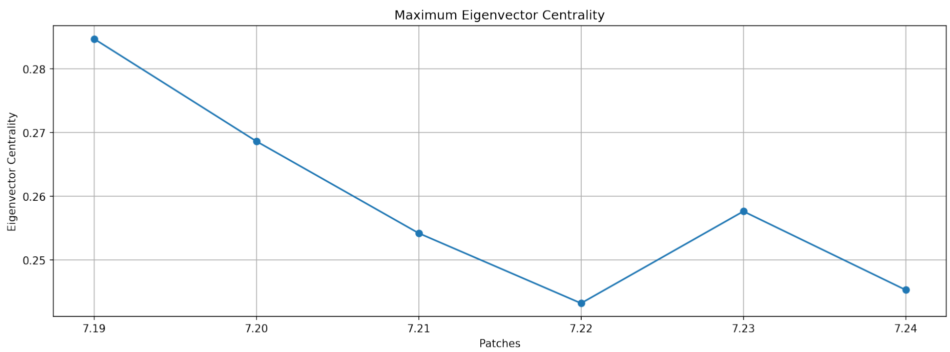

Figure 6: Evolution of the maximum eigenvector centrality across 6 patches.

One interesting observation here is the spike at patch 7.23 wherein there was a drastic change to the original game dynamics. Because apart from changing the existing items and heroes, the developers also introduced 62 new items along with 2 new heroes. This would understandably shake up the balance of the game.

We now compare the rankings of the heroes in Dota 2 using the centrality measures in the generated win rate network. Table 1 summarizes the list of the most powerful heroes in Dota 2 in terms of win rate, in-degree centrality, and eigenvector centrality.

Rank	Average Win Rate	In-Degree Centrality	Eigenvector Centrality
1	Underlord	Slardar	Slardar
2	Slardar	Underlord	Underlord
3	Meepo	Vengeful Spirit	Vengeful Spirit
4	Clockwerk	Ogre Magi	Meepo
5	Vengeful Spirit	Clockwerk	Clockwerk
6	Ogre Magi	Lifestealer	Lifestealer
7	Bloodseeker	Bloodseeker	Ogre Magi
8	Huskar	Huskar	Huskar
9	Naga Siren	Meepo	Bloodseeker
10	Riki	Jakiro	Riki

Table 1: Summary of the top 10 most powerful heroes in Dota 2 in terms of the following measures: (1) average win rate, (2) in-degree centrality, and (3) eigenvector centrality.

3.1 Average Win Rate vs In-Degree Centrality

We take a closer look at the difference in rankings when looking at the average win rates contrasted with the in-degree centrality. Refer to Figure 7 for the ranking of the top 10 heroes in terms of average win rates. In contrast, we look at Figure 8 for the heroes that displayed big jumps in rank when looking at average win rates and in-degree centrality.

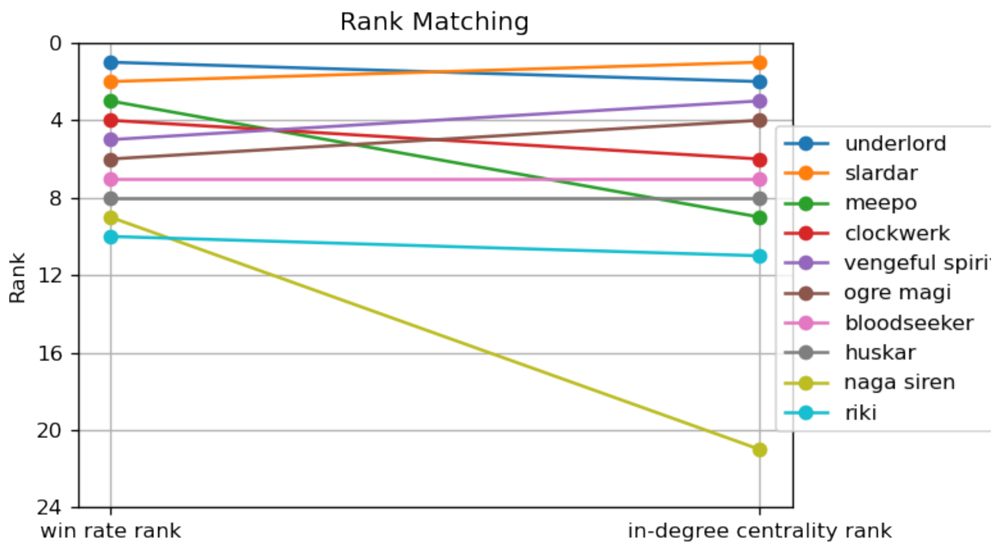

Figure 7: Difference in ranks of Dota 2 heroes in terms of average win rates and in-degree centrality. Here, we focus on the top 10 heroes in terms of average win rates.

It is interesting to look at the difference in rank for Naga Siren and Lifestealer. Naga Siren is an illusion-based hero, and there are many heroes in Dota 2 that can easily counter that ability. This could explain why we observe the big drop in rank for Naga Siren. In contrast, the big jump in the rank of Lifestealer can be explained by the fact that Lifestealer is an all-around hero. This means it is a good counter for a lot of other heroes in Dota 2.

3.2 Average Win Rate vs Eigenvector Centrality

We take a closer look at the difference in rankings when comparing the use of average win rates and eigenvector centrality. Refer to Figure 9 for the ranking of the top 10 heroes in terms of average win rates. Looking closely at the rank of the hero Vengeful Spirit, it is 5th in rank in terms of average win rate, but 3rd in rank when using eigenvector centrality. This is due to the fact that Vengeful Spirit can be used effectively against Slardar, the top-ranked hero in terms of eigenvector centrality. This demonstrates the impact of the neighbors of a certain hero when determining its ranking when using eigenvector centrality.

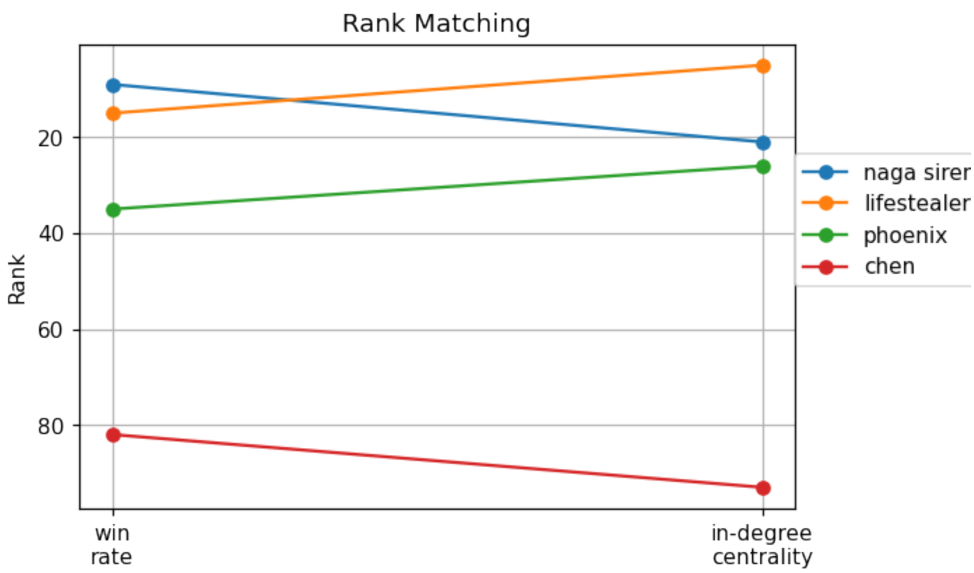

Figure 8: Difference in ranks of Dota 2 heroes in terms of average win rates and in-degree centrality. Here, we focus on heroes who jumped more than 8 ranks (up or down) when using different measures.

We also explore the heroes of Dota 2 that displayed a big jump in rank when using average win rates and eigenvector centrality. See Figure 10. This time, we highlight the big jump in ranking of the hero Broodmother. The eigenvector centrality of this hero is relatively high because Broodmother is a very good counter against Clockwork, which is 5th in rank in terms of eigenvector centrality (from Figure 9).

4 Conclusions

We have shown that win rates alone are not enough to justify if a hero is strong or weak because it fails to factor in directionality. By creating a win rate network of the heroes in Dota 2, we get a more holistic and efficient approach to quantifying balance. One could explore the in-degree centrality to get an overview of the effectivity of one hero compared with the other heroes. One could also look at the eigenvector centrality because it rates a hero according to how relevant are the other heroes that it can beat, and how frequent can those heroes be beaten. This allows developers to perform indirect balancing which are changes targeted at the connections of a hero rather than the hero itself.

The maximum eigenvector centrality of each succeeding patch was shown to follow a decreasing trend, implying that the developers are getting better at balancing the game over time. This opens the possibility for AI guided balancing simulations where the eigenvector centrality is the target and game parameters are the targets.

Additionally, balance changes may sometimes subvert the intended design of a hero. During the concept creation phase, some heroes are meant to be good all-around, while others are meant to be highly specialized. One way to address this is by looking at the in-degree centrality where we can rank heroes according to how many other heroes it is good against.

One way to improve this study is to look at the data for the players who play competitively or those with a very high skill level, because these players have explored the possibilities they could do with these heroes and hence be more reflective of the real advantage of one hero over another hero. Another possibility to explore is to look at the impact of the items being used by the heroes during the game. The items that a hero uses could significantly boost their skills and could potentially turn the tide. Further extensions of this study should take into consideration the roles and conceptual design of the heroes in question. For instance, Lifestealer were intended to be very good against strength heroes but weak against high mobility ranged heroes. Meanwhile, Clockwerk was intended to be strong against back line heroes but weak against summoning heroes. Adding a dimension for the characteristics of each hero would therefore make for a more meaningful analysis of the network.

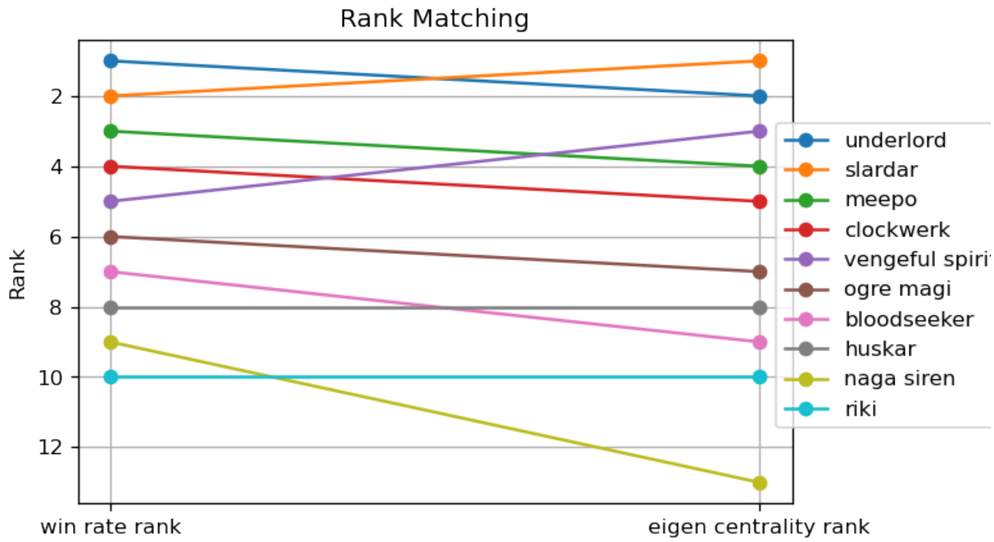

Figure 9: Difference in ranks of Dota 2 heroes in terms of average win rates and eigenvector centrality. Here, we focus on the top 10 heroes in terms of average win rates.

5 Acknowledgments

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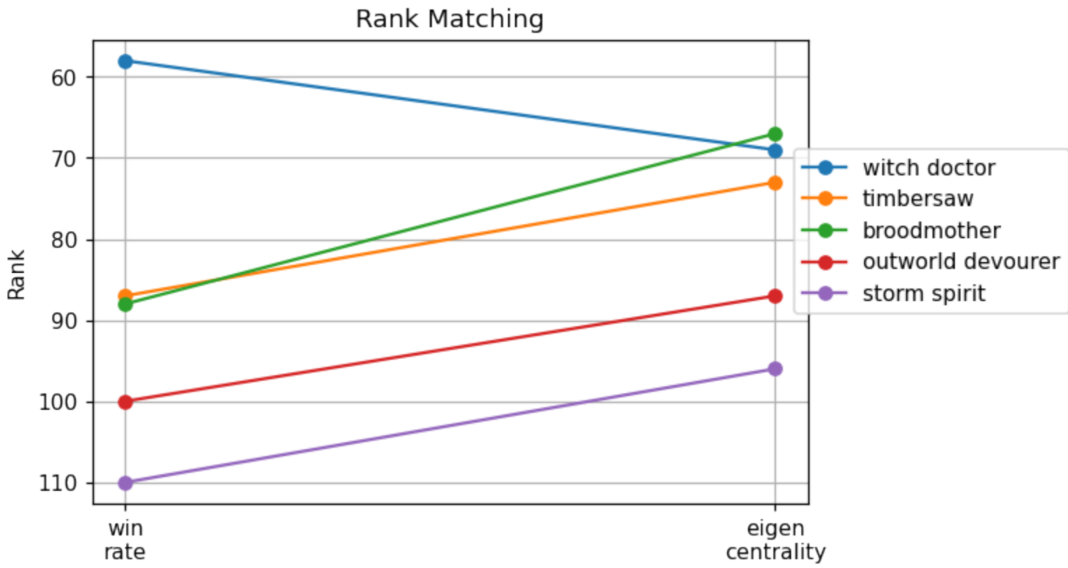

Figure 10: Difference in ranks of Dota 2 heroes in terms of average win rates and eigenvector centrality. Here, we focus on heroes who jumped more than 10 ranks (up or down) when using different measures.

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