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Space-Time Cube Visualization for In-Game Data

Master's Thesis

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Brno, Spring 2022

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FACULTAS ARTIS INFORMATICÆ • UNIVERSITAS MASARYKIANA •

Declaration

Hereby I declare that this paper is my original authorial work, which I have worked out on my own. All sources, references, and literature used or excerpted during elaboration of this work are properly cited and listed in complete reference to the due source.

Adam Šufliarsky

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Abstract

The thesis describes Multiplayer Online Battle Arena (MOBA) game genre and closer explains games *Dota 2*, *League of Legends* and *Heroes of the Storm*. Subsequently it describes visualization technique space-time cube and its adaptation to visualize in-game data. The practical output of the thesis is parsing tool used to extract and serialize important information from *Heroes of the Storm* replay files (.StormReplay) and interactive web application designed to visualize the serialized data using adapted space-time cube technique. Furthermore, user research was conducted to evaluate, whether and how effective can participants use the web application to analyze *Heroes of the Storm* matches.

Keywords

Visualization, Post-match analysis, Games, MOBA, Evaluation, Gameplay analysis

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Introduction

Computer gaming started in the 1960s and early 1970s. The very first known game was *SpaceWar*, developed at MIT using simple vector graphics. Shortly after, *Pong*, a tennis-style sports game was released not only for computers but also for arcade machines [1]. Throughout the years gaming evolved and gained a lot of success. Today, we can divide gaming into subgroups with respect to either platform (PC gaming, console gaming, mobile gaming etc.), level of competitiveness (competitive, casual etc.), number of players involved (single-player, multiplayer) and many more. Gaming is accessible as it never had been. The majority of the world population is carrying a personal computer in a pocket, a smart phone.

Gaming industry and competitive gaming became so popular, that nowadays events, similar to the football matches when it comes to the number of spectators, are happening regularly all around the world. There is a large number of titles that have their own professional leagues and even larger number of platforms, where people can watch the professional matches live [2]. E-sport gained such a popularity, that it might just be a matter of time, until it is a part of the Olympic games.

The increasing popularity of online multiplayer gaming has attached great importance to in-game and post-game statistics in order to allow players recap their performance and compare it with others. This growing interest is reflected by the emergence of the new field of game analytics [3]. Game analytics heavily relies on visualization techniques to assist developers and players alike to understand, analyze, and explore the data. Visualizations can be helpful to discover unexpected paths which have been taken by the players, to identify possible design and balancing problems, to find common patterns in the behavior of the players or to analyze player performance in order to improve gameplay [3]. Generally, the used visualization technique depends on the type of the data and to visualize more complex data it is often required to use multiple visualization techniques. Our aim is, to extract as much useful game data, as possible, and visualize the data using single adapted visualization technique, that have not yet been used to visualize in-game data.

In this thesis, we are going to focus on competitive gaming in Multiplayer Online Battle Arena games – MOBAs. The main part of the thesis is an online post-match analysis tool that allows users to visualize played matches. Such tool can be used either by individuals to self-improve, potentially by an e-sport organization to extract important information and analyze team performance or by the game developers to detect behaviour patterns of players to uncover any design issues. We are going address how effectively the developed tool and the adapted visualization technique can be used to analyze played matches by group of potential users – players of MOBA games. To do so we conducted a user study, where players were asked to perform several tasks using the visualization tool. We decided to divide the players into two groups with respect to their preferred MOBA game and focus on the most fundamental questions:

1. Can users understand and use a space-time cube system effectively to analyze a *Heroes of the Strom* match?

2. Are there performance differences in terms of accuracy of deducted information between *Heroes of the Storm* players and other MOBA players, such as *League of Legends* and *Dota 2* players?

3. Are there performance differences in terms of accuracy of deducted information between *Heroes of the Storm* players and other MOBA players, such as *League of Legends* and *Dota 2* players, for specific categories of questions?

4. Are there differences in terms of answer confidence and effort required to answer the questions between *Heroes of the Storm* players and other MOBA players, such as *League of Legends* and *Dota 2* players?

In the following part of thesis, the related research areas are described. Later we explain the core mechanics of the genre MOBA and present concrete game examples. The game, *Heroes of the Storm*, for which the tool was implemented is described in more detail. Next part describes the chosen visualization technique – a space-time cube visualization. Examples, how the technique was already used in a

non-gaming related problems are included together with a justification, why the chosen technique is the best candidate among similar others for our task. The part about the tool as whole follows, where the process of extracting raw data from game replay files is explained as well as the used libraries and design decisions for visualization sub-problems. Next parts describe the user study methods and results followed by the discussion chapter. In the last part possible improvements are presented together with the benefits of the thesis and opportunities for its further use.

1 Related Work

Information needs of players on post-game visualizations are more demanding as the game complexity increases [4]. Variety of visualization techniques have been used so far to visualize in-game and post-game data. Some of the simpler widely used visualizations in gameplay analytics are charts, heatmaps, movement visualizations, and node-link representations [3]. However, these visualization techniques are suitable to only visualize certain type of game data.

Charts are pictorial representations of information and exist in a variety of forms, each of them having different advantages and disadvantages [5]. Charts can be used to show the relationships between variables, to convey relative proportions, to show the distribution of values or to visualize trends over time [6, 7]. Visualization of more complex data, e.g. player movement is impossible using charts.

Heatmaps are two-dimensional maps which use colors to indicate the frequency of occurrence of a variable across the map [8]. Usually, shades of blue represent low rates of occurrence and shades of red represent high levels of occurrence. Heatmaps are easy to create and well-suited to recognize patterns of behavior [3]. However, the disadvantage is that heatmaps smooth over differences in individual behaviors [9]. Results of a user study also suggest that the continuous color representation makes it difficult to judge the actual amounts and to compare areas of similar frequency of occurrence [10].

To track player movements it is necessary to record at least their position at regular time intervals[11]. In addition, further variables like orientation or player health can be logged as well in order to provide more contextual information. Visualizations can be helpful to analyze and extract meaningful information from the accumulated data [12, 13]. Sampled player locations can be represented as point clouds or tracked positions can be connected with a straight line segment. With the increasing number of players, map and game complexity, the use of more complex visualization techniques is necessary.

Node-link approaches provide an intuitive way to visualize the relational structure of data items. Nodes represent the data objects themselves and links show the relationships between them, e.g. global player movement [14]. Representation can also be used to visualize

abstract or high-dimensional data [15]. As the amount of data and the number of edge crossings increase, node-link diagrams tend to become visually cluttered and therefore hard to interpret. To address this issue, adjacency matrix visualizations are available to be used [16, 17].

The main contribution of this work is to showcase the use of space-time cube visualization technique in game-related setting. The output is a tool in form of a web application which allows players and developers to visualize and analyze played matches in the MOBA game *Heroes of the Storm*. In previous paragraphs, use-cases of several visualization techniques were described. The techniques are suitable of a specific type of data and often simultaneous representation of time and space is not possible. Our approach tries to address these limitations and how we managed, is shown in the results of performed user study and discussed in the discussion chapter.

2 Multiplayer Online Battle Arena (MOBA) Genre

Multiplayer online battle arena (MOBA) is a competitive genre of video games in which two teams of players compete against each other on a predefined battlefield [18]. The most common game modes are 3 vs 3 and 5 vs 5. Each player controls a single character with a set of distinctive abilities. The typical objective is to destroy opponents' main structure, located at the opposite side of the battlefield. The strategy, how the main structure can be damaged depends on the game or on the battlefield itself. In some games or game modes, the objective can be defeating every player of the enemy team.

Players are assisted by computer-controlled units, called minions, that periodically spawn in groups (mobs) and march forward along set paths toward the enemy's base. Minions are divided into four major groups: objective minion, major minion, melee minions and ranged minions. Depending on the game or the battlefield, additional non-player characters might be present throughout the match that grant player or the whole team advantage.

This type of multiplayer online video game originated as a sub-genre of real-time strategy games, although in the most cases players are not allowed to build structures, harvest resources and spawn units. As was already mentioned, the control is also restricted to a single unit, also called hero or champion. The player is allowed to control multiple units only in special cases as, for example, if the chosen champion was designed in such a way, that the player controls character and its pet.

The genre rapidly gained popularity. We can assume the reason for such a skyrocket in terms of player base is, that the most of MOBA games are free to play with no gameplay impacting micro-transactions. By the early 2010's, the genre had become a big part of e-sport. Major e-sport professional tournaments are held in venues that can hold tens of thousands of spectators and are streamed online. A strong fan base has opened up the opportunity for sponsorship and advertising, eventually leading the genre to become a global cultural phenomenon [19].

2.1 History of MOBA Games

It all started as a fan-made custom map created for *StarCraft*, a real-time strategy game published by *Blizzard Entertainment* (today's *Activision Blizzard*). The custom map named *Aeon of Strife*. The first version's gameplay consisted of four players controlling single powerful units while fighting alongside weaker computer-controlled units against the computer [20]. The game ended if critical buildings inside either team's base were destroyed or if all four players died. Such a gameplay resembles today's vs AI game modes. A subsequent version of the custom map enabled Player versus Player (PVP) combat in the format of 2 vs 2.

Blizzard Entertainment was known for providing tools for its players to create their own customized maps in its real-time strategy titles. Their next published RTS title was *Warcraft* 3, that also included custom map editor. Ground-breaking was, that the game also included Role-Playing Game (RPG) elements. Combat was no longer solely the domain of armies. It revolved around heroes, powerful individual units that leveled up over time, had unique skills, and could be equipped with items. The editor also enabled the creation of custom items and unique heroes with original spells and abilities, meaning that the hero pool was not limited only by the heroes provided by the game.

It did not take long until the community took advantage of new editor tools and recreated the *Aeon of Strife* in *Warcraft 3* map editor. The new map was called *Defense of the Ancients*. *Warcraft 3* lore revolved around several races. One of the races were the Night Elves, whose primary magic came from nature. The ultimate goal in the custom map was to destroy enemies' main structure in the form of the Night Elf's Ancient Tree, while protecting your own. That is how the name was derived. It became moderately popular in the custom game scene [21], though its players found it easier to abbreviate it to an acronym: *Dota*.

With the release of *Warcraft 3*'s expansion *The Frozen Throne*, *Dota* map code went open-source, allowing other mapmakers to try their hand at improving already popular custom game mode. The new expansion also brought several significantly more powerful map editor tools. Community used the opportunity to upgrade the original

Defense of Ancients with dozens of versions adding new playable hero characters. These various disparate versions of *Dota* were eventually combined in one "All-Stars" map. *Dota Allstars* was a wild hit, developing a thriving community with entire websites devoted to it. We even saw official tournament events at *BlizzCon*, one of the most famous gaming festivals [20]. For all of its popularity, *Dota Allstars* was still just a custom map in a different game.

In late 2000's and early 2010's a few stand alone titles emerged: *Demigod*, *Heroes of Newerth* and *League of Legends* [20]. All of the mentioned titles followed *Dota* formula. Unlike *Newerth* and *Demigod*, *League of Legends* was free. Players could initially only choose from a stable of 10 characters within a weekly rotation. The characters, or so called champions, could be permanently purchased using either points earned in-game or real-money in form of micro-transactions. Catching the upswing of the growing free-to-play market, *League of Legends* became a massive success [22]. Studio *Riot*, creator of *League of Legends* coined a new name for the game genre: Multiplayer Online Battle Arena, or MOBA.

Dota was unquestionably one of the most successful mods of all time, it was just a matter of time for big studios to come with their own adaptations. At *BlizzCon 2010*, *Blizzard* revealed its own *Blizzard Dota*, a *StarCraft 2* mod, starring characters from the *Warcraft*, *StarCraft* and *Diablo* universes [20], a predecessor of today's *Heroes of the Storm*. *Valve* publicly unveiled *Dota 2* at *Gamescom 2011* with a tournament it called *"The International"*, featuring a then-record prize-pool money of 1.6 millions of dollars. *Dota 2* was presented as a direct sequel to the original *Warcraft 3* map. The game was officially launched in summer of 2013 as a free-to-play title [20].

In order to better understand the general MOBA games' mechanics, the following sections further describe MOBA games *Dota 2*, *League of Legends* and *Heroes of the Storm*. Each games' battlefield, basic gameplay, playable characters and unique mechanics are described in similar manner, so it easy is to compare the games' characteristics.

2.2 Dota 2

Dota 2 is a MOBA game developed by *Valve*. With its vast lore, multiple heroes and game mechanics, a new *Dota 2* player can get overwhelmed. By the MOBA game definition, *Dota 2* is a team vs team battle game where players have to defend their control zones and capture the enemy's control zones. In a *Dota 2* game, players are playing for either the radiant (green) side or the dire (red) side.

2.2.1 Map

The battlefield is segregated into lanes and jungle (Figure 2.1). Each team has a main structure called the ancient (in reference to the *Defense of the Ancients* mod) from which there are three outgoing lanes. The lanes are the following: the top lane – also called TOP, middle lane – also called MID and the bottom lane – also called BOT. The map is of square shape while top and bottom lane cover the perimeter and middle lane is a diagonal from the bottom left corner to the top right corner.

Each team has 9 towers, structures that automatically attack opponent's unit, 3 per each lane. These structures are ranked by tiers, the furthest ones being tier 1 and the closest ones to the ancient being tier 3 [23]. There are also two extra towers designated only to defend the ancient, sometimes also ranked as tier 4.

In between the lanes there is an area called jungle, where players can find neutral creep campsites. A creep is a monster that upon defeat grants the players gold and experience.

2.2.2 Basic gameplay

In *Dota 2* players collect gold and experience. Experience levels up player's heroes and gold allows players to buy items in shops, further increasing their power. These currencies are gained from multiple activities: defeating opponent's team heroes, units or destroying structures, defeating jungle creep sites etc. The ultimate team goal remains the same – destroying the enemy's ancient while defending theirs.

We already know, that the three major lanes are called TOP, MID and BOT. *Dota 2* has special naming convention for TOP and BOT lane:

safe lane and off lane. The rule is as follows: a safe lane is the lane that is horizontally aligned to the base and an off lane is vertically aligned with the base. The safe lane is a lane where a tier 1 tower is closer to a creep campsite while the offlane is a lane where the creep campsite is far from the tier 1 tower. The radiant's safe lane meets up with the dire's off lane and vice-versa [23].

Figure 2.1: Dota 2 map [24]

2.2.3 Heroes and Roles

Each player controls a unique hero out of a pool of more than one-hundred heroes. *Dota 2* only allows there to be one of a specific hero in a match. Each hero has unique stats, abilities, and talent trees. Heroes start at level 1 and max out at level 25. Heroes are divided into categories based on their primary attribute: strength, agility, intelligence and role: safe lane, MID lane, off lane, soft support, hard support. The combination of a hero's stats, attributes, spells, and talent tree gives a hero unique strengths, weaknesses, and optimal item choices. A good team composition has heroes that cover each other's weaknesses and complement each other's strengths [25].

2.2.4 Interesting and Unique Mechanics

Apart from following the already known *Dota* formula, each MOBA game has its own interesting and unique mechanics. *Dota 2* is not an exception. In terms of player mobility, *Dota 2* offers players a special item called Town Portal Scroll which enables players to teleport to the base or a nearby allied building. This item, however, is consumed on use and has to be bought again from the item shop. Additionally heroes now gain 1 Town Portal Scroll for free upon dying [26].

Map control is a key element to the victory in the most of MOBA games. Players can buy wards, items that are also consumed on use. Observer Ward is a watcher that gives ground vision in a defined radius for 6 minutes for corresponding team [27]. Sentry Ward is very similar to Observer Ward, additionally it grants true sight, an ability to see invisible enemy units and wards, in impacted area for 7 minutes [28]. Wards can be attacked by the owner, under special conditions by the allied players and by the enemy units or heroes. *Dota 2* added a special functionality to this item. When placed on a neutral creep camp, it stops the camp from respawning. In a similar fashion, the item blocks destroyed trees from re-growing [27, 28]. It is possible to use such a functionality to grant the team an advantage.

Another unique mechanic is so called denying. The mechanics revolves around last-hitting own units. Doing so, the enemy only receives 40% of the experience and loses their chance of getting the gold by scoring a kill [25]. In comparison to the other two games that

will be described in more detail, denying mechanic is present only in *Dota 2*, making it indeed a very unique concept.

Worth mentioning also is the shop item delivery service. Each player get a courier at the beginning of the match, that delivers items from a shop to the player. It can be killed as any other unit and after doing so, the courier respawns after set amount of time [29]. Having access to such a feature encourages players to stay in action longer, without the need to retreat to buy new items.

2.3 League of Legends

League of Legends launched more than a decade ago, but *Riot's* MOBA is still receiving constant tweaks, adjustments and a new content in form of champions and skins. Following the MOBA game definition, *League of Legends* also is a PVP team battle game where the objective is destroying opponent's main structure, nexus. In a *League of Legends* match, players are playing for either the blue side or the red side.

2.3.1 Map

The map is called *Summoner's Rift* and is similarly divided into lanes and jungle (see Figure 2.2). Left bottom and right top corners of the map are the designated places for team bases, where also the main structure, called nexus, is located. The battlefield again has a square shape while top and bottom lane covering the perimeter and middle lane being a diagonal.

Each team also has 9 towers, 3 per each lane, that are in the same fashion ranked by tiers and additional building called inhibitor. At least one inhibitor has to be destroyed in order to be able to damage the nexus. Two extra towers defending the nexus are as well present.

The jungle can not be missing. In addition to experience and gold, some defeated neutral monsters also give a buff for a certain duration or after repeated kills a permanent buff [30].

2.3.2 Basic gameplay

Players mainly focus on getting ahead of their lane enemies similarly by collecting gold and experience killing monsters, enemy units,

structures and champions while trying to destroy opponent's nexus. Periodically, a minor objective appear on the map in form of big neutral monster: Dragon (light yellow circle) or Rift Herald, later Baron Nashor (purple circle). If a team manage to score a kill on one of mentioned monsters, that given team gains an advantage in form of a buff apart from huge amount of experience and gold.

For another minor objective players can consider destroying an inhibitor. Team that destroyed the inhibitor is rewarded with temporal lane effect - major minions are transformed into more powerful superminions. This effect is temporal because after certain amount of time the inhibitor respawns [31].

Winning strategy consists of balance between map and structure objectives, individual and team performance.

2.3.3 Champions and Roles

In *League of Legends* also offers a pool of more than 140 champions to play [32]. As well as in *Dota 2*, players are only allowed to play one of a specific champion in a match. Similarly, each champion has unique abilities and stats, however the talent system is extracted and talents or so called runes, are not selected per champion but globally. In contrast to *Dota 2*, champions max out at level 18, having all basic abilities at level 5 and an ultimate ability at level 3. Ultimate ability is unlocked at level 6 and upgraded every 6 levels giving players large power increase.

League of Legends offers more freedom in terms of roles tied to the champions. A champion can be played in a multiple roles, depending on item choices. The roles are closely connected to the lanes as follows: Top, Jungle, Mid/APC (Ability Power Carry), Bot/ADC (Attack Damage Carry) and Support. Looking at players movement, Jungle and Support roles are the most mobile ones that have also impact on multiple lanes. It is not for nothing that these roles are considered to be harder than the remaining ones in terms of macro management - keeping track of what is happening in each lane.

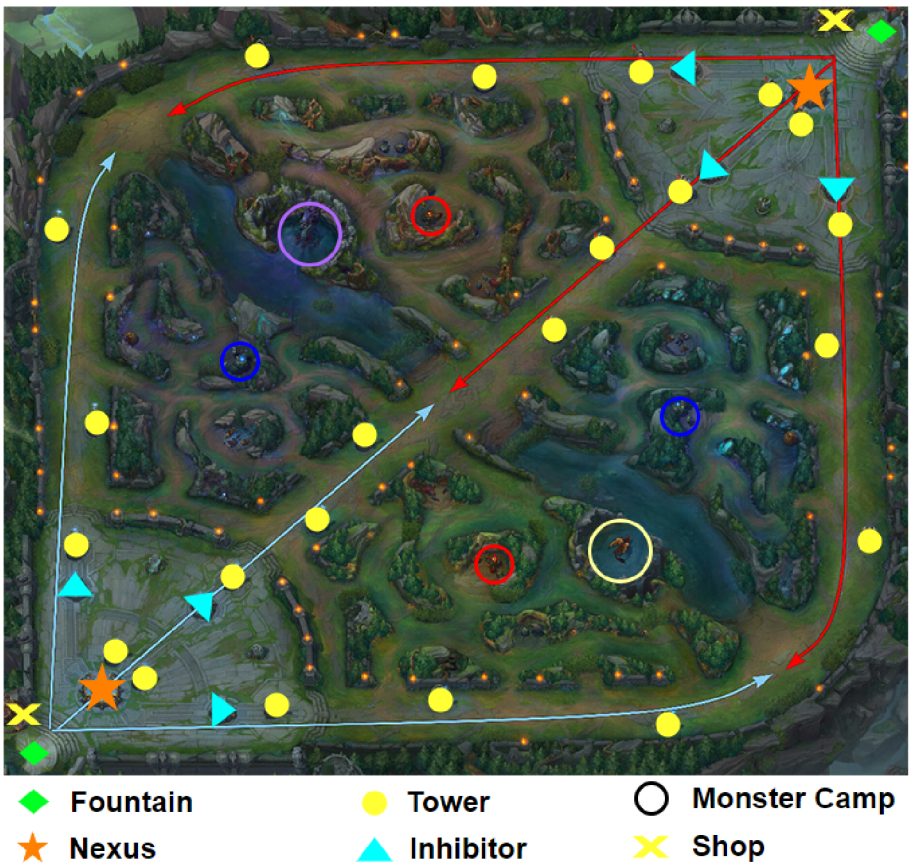


Figure 2.2: League of Legends map

2.3.4 Interesting and Unique Mechanics

League of Legends is not an exception in terms unique and interesting mechanics. One of those are already mentioned inhibitors. The unique approach in this case is, that the inhibitors respawn after certain time, so the bonus, periodical spawn of super-minions in given lane, is also time-limited. In order to regain the bonus, the inhibitor has to be destroyed again. That is not all, also the ability to damage the nexus revolves around inhibitors. In order to be able to damage the nexus, at least one of the inhibitors has to be destroyed [31], making it a priority for the team that suffered an inhibitor loss, to defend and not letting it happen repeatedly.

In current version of the game, there are several dragon types spawning throughout the game. Each dragon has not only a limited buff for the team that scored a kill, but also changes the map. For example once the fire dragon is slain, some of the bushes, areas that can hide heroes from outside, are burned, thus removed. Teams also have an option to obtain a permanent buff. The first team to score four dragon kills gains permanent enhanced version of the dragon buff [30].

Speaking of monsters buffs, another interesting one is buff granted after killing the Baron Nashor. Not only it buffs champions but if the player with the buff is in a proximity of lane minions, those minions are also buffed, gaining stats and attack range [30]. Scoring a Baron Nashor kill can be considered as a win condition later in the game.

Looking at champion abilities and comparing the past versions to the present ones, it can be seen, that League of Legends moved from simple click-to-execute abilities to more sophisticated and skill-shot oriented one. Skill-shot ability is such an ability that has to be aimed and often has limited range. It can be imagined as a beam emitting from a champion to the mouse cursor while the width and length depends on the ability itself. As a more sophisticated abilities we can consider the ones that require more player interaction, for example, longer press in order to charge up the ability or repeated press in a given time-window in order to execute so called, recast ability. In today's MOBA games, unique and innovative abilities are considered as a tool to differ from others.

2.4 Heroes of the Storm

The youngest MOBA game amongst the other two is *Heroes of the Storm*, developed by *Blizzard Entertainment* (today's *Activision Blizzard*) and released in June 2015. *Heroes of the Storm* is also the game, which the match visualization tool was implemented for, that will be described in more detail in the following chapter.

As was already mentioned, direct predecessor of *Heroes of the Storm* was a *StarCraft* 2 mod, that starred characters from multiple *Blizzard's* universes. The game follows the trend and in current version (v2.55.2) hero pool features heroes from *Warcraft*, *Diablo*, *StarCraft*, *Overwatch*

and own *Heroes of the Storm* universe. It is no surprise, that also *Heroes of the Storm* is a team PVP game with the objective to destroy the enemy's main structure, the core, while players playing from either blue or red team.

2.4.1 Basic gameplay

Heroes of the Storm took a different approach, making the basic gameplay even more team oriented. Players are not leveling individually, but the experience is shared, meaning the player's actions contribute to the team level, rather than to the individual level.

Instead of purchasing items, players choose from set of talents, that are being unlocked as the team levels up, so the currencies that players have to collect are reduced to the experience only. The talent unlocking level milestones are as follows: level 1, level 4, level 7, level 10, level 13, level 16 and level 20. The effect of talents can vary. It can either enhance one or multiple abilities, unlock an extra ability or grant one of abilities, that are shared among multiple heroes. Worth mentioning is the level 10 talent choice, because that is the milestone when players choose from two hero abilities. The team that reaches this milestone sooner has a huge advantage until the opposing team catches up.

The major objective stays the same but *Heroes of the Storm* offers wide range of maps in which the strategy to destroy opponent's core differs [33]. Apart from the strategy, also the layout and minor map objectives is unique per map, meaning players have to adapt accordingly. Maps are further explained later in the section.

2.4.2 Heroes and Roles

Combining multiple game universes resulted in pool of 90 heroes to choose from. Heroes of the storm is not an exception, players are also able to play only one of a specific hero in a match. Heroes have unique abilities and talents further enhancing hero power, that are unlocked during the game. No global systems are introduced, meaning hero power depends purely on talent choices. Heroes max out at level 30 while having unlocked all talent choices by level 20.

Heroes are divided into several categories: tank, bruiser, support, healer, ranged assassin and melee assassin. When it comes to roles,

those are not strictly set. Each map favours different heroes and team compositions. In general, the team composition of two front line heroes (tank or bruiser) one healer and two assassins has the highest win-ratio [34].

2.4.3 Maps

In comparison to other MOBA games, that mainly focus on one battlefield, *Heroes of the Storm* has 15 unique maps [33], each one having a different and unique map objective to assist players as they pursue the ultimate goal, destroying the opponent's core. Although, in non-ranked modes, all of the maps are available, in the ranked mode only a subset is chosen depending on map balance.

Apart from classic three-lane or two-lane maps, also special one-lane map is introduced at the end of section, that was created for All Mid All Random (ARAM) mode. Visualization of all of the mentioned maps is supported in the implemented tool.

Regarding the structures, it is no surprise, that also *Heroes of the Storm* has towers which attack enemies that get in range. Additionally, each structure tier has building called fort, impassable walls, gate and fountain. The are only 2 structure tiers and all of the mentioned structures can be destroyed.

Fort is a structure, that not only attacks the enemies within the range but also has true-sight, an ability to see invisible unit and moreover, the attacks gradually decrease hero armour. Sometimes, the tier 2 (the one, closest to the core) fort is also called keep. When team destroys a fort, they gain a catapult, a strong sieging minion, to spawn in every 3rd minion wave. When team destroys a keep, they gain catapult to spawn in every minion wave, making it one of major objectives, considering that forts and keeps do not respawn [35, 36].

Walls and gates are welcomed space-defining addition. The defense line before each fort and keep is a wall that has a gate in the middle, surrounded by 2 towers, so attacking either fort or keep directly, is not possible.

The last structural map addition are fountains. Fountains are quality of life improvement as the players do not always need to teleport back to the base to recover but the recovery rate is reasonably slower.

Using fountain also has a recharge time and in the most game modes, fountains can be destroyed.

When it comes to neutral monsters, the area between the lanes is not called a jungle and the capturable monster camps have considerably longer respawn time, meaning the common MOBA role, jungler, does not exist in *Heroes of the Storm*. There are three main camp types: boss camp, siege camp and bruiser camp. In the later added maps a new camp types were also added. Those are covered in map sections.

Boss camp is a single powerful monster that has special abilities and often requires multiple players to defeat it. Once slain and captured, the monster marches to the closest lane to assist the capturing team. Each map, in which there is a boss camp, has a different monster representing the camp. Monster's visuals and abilities are map-themed, this also applies to other camps in maps that were added into the game later or are inspired by other game universe.

Siege camp consist of two ranged monsters whose projectiles affect wide area and deal increased damage to the structures. This is considered to be the easiest camp to slain and capture, because players can dodge the projectiles thus avoiding the damage. In order to capture the camp no more than one player is required. Once slain and captured, the monsters again assist the capturing team in the closes lane.

Bruiser camp, or sometimes also called mercenary camp is a group of four monsters - one ranged mage and three melee warriors. The ideal strategy is to focus the mage first, as he provides the damage reduction aura for all nearby units. Some heroes might struggle to clear and capture the camp solo, so the heroes that have are more suited for the job should aim to do it. Similarly to other camps, after being defeated and captured, the monsters support the capturing team in the closes lane.

Alterac Pass

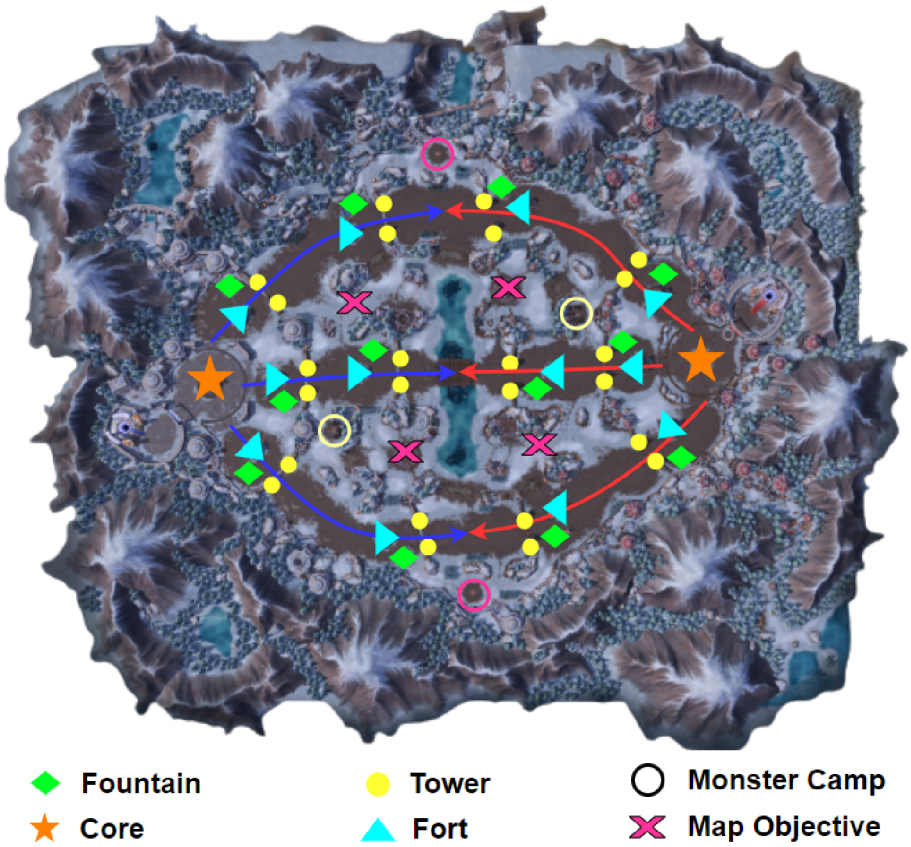


Figure 2.3: Map Aterac Pass

The map *Alterac Pass* (see Figure 2.3) is the most recent map inspired by the battleground in another *Blizzard's game*, the *World of Warcraft*. The map follows 3 lane pattern. Map objective is to capture the enemy prison camp to summon cavalry [37]. Camps can be retaken by heroes and minions, meaning it has to be defended for a certain amount of time. Objective takes place either on top or bottom side and the camp that has to be captured is always closer to the enemy base. Once captured, a major unit spawns in each lane with an aura that increases speed and damage for all allied units and heroes within the range.

Another points of interest are 2 siege camps highlighted by yellow and 2 boss camps highlighted by purple color. Siege camps are different than the generic ones present in original *Heroes of the Storm* maps. It consists of 3 Hoggers, a famous *World of Warcraft* NPC (Non-Player Character), whose attacks also reduces armor. Apart from that, mud pits are spread around the map. Any hero that enters a mud pit finds their movement speed reduced by 16% per second, to a maximum of 60%, for as long as they remain there [38], making it great place for an ambush.

Additionally, each team's core has been replaced by a faction general who fights against attacking enemies. Destroying a keep reduces the general's armor, making it a key to the victory.

The most common map approaches are the following: group of four players rotating between the middle and top lanes while one player stays in the bottom lane or one player rotating between the top and middle lanes and group of four players occupying the bottom lane [39].

Battlefield of Eternity

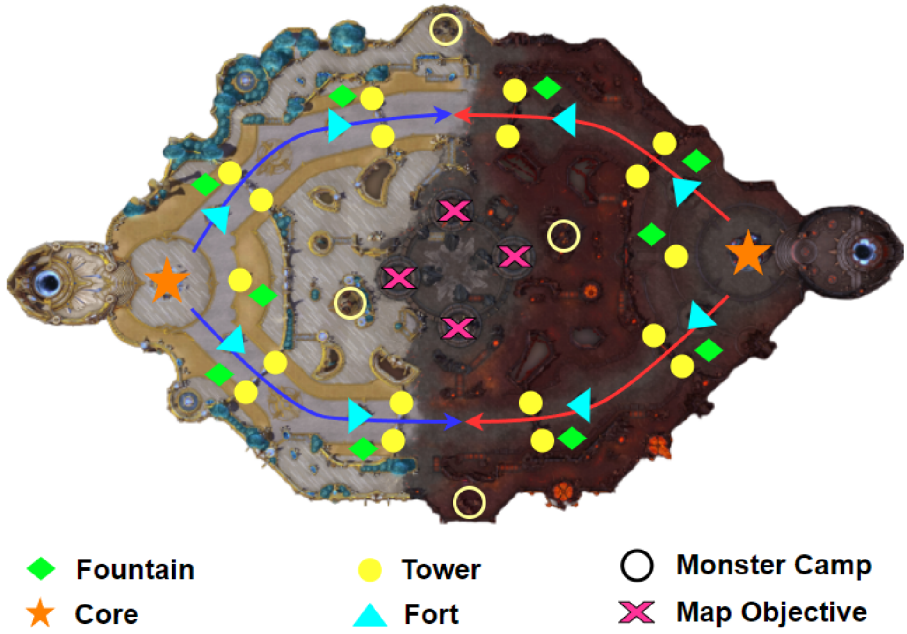


Figure 2.4: Map Battlefield of Eternity

Battlefield of Eternity is a two-lane, *Diablo* themed, battleground (see Figure 2.4) with no boss camps, 2 bruiser camps, in the middle section of the map and 2 siege Camps in to top and bottom section of the map, highlighted by yellow color. Both, bruiser and siege camps have different mechanics that the generic ones in original *Heroes of the Storm* maps. Bruiser camp is represented by a beast caller accompanied by two beasts. When slain and captured, the caller continuously summons beasts so in order to effectively clear the camp in the lane it is important to focus the caller down first. Siege camp consists of three monsters, rather than two and their attacks are ranged and only affect one target, meaning while clearing the camp, the damage can no longer be avoided.

Periodically, the two immortals start to fight in the middle of the battleground (one for each team). The map objective is to defeat the enemy immortal while defending your own [40]. The health of each

immortal is displayed when the event is active and once one of the bars is depleted, the winning immortal spawns to support the winning team in one of the lanes. When one of the immortals reaches 50% health, immortals become invulnerable for a short time window and the positions of immortals reshuffle to again occupy two of fours possible immortal positions. The remaining health from the event is transferred into the immortal's shield. While shield is active, the immortal attacks from the range are the attack are more powerful, making the defence of the immortal also an important part of the event.

The map in general is smaller in comparison to three-lane maps. The most common approach is to have one player at the top lane and the rest of the team at the bottom line [39]. Solo players always rotate to the lane, which is not occupied by the immortal. Capturing the camps just before the event can result in a passive line pressure and the longer the map objective event takes, the more impact well-timed camp captures have. If a player is forced to clear a camp on any of the lanes, the player's team is outnumbered during the event, which might result in severe immortal health loss.

Blackheart's Bay

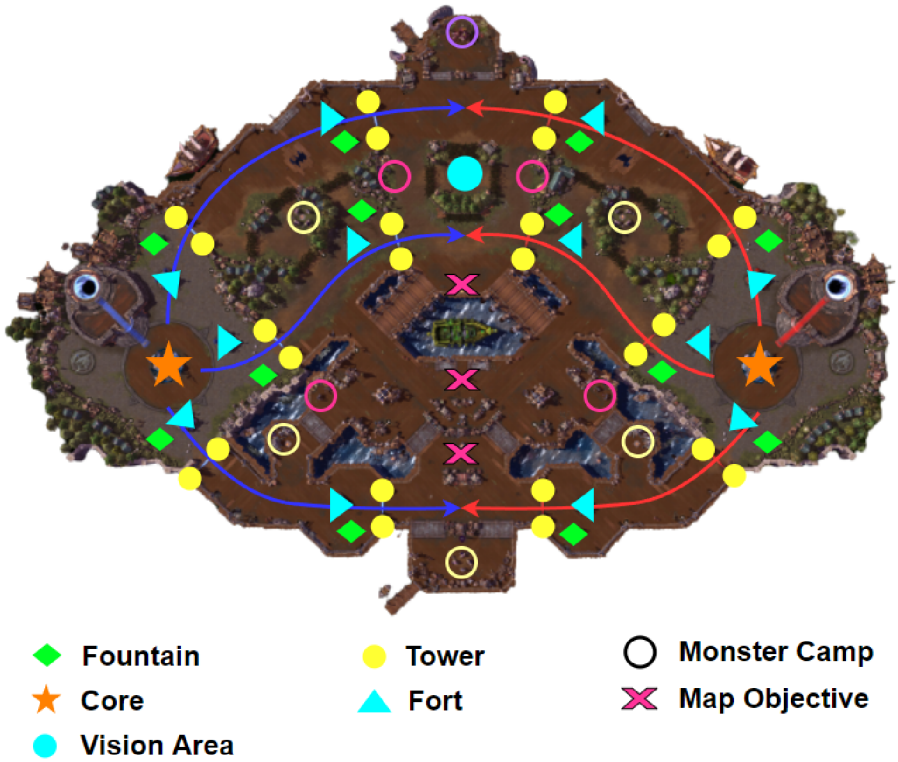


Figure 2.5: Map Blackheart's Bay

Blackheart's Bay is a three-lane battleground (see Figure 2.5) with 1 boss camp, in the top section of the map, 3 bruiser camps, 2 being between the top and the middle lane and one 1 at the bottom of the map and 2 siege camps located between the middle and bottom lane. The map is one of the original *Heroes of the Storm* maps.

The main objective is to collect doubloons, a special map currency, and bringing them to the ghostly pirate captain Blackheart, located in the middle [41], between the middle and bottom lanes. We can see multiple markers highlighted by the pink color, which is used for denoting the map objective, meaning there is multiple sources of the special map currency. Map objective markers that are close to either the middle or the bottom lane represent treasure chests that periodically

spawn throughout the match. Each chest contains 5 doubloons. Pink monster camp markers represent camps that drop 2 doubloons after being defeated. These camps can not be captured and do not provide other bonuses, just the map currency. The regular camps, highlighted by yellow and purple, in addition to the lane support effect, also drop 2 doubloons each. If a player, that carries the doubloons, dies, the doubloons are dropped and can be picked up either by the enemy team players or the player's teammates. After receiving enough doubloons from any of the team, Blackheart bombards the opposing team structures. The number of required doubloons is unique per team and increases after each payment.

Players should prioritize picking heroes, that excel at clearing camps and those that quick move around the map (teleports etc.), because the map is large. The team distribution again has two options. Either sending one player to the bottom lane and four players rotate the top and middle lane or the other way around. In scoreboard players can see how many doubloons each player has, looking for an opportunities to kill the player who is carrying a lot of doubloons and succeeding can easily turn the game around [39].

Braxis Holdout

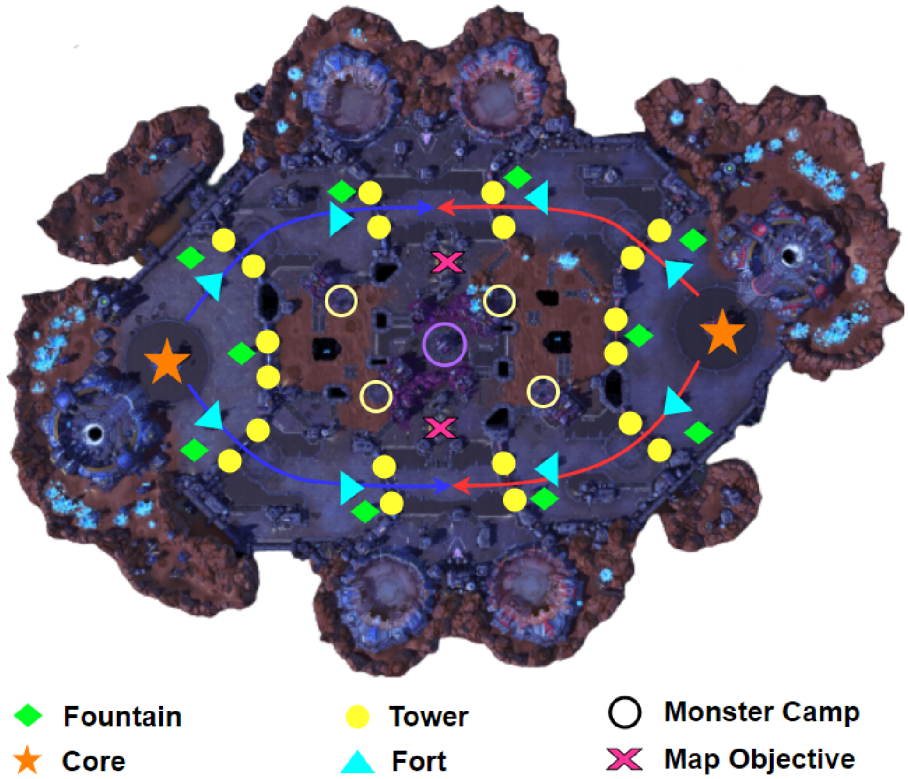


Figure 2.6: Map Braxis Holdout

Braxis Holdout is a *StarCraft* inspired two-lane battleground (see Figure 2.6) with 1 boss camp in the middle, 2 bruiser camps (top-left and bottom-right camp) and 2 siege camps (bottom-left and top-right camp). All of the mentioned camp are also *Starcraft* themed, meaning the bonuses are very similar but the visuals are different from the generic camps that are present in original *Heroes of the Storm* maps. Worth mentioning is the siege camp change. In the *Braxis Holdout*, siege camp consists of two melee robots that have a AoE (Area of Effect, areal attack) flamethrower ability, which also reduces armor of all hit heroes.

During the match, periodically two beacons are activating. Capturing both fills a meter, Zerg holding cell. Once one of the teams

manages to fill the meter to full, both holding cells are released to the opposing lanes [42], never at the same lane and those lanes swap after each completed objective. The progress of the other team, which did not manage to fill the meter, is also accounted into the resulting number of spawned minions, Zergs, aiding the team, that lost the objective. Zerg faction is a reference to the *StarCraft* faction. Zergs not only attack buildings but some of them prioritize attacking heroes.

Team again splits into one player going top and four players going bottom. Due to the nature of the objective, it is important to have a sustain healer, in order to have the beacon captured as long as possible. Player that stays solo should also play a hero that has some kind of self-healing ability and that is not vulnerable to flanks [39]. Timing the monster camps before the Zerg wave can either help with the defence or help with the push. Each team should pick at least one hero that specializes in dealing a lot of siege damage, in order to kill the Zerg waves quickly.

Cursed Hollow

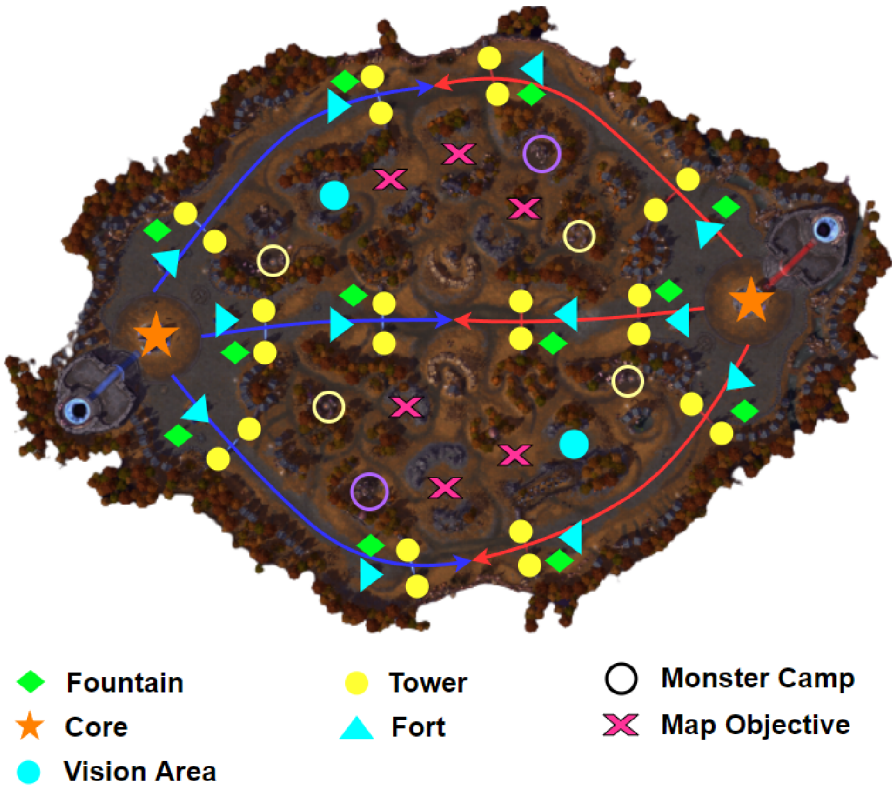


Figure 2.7: Map Cursed Hollow

Cursed Hollow is also one of the original *Heroes of the Storm* maps. It is a thee-lane battleground (see Figure 2.7) with 2 boss camps, 2 bruiser camps (the camps closer the the boss camps), and 2 siege camps (the camps further from the boss camps). It also is one of the largest maps.

Periodically, one of the map objective spots is chosen where the Raven Lord creates a tribute. The goal is to capture three tributes in order to curse enemy team structures and minions for a certain duration. Cursed structures can not attack and cursed minions have health reduced to 1 [43]. This does not apply on the captured monster camps, meaning camps can be used as a last resort of defence or to make the curse window even deadlier.

Teams often send one player top, one player bottom and three players middle or one player top and two players in the middle and bottom. Considering the fact, that the map is huge and requires a lot of movement, heroes that have an ability to move quickly around the map are the priority picks [39]. If a team manage to capture boss just before or shortly after capturing the third tribute, there is a high chance the keep (tier 2 fort) falls or it is a final push of the game.

Dragon Shire

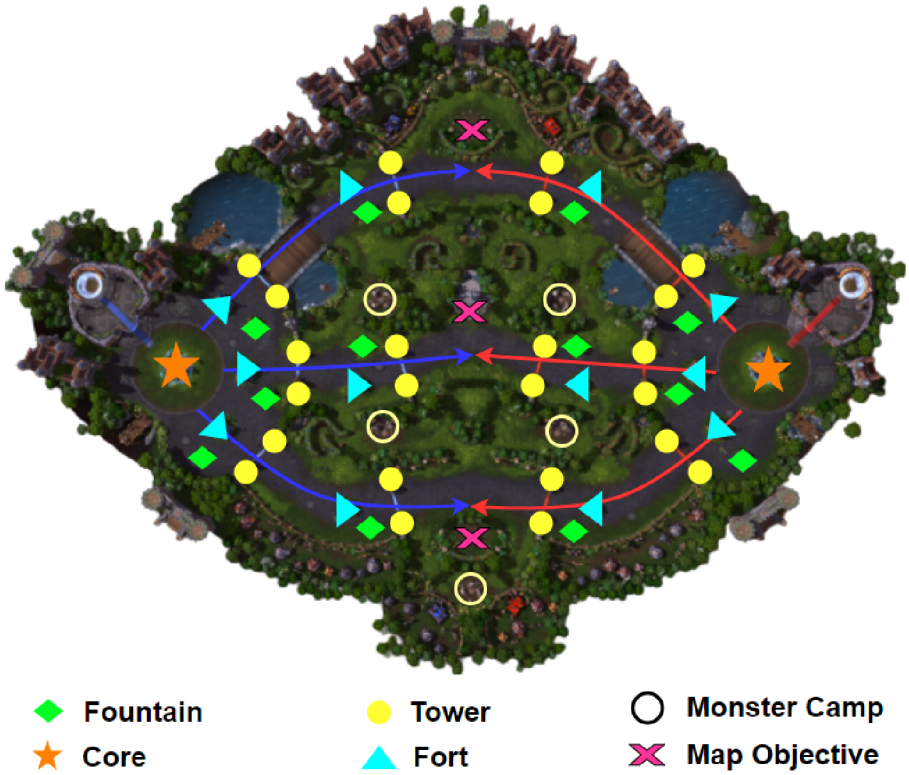


Figure 2.8: Map Dragon Shire

Dragon Shire is yet another original *Heroes of the Storm* map. It is a three-lane battleground (see Figure 2.8) with no boss camps, 3 bruiser camps (the camps between the top and middle lane and the one at

the bottom of the map) and 2 siege camps (the camps between the middle and bottom lane).

The major objective is to control dragon knight statue located in the middle lane. In order to do so, a team needs to control both shrines, that are located in the top and bottom sections of the map, simultaneously [44]. Taking control has to be done by a player and the act has a cast time that can be interrupted by taking damage. Once taken control, the player becomes a dragon knight and is granted a new set of abilities: flame breath - AoE ability effective against the minions and charge - ability that knocks targets away in the direction of charge. Apart from new abilities, also basic attacks are more powerful, making the dragon knight effective weapon against targets of all types.

The general strategy is to send one player top and bottom, while a group of three players roams the map, supporting the lanes in need. The conditions for successfully taking control of the dragon knight statue are tough. The combination of strong solo heroes and heroes that can easily move around the map and heroes that can interrupt the channel from afar can bring advantage in one of the sub-objectives [39].

Garden of Terror

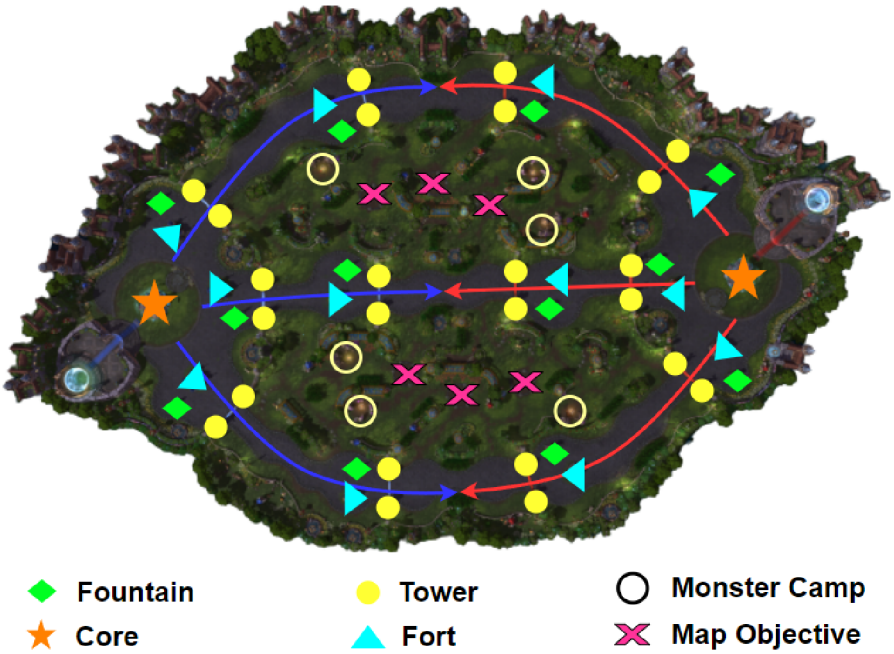


Figure 2.9: Map Garden of Terror

Garden of Terror is a three-lane battleground (see Figure 2.9) with no boss camps, 2 bruiser camps (the closest camps to the top and bottom forts), and 4 siege camps. It also is one of the original *Heroes of the Storm* maps, although the map went through multiple changes. The initial version had very similar phase as the *Dragon Shire* map. Periodically a seed spawned somewhere in the map which could be consumed by a player in order to become a Garden Terror, a creature controlled by the player with a new set of abilities. Current version combines the mechanics from maps *Alterac Pass* and *Cursed Hollow*.

Seed are still periodically spawning during the game, together with the seed defenders. Upon gathering three seeds, computer-controlled Garden Terrors immediately burrows to each lane to assist the given team. Garden Terrors have an ability to disable enemy structure attacks [45], making it a great tool to destroy enemy team defences.

The map is large. General strategy is to send one player to the top lane and one player to the bottom lane, while team of three players roams the map and captures the camps. Once the seed is spawned, it is suggested that all players join the fight for the objective, meaning the heroes that can quickly move around the map are priority picks. Heroes that excel at clearing camps and minion waves can refine the impact of Garden Terrors [39].

Hanamura Temple

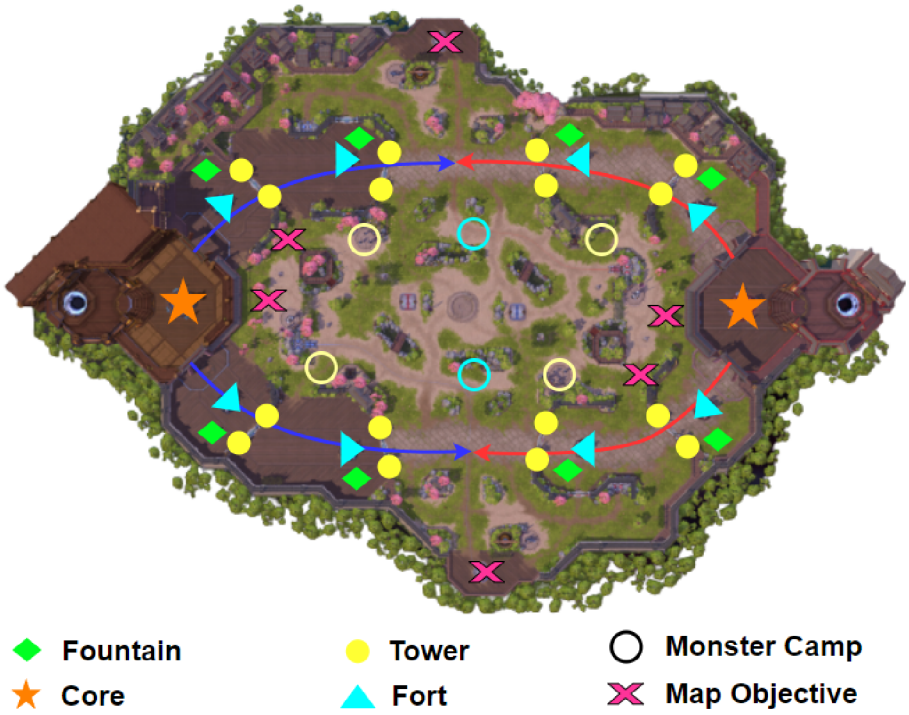


Figure 2.10: Map Hanamura Temple

Hanamura Temple is *Overwatch* themed two-lane battleground (see Figure 2.10). *Overwatch* inspired maps are known for their different camps and mechanics. It is a map with no boss camps, 2 sentinel camps, 2 fortification camps, and 2 recon camps.

Sentinels are boss-like robots, that have a AoE cleave ability. In terms of difficulty to kill and capture the camp, it lays in-between boss and bruiser camp, meaning only some heroes are able to solo capture those. Sentinel camps are the bottom-left and top-right monster camps.

Fortification camp is a new type of camp, that after being captured drops an usable items rather than spawn minions to support the closest lane. In this case, the dropped item is a turret that attacks enemies in range after the deployment. Players can pick up these items and use them with an extra action button. Worth mentioning is also the fact, that the items can also be dropped from players, if not used before being slain. Fortification camps are the top-left and bottom-right monster camps.

Recon camps is another new type of camp. Recons are humanoid robots that are fairly easy to kill and grant vision around the camp area, rather than spawning minions to support the closet lane. The effect is similar to the vision areas in other maps. The major difference is, that in order to grant vision, a robots need to be defeated instead of just capturing a control point.

Map objective is also inspired by payload game mode from game *Overwatch*. At regular intervals, one destination point is chosen (denoted as a pink cross) and a payload is spawned at the center of the battleground that can be contested by both team. Standing next to the payload moves it to its destination. If players from both teams are in the range of the payload, the payload stops. On arrival to its destination, payload fires upon the enemy's structures [46].

The general strategy is to have one player in the top lane and a group of four players in the bottom lane. Monster camps have relatively short respawn time and map objective is not very powerful, thus does not have a huge impact on the game. As a consequence, the heroes that are good at capturing camps bring a huge benefit to the team [39].

Infernal Shrines

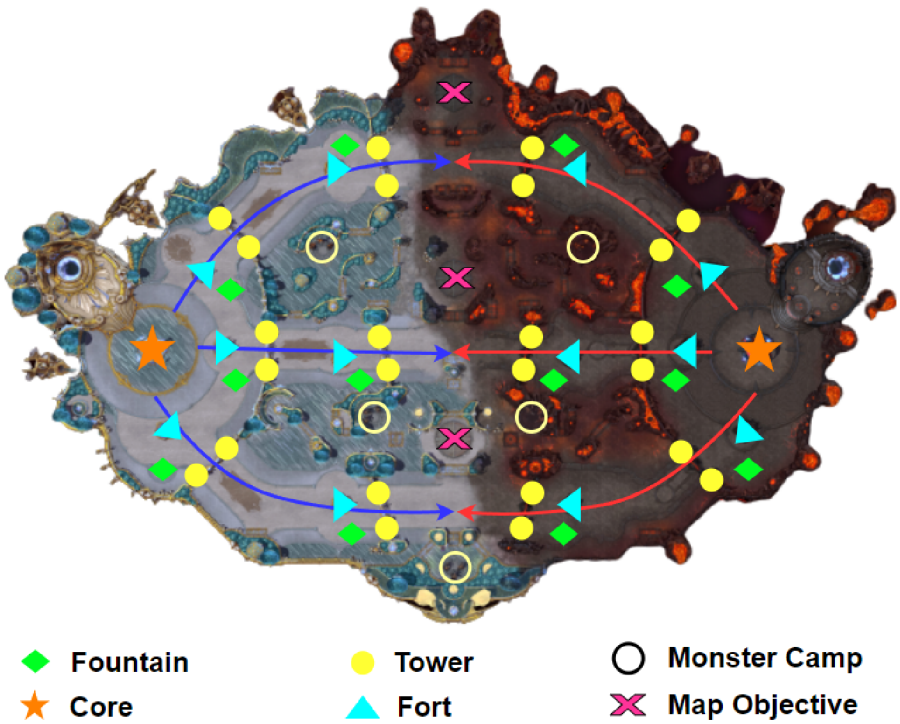


Figure 2.11: Map Infernal Shrines

Infernal Shrines is another *Diablo*-themed battleground. It is a three-lane battleground (see Figure 2.11) with no boss camps, 2 bruiser camps (camps between the top and middle lanes) and 3 siege camps (camps in the bottom section of the map and between the middle and bottom lanes). The fact, that it is inspired by *Diablo* universe, also affect camps. Instead of the generic ones, bruiser and siege camps are the same as in the *Battlefield of Eternity* map.

The objective is to activate a shrine that periodically spawns at one of the map objective locations and defeat 40 shrine guardians before the enemy in order to summon a mighty punisher for objective-winning team [47]. There are three types of punishers: arcane, frozen and mortal. Each type has a signature ability corresponding to the type together with one generic ability - leap to the closest enemy hero

and unleashing a flurry of punches. The punisher always supports the lane that is the closest to the shire and both of his abilities prefer to target heroes.

There are two approaches how to play this map. Either one player rotates between the top and the middle lanes while a group of four players stays bottom or the other way around. Map is not as large as it might seem, so prioritizing heroes that can annihilate shire guardians quickly are the priority picks together with heroes that can deal large single target damage to kill the punisher faster [39].

Sky Temple

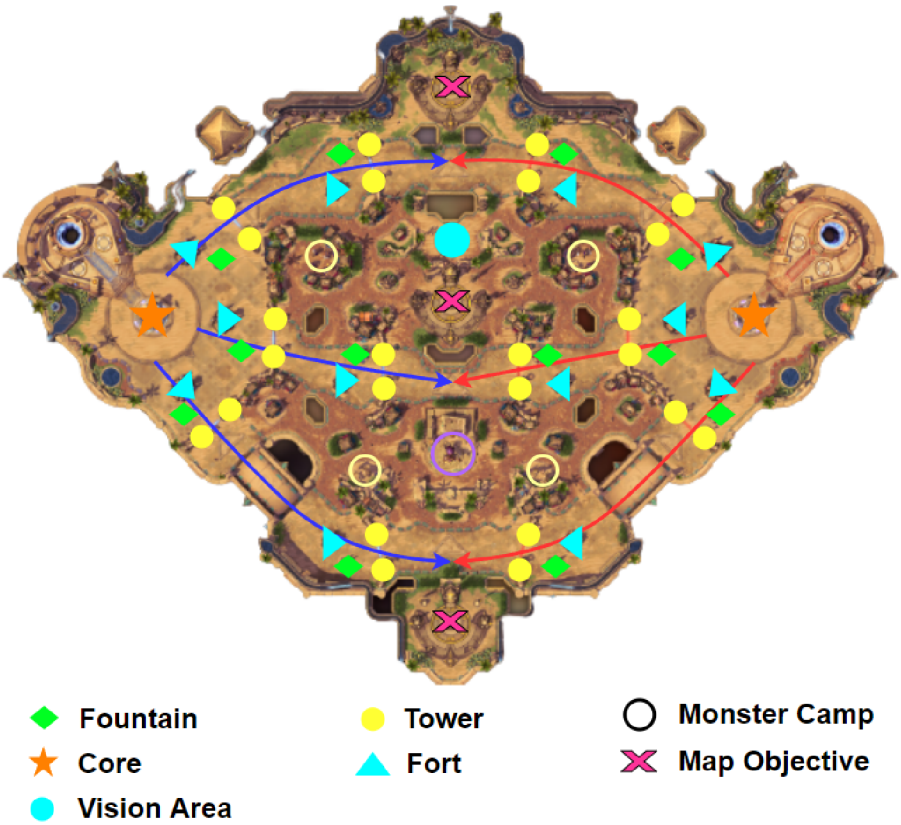


Figure 2.12: Map Sky Temple

Sky Temple is another original *Heroes of the Storm* map. It is a three-lane battleground (see Figure 2.12) with 1 boss camp (purple monster camp between the middle and the bottom lane), 2 bruiser camps (camps between the top and the middle lanes) and 2 siege camps (camps between the middle and the bottom lanes).

During the match, temples periodically activate. The objective is to stand within their grounds to capture their power and unleash a blistering onslaught on enemy's structures [48]. While equal number of players from both teams are within the temple area, the temple deactivates. The shrines are more powerful the longer the game takes, making it the ultimate tool to destroy enemy's core in the late game.

Regarding the approach, this map is offers several ways. Either one player is sent to the top lane and one player is sent to the bottom lane, while a group of three players is capturing monster camps and supporting lane in need or one player rotates between the top and middle lanes while the group of four players is pressuring the bottom lane. As the map revolves around team-fights and outnumbering the opponent, preferred heroes are the ones that excel in PVP combat and quick movement around the map [39].

Tomb of the Spider Queen

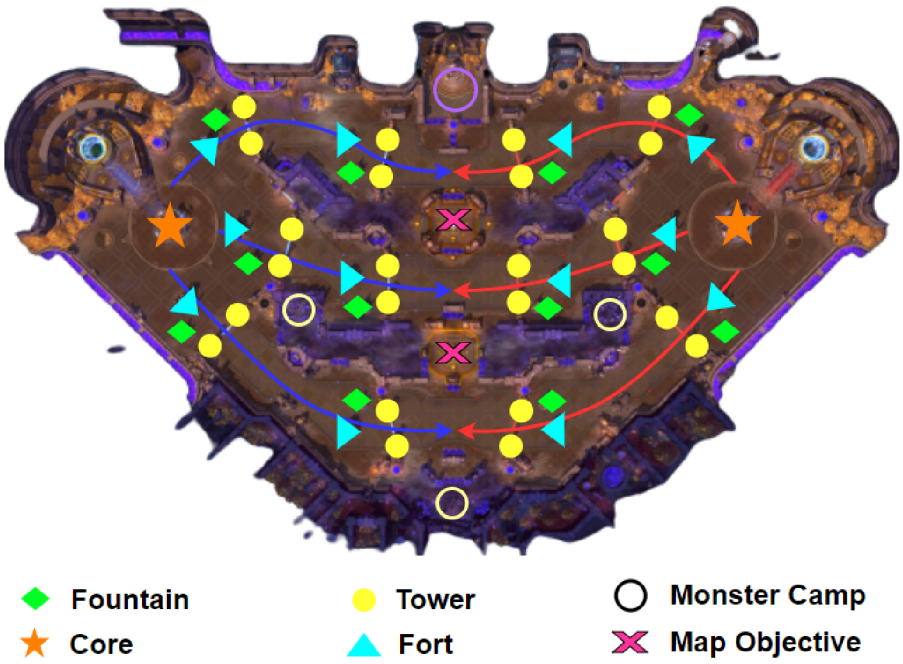


Figure 2.13: Map Tomb of the Spider Queen

Tomb of the Spider Queen is also one of the original *Heroes of the Storm* maps. It is a three-lane battleground (see Figure 2.13) with 1 boss camp (purple camp in the top section of the map), 2 bruiser camps (camps between the middle and the bottom lane) and 1 siege camp (camp in the bottom section of the map). Despite the fact, that it is one of the original maps, the ranged minions that are coming in waves are transformed into spiders.

At regular intervals a spider queen's altar spawns at one of the map objective locations. The goal is to collect gems, that mainly drop from spider minions [49]. If not picked up, the gems disappear. Players can hold unlimited amount of gems, but those gems are dropped if the player is killed, giving the team mates short time window to pick them up again. Killing multiple team members and making sure the gems disappear is a valid strategy to deny the enemy team from fulfilling the

objective. Once team have enough of gems, it is required for players that hold the gems to relinquish them at the active altar. The act is channeled and can be interrupted by taking damage. Whichever team turns in enough gems first, unleashes the Webweavers to each lane to destroy their enemy's defenses. Webweavers are powerful monsters that periodically spawn spider creatures and bombard structures together with players using channeled ability, that deals high amount of damage. The ability can be interrupted if the Webweaver is killed before the cast finishes.

The standard strategy is to send one player to the bottom lane while a group of four players rotates between the top and middle lanes collecting all possible gems. Heroes that are good at clearing waves are the priority picks together with heroes that have a long range abilities to interrupt when the gems are being turned in [39]. Despite the fact, that *Tomb of the Spider Queen* is three-lane map, the map is relatively small.

Towers of Doom

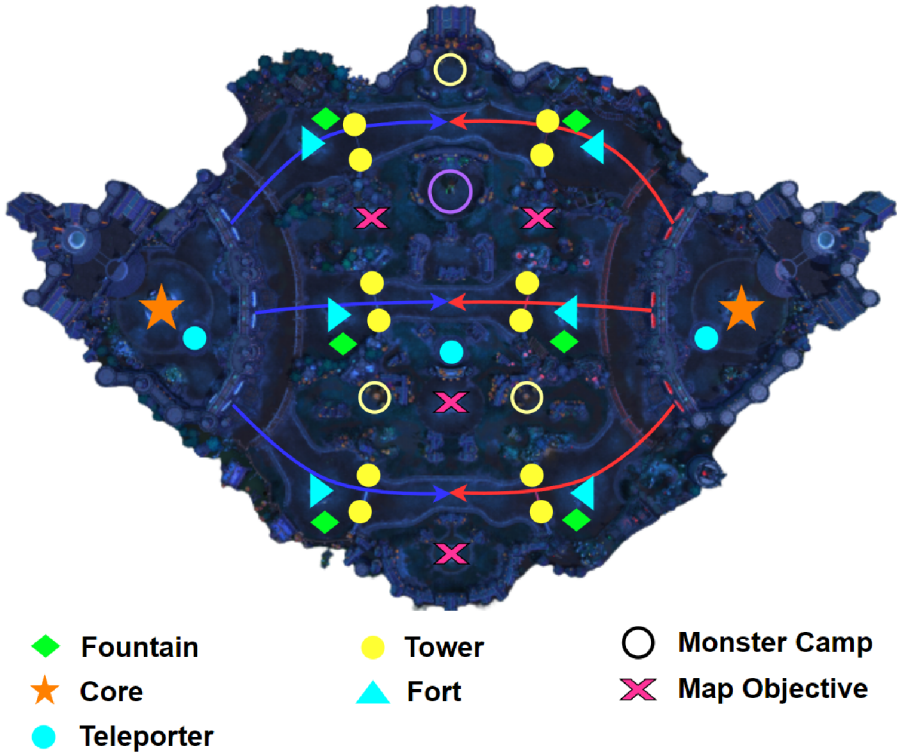


Figure 2.14: Map Towers of Doom

Towers of Doom is a three-lane battleground (see Figure 2.14) with a lot of unique mechanics. Despite the fact that the map is not inspired by any other game universe, there also is a new camp type. In the battlefield there is 1 boss camp, and 3 sapper camps.

Sappers are monsters that sacrifice themselves when near a structure to deal high amount of siege damage. Each camp consists of three such monsters, once captured, sappers march to the closest lane. To interrupt the sacrifice, sappers need to die before they reach any structure proximity.

We can see that there are no tier 2 structures. In *Towers of Doom* the cores can only be damaged by winning the objectives, not by players directly. Periodically, a subset of map objective locations is chosen

where the altars spawn. Activating altars results in all major structures firing once at the enemy's core. The number of fired projectiles depends on the number of major structures controlled by the team [50]. At the start of the game, each team's core has 40 health and each team is able to fire 4 shots on the enemy's core (1 core + 3 forts). Destroying any major structure means capturing it, adding one shot to the team that destroyed the structure and subtracting one shot from the team that lost the structure. After some time, structures can be destroyed again, in order to retake it back. The altar activation process is again channeled and can be interrupted by taking damage. Apart from activating altars, also sappers and boss camp can damage the enemy's core. Sappers can sacrifice in order to fire at enemy's core once they reach the end of the lane and when the boss camp is captured, instead of spawning a minion to assist the closest lane, 4 projectiles are fired at the enemy's core. If all major structures are captured by any of the teams, the core of that team fires one projectile on the enemy's core till at least one of the major structures is not retaken back.

The most common approach is to send one player to the top lane while a group of four players rotates between the middle and the bottom lanes, trying to capture as much sappers as possible. There can be multiple altars active at once so heroes that can move around the map quickly are the priority picks [39]. Players can also use the map telepoter to get into the action quickly after either respawning or retreating back. This teleporter is active after 12th minute of the match.

Volskaya Foundry

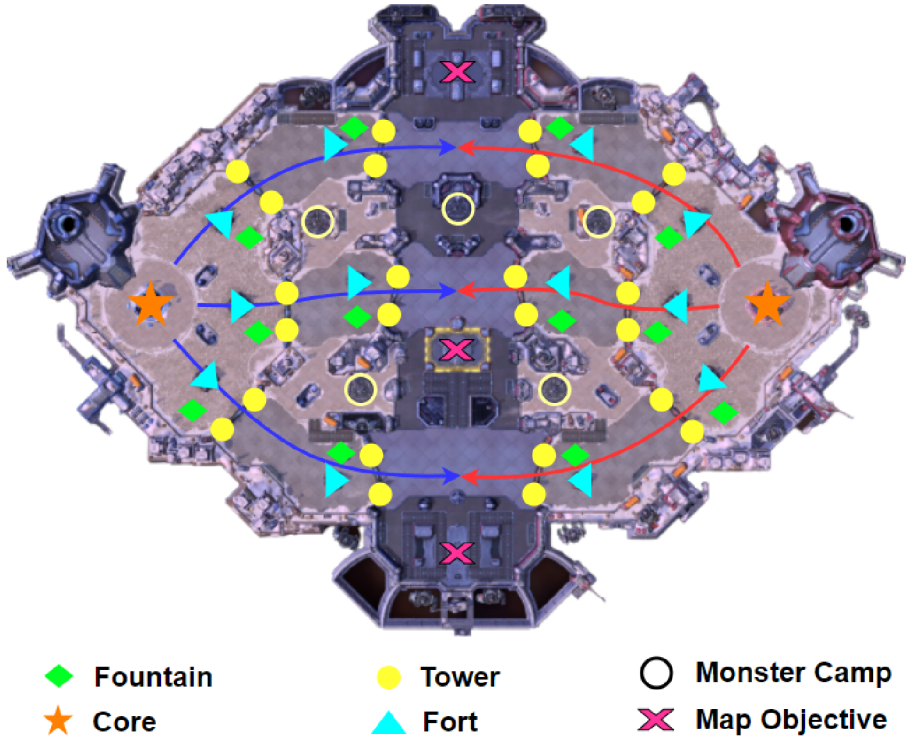


Figure 2.15: Map Volskaya Foundry

Volskaya Foundry is another *Overwatch* inspired map. It is a three-lane battleground (see Figure 2.15) with no boss camps, 1 sentinel camp (the middle camp between the top and bottom lanes), 2 fortification camps (camps between the middle and bottom lanes) and 2 siege camps (the left and right camps between the top and the middle lanes). Sentinel camp is different from the one described in *Hanamura Temple*. Here once captured, sentinel does not summon a robot to support the closest lane but instead drops an AoE healing item that can be carried by heroes and deployed using extra action button. Fortification camps share the same functionality as in *Hanamura Temple*, capturing them grants a deployable turret. Siege camps are very similar to ones that

can be found in *Diablo* inspired maps but with the different visuals. It consists of three robots that attack a single target from afar.

Map objective is also inspired by the *Overwatch* game mode, control points. Control points activate occasionally. Players have to stand within them to capture them [51]. Game mechanic overtime is also present here, meaning in order to fully capture the point, for a certain amount of time there can not be any player from the enemy team within the point area. Fully capturing a point grants the given team a control of a giant mech, called Triglav Protector. The mech is controlled by two players: one pilot and one gunner. Players controlling the mech obtain new set of abilities. The pilot's abilities defensively oriented, while the gunner's abilities are more offensively oriented. The mech is more powerful the longer the game takes, making it an ultimate weapon to finish the game in the late game phase.

As a point of interest we can also consider moving walkways, called conveyor belts. Those can be found around the capture point areas and the bottom lane [52]. Stationary heroes can use these treadmills to reposition themselves effectively.

The standard strategy is either to send one player to the top lane and others move as group of four or to send one player to the bottom lane while others move as group. Considering that the objective takes a while to be secured, heroes that shine in prolonged team fights, in particular sustain healers are the key to the victory [39]. The mech also has a high total health, so heroes that deal percentage based damage can destroy the mech in no time.

Warhead Junction

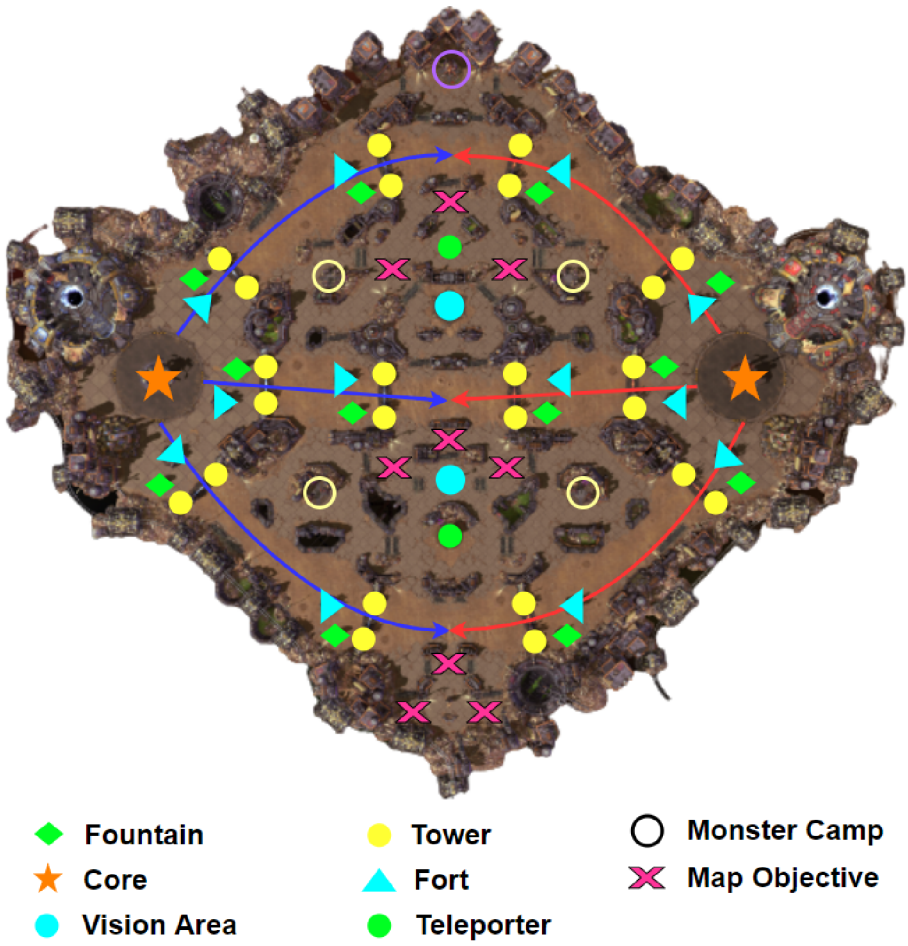


Figure 2.16: Map Warhead Junction

Warhead Junction is *StarCraft* themed three-lane battleground (see Figure 2.16) with 1 boss camp (camp at the top section of the map), 2 bruiser camps (camps between the top and the middle lanes), and 2 siege camps (camps between the middle and bottom lanes). All camps apart from boss camp share the same mechanics as the camps in the *Braxis Holdout* map.

Multiple warheads spawn periodically across the battleground in the map objective locations. The objective is to pick up a warhead in order to activate the nuke [53]. Warhead is carried similarly to deployable items. Hero can carry only one warhead that can be launched using the extra action button. Picking up and launching the warhead has a channel time. Picking up can be interrupted by taking damage but launching can only be interrupted by CC (Crowd Control) abilities (stuns, fears etc.). If a player is slain while carrying a warhead, the warhead is dropped and can be picked up by either team mates or enemies. After successful deployment, an area, big enough to cover towers and fort is struck by the nuke. Nuke has a limited range so the player has to be reasonably close to the desired nuke target.

Team movement depends on the number of spawned nukes so there is no general rule how to split the team and each team has to adapt to the situation. A teleporter is active from the start and can be used as a tool to relocate quickly. The map is huge, so the heroes that excel at moving around the map quickly are always picked first. Heroes that are able to interrupt nuke launches and excel in PVP combat are also beneficial [39].

Haunted Mines (inactive)

Figure 2.17: Map Haunted Mines

Haunted mines is one of the original *Heroes of the Storm* maps. It has been reworked multiple times in order to balance it. The attempts were not successful, that is why the map is only available in custom games, which is sad, because the map offer very unique experience. In the current state, the main map is a two-lane battleground with 2 sapper camps (camps closest to the lanes) and 2 siege camps. Sappers work similarly to ones that are present in the map *Tower of Doom* and siege camp consists of 2 generic AoE ranged monsters.

The map objective is to descend to the mines using the teleporters and collect skulls from fallen monsters in order to empower a super minion that spawns for each team [54], similarly as in the map *Braxis Holdout*. After each objective the lanes, in which super minions spawn for each team, swap.

The reason why the map is no longer active might be, that one strategy was to just pressure one lane as a whole team. The other team was forced to defend, thus the objective was completely ignored the whole game. For such an experience, there are more suitable game modes.

Lost Cavern (ARAM)

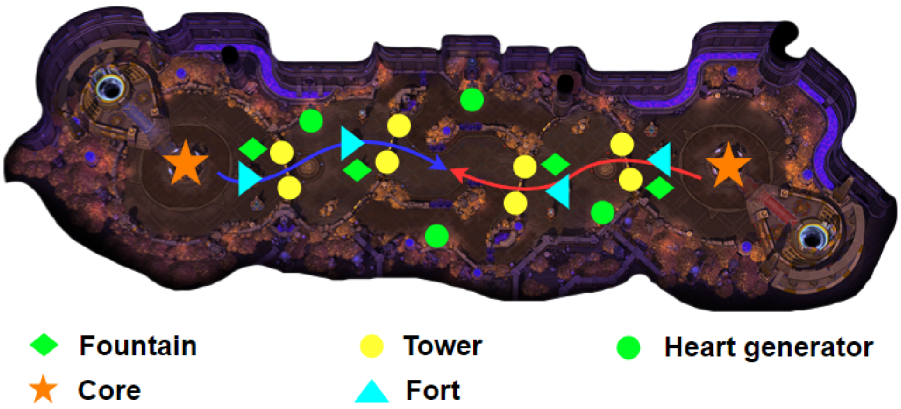


Figure 2.18: Map Lost Cavern

Lost Cavern is a single-lane map used solely for the All Random All Middle (ARAM) mode. As the mode name suggests, players choose one from three randomly assigned heroes. There are no camps to capture, so players can fully focus on PVP combat. *Heros of the Storm* offers in total 4 ARAM maps – *Braxis Outpost* (*StarCraft*), *Industrial District* (*Overwatch*), *Silver City* (*Diablo*) and *Lost Cavern*.

Teleporting back to the base is disabled and does not regenerate health. Health can either be healed by a healer, by drinking from a fountain or by collecting a regenerating globe, shaped as a heart. These globes affect all heroes nearby. In ARAM mode, fountains are indestructible. The only way to destroy a fountain is to destroy a fort, because the fountain only falls together with the fort.

The ultimate goal is to destroy the enemy core. What makes this mode interesting is the chance of getting to play with or against the multiple instances of the same hero as the rule that each player has to control unique hero is ignored.

2.4.4 Interesting and Unique Mechanics

When it comes to interesting and unique game mechanics that *Heroes of the Storm* has to offer, one of those is already several times mentioned

map variety. The fact that there is more than one map brings headroom for many different match approaches and even same hero can have different role depending on the map.

Unique hero design is also something that we can find several examples of in *Heroes of the Storm*. Looking at hero Cho'Gall, the name suggests that the hero is played by two players. One player is controlling Cho, meaning that player controls the hero movement and mobility oriented abilities while the other player controls Gall, a powerful whose abilities are mainly focused on dealing damage. Gall players does not need to move at all, the movement is covered by the player, that plays Cho.

Another hero with interesting design is called Abathur. His basic abilities are periodic monster spawn from his position, global teleport, mine spawn and a symbiosis. Last mentioned ability allows him to affect allied heroes or units anywhere on the battlefield. While affecting unit or a hero, Abathur gains another set of abilities – skill-shot with 3 charges, surrounded area affecting explosion and a shield. Those abilities are cast from or on the affected target. Looking at Abathur's ultimate ability, he can choose either to create a copy one of allied heroes for a certain duration or to spawn powerful sieging monster, that can also be a target for symbiosis ability. Such a ability set makes Abathur unique and very powerful support hero.

Rexxar, on the other hand is one of the strongest solo lane heroes on the maps, where the objective is to control an area. While playing Rexxar, player has the ability to fully control not only the hero itself, but also his pet Misha, that is by the game mechanics considered as a regular hero – can capture camps and control points. The only limitation is, that Misha has to be within certain range of Rexxar.

Controlling multiple hero units is not very common in MOBA games but *Heroes of the Storm* offers yet another exception in form of hero called The Wild Vikings. No doubts it is the most complex hero, because it consists of three controllable units, that movement is not limited in any way. The fact that several maps has exactly three lanes makes The Wild Vikings one of the best, if not the best hero in terms of experience contribution because one player is able to cover all lanes on his own.

Heroes of the Storm introduced several engaging mechanics into the MOBA genre, it is shame that the new content is being added less

frequently and *Blizzard* decided not to support the e-sport. Despite the mentioned facts, queue times are still reasonably short for all game modes and game feels alive.

3 Space-Time Cube (STC) visualization technique

3.1 STC in general

At the end of the 1960s Hägerstrand introduced a space-time model which included features such as a space-time path. His model is often seen as the start of the time-geography studies. Since then, space-time cubes have been employed in a number of interactive visualization systems [55]. However, they have never been used in gameplay visualization problems.

The term space-time cube originates from cartography, where it refers to a geographical representation where time is treated as a third dimension. A cube's base represents geography (along the x- and y-axis), while the cube's height represents time (z-axis). A typical space-time cube could contain the space-time paths of individuals. However, when the concept was introduced the options to create the graphics were limited to manual methods. The user could only experience the single view created by hand. An alternative view on the cube would mean to redraw everything [56]. Today's software has options to automatically create the cube and its contents from acquired data.

Up to this date, the space-time cube visualization technique has been used in many different contexts. For example as a narrative tool to revisit a historical event [57], in context of geospatial visualization [58, 59, 56], to visualize eye movement [60], movement of animals [61], sport [62] and even spatiotemporal patterns for *COVID-19* in China [63]. Apart from common virtual environments, the space-time cube visualization technique has also been applied in mixed reality [64] and VR [65]. In this work we use the visualization technique in a similar fashion as in related works but in a very specific context, gameplay analytics.

3.2 Our adaptation of STC

In the previous sections the basic gameplay and flow of one match in a game *Heroes of the Storm* was indicated. Apart from movement of individuals, in this case players, to capture all crucial events that

happened throughout the game, additional elements had to be added to the visualization. With increasing complexity, 2D methods were no longer an option as it would require user to evaluate a lot of complex spatiotemporal patterns in 2D. As shown here [66], space-time cube representation does give users a better understanding of complex spatiotemporal patterns compared to a 2D representation, while also giving us more space to add additional elements in order to visualize crucial game events.

Apart from additional space to work with, space-time cube technique allows us to use exact player and event positions (x, y map coordinates) and exact time. As a result, each element has the exact 3D position (x, y, t) in the visualization.

To visualize player's movement, a space-time path feature, included in original model, is used. Often the path is not continuous because every time a player dies, the corresponding line, representing the space-time path, is interrupted.

With the addition of multiple other visualization elements, the visualization quickly became cluttered and hard to read. To overcome this issue, a various filters had been added. More detailed technical information about the visualization can be found in the following section.

Despite the fact that the technique being applied outside of its traditional context it is argued that the ability to model movements and relationships at the individual level makes it a powerful visualisation tool able to provide valuable insights into objective-oriented MOBA game, *Heroes of the Storm*.

4 Implemented tools

In this section we are going to describe all the tools and decisions that led to the final product. The implementation part is divided into two sub-parts:

- an application used to parse *Heroes of the Storm* match replay files (.StormReplay) and export useful information to .json file
- a web application used to visualize parsed (.json) *Heroes of the Storm* matches

source code and link are attached in the additional materials.

4.1 Match parser

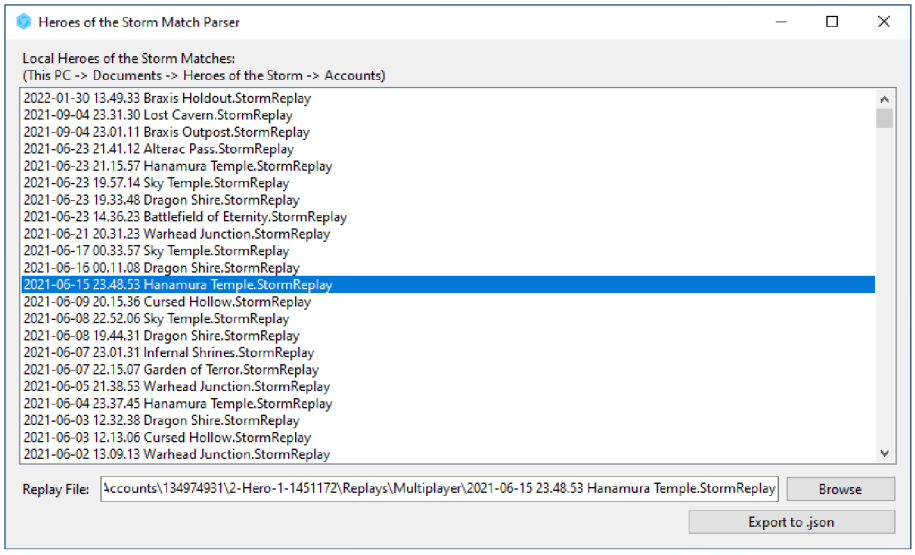


Figure 4.1: Match parser application

Implemented windows forms application (.NET Core 3.1) offers very simple functionality (see Figure 4.1) and is built upon a C# library *Heroes.ReplayParser* [67]. On startup it tries to find .StormReplay

matches locally in default folder (*Documents -> Heroes of the Storm -> Accounts*). If no matches were found, a message box, telling that no matches were found, is displayed and a list box, used to itemize played matches is left empty. Users can either select one match from the list or use the Browse button to locate a replay file in other directory. After the selection is done, button Export to .json prompts user to choose name and saving location of parsed match and a .json file is created using *Newtonsoft.Json* package [68].

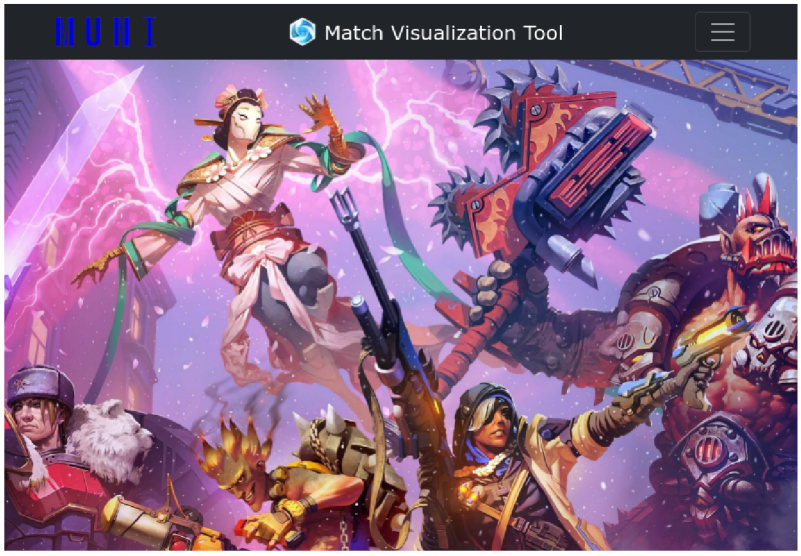
Our main objective was, to be able to periodically sample players' positions. Other available parsers [67, 69] were not providing enough needed data, meaning the positions of players were not sampled frequently enough. *Heroes.ReplayParser* tries to provide position data for each player every second. Sometimes there are time intervals without the position data, in that case we decided to linearly interpolate the last known and next known position. Fortunately, during the testing, the found intervals without the data were not greater than tens of seconds.

Apart from positions of players each second, we also extract other useful information, such as match specific data (map, game length), player deaths, team levels, map objectives, destroyed structures and major camp captures. The data is stored in structures and dictionaries in order to be easily read by the web visualization tool.

4.2 Online match visualizer

The web application consists of two static .html pages. A home page contains (see Figure 4.2) list of supported and tested web browsers and instructions, how to control the visualization. It also covers methods how to visualize a preloaded and an uploaded matches and indicates, how the visualization looks like. Lists of supported and unsupported game modes are also displayed together with authors and asset credits.

In order to follow the most recent web design practices, a free bootstrap template was used [70]. The template supports full width images and has predefined, easily extensible navigation. Apart from mentioned highlights, by using a bootstrap template, all of the other bootstrap components (e.g. buttons) were also included and ready to be used.



Space-Time Cube Visualization for In-Game Data

Supported and Tested Browsers

- Google Chrome
- Microsoft Egde
- Mozzila Firefox

If you are experiencing any performance issues, please make sure your browser has **hardware acceleration enabled**.

Visualization Tool Controls

LMB: Rotate (Perspective view)
RMB: Pan (All views)

Other controls can be found in the menu at **top right**. Start with Visualization →

In-Game Data

Users can choose from the following options:

- Inspecting one of preloaded matches, the selection will be available in the top navigation bar after switching to the **Visualization Tab**.
- Uploading their own parsed match parsed using the upload button in the Visualization Tab. The parsed match has to be in .json format and has to have special structure. Provided match parser is modified version of Heroes.ReplayParser available here.

↓ Download Match Parser

Figure 4.2: Web application – home page

The site was published using *GitHub Pages* [71], a free hosting service for smaller projects, that do not require complicated back-end. Our site meets the requirements, as it consists of two static .html pages backed up by .js file. The only limitation for free users is, that the site domain can not be changed and has a predefined form. The form is as follows: username.github.io/projectname.

4.2.1 Visualization page

Let us take a closer look at the visualization page (see Figure 4.3). After proceeding from the home page, users are immediately prompted to either select one of the preloaded matches or to upload their own parsed match. They can do so by using the extra navigation buttons, that are displayed exclusively in the visualization page. Shortly after using one of the options, a match visualization is displayed.

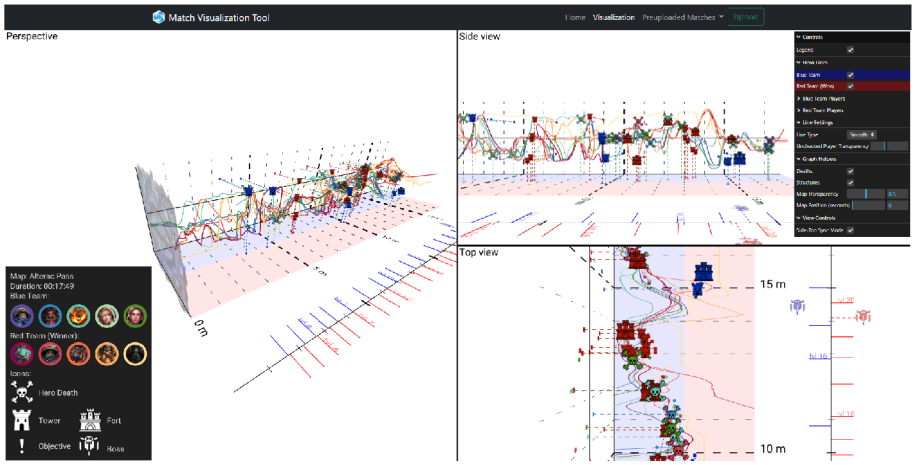


Figure 4.3: Web application – visualization page

Multi-view panel

The visualization is divided into two major parts: UI (User Interface) and multiple-view match visualization. To get better understanding how the tool works and what actually can be seen in the visualization, we are going to describe the multi-view match visualization first.

To implement the multi-view visualization, we used *Three.js* library [72], that is broadly supported by the web browsers and is suited to create 3D scenes. *Three.js* uses *WebGL* API (Application Programming Interface) and also allows us to incorporate GPU-accelerated 3D animations and scene views into a web page. The library offers general computer graphics tools, for example vectors, cameras, lights, materials, shapes and so on. It is well documented and the source code can be found in the *GitHub* repository under MIT licence [72]. Together with the library, there are a lot of community examples, that implement commonly used features as HUD, orbital camera and many others.

The match visualization consists of one primary and two secondary views (see Figure 4.4). All of the views are using perspective camera and are displaying one scene from different angles. The primary view, also called perspective, supports free form movement, while the side and top views have fixed orientation, are able to move only in the time (z-axis) direction and can not move out of the interval defined by the match length. The controls of each view are separated, meaning the view reacts to the mouse inputs initiated only within the view area. Only if the sync mode for the side view and the top view is enabled, then the movement of the views is synchronized. As was already mentioned, views are controlled exclusively using the mouse. Left mouse button controls the rotation in perspective view and right mouse button controls the pan in all views.

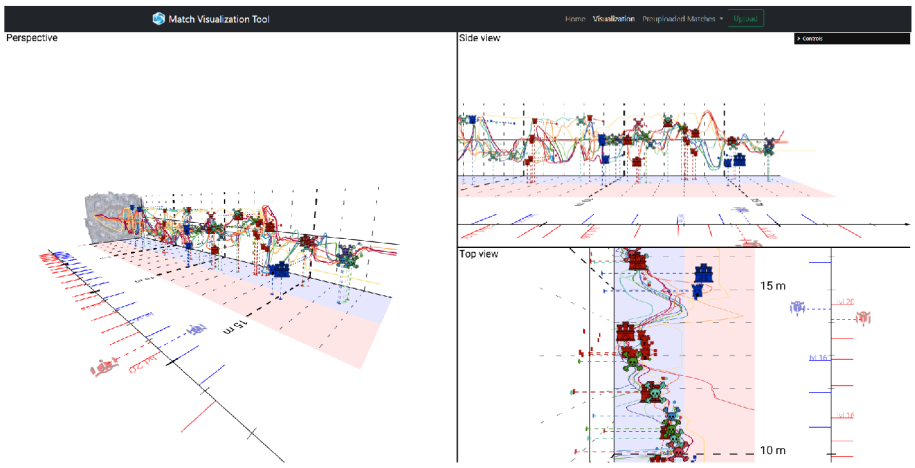


Figure 4.4: Web application – views

To go into more technical details, each view is displayed by a corresponding html canvas element. All three canvas elements are in a container, that displays its elements in a grid, to achieve the resulting screen distribution. Each view also has its designated WebGLRenderer (*Three.js* object) and its own camera that are responsible for rendering a corresponding scene view. In order to separate the view controls, each camera reacts only to the inputs executed within the canvas elements.

The visualization 3D graph is adaptation of space-time cube visualization technique in our specific context. It shows a map, space-time paths and a time-axis, as in the original space-time cube model, together with additional elements. The minor difference is the cube orientation. While in the original model and related work, the bottom face of the cube represents map and cube's height represents time, we rotated the model and as a result, the map is represented by the front face of the cube and time is represented by the z-axis. Graph can be divided into a main graph, where the majority of game events are displayed, and a sub-graph that contains information which do not need to be displayed in the map-space, defined as a block area where base is a map and height is the time-axis.

Main graph

Starting of with the main graph (see Figure 4.5), the crucial part is already mentioned map. Under the hood it is nothing else than a textured plate from both sides. To achieve a transparency at the empty parts, background had to be removed and the material had to be marked as a transparent. An addition to the original model is the ability to move the map along the time-axis and the option to modify the map transparency. The added features are meant to provide users a tool to analyze the location of game event more precisely.

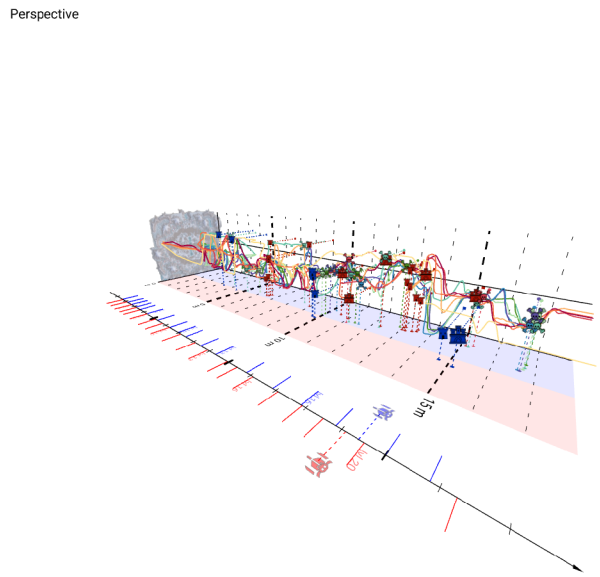


Figure 4.5: Web application – main graph

The original model introduced a concept of spate-time paths, in this work we use the concept to visualize the players' movement. The tool supports two display modes, either the raw players' positions (x, y coordinates each second) are used to draw the lines representing the spate-time paths or the raw positions are smoothed using modified version of average noise filtering, before the lines are drawn. The average noise filtering is in this case modified in a sense, that first and last n position points, where n is equal to the depth of the filter, are treated differently, in order to preserve as much original information

in the n initial and n final player's positions, as possible. The lines themselves are nothing else, just a line segments connecting either smoothed or non-smoothed 3D points (x, y, t).

Looking at the total number of players in each game, we needed to distinguish two teams of five players while also trying to preserve the basic color scheme of each team: red and blue. To do so, we used a *ColorBrewer 2.0* [73], a color advice tool for cartography, where the starting point was selecting the nature of data to diverging and the number of data classes to number 11. We were not satisfied with the light blue shades, so instead, we used used shades of green. As a result, the blue team is represented by cold colors – shades of blue and green, and red team is represented by warm colors – shades of red, orange and yellow.

Not only players' space-time paths had to be color-coded, but also players' deaths. Whenever a player's space-time path is interrupted, it means that the player died. The death is visualized as a color-coded skull with crossed bones. For this purpose, a sprite object was used. The sprite is a plane that always faces towards the camera (billboarding effect), generally with a partially transparent texture applied. Initially, the sprites were rendered regularly, but it was hard to see and distinguish the sprites while being occluded by the spate-time paths. In order to fix the mentioned issue, we decided to ignore depth testing, while rendering the skull sprites, to have them always drawn in front of other graph elements. The player's respawns is visualized as a start of a next space-time path belonging to the given player, which originates from a corresponding base position.

Destroying enemy structures and weakening the defence is also considered as a major event in MOBA games. We distinguish two types of structures, each one having its own visualization icon. Again, we wanted to highlight these events, so we used similar approach to the one used to visualize deaths – ignoring depth test in order to have the sprites drawn in front of other graph elements. Structure destruction is a team accomplishment, so the sprites either have blue or red color. Blue structure represents a structure destroyed by blue team, and vice versa.

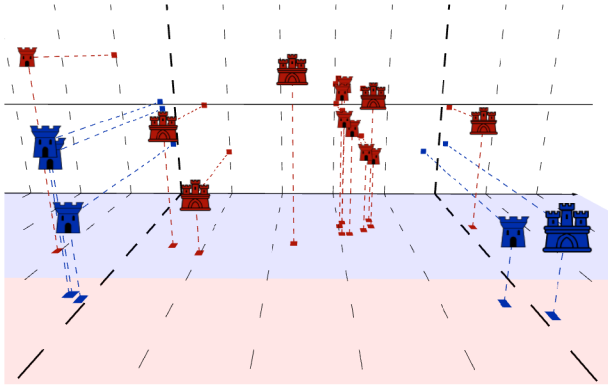


Figure 4.6: Web application – structures

Visualizations of deaths and destroyed structures are also projected on the bottom and left planes of the cube using dashed lines and shapes – circle for deaths and square for structures (see Figure 4.7). Projections of deaths are also color-coded in the same way as are the death sprites and space-time paths. The projections are meant to illustrate the events' x and y coordinates, so the users have the information in which lane and on which side of the map given event happened.

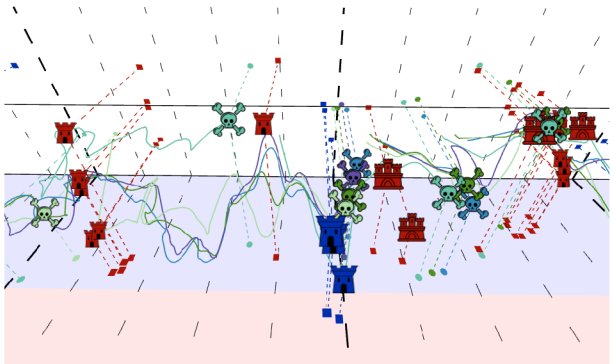


Figure 4.7: Web application – projections

Apart from space-time paths and graph elements, that illustrate game events, the bottom face of the cube is divided into halves which

are team-colored, in order to easily tell, in which team's territory the crucial game events are happening.

The time-axis is visualized as a z-axis in the $-z$ direction. Each minute is visualized using dashed lines while each fifth minute also has a label and the dashed line is thicker (see Figure 4.8). Combining all the graph elements together, it should be clear to distinguish when and where a game event happened.

Sub-graph

Visualizing level milestones, map objectives and major camp captures is also as important as visualizing the position and the time of the game events. We did not want to clutter the main graph, that is why we decided to visualize the mentioned level milestones, map objectives and major camp captures in a separate sub-graph (see Figure 4.8), that is located outside the space-time cube. The sub-graph is displayed on the xz plane to the right of the main graph. It contains time-axis and team-colored elements. Level milestones are visualized as a lines and the talent-unlocking milestones (levels 4, 7, 10, 13, 16 and 20) also have a label. Map objectives are visualized as a team-colored exclamation marks and are also projected on the time-axis using dashed line. Major boss camps have its own icon and similarly as the map objectives, are team-colored and projected on the time-axis.

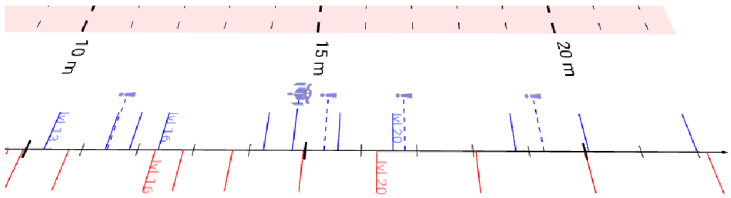


Figure 4.8: Web application – sub-graph

User interface (UI)

No less important part of the visualization is the user interface. It consists of two elements: graph legend that is located at the bottom

left corner of the screen and a controls panel, located at the top right corner of the screen. Legend (see Figure 4.9) is created in a separate UI scene and is rendered as a HUD (Heads Up Display) using orthographic camera. It contains map name, match duration, color-coded hero icons for each team and icon explanations. Depending on the screen resolution, the legend can take up a lot of the screen-space. That is why we included a toggle in the controls panel, which determines whether the legend is visible.

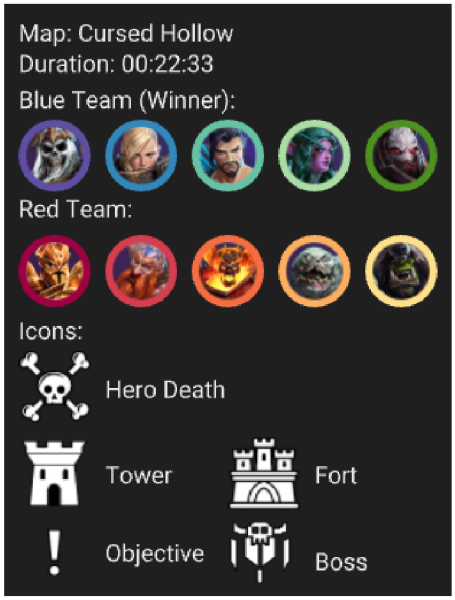


Figure 4.9: Web application – legend

Controls panel (see Figure 4.10) is implemented using *lil-gui* library [74] and allows users to choose what and how the graph elements are displayed. The controls are grouped into the folders. In Hero Lines folder users can choose which space-time paths and death visualizations are shown either on team basis or per player. Line Settings folder contains an option to either draw lines from raw or smooth data, together with the slider for the transparency of unchecked player lines, with default value of 1, meaning the unchecked player lines are fully transparent. In Graph Helpers folder toggles to either show or hide visualization of destroyed structures and death can be found,

together with sliders to control the transparency and position of the map. The position slider works with seconds, meaning the map is moved along the time-axis. In the last folder, View Controls, the side view and the top view movement can be synchronized, in order to analyze specific time frame from multiple angles at once.

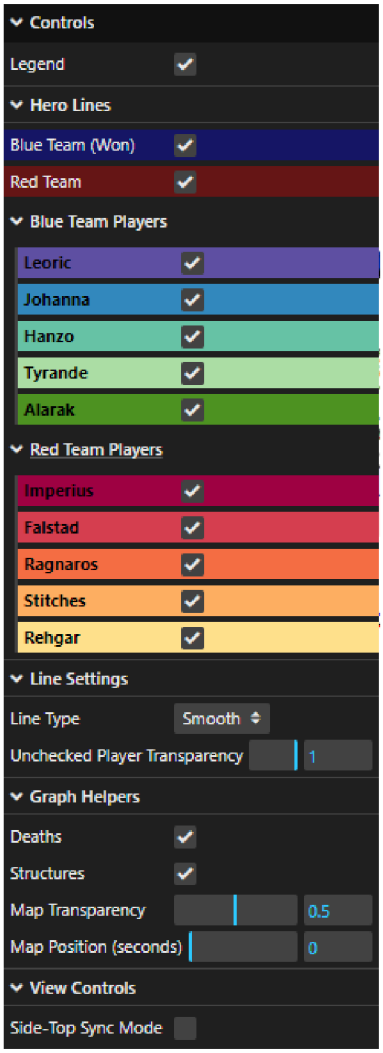


Figure 4.10: Web application – controls/filters

The amount of interaction options is high and new users can feel a bit overwhelmed at start. That is why we suggest users to familiarize themselves with the user interface, and the controls first, in order to efficiently use the visualization tool.

5 User study

The goal of a study was, to find out, how efficient can users find desired information in the visualization and measure their performance with respect to their preferred MOBA game.

5.1 Method

Thirty participants were recruited using either Reddit, Discord or Facebook communities. Some of them being author's close friends, colleagues or family. Each participant had some previous experience with game genre MOBA – is/was actively playing or passively watching. Each completed survey was conducted on either laptop or personal computer, as the mobile devices are not supported.

The first part of survey consisted of demographic and general questions, where participants were asked about their:

- Age
  - Drop-down field with values from <18 to 65
- Gender
  - Female
  - Male
  - Non-binary
  - Prefer not to disclose
  - Other
- Interest in post-match game analysis
  - Scale from 1 (Not at all interested) to 7 (Very interested)
- Experience with post-match game analysis
  - Scale from 1 (No at all experienced) to 7 (Very experienced)
- Experience with gameplay visualization

  - Scale from 1 (No at all experienced) to 7 (Very experienced)

- Preferred MOBA game
  - *League of Legends*
  - *Dota 2*
  - *Heroes of the Storm*
  - Other

Depending on the preferred MOBA game, the following questions were game-specific and covered the following:

- Experience in given game
  - Text input field
- Hours spent playing per week
  - Text input field
- Preferred role in given game
  - Check-boxes with game specific roles or text input field

After the initial part, we asked participants to read the overview at the home page of the tool and then proceed to the visualization and familiarize themselves with the user interface, and the controls. To assess the participants' understanding of the visualization, a set of 10 questions was designed. The questions were designed carefully to cover large difficulty spectrum. Along with a description of each question and answer fields, participants were also asked to fill the answer confidence on a scale from 1 (not confident at all) to 7 (completely confident) and mental-effort on a scale from 1 (very, very low mental effort) to 9 (very, very high mental effort) according to Pass.

To lower the number of required steps and not to cause confusion, we decided to preload and enable only a subset of matches, which are the subject of research. Questions cover 4 matches on different maps – Blackheart's Bay (Figure 2.5), Battlefield of Eternity (Figure

2.4), Towers of Doom (Figure 2.14) and Cursed Hollow (Figure 2.7). We decided to use multiple matches, because each match offers completely different visualization graph and contains different series of interesting game events, e.g. turn-around victory etc. Questions and are divided into several categories with respect to which variable (e.g. time, space) is fixed and what is the subject of the correct answer (e.g. if an event happened, how many times an event happened). The question categories are listed here, together with some examples:

Category 1: Simple reading form the visualization – First destroyed structure type?, Was the boss captured in this match?

Category 2: Analyzing which events happened at certain time – Check all correct statements, that describe what happened between 6 - 7 minute of the match.

Category 3: Analyzing how many events of the same type happened at certain time – How many RED team players respawned between 9 - 11 minute?

Category 4: Analyzing how many times an event happened throughout the game – How many times the player, that played CASSIA, died?, Which team finished the game with more levels?

Category 5: Analyzing position of the events – In which lane the final push happened?

Category 6: Analyzing when the certain events happened – Identify time frame, when the large number (3+) of structures were destroyed by BLUE team.

Category 7: Combined questions – How many RED team members were dead when BLUE team destroyed the first structure?

Category 8: Open questions – Which are the three main insights you can get when analyzing this match with the visualization?

In the final part, denoted as a Conclusion and Feedback, participants were asked asked the following questions:

- How useful was the 'Perspective' for you?

  - 1 (Not useful at all) - 7 (Very useful)

- How useful was the 'Side View' for you?
  - 1 (Not useful at all) - 7 (Very useful)
- How useful was the 'Top View' for you?
  - 1 (Not useful at all) - 7 (Very useful)
- How useful was the 'Legend' for you?
  - 1 (Not useful at all) - 7 (Very useful)
- How useful was the 'Controls/Filters' for you?
  - 1 (Not useful at all) - 7 (Very useful)
- Please, if possible, name 3 points that you liked about the visualization.
  - Large text input field
- Please, if possible, name 3 points that you have seen as weaknesses of the visualization.
  - Large text input field
- How can the visualization be improved?
  - Large text input field
- What else would you like to have analyzed and which additional features would you like to be added in the future?
  - Large text input field
- Feel free to give any other feedback.
  - Large text input field

Where usefulness was measured using linear scale from 1 (not useful at all) to 7 (very useful).

After the survey session, some of the participants also provided vocal feedback, elaborating on the feedback comments left in the final part of the questionnaire. The survey was designed to require a maximum of 30 minutes of participants' time.

5.2 Results

In the general questions and visualization questions the results were divided into two groups depending on the participants' preferred MOBA game. The groups consist of *Heroes of the Storm* players and players of *League of Legends* and *Dota 2* combined. Doing so allows us to see contrasts and similarities between the players that have deeper understanding of *Heroes of the Storm* game mechanics in comparison to the players that have general knowledge of MOBA game mechanics acquired in other games. The limitation lies in the generalisability of the research as we were unable to recruit enough *Dota 2* players to have the result group per each covered game.

In the following sections, survey questions, answers and results are presented.

5.2.1 Demographic Questions

Age

Age of participants was between 18 and 40 years old with a mean age of 27.066 (Table 5.1 for detailed statistics). In boxplot, the dashed line represents mean, regular line represents median, left side of the box represents Q1 and right side of the box represents Q3. Whiskers show min and max values, not counting in outliers (see Figure 5.1)

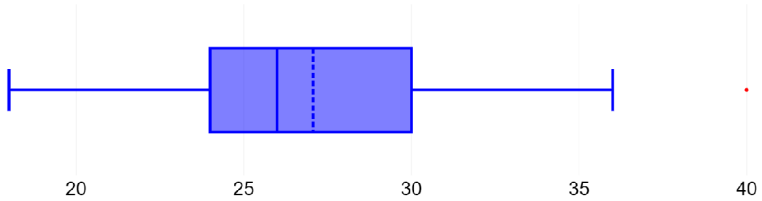


Figure 5.1: Age of respondents

Table 5.1: Statistical values of age

Min	Median	Mean	Max
18	26	27.066	40

Gender

The distribution of gender was 4 females and 26 males (see Figure 5.2).

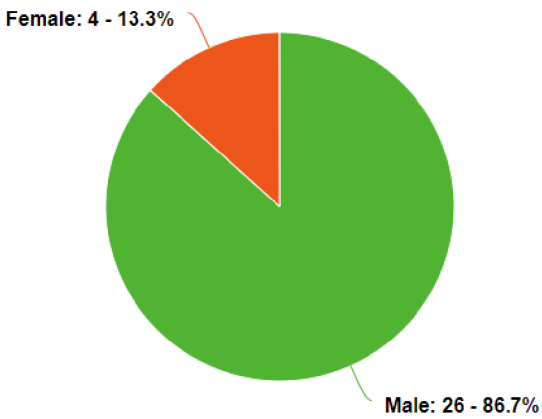


Figure 5.2: Gender representation of respondents

5.2.2 General Questions

Interest in post-match game analysis

The interest in post-match game analysis was measured on a scale from 1 (Not at all interested) to 7 (Very interested). *Heroes of the Storm* players were more interested in post-match game analysis. For results, see Figure 5.3.

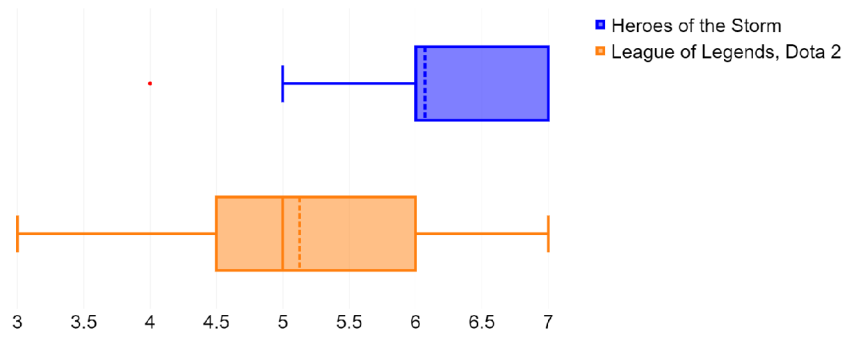


Figure 5.3: Interest in post-match game analysis per group

Experience with post-match game analysis

The experience with post-match game analysis was measured on a scale from 1 (No at all experienced) to 7 (Very experienced). Both groups were similarly experienced. For results, see Figure 5.4.

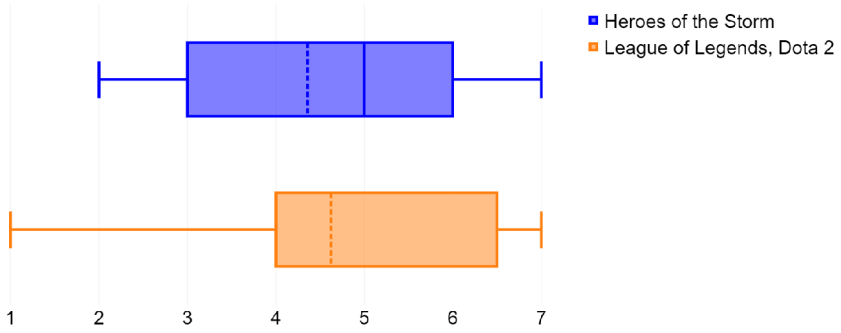


Figure 5.4: Experience with post-match game analysis per group

Experience with gameplay visualization

The experience with gameplay visualization was measured on a scale from 1 (No at all experienced) to 7 (Very experienced). Both groups were similarly experienced. For results, see Figure 5.5.

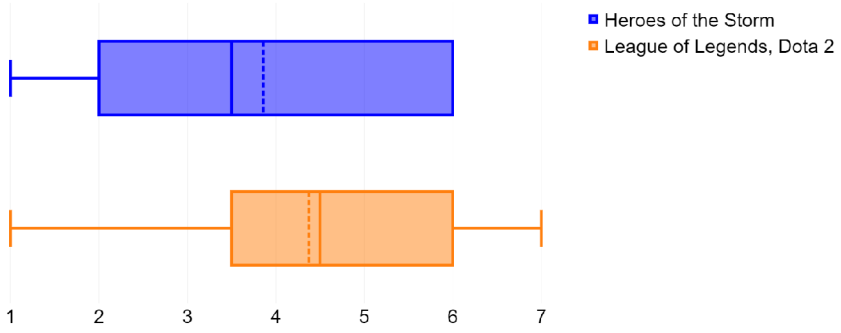


Figure 5.5: Experience with gameplay visualization per group

Experience in preferred MOBA game

The highest and the lowest ranks achieved by the participants per game are presented in Table 5.2.

Table 5.2: Min and max experience per game

Game	Min Experience	Max Experience
Dota 2	1000 MMR	2800 MMR
Heroes of the Storm	Unranked / Bronze 4	Master
League of Legends	Unranked / Bronze 1	Diamond 2

Favorite role in preferred MOBA game

The least favorite and the most favorite roles amongst the participants per game are presented in Table 5.3.

Table 5.3: Least and most favorite roles per game

Game	Least favorite role	Most favorite role
Dota 2	Safe lane	Mid / Ssupport
Heroes of the Storm	Support	Bruiser / RAssassin
League of Legends	Adc / Jungle	Top / Mid

Average hours spent playing per week

Regarding the average hours spent playing per week, the participants are divided into groups with respect to the preferred game. For results, see Figure 5.6.

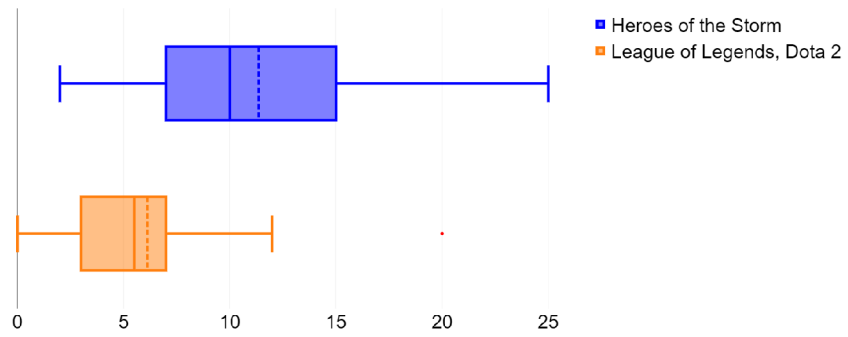


Figure 5.6: Average hours spent playing per week per group

5.2.3 Question 1 - Blackheart's Bay

Check all correct statements, that describe what happened between 6 - 7 minute of the match **(Category 2)**:

1. Both teams reached level 10
2. Blue team gained more than 1 level
3. Red team gained more than 1 level
4. Blue team destroyed a structure
5. Red team destroyed a structure
6. Member of blue team died
7. Member of red team died
8. One of the teams reached the objective
9. One of the teams captured the boss

The question had relatively high success rate, for more details and correct answer see Table 5.4.

Table 5.4: Question 1 - Results

Option	Hots (14)	Lol, Dota 2 (16)	Is Correct?
1.	100% (14)	81.25% (13)	Yes
2.	78.57% (11)	68.75% (11)	Yes
3.	7.14% (1)	12.5% (2)	No
4.	85.71% (12)	81.25% (13)	Yes
5.	21.42% (3)	31.25% (5)	No
6.	78.57% (11)	93.75% (15)	Yes
7.	100% (14)	87.5% (14)	Yes
8.	85.71% (12)	68.75% (11)	Yes
9.	7.14% (1)	0% (0)	No

Answer confidence

Answer confidence was measured on a scale from 1 (Not confident at all) to 7 (Completely confident). Both groups were similarly confident, while *League of Legends* and *Dota 2* players had more variable answers. For results, see Figure 5.7.

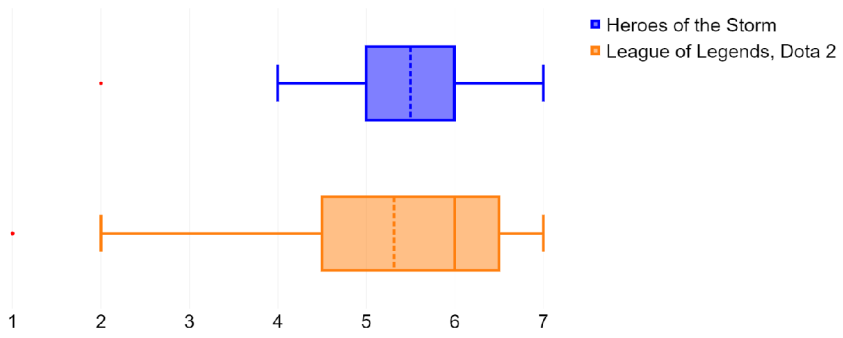


Figure 5.7: Question 1 - Answer confidence

Effort

Mental effort was measured on a scale from 1 (very, very low mental effort) to 9 (very, very high mental effort). *Heroes of the Storm* players considered the question to be more mentally demanding. For results, see Figure 5.8.

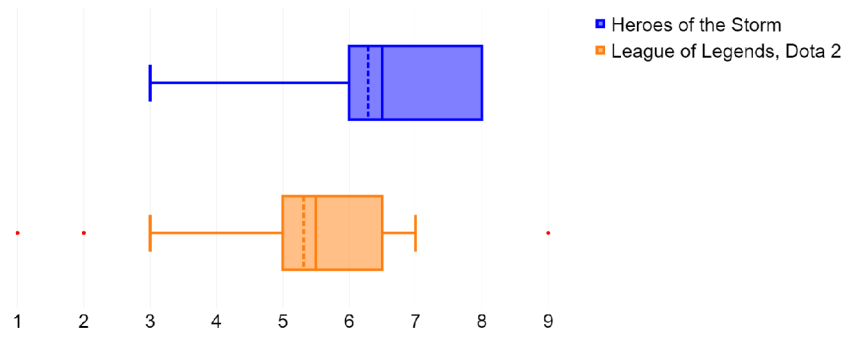


Figure 5.8: Question 1 - Effort

5.2.4 Question 2 - Blackheart's Bay

2.1 Check member(s) of BLUE team that died between 6 - 7 minute of the match **(Category 2)**:

1. Abathur
2. Muradin
3. Zeratul
4. Lúcio
5. Probius

Participants were able to identify correct answers with high success rate, but some also selected wrong options. For more details and correct answers see Table 5.5.

Table 5.5: Question 2.1 - Results

Option	Hots (14)	Lol, Dota 2 (16)	Is Correct?
1.	0% (0)	0% (0)	No
2.	0% (0)	0% (0)	No
3.	85.71% (12)	100% (16)	Yes
4.	14.28% (2)	12.5% (2)	No
5.	14.28% (2)	0% (0)	No

2.2 Check member(s) of RED team that died between 6 - 7 minute of the match **(Category 2)**:

1. Samuro
2. Stitches
3. Nazeebo
4. Zul'jin
5. Tyrande

Participants were able to identify correct answers with relatively high success rate, but 3 *Heroes of the Storm* players also selected wrong option. For more details and correct answers see Table 5.6.

Table 5.6: Question 2.2 - Results

Option	Hots (14)	Lol, Dota 2 (16)	Is Correct?
1.	92.85% (13)	100% (16)	Yes
2.	7.14% (1)	6.25% (1)	No
3.	0% (0)	0% (0)	No
4.	21.42% (3)	6.25% (1)	No
5.	71.42% (10)	87.5% (14)	Yes

Answer confidence

Answer confidence was measured on a scale from 1 (Not confident at all) to 7 (Completely confident). Both groups were similarly confident. For results, see Figure 5.9.

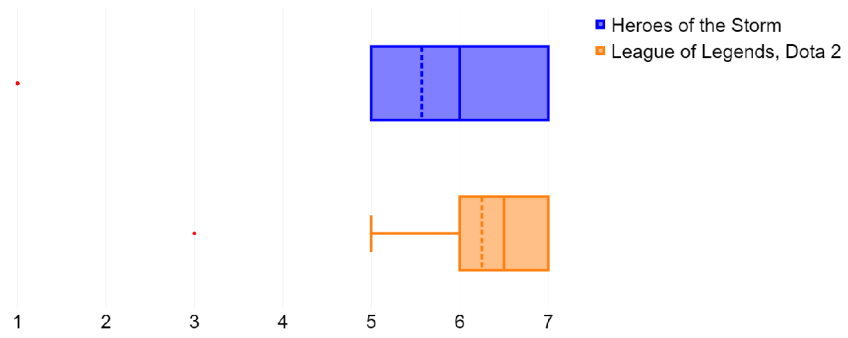


Figure 5.9: Question 2 - Answer confidence

Effort

Mental effort was measured on a scale from 1 (very, very low mental effort) to 9 (very, very high mental effort). *Heroes of the Storm* players considered the question to be more mentally demanding and also had more variable answers. For results, see Figure 5.10.

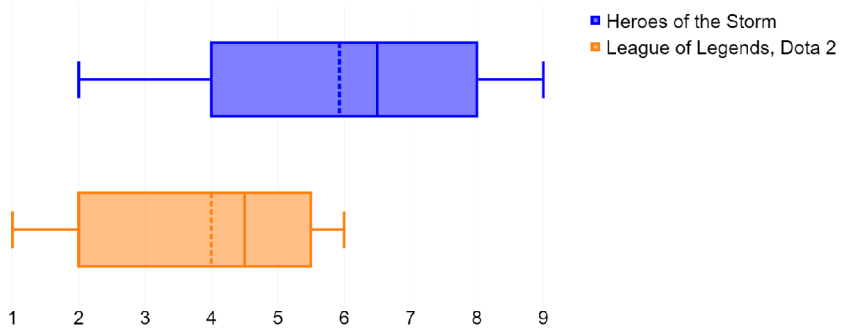


Figure 5.10: Question 2 - Effort

5.2.5 Question 3 - Blackheart's Bay

Which are the three main insights you can get when analyzing this match with the visualization? **(Category 8)**

Worth-mentioning insights and correct assumptions that were analyzed by *Heroes of Storm* players:

- Probius and Nazeebo double-soaking the experience from top and middle lanes
- Red team had a comeback victory with boss capture
- Samuro died a shockingly high number of times, which probably contributed to Red team being behind most of the game
- Red and only red team destroyed structures without the map objective
- Red never slipped too far behind on levels despite losing significantly more structures and having fewer turn ins (map objective)

Worth-mentioning insights and correct assumptions that were analyzed by *League of Legends* and *Dota 2* players:

- Both teams were even until approximately minute 17

- Hero Abathur has a different, passive play-style
- Red team got wiped out around minute 12 causing blue team to overestimate themselves and loose at minute 20
- Most of the deaths occurred at the center of the map
- Second half of the game was more death intensive

Effort

Mental effort was measured on a scale from 1 (very, very low mental effort) to 9 (very, very high mental effort). Both groups considered the question similarly demanding to answer. For results, see Figure 5.11.

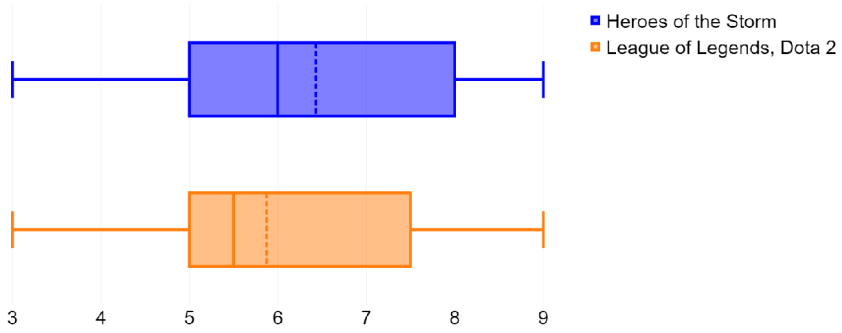


Figure 5.11: Question 3 - Effort

5.2.6 Question 4 - Battlefield of Eternity

4.1 Check the correct statement about the map **(Category 1)**:

1. Battlefield of Eternity is a ONE lane map (All Mid)
2. Battlefield of Eternity is a TWO lane map (Top / Bot)
3. Battlefield of Eternity is a THREE lane map (Top / Mid/ Bot)

Participants were able to identify correct answers with high success rate.*Heroes of the Storm* players were slightly more successful. For more details and correct answers see Table 5.7.

Table 5.7: Question 4.1 - Results

Option	Hots (14)	Lol, Dota 2 (16)	Is Correct?
1.	0% (0)	6.25% (1)	No
2.	100% (14)	87.5% (14)	Yes
3.	0% (0)	6.25% (1)	No

4.2 In which lane did the first death happened? **(Category 5)**

1. Top
2. Mid (Middle)
3. Bot (Bottom)

Participants were able to identify correct answers with high success rate.*Heroes of the Storm* players were relatively more successful. For more details and correct answers see Table 5.8.

Table 5.8: Question 4.2 - Results

Option	Hots (14)	Lol, Dota 2 (16)	Is Correct?
1.	0% (0)	6.25% (1)	No
2.	0% (0)	12.5% (2)	No
3.	100% (14)	81.25% (13)	Yes

4.3 In which lane the first structure was destroyed? **(Category 5)**

1. Top
2. Mid (Middle)
3. Bot (Bottom)

Participants were able to identify correct answers with high success rate.*Heroes of the Storm* players were relatively more successful. For more details and correct answers see Table 5.8.

Table 5.9: Question 4.3 - Results

Option	Hots (14)	Lol, Dota 2 (16)	Is Correct?
1.	100% (14)	81.25% (13)	Yes
2.	0% (0)	6.25% (1)	No
3.	0% (0)	12.5% (2)	No

4.4 In which lane the final push happened? **(Category 5)**

1. Top
2. Mid (Middle)
3. Bot (Bottom)

Participants were able to identify correct answers similarly in both groups, but some selected incorrect option. For more details and correct answers see Table 5.10.

Table 5.10: Question 4.4 - Results

Option	Hots (14)	Lol, Dota 2 (16)	Is Correct?
1.	21.42% (3)	31.25% (5)	No
2.	0% (0)	0% (0)	No
3.	78.57% (11)	68.75% (11)	Yes

Answer confidence

Answer confidence was measured on a scale from 1 (Not confident at all) to 7 (Completely confident). *Heroes of the Storm* players were significantly more confident and their answers were less variable. For results, see Figure 5.12.

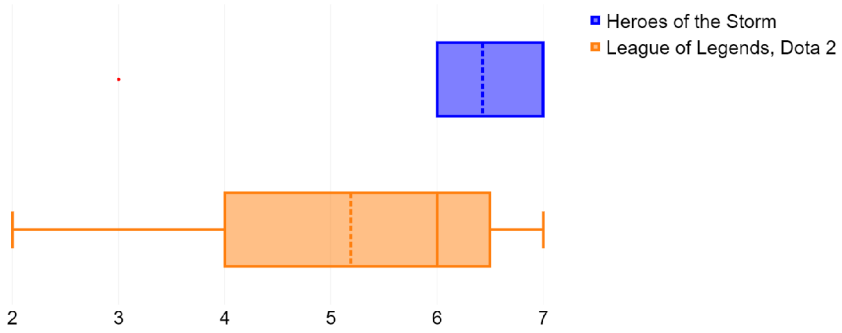


Figure 5.12: Question 4 - Answer confidence

Effort

Mental effort was measured on a scale from 1 (very, very low mental effort) to 9 (very, very high mental effort). Both groups considered the question similarly demanding to answer, while the answers of *Heroes of the Storm* players were more variable. For results, see Figure 5.13.

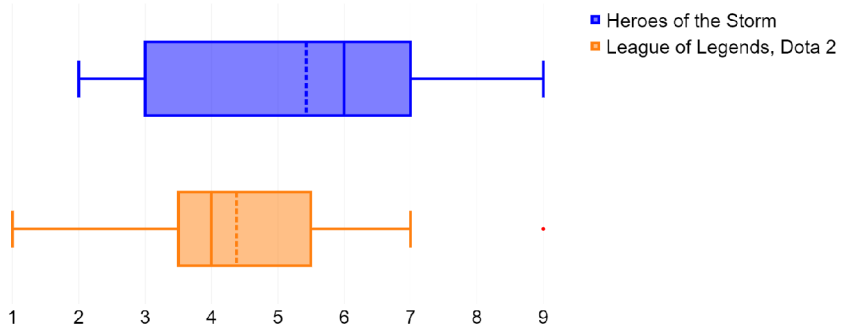


Figure 5.13: Question 4 - Effort

5.2.7 Question 5 - Battlefield of Eternity

How many RED team members were dead when BLUE team destroyed the first structure? **(Category 7)**

Participants were unable to identify correct answer in both groups. For more details and correct answers see Table 5.11.

Table 5.11: Question 5 - Results

Answer	Hots (14)	Lol, Dota 2 (16)	Is Correct?
0	14.28% (2)	37.5% (6)	No
1	21.42% (3)	18.75% (3)	No
2	0% (0)	12.5% (2)	No
3	7.14% (1)	6.25% (1)	Yes
4	57.14% (8)	25% (4)	No
5	0% (0)	0% (0)	No

Answer confidence

Answer confidence was measured on a scale from 1 (Not confident at all) to 7 (Completely confident). Both groups had relatively high answer confidence despite the fact, that almost nobody answered correctly. For results, see Figure 5.14.

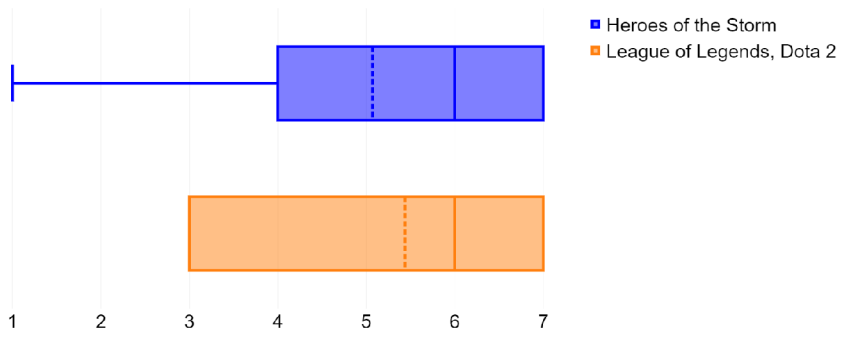


Figure 5.14: Question 5 - Answer confidence

Effort

Mental effort was measured on a scale from 1 (very, very low mental effort) to 9 (very, very high mental effort). Both groups considered the question similarly demanding to answer and answers were similarly variable. For results, see Figure 5.15.

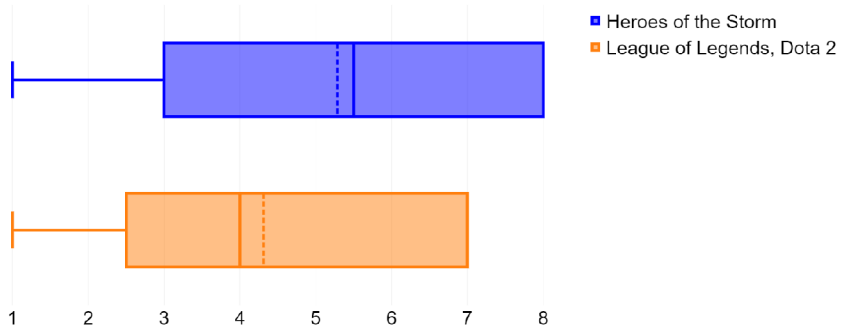


Figure 5.15: Question 5 - Effort

5.2.8 Question 6 - Battlefield of Eternity

6.1 How many RED team players respawned between 9 - 11 minute? **(Category 3)**

The success rate in both groups was relatively low, while not even half of *Heroes of the Storm* players were able to answer the question correctly. For more details and correct answers see Table 5.12.

6.2 Analyze gameplay between 14 - 15 minute. How many players moved together in the biggest group? **(Category 3)**

More than half of the participants were able to identify correct answer in both groups but several incorrect options had been also selected. For more details and correct answers see Table 5.13.

Table 5.12: Question 6.1 - Results

Answer	Hots (14)	Lol, Dota 2 (16)	Is Correct?
0	7.14% (1)	0% (0)	No
1	0% (0)	12.5% (2)	No
2	0% (0)	12.5% (2)	No
3	50% (7)	12.5% (2)	No
4	35.71% (5)	56.25% (9)	Yes
5	7.14% (1)	6.25% (1)	No

Table 5.13: Question 6.2 - Results

Answer	Hots (14)	Lol, Dota 2 (16)	Is Correct?
2	0% (0)	6.25% (1)	No
3	0% (0)	6.25% (1)	No
4	0% (0)	12.5% (2)	No
5	64.28% (9)	62.5% (10)	Yes
6	0% (0)	6.25% (1)	No
7	7.14% (1)	0% (0)	No
8	14.28% (2)	0% (0)	No
9	7.14% (1)	0% (0)	No
10	7.14% (1)	6.25% (1)	No

6.3 At 15 minute a team-fight happened. How many players were involved? **(Category 3)**

Relatively high number of *Heroes of the Storm* players were able to identify correct answer, but only half of the *League of Legends* and *Dota 2* players were able to do as well. For more details and correct answers see Table 5.14.

Table 5.14: Question 6.3 - Results

Answer	Hots (14)	Lol, Dota 2 (16)	Is Correct?
2	0% (0)	0% (0)	No
3	0% (0)	0% (0)	No
4	0% (0)	0% (0)	No
5	0% (0)	18.75% (3)	No
6	0% (0)	6.25% (1)	No
7	14.28% (2)	6.25% (1)	No
8	14.28% (2)	6.25% (1)	No
9	7.14% (1)	12.5% (2)	No
10	64.28% (9)	50% (8)	Yes

Answer confidence

Answer confidence was measured on a scale from 1 (Not confident at all) to 7 (Completely confident). Both groups were similarly confident. For results, see Figure 5.16.

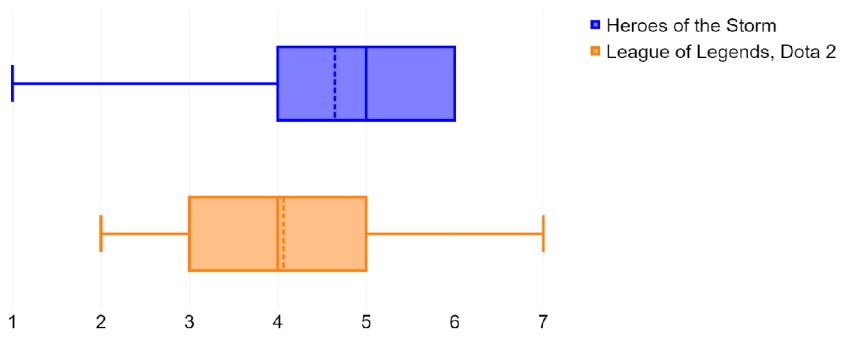


Figure 5.16: Question 6 - Answer confidence

Effort

Mental effort was measured on a scale from 1 (very, very low mental effort) to 9 (very, very high mental effort). Both groups considered the

question similarly demanding to answer and answers were similarly variable. For results, see Figure 5.17.

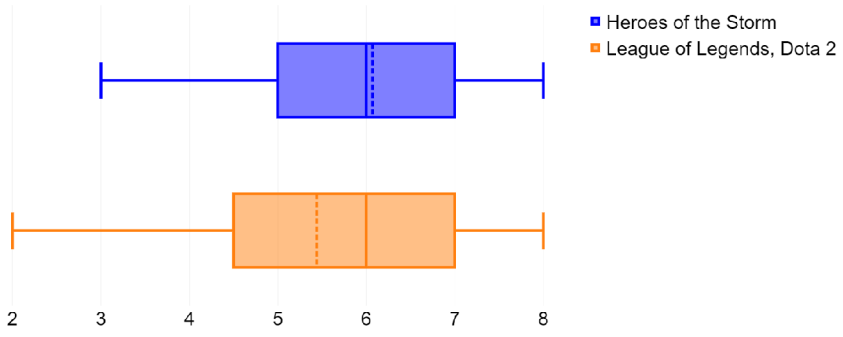


Figure 5.17: Question 6 - Effort

5.2.9 Question 7 - Towers of Doom

7.1 How many times the player, that played CASSIA, died? **(Category 4)**

7.2 In which lane the LAST death of the player, that played CASSIA, happened? **(Category 5)**

1. Top
2. Mid (Middle)
3. Bot (Bottom)

Participants were able to identify correct answers with high success rate in both groups, in both questions. For more details and correct answers see Table 5.16 and Table 5.15.

Table 5.15: Question 7.1 - Results

Answer	Hots (14)	Lol, Dota 2 (16)	Is Correct?
0	0% (0)	0% (0)	No
1	0% (0)	0% (0)	No
2	0% (0)	0% (0)	No
3	0% (0)	0% (0)	No
4	7.14% (1)	12.5% (2)	No
5	85.71% (12)	81.25% (13)	Yes
6	7.14% (1)	0% (0)	No
7	0% (0)	6.25% (1)	No
8	0% (0)	0% (0)	No
9	0% (0)	0% (0)	No
10	0% (0)	0% (0)	No

Table 5.16: Question 7.2 - Results

Option	Hots (14)	Lol, Dota 2 (16)	Is Correct?
1.	92.85% (13)	87.5% (14)	Yes
2.	7.14% (1)	6.25% (1)	No
3.	0% (0)	6.25% (1)	No

Answer confidence

Answer confidence was measured on a scale from 1 (Not confident at all) to 7 (Completely confident). Both groups were highly confident with some outliers. For results, see Figure 5.18.

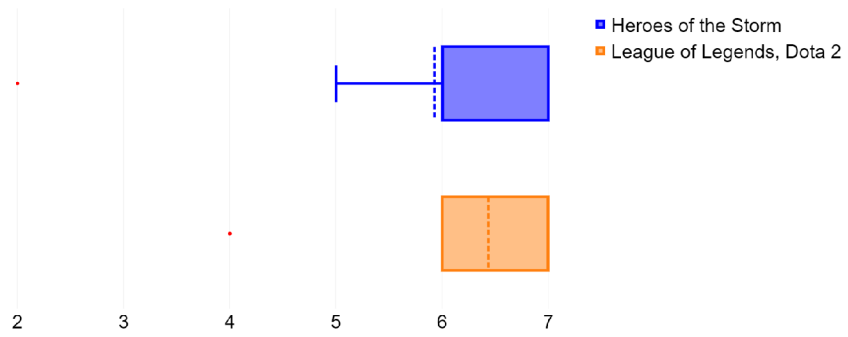


Figure 5.18: Question 7 - Answer confidence

Effort

Mental effort was measured on a scale from 1 (very, very low mental effort) to 9 (very, very high mental effort). *Heroes of the Storm* players considered the question as more demanding and their answers were also more variable. For results, see Figure 5.19.

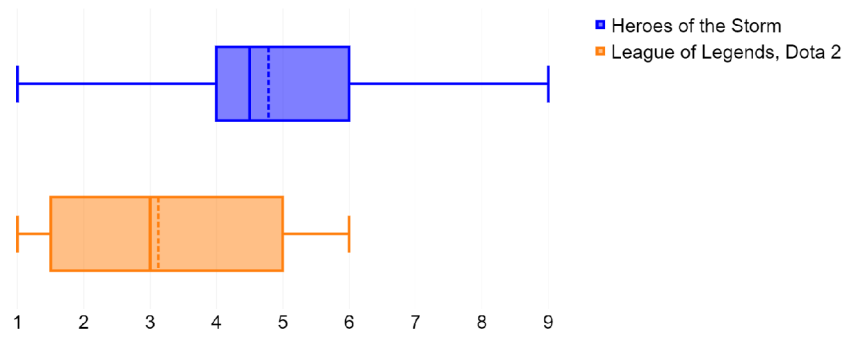


Figure 5.19: Question 7 - Effort

5.2.10 Question 8 - Towers of Doom

8.1 Which team managed to reach more objectives? **(Category 4)**

1. Blue
2. Red
3. Both equally

All participants answered the question correctly. For results and correct answers, see Table 5.17.

Table 5.17: Question 8.1 - Results

Option	Hots (14)	Lol, Dota 2 (16)	Is Correct?
1.	100% (14)	100% (16)	Yes
2.	0% (0)	0% (0)	No
3.	0% (0)	0% (0)	No

8.2 Which team finished the game with more levels? **(Category 4)**

1. Blue
2. Red
3. Both equally

Participants were able to identify correct answers with high success rate in both groups. For more details and correct answers see Table 5.18.

Table 5.18: Question 8.2 - Results

Option	Hots (14)	Lol, Dota 2 (16)	Is Correct?
1.	85.71% (12)	81.25% (13)	Yes
2.	7.14% (1)	0% (0)	No
3.	7.14% (1)	18.75% (3)	No

8.3 Was the boss captured in this match? **(Category 1)**

Participants were able to identify correct answers with very high success rate in both groups. For more details and correct answers see Table 5.19.

Table 5.19: Question 8.3 - Results

Answer	Hots (14)	Lol, Dota 2 (16)	Is Correct?
Yes	92.85% (13)	93.75% (15)	Yes
No	7.14% (1)	6.25% (1)	No

Answer confidence

Answer confidence was measured on a scale from 1 (Not confident at all) to 7 (Completely confident). Both groups were highly confident with some outliers. Answers of *League of Legends* and *Dota 2* players were also more variable. For results, see Figure 5.20.

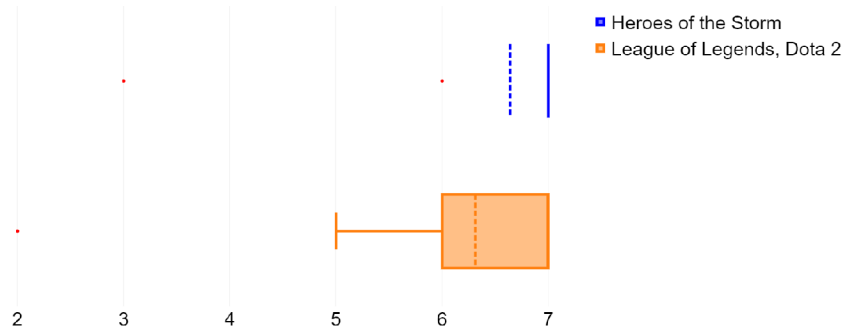


Figure 5.20: Question 8 - Answer confidence

Effort

Mental effort was measured on a scale from 1 (very, very low mental effort) to 9 (very, very high mental effort). Both groups considered the

questions similarly demanding while answers of *Heroes of the Storm* players were more variable. For results, see Figure 5.21.

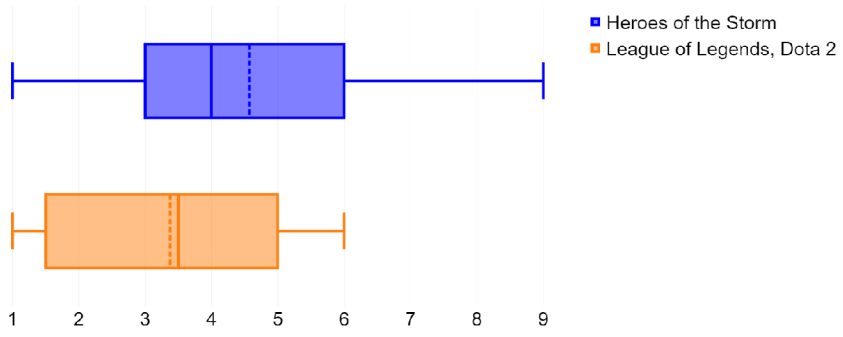


Figure 5.21: Question 8 - Effort

5.2.11 Question 9 - Cursed Hollow

9.1 Identify time frame, when the large number (3+) of structures were destroyed by BLUE team. Write you answer in following format: starting minute - ending minute (e.g. 1 – 3) **(Category 6)**

71.42% of *Heroes of the Storm* players answered correctly and 87.5% *League of Legends* and *Dota 2* answered correctly. For more details and correct answers see Table 5.20.

Table 5.20: Question 9.1 - Results

Answer	Hots (14)	Lol, Dota 2 (16)	Is Correct?
3 – 8	7.14% (1)	0% (0)	No
6 – 8	7.14% (1)	6.25% (1)	No
7 – 11	7.14% (1)	0% (0)	No
11 – 12	7.14% (1)	6.25% (1)	Yes
11 – 13	64.28% (9)	81.25% (13)	Yes
15 – 18	7.14% (1)	0% (0)	No
16 – 17	0% (0)	6.25% (1)	No

9.2 Check everything that also happened in the given time frame, you entered above **(Category 2)**:

1. Multiple (2+) members of BLUE team died
2. Multiple (2+) members of RED team died
3. BLUE team reached the objective
4. RED team reached the objective
5. Boss was captured
6. BLUE team gained more than 2 (>2) levels
7. RED team gained more than 2 (>2) levels

As there were two correct answers in previous question, we divided this question into two cases – see Table 5.21 and Table 5.22.

Table 5.21: Question 9.2 – Interval 11 - 12 Results

Option	Hots (1)	Lol, Dota 2 (1)	Is Correct?
1.	X		No
2.	X	X	Yes
3.	X	X	Yes
4.			No
5.			No
6.	X	X	Yes
7.			No

Both results combined (Table 5.21 and Table 5.22), the question had high success rate in both groups.

Table 5.22: Question 9.2 – Interval 11 - 13 Results

Option	Hots (9)	Lol, Dota 2 (13)	Is Correct?
1.	88.88% (8)	76.92% (10)	Yes
2.	100% (9)	100% (13)	Yes
3.	100% (9)	92.3% (12)	Yes
4.	0% (0)	0% (0)	No
5.	12.5% (1)	0% (0)	No
6.	100% (9)	84.61% (11)	Yes
7.	0% (0)	23.07% (3)	No

Answer confidence

Answer confidence was measured on a scale from 1 (Not confident at all) to 7 (Completely confident). Both groups were similarly confident, while answers of *Heroes of the Storm* players were less variable. For results, see Figure 5.22.

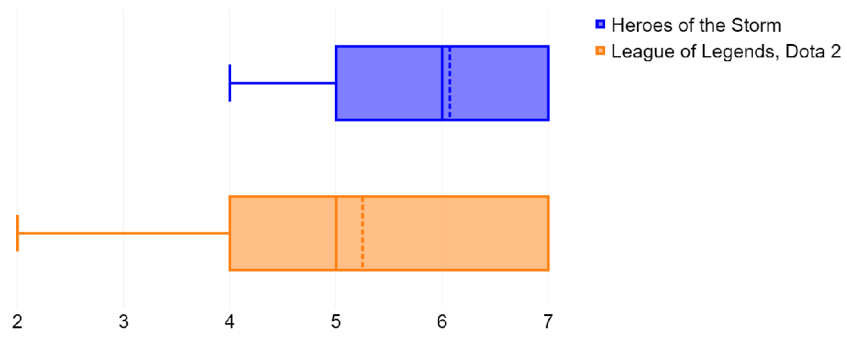


Figure 5.22: Question 9 - Answer confidence

Effort

Mental effort was measured on a scale from 1 (very, very low mental effort) to 9 (very, very high mental effort). Both groups considered

the questions almost equally demanding with same answer variability. For results, see Figure 5.23.

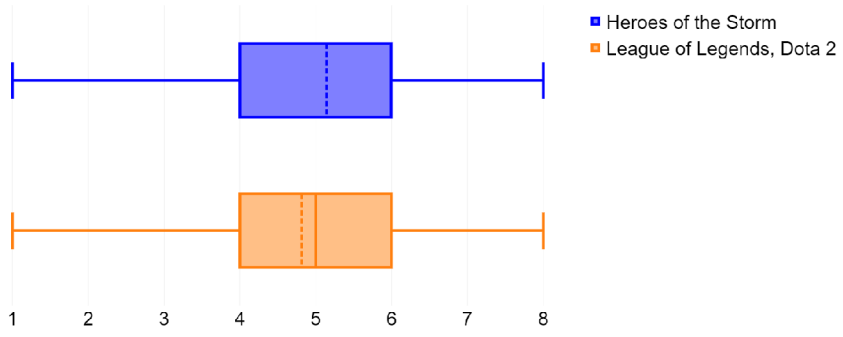


Figure 5.23: Question 9 - Effort

5.2.12 Question 10 - Cursed Hollow

10.1 Identify the game length in minutes (1 minute tolerance, non-numeric answer will be considered as incorrect) **(Category 1)**:

92.85% of *Heroes of the Storm* players answered correctly and 93.75% *League of Legends* and *Dota 2* answered correctly. For more details and correct answers see Table 5.23.

Table 5.23: Question 10.1 - Results

Answer	Hots (14)	Lol, Dota 2 (16)	Is Correct?
20	0% (0)	6.25% (1)	No
21	7.14% (1)	0% (0)	No
22	85.71% (12)	81.25% (13)	Yes
23	7.14% (1)	12.5% (2)	Yes

10.2 Time (in minutes), when the both teams reached level 10 (1 minute tolerance, non-numeric answer will be considered as incorrect) **(Category 1)**:

92.85% of *Heroes of the Storm* players answered correctly and 100% *League of Legends* and *Dota 2* answered correctly. For more details and correct answers see Table 5.24.

Table 5.24: Question 10.2 - Results

Answer	Hots (14)	Lol, Dota 2 (16)	Is Correct?
6	28.57% (4)	25% (4)	Yes
7	64.28% (9)	75% (12)	Yes
8	7.14% (1)	0% (0)	No

10.3 Time (in minutes), when the first structure was destroyed (1 minute tolerance, non-numeric answer will be considered as incorrect) **(Category 1)**:

85.71% of *Heroes of the Storm* players answered correctly and 75% *League of Legends* and *Dota 2* answered correctly. For more details and correct answers see Table 5.25.

Table 5.25: Question 10.3 - Results

Answer	Hots (14)	Lol, Dota 2 (16)	Is Correct?
4	7.14% (1)	6.25% (1)	No
7	42.85% (6)	37.5% (6)	Yes
8	42.85% (6)	37.5% (6)	Yes
9	7.14% (1)	18.75% (3)	No

10.4 First destroyed structure type? **(Category 1)**

All participants answered the question correctly. For results and correct answers, see Table 5.26.

Table 5.26: Question 10.4 - Results

Answer	Hots (14)	Lol, Dota 2 (16)	Is Correct?
Tower	100% (14)	100% (16)	Yes
Fort	0% (0)	0% (0)	No

Answer confidence

Answer confidence was measured on a scale from 1 (Not confident at all) to 7 (Completely confident). Both groups were highly confident, with similar answer variability and some outliers. For results, see Figure 5.24.

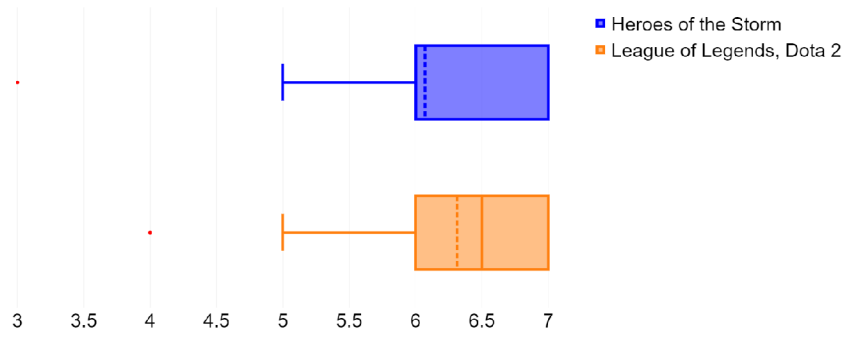


Figure 5.24: Question 10 - Answer confidence

Effort

Mental effort was measured on a scale from 1 (very, very low mental effort) to 9 (very, very high mental effort). Both groups considered

the questions similarly demanding with answers of *Heroes of the Storm* players were more variable. For results, see Figure 5.25.

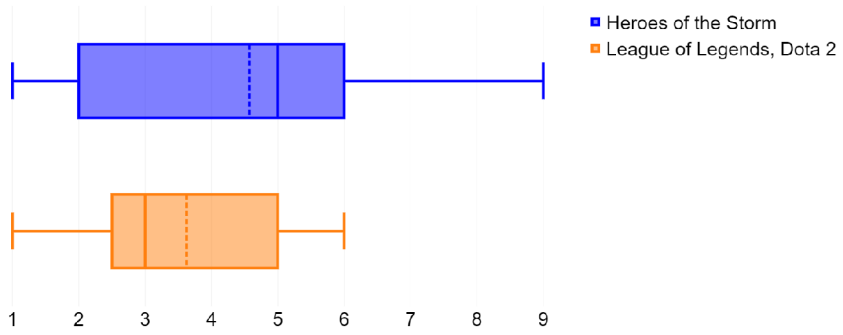


Figure 5.25: Question 10 - Effort

5.2.13 Conclusion and feedback

The usefulness of visualization parts was measured on a scale from 1 (Not useful at all) to 7 (Very useful). Participants considered controls/-filters and legend as the most useful parts (see Figure 5.29 and Figure 5.30) together with the perspective view (see Figure 5.26). Their opinion about side view and top view was neutral with a lot of variability (see Figure 5.27 and Figure 5.28).

How useful was the 'Perspective' for you?

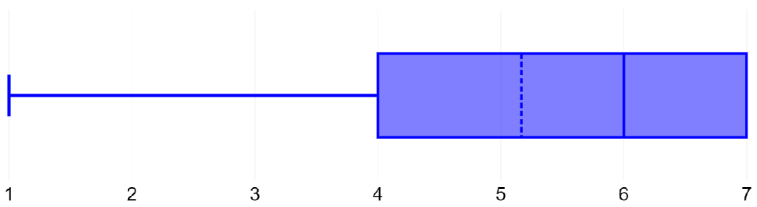


Figure 5.26: Feedback – Perspective

How useful was the 'Side View' for you?

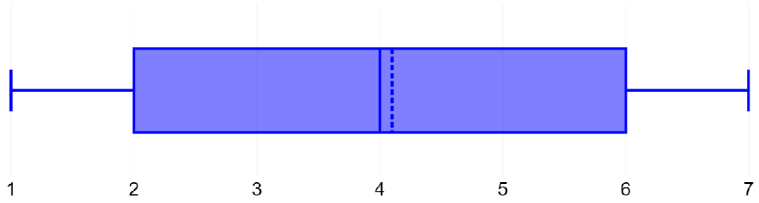


Figure 5.27: Feedback – Side View

How useful was the 'Top View' for you?

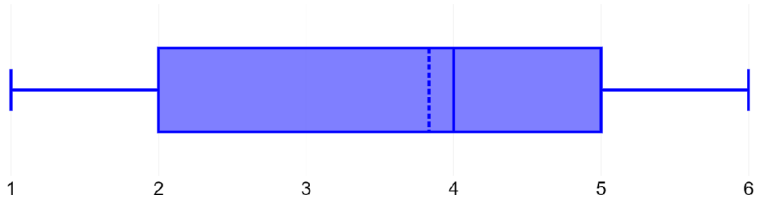


Figure 5.28: Feedback – Top View

How useful was the 'Legend' for you?

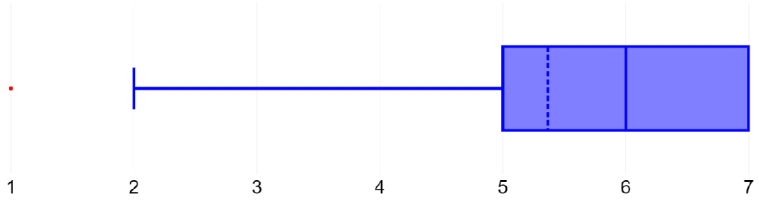


Figure 5.29: Feedback – Legend

How useful was the 'Controls/Filters' for you?

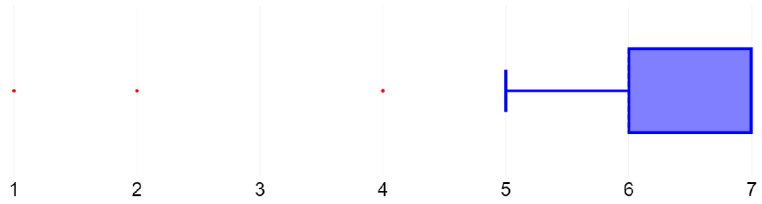


Figure 5.30: Feedback – Controls/Filters

In following sections, the numbers in brackets represent how many participants made a given statement.

Features, that users repeatedly liked:

- Visualization of player (hero) movement (3)
- Distinguishable markers for game events (7)
- Adjustable map position (2)
- Clear relationship between events and their timing (5)
- Intuitive navigation, controls/filters (9)

Weaknesses, that users repeatedly pointed out:

- Respawn of players is poorly visualized (3)
- Color-coding of players, hard to distinguish the color (6)
- Movement of the map using seconds feels clunky (3)
- Not clear what colored structures mean - if the team destroyed the structure or suffered a loss (2)

Suggested visualization improvements:

- Top and side view to be orthogonal or at least have an option to switch between (5)
- Better respawn visualization (2)
- Hovering over the icons could provide additional information (4)
- Add controls description to the legend (3)
- Option to enlarge specific time frame to provide more detailed information (5)
- Ability to highlight one or group of players (5)

Suggested data to be visualized and additional features:

- Talent choices (4)
- Post-game statistics (3)
- Representation of monster camps and minion waves (5)
- Numeric information as damage in team fight, healing done, experience contribution etc. (9)

6 Discussion

Our aim was to visualize data using single adapted visualization technique, that have not yet been used to visualize in-game data and evaluate how effectively the developed tool and the adapted visualization technique can be used to analyze played *Heroes of the Storm* matches by group of potential users – players. In the following part research questions are answered one by one.

- Can users understand and use a space-time cube system effectively to analyze a *Heroes of the Strom* match?

The data suggest that players were mostly able to identify required information from the visualization, except for question 5 and question 6.1. Both questions examine the ability to detect respawn of players. The reason for low success rate, might be the pointed out poor visualization of players' respawn. Also questions 6.2 and 6.3 have considerably lower success rate while both examine the ability to distinguish grouping of players. The result of mentioned questions suggests, that it is not clear, when players are moving in groups and interacting together.

- Are there performance differences in terms of accuracy of deducted information between *Heroes of the Storm* players and other MOBA players, such as *League of Legends* and *Dota 2* players?

In general the data support the theory that *Heroes of the Storm* players were slightly more successful in terms of total score, but the difference was marginal, so knowledge of game specific mechanics is not a requirement but rather a slight advantage, e.g. Question 1 (Table 5.4), Question 8.2 (Table 5.18), Question 8.3 (Table 5.19).

- Are there performance differences in terms of accuracy of deducted information between *Heroes of the Storm* players and other MOBA players, such as *League of Legends* and *Dota 2* players, for specific categories of questions?

Looking at the groups' performance per question category, question 3 – category 8 is a perfect example where the deeper knowledge of game specific mechanics is reflected. *League of Legends* and *Dota 2* players listed mostly simple, general insights while *Heroes of the Storm* players came up with more complex assumptions. Other than that, the results of question categories, that required minimal to none game specific knowledge were almost identical – category 1. Bigger impact on the success rate had content of question, rather than the category.

- Are there differences in terms of answer confidence and effort required to answer the questions between *Heroes of the Storm* players and other MOBA players, such as *League of Legends* and *Dota 2* players?

The analysis identifies, that confidence of the answers is closely connected to the knowledge of game specific mechanics. The difference in the answer confidence while performing tasks, that consisted of simple visualization reading or counting the event occurrences, was marginal. On the other hand, if the question examined the ability to read or deduct game specific situation, the difference was more significant – *Heroes of the Storm* players were more confident answering such questions.

Surprising is, that in general, *League of Legends* and *Dota 2* found it easier to perform the given tasks in comparison to *Heroes of the Storm* players. The reason might be, that *Heroes of the Storm* players were trying to figure out more in-depth insights and assumptions about the match, while answering the questions.

Our results also show that novice users are generally more error prone when answering simple questions – categories 1, 4, 5. It can be clearly seen, that the tasks, that required users to analyze nontrivial spatiotemporal patterns with the tool – categories 2, 3, 6, can also be solved quite successfully using the adapted space-time cube representation, which support the hypothesis, that the real benefit of the space-time cube is in supporting users when observing spatiotemporal patterns that require a "bird's-eye" view of the data set [58, 59, 56].

Users consider the interactive and descriptive parts of the tool as the most useful ones together with the perspective view. Players appreciated distinguishable markers for game events and intuitive

navigation and controls. Color-coding of players seemed to be harder to distinguish, but the questions examining exactly that, had a relatively high success rate. Additional filters, highlighting and ability to switch between the perspective and orthogonal camera were some of the suggestions for future work. *Heroes of the Storm* players also suggested to include other missing game specific mechanics as talent choices and representation of monster camps. In general, players were also interested in more raw data as damage dealt, healing done and other numerical statistics.

We have primarily shown that there is empirical evidence that our adapted space-time cube representation of in-game data does indeed give users an ability to understanding of complex spatiotemporal patterns together with general match specific information, all in single visualization.

6.1 Limitations

Space-time cube in combination with online questionnaire might be difficult to evaluate. Once evaluated, there is a delicate trade-off between drawing too wide and too narrow conclusions from the findings. There is also a danger that empirical evaluation of information visualization interfaces might be avoided altogether due to the difficulties in producing results that generalize convincingly. Several researchers have reflected on this before [75, 76]. In our case, we are aware, that the number of recruited *Dota 2* was not sufficient to create a separate group of players per each covered MOBA game representative.

We reemphasize that every effort was made to ensure that the experiment would be as unbiased as possible, but as some of the respondents know the author personally in comparison to those, recruited using online communities, an effort to answer the survey questions might differ per respondent.

6.2 Future work

Based on the results, we suggest two lines of future work. First, the comparison of success rate and response time using this adapted space-time cube representation and combination of multiple more

commonly used 2D techniques to visualize in-game data. We have shown that this space-time cube can be used effectively to analyze in-game data. But we would also like to find out, if the approach is more effective in comparison to commonly used 2D techniques (e.g. timeline of game events in combination with movement visualization on a 2D map), while analyzing complex spatiotemporal patterns using same domain – *Heroes of the Storm* matches.

Second, using this adapted space-time cube representation to visualize in-game data of other competitive genres (e.g. first person shooters – *Counter Strike: Global Offensive*, *Overwatch*, *Valorant*, real-time strategies – *Starcraft 2*, battle royal games – *Apex Legends*, *Fortnite*, *Players Unknown Battleground*) and measure whether users are able to effectively analyze gameplay using the adapted space-time cube representation in given setting.

7 Conclusion

Within the thesis, we described the MOBA genre together with game examples. We presented commonly used visualization techniques, that are applied to visualize various types of data and visualization technique space-time cube together with its uses up to date. We discussed, how can the technique spate-time cube be used to visualize in-game data and to support the discussion, tools, that allow users to parse and visualize *Heroes of the Storm* matches, were implemented. Whether and how effectively can the visualization be used to analyze *Heroes of the Storm* matches, was evaluated via conducted user study. We have shown, that the visualization can be effectively used in given context. Lastly, we acquainted readers with potential limitations of our research and proposed two lines of future work – comparing the tool performance to combination of 2D techniques in the same context and using the tool and measure its performance in a different context.

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A An appendix

Files:

1. WebApplication.zip
2. ExampleReplayFiles.zip
3. ReplayParser_Build.zip
4. ReplayParser_Code.zip

Site: `https://sessax1543.github.io/hotsvisualizer/index.html`