Puzzle-Mopsi: Location-based puzzle game

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Abstract: As a novel game type, the location-based game has been loved by many players in recent years. Unlike many traditional video games, players can interact more effectively with reality through the game. However, most mainstream developers are currently publishing this type of game on mobile platforms, players on non-mobile terminals have a limited number of games to choose from. We developed a location-based puzzle game: Puzzle-Mopsi (cs.uef.fi/o-mopsi/PuzzleGame). It can support playing on the computer web side. Puzzle-Mopsi combines the features of puzzle game and location-based game. All targets in the game consist of geotagged images. Players must match a set of target images given by the system to their corresponding positions on the map. The form of the puzzle requires the player to think about the relationship between the image and the geographic information in the map or other imagery in the game. In this thesis, we will detail the technical construction of Puzzle-Mopsi and the theoretical knowledge that may be involved.

Keywords: Location based game, Puzzle game, GIS, Web page

Foreword

This thesis was done at the School of Computing, University of Eastern Finland during the 2021-2022.

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List of abbreviations

AJAX	Asynchronous JavaScript and XML
API	Application Programming Interface
CDAE	Color Decomposition based Adversarial Examples
CGIS	Canadian Geographic Information System
CNN	Convolutional Neural Networks
DOM	Document Object Model
GIS	Geographic Information System
GPS	Global Positioning System
ICT	Information and Communication Technology
IP	Internet Protocol
LBS	Location Based Service
LBGs	Location Based Game
MOPSI	Mobile Location-based Platform
MST	Minimum spanning tree
OSM	OpenStreetMap
PC	Personal Computer
RFID	Radio Frequency Identification
TSP	Travelling Salesman Problem
URL	Uniform Resource Locator
UWB	Ultra-Wide Band
WIFI	Wireless Fidelity
WWW	World Wide Web

CONTENT

1. INTRODUCTION

In the 21st century, the network plays an important role in various aspects of human life. From the promulgation of the E911 directive in 1996 to the introduction of the global positioning system, web 2.0 paradigm and 3G broadband wireless services in 2005, *location-based services* (LBS) has been developing favorably (Bellavista et al., 2008). With the continuous update and progress of LBS technology, *location-based game* (LBG) as an application direction of LBS is also constantly innovating. By combining real objects with virtual maps, researchers have created a lot of LBGs. For instance, *Pokémon GO* (Rauschnabel et al., 2017), *Geocaching* (Schlatter & Hurd, 2005), *Ingress* (Majorek & Du Vall, 2016), and *O-Mopsi* (Tabarcea et al., 2013). By introducing the functions of the global positioning system and personal mobile data circulation, these games allow people to interact with the map itself in an interesting way (Lammes & Wilmott, 2018). The creation of these games also led researchers to the discovery that LBGs could be combined with other things, especially in the context of the COVID-19 epidemic that started at the end of 2019 (Laato et al., 2020). The epidemic has had a great impact on people's lives, such as restricting travel. How to allow players to experience LBGs without travelling has become a question worth exploring.

We propose a game that combines puzzle game and location-based game: Puzzle-Mopsi. The main idea is to match the picture with geographic information to the coordinates on the map. The data source for the game is an image dataset provided by O-Mopsi. The game is presented in (Fränti & Kong, 2022), and its details covered by this thesis.

This thesis consists of 7 chapters between the introduction and conclusion. Chapters 2 and 3 clarify the background and introduction related to location-based, including application, service, and games. The Chapter 4 is about the related concepts and meanings of puzzle games and briefly introduces several mainstream puzzle games. The description of the actual content of this article will begin with Chapter 5. We'll start by explaining our motivation, the main rules of the game, and an example to demonstrate a possible way to solve the puzzle. In Chapter 6, we will introduce the overall design of the game in detail, especially the challenges encountered in the development process in Chapters 6.3-6.5.

2. LOCATION BASED APPLICATIONS

Many user-centric, location-based applications are expanding through *geographic information system* (GIS) and *global positioning system* (GPS) technologies. Applications can provide mobile users with *location-based services* (LBS) via devices that support wireless communications and mobile computing (Dao et al., 2002). Most of today's popular social software's use location-based content such as geographic location or real-time location.

For example, as a social platform with one of the largest numbers of registered users in the world today, Facebook can choose to add a location when users share their news. In this case, users can make the published information more complete (Figure 1). The first image in Figure 1 shows the user interface for creating posts. Users can click the red mark pointed by the arrow in the lower right corner of the interface to add location. These launches search of location and user can enter the name of the location or choose directly from the list of recommended locations. Once selected, the location information will appear in the published post page.

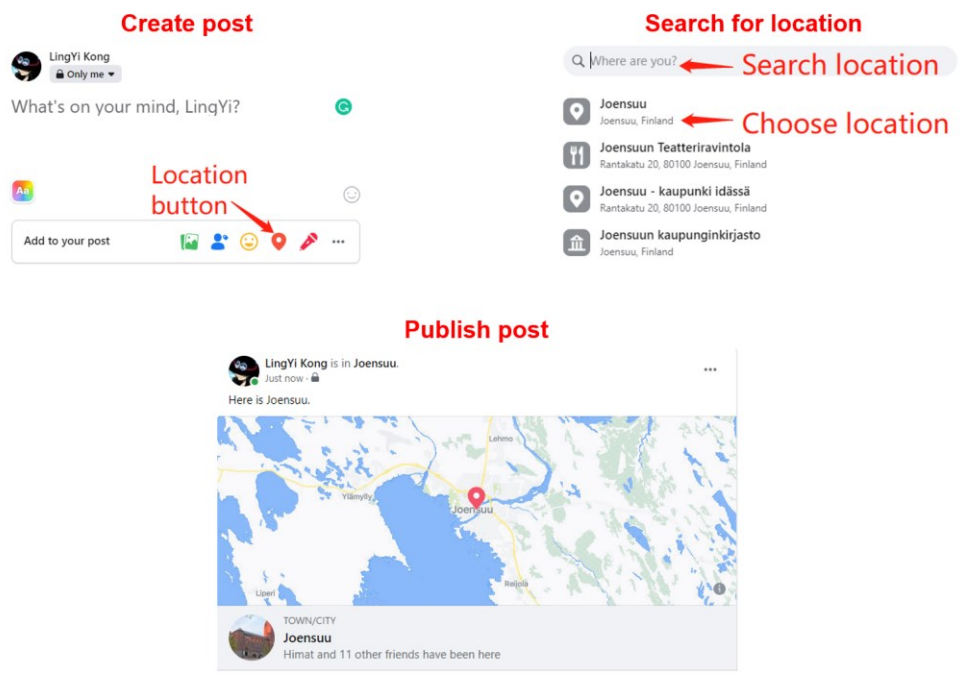

Figure 1: Location information added via Facebook.

2.1 GEOGRAPHIC INFORMATION SYSTEM

In 1963, the *Canadian geographic information system* (CGIS) was created and three years later in 1966, researchers working with CGIS first coined the term "geographic information system" (Maliene et al., 2011). *Geographic information system* (GIS) is a computer system for capturing, storing, querying, analyzing, and displaying geospatial data (Eray, 2012). Geospatial data refers to the location and attributes of objects with spatial characteristics (Gortari et al., 2012). For example, when describing a statue, its location (geographical location) and its properties (size, texture, shape, etc.) are described accordingly. By 1995, the UK was the first to use standard-scale digital maps to cover the whole of the UK (Morris & Therivel, 2005).

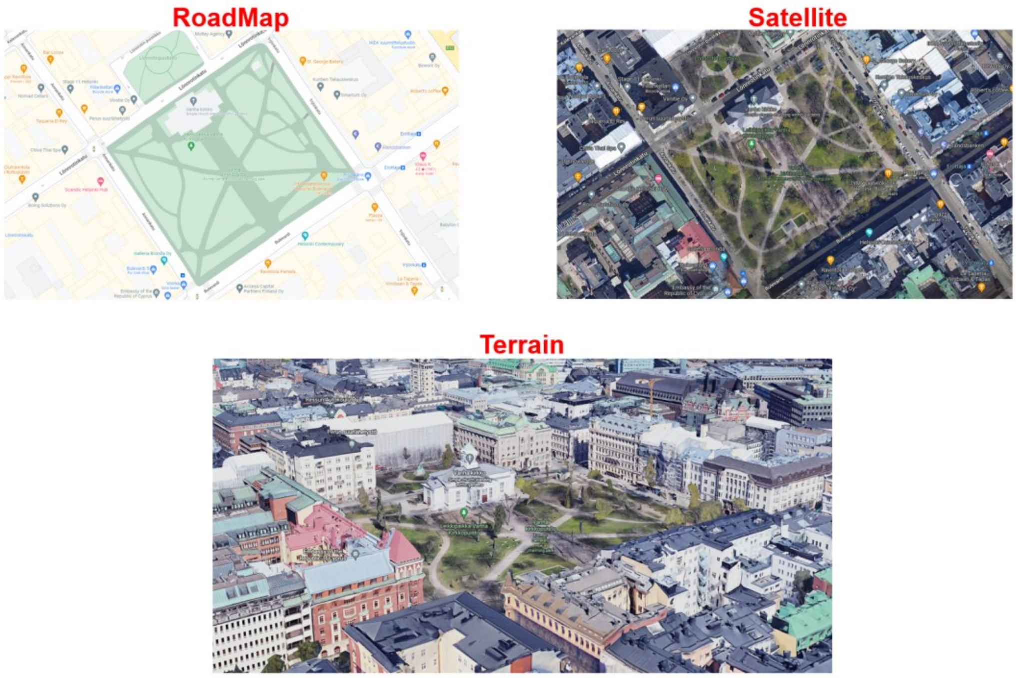

Figure 2: Map types on the Google Maps.

Since then, GIS has entered a stage of rapid development. Now on google maps we can see the geographic information of almost all regions in the world. Not only that, users can also observe places on google maps from different modes. Figure 2 shows the three map types possible on google maps: Roadmap, Satellite and Terrain. The roadmap mostly depicts the default roadmap view. Among the three types, it is the most common and relatively the most concise. Satellite Image shows a Google Earth satellite image. The user can see the real image in the corresponding geographic location more clearly. Terrain Image shows a physical map based on terrain information. The main difference between terrain and satellite is that the terrain is presented through three-dimensional graphics. The map can be classified in more details, for instance, on OpenStreetMap, the roadmap can be divided into Standard, CyclOSM, Cycle Map, Transport Map, ÖPNVKarte and Humanitarian. In the follow-up development, LBS technology derived from GIS is considered to be one of the most promising applications in the direction of GIS at present (Sadoun & Al-Bayari, 2007).

2.2 LOCATION BASED SERVICES

Location-based services can be defined as any associated service that takes into account the geographic location of an entity (Dey et al., 2010). Compared with the previous GIS, the development history of LBS can be said to be more rapid (Figure 3). From the E911 (Lock location by user IP) directive passed by the US government in 1996 to the advent of the First GPS-capable phone (iPh-one) in 2008 until today, LBS has played an active role in many aspects of people's lives.

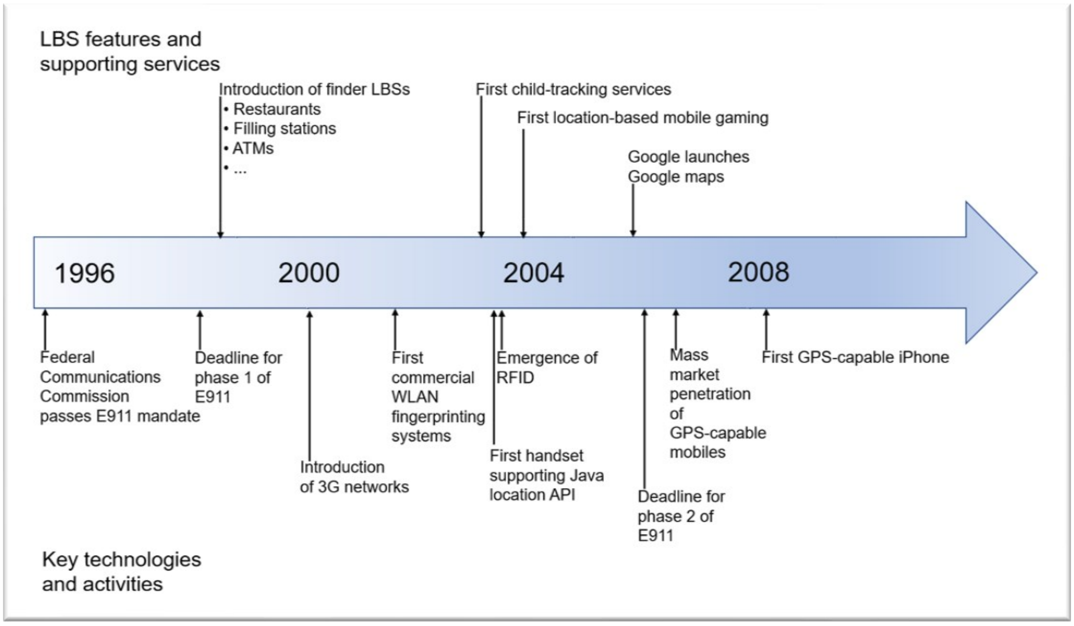

Figure 3: The evolution of location-based services (Bellavista et al., 2008).

LBS can be classified as *triggered* and *user-requested* from the perspective of interacting with the user (D'Roza & Bilchev, 2003). Triggered LBS can be understood as retrieving the location of a given device if the triggering conditions are met under pre-set conditions. A possible example is that when the user makes an emergency call, the mobile network operator will automatically trigger the corresponding automatic location request. User-requested can be interpreted as a response to a user's location request and will be used in subsequent requests for location-related information (Bellavista et al., 2008). Another example is user's route navigation, it belongs to user requested.

At the application level, LBS can also support a reasonable combination of user-recorded data and electronic maps (Dao et al., 2002). For example, the label shown in the circle in Figure 4 represents a location by a river. The information we can get from the map is the relationship between the location and the surrounding environment on the ground and the possible route to reach. Google maps provides us with more possible information (Figure 5) including real pictures, introductions, and reviews.

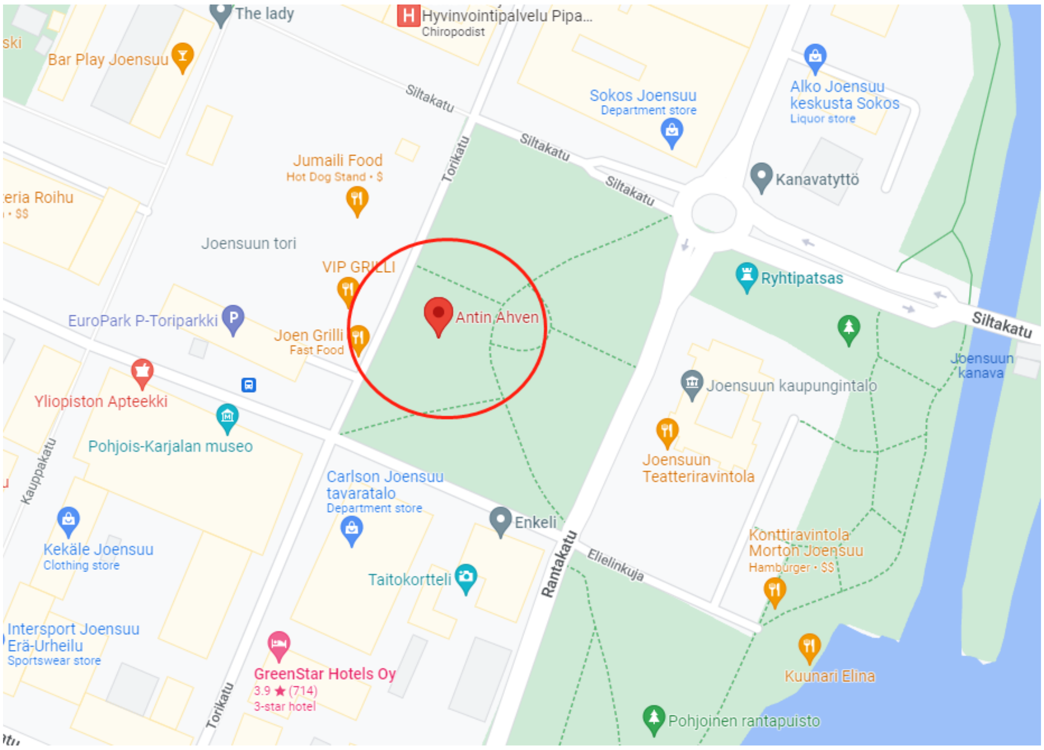

Figure 4: Example of a target location in Google Maps.

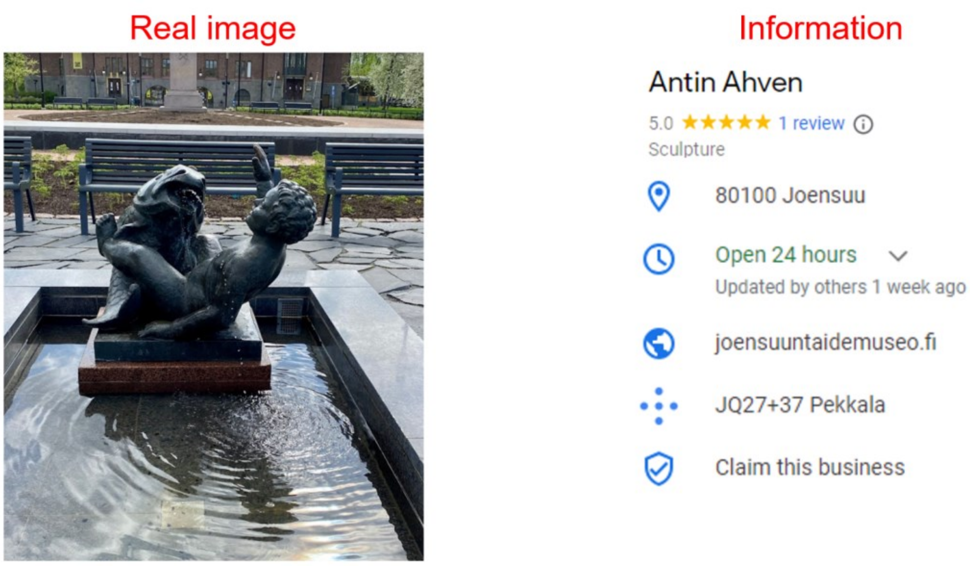

Figure 5: More information about the target.

Associating locations on the map with more relevant information is an important challenge. The main solution is to parse the *document object model*

(DOM) of the web page and select the tags that contain the desired ones (Fazal et al.). During the data transmission process, the latitude and longitude information of the location will be matched with the latitude and longitude information in the image. If the latitude and longitude are the same, other associated information will be stored with the image in the label of that location.

3. LOCATION BASED GAMES

What is the game? Salen and Zimmerman (2004) proposed the following definition: "A game is a system in which players engage in artificial conflict defined by rules, resulting in quantifiable outcomes." Games, as an inseparable part of human life, have been developing with the continuous progress of human society. Location-based game (LBG) is a new concept in the video game field, and it stems from the use of mobile and geospatial technologies in real-world games (Ahlqvist, 2017). Geo-caching is the oldest and still popular location-based game (Fränti et al., 2017). The *Cache Owner* hides the geocache at a certain location and record its location with GPS. The player will search the corresponding geocache through the GPS information (Figure 6).

Figure 6: Geo-caching in Finland (https://www.nationalparks.fi/geocaching).

Many LBGs have appeared but only few remained popular after the Geo-caching published more than ten years ago. Early LBGs faced several technical issues, such as the accuracy and stability of GPS signals, internet, and battery life (Fränti et al., 2017). With the advancement of smartphones and GPS technology, many interesting LBGs have been recently developed such as Pokémon GO and Ingress (Figure 7). These games use digital maps such as Google Maps and Open Street Maps and guide players through these maps to experience various interesting activities (Lammes & Wilmott, 2018).

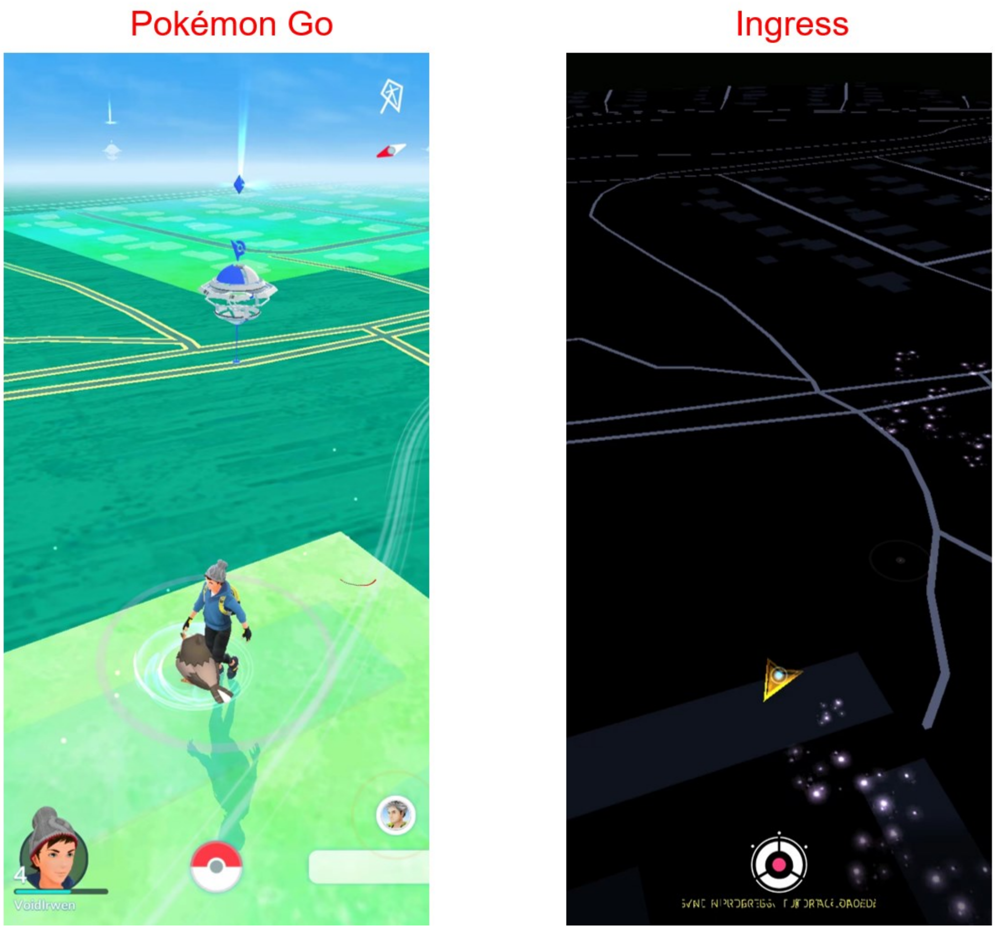

Figure 7: Screenshots of two location-based games.

We will discuss LBGs through the following points:

- The way to use location and how to verify it,
- The value and significance of the game,
- An example of an LBGs: O-Mopsi.

3.1 USE AND VERIFICATION OF LOCATION

LBG gameplay requires positioning and tracking of the player's location (Ferreira et al., 2018). Lehmann (2012) divided LBGs into the following four categories from the perspective of how the location is used (Figure 8):

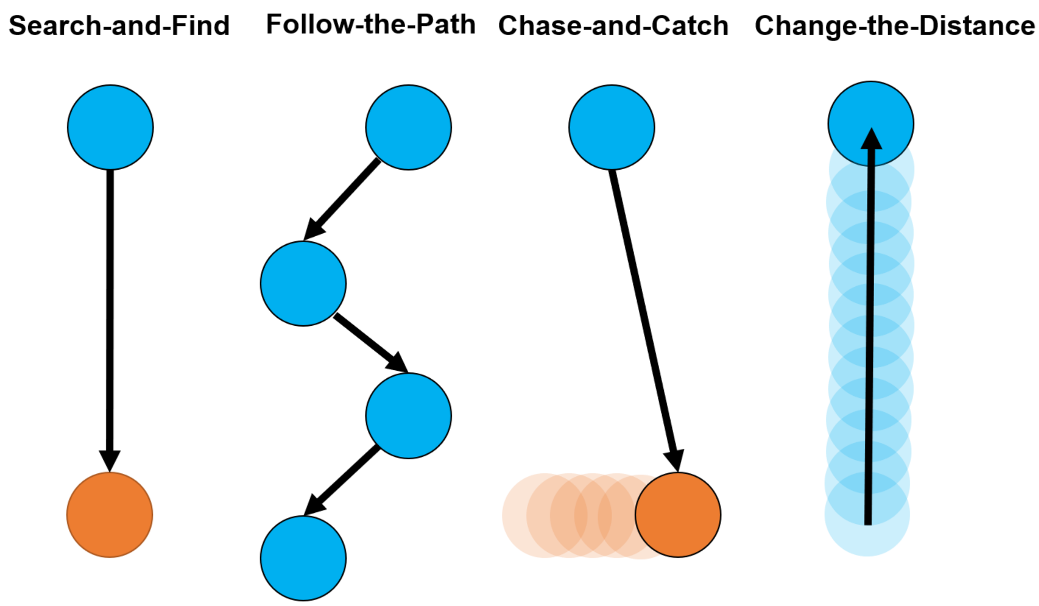

Figure 8: Graphical overview over the four categories of LBG (Lehmann, 2012).

Search-and-Find is the most popular categories. In this category, players need to focus on finding the target location moving to that location. The location of the target point is fixed. The player builds a connection with a virtual network and reality through this fixed location (Ferreira et al., 2018). A typical target example is geocache in Geo-caching and 'Pokémons' in Pokémon GO.

Follow-the-Path and *Search-and-Find* have the same requirements for the target point. Different from *Search-and-Find*, *Follow-the-Path* requires a fixed target point, while more important is how the player comes to the target location. This category will show the player a preset route before the game starts. There may be penalty if the player does not choose to follow the predetermined route during the game. This rule can be understood as online orienteering where player must find the target in the predefined order. In *Tourality*, if the player chooses a shortcut regardless of the order, they will be punished by deduction of points.

Chase-and-Catch is different from the first two categories. It puts more emphasis on dynamic position changes. Player needs to make his own judgments in real-time according to the moving target and implement them quickly. A fun game example, *Zombies, Run* (Witkowski, 2018), player will run in the real world to escape the zombie who is chasing the player in the virtual world.

Change-of-Distance is like *Chase-and-Catch* as it also does not need to sprint to a fixed point and it has no fixed path to limit. The difference is that *Change-of-Distance* conceals the need for location and focuses more on the movement itself. This makes it popular among many sports and fitness enthusiasts. *Ring Fit Adventure* (Jiang & Tham, 2022) is a good example. Player can try running, jumping, squats and other sports in the game. Player can perform these movements on a small scale by interacting with Ring-Con.

Figure 9: Screenshot when using Ring-Con movement.

Verification of location

Most LBGs require the location of the user and target. How to verify the location is a matter of concern and discussion. The current mainstream verification methods are GPS, Cell-ID, IP-Geolocating, and photography (Lehmann, 2012). Since the accuracy of positioning technologies varies widely between indoor and outdoor, researchers have attempted to provide more possible positioning methods at indoor ranges. For the verification methods of indoor users, there are WIFI, Bluetooth, radio frequency identification (RFID), and ultra-wide band (UWB) (Qin et al., 2021).

The technology of verifying the location can be divided into the positioning technology based on infrastructure and the positioning technology without infrastructure. The *infrastructure-based positioning* technology needs to arrange specific auxiliary positioning equipment in advance. When the device receives the signal of the auxiliary equipment, the positioning calculation is performed. The most typical example is GPS. When the signal is stable, the accuracy that GPS can achieve is 30-500 cm.

There are many kinds of positioning technologies without infrastructure, such as Cell-ID, WIFI, IP-Geolocating. Compared with infrastructure positioning technology, it does not require specific equipment support, which can reduce a large part of the cost. The downside is that the accuracy is often not comparable to GPS. For example, Cell-ID can only determine that the user is in a certain cell. An emerging CCpos positioning system (WIFI fingerprint positioning system based on CDAE and CNN) currently has an accuracy range of 1.05 - 12.4 m (Qin et al., 2021).

3.2 SIGNIFICANCE OF THE GAME

Many traditional video games are just for entertainment. LBG tries to combine aspects such as education, culture, data collection, and promotion with the game itself in its unique way.

Physical Activity

How can players become healthier while experiencing the game? LBG provides some possibilities. Most LBGs require the player to perform some levels of movement, such as moving from one place to another. Compared to traditional games, LBG puts more emphasis on physical exercises in the game (Laato et al., 2019). It could even be argued that some LBGs are designed for exercise (Althoff et al., 2016). Lots of interesting settings allow players to exercise themselves while enjoying the game. Such as catching Pokémons in Pokémon GO, escaping the pursuit of zombie in *Zombie*, *Run*, and finding the corresponding location of image in O-Mopsi.

Education

Information and communication technology (ICT) has been integrated into every aspects of student life today (Huizenga et al., 2009). Combining the knowledge with emerging technology is a question of inquiry. Compared to traditional learning methods, learning through play provides today's young people with new ways of learning and enables them to engage in meaningful learning more successfully (David Williamson Shaffer, 2006; Gee, 2003). LBGs for educational purposes can primarily support situated language learning, participatory simulations and educational action games (Avouris & Yiannoutsou, 2012). Players often need to watch the screen and interact with the real world during the game. In communicating with real world, players can naturally integrate into their situation to explore and learn. For example, Oppermann et al. (2018) created an online authoring system *MILE* for a LBG. This authoring system supports combining multiple teaching tasks into an educational geography game. Supported tasks include but are not limited to knowledge of location culture, shortest paths, and troubleshooting of incorrect location information.

Data Acquisition

LBG can also acquire data generated by players to serve other players. The collected data can help to create more detailed maps. Like an infinite number of puzzles, players can add more geographic 'puzzle pieces' to the map in the process of experiencing the game. In O-Mopsi, for example, players can upload photos to create games. During the upload process, if the image itself does not have geographic information, it can also be added manually. Not only geographic information, for instance, name and introduction can be added to make the image information more complete. After players publish the game, a new level of custom gameplay will appear on the O-Mopsi map. As players continue to create and publish, the information carried on the map has been increased.

3.3 O-MOPSI

O-Mopsi is an outdoor orienteering game, where players use smartphones to find real-world targets (Fränti et al., 2017). Similar to traditional orienteering, O-Mopsi will provide players with a map showing all the target locations. The difference is that players are no longer limited to a prescribed order (Figure 10). The lack of a fixed sequence means that players must plan a route that is as short or easy as possible based on their knowledge and understanding. This corresponds to the open loop *travelling salesman problem* (TSP). Not only the strategy of the mind, the player's physical strength and athletic ability are also important factors that determine the outcome of the game.

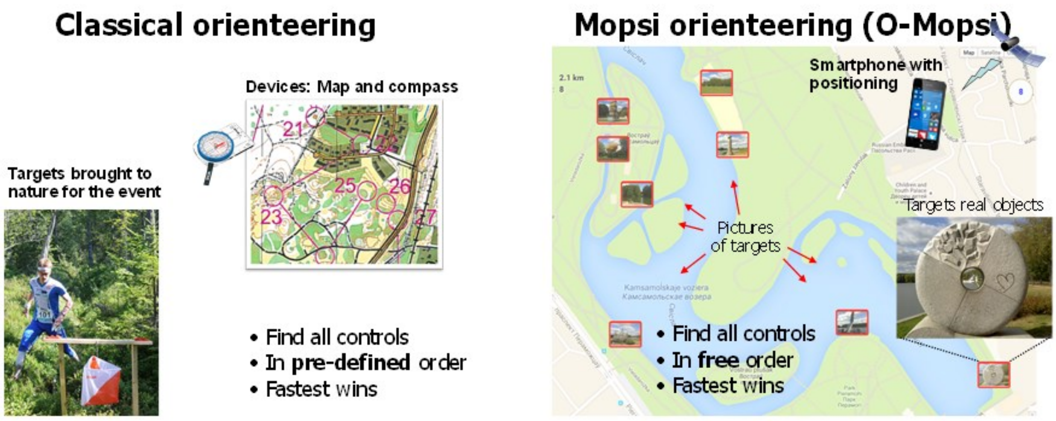

Figure 10: Traditional orienteering (left) versus location-based orienteering game called O-Mopsi (right) (Fränti & Fazal, 2020).

Since 2013, O-Mopsi can be experienced on Android, iPhone, and Windows phones (Fränti et al., 2017). On the game's web page, players can query the image set of all games, the play records of all players, and game path planning recommendations. Not only that, if players log in to their account, they can also create new O-Mopsi games on the web. When players try to create a new game, they can choose from Mopsi photos, and Mopsi services or upload their photos as game goals (Wan, 2014). When uploading an image, players can modify the photo name, add a short description and confirm the coordinates of the image on the map (Tabarcea et al., 2013). After the image is uploaded successfully, it will be stored in the database in the form of Figure 11.

Photo ID: 010910_20-25-19_1836823942.jpg
Photo name: Joensuu Areena
Photo description: Sun set at Joensuu Areena
Latitude: 62.601468801642994
Longitude: 29.747247681237
Address: Länsikatu 27, 80100 Joensuu, Finland
City: Joensuu
Country: Finland

Figure 11: An example image and information in O-Mopsi.

4. PUZZLE GAME

To study puzzle games, there is a terminological question worth discussing: what exactly is a puzzle game? In our daily life, many people default puzzle as jigsaw puzzle game. In the perception of many people, there is an instinctive sense of the blurred line between what is called a game and what might be called a puzzle (Johnson, 2019). In fact, strictly speaking, the puzzles are static and single-player, which is different from the interaction that the game emphasizes (Karhulahti, 2013). As a puzzle game that integrates the two, it is necessary to fuse the features of the two elements of the puzzle and game. As a category of games, a puzzle game needs to control the overall difficulty (not too hard and not too easy) and provide enough fun. The characteristics of the puzzle make the puzzle game need a clear solution and a definite result. The overall game idea is to solve the puzzles provided by the designer through learning, thinking, and memory (Melero et al., 2011). Players are motivated by finding solutions and interested in continuing to solve the next puzzle.

Figure 12: Luban Lock

The earliest puzzle games have not been formally defined. According to our search, the earliest possible puzzle game is Luban lock (Figure 12). Lu Ban, the originator of Chinese architecture, invented it around 500 BC. The entire lock body is composed of six wooden sticks that are the same size but different in the middle. Because of the tenon-and-mortise structure, the whole does not need any ropes or screws and other parts to help strengthen it to ensure firmness. Players need to disassemble or assemble step by step in a particular order. Puzzle game is now one of the most popular game categories. Below we will introduce several typical puzzle games.

4.1 JIGSAW PUZZLE GAME

The jigsaw puzzle game is one of the most popular puzzle games out there. For many people, when they see the word 'puzzle game' they automatically match it with a jigsaw puzzle game (Antonova & Bontchev, 2019). Each jigsaw puzzle game consists of a certain number of puzzle pieces. The player's task is to find the connection between these pieces and put them together to form a complete pattern or shape (Figure 13). The connection between pieces may come from the pattern drawn on the piece (front or back) or the shape of the piece itself. After successful splicing, each piece should form an interlocking relationship with the adjacent pieces (Huang et al., 2007).

Figure 13: Jigsaw puzzle game

The characteristics of jigsaw puzzles determine that there must be an irreplaceable connection between each piece and its adjacent pieces. When the number of pieces increases (100 pieces - 5000 pieces or more) or the connection becomes weaker (for example, the pattern features are more blurred, or even only solid colors) the game difficulty will become higher.

4.2 SUDOKU

Sudoku can be regarded as the most famous number puzzle game at present (Huang et al., 2007). The game is played on a 9 * 9 square. In these 81 squares, each row, column, and nine independent nine-square grids need to be filled with the numbers 1-9 (Figure 14). If any number in the same column, row or grid is repeated, then there must be an error in the numbers that have been filled in so far. The result of each Sudoku is unique. Players can gradually solve out the complete arrangement by finding the connection between numbers through their own logical thinking and memory ability.

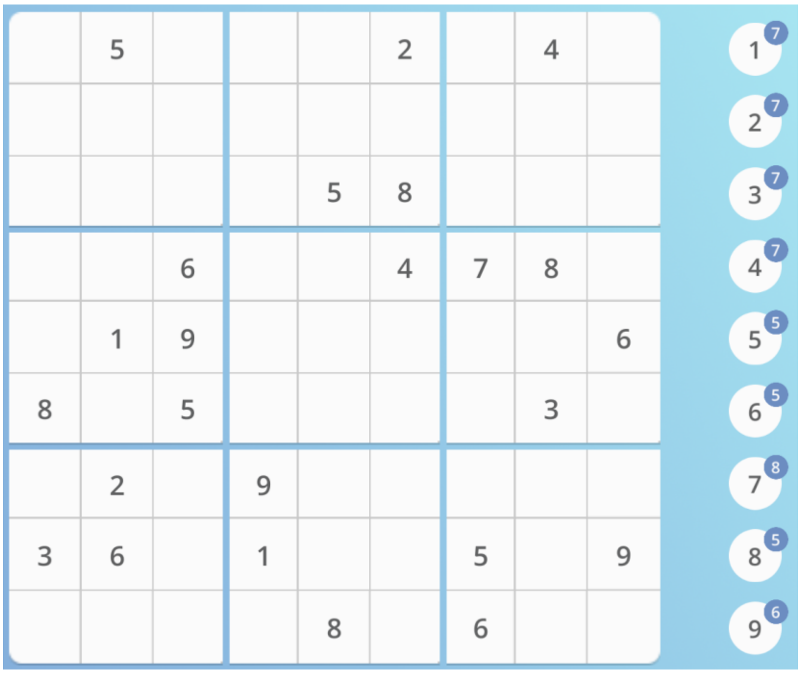

Figure 14: Video game 'Sudoku Universe' screenshot.

The difficulty of the game will appear on the hinted numbers. As shown in Figure 14, the designer will place some numbers in the square in advance. This is both a hint to the player and a limit to the overall number arrangement. When the number of hints is smaller or more spread out, the players search space will be larger. This means that players often need to go through more attempts and backtracking to get the correct answer.

4.3 ROOM ESCAPE

Escape Room is a novel type of puzzle game. The first real Escape Room was the 'Crimson Room' created by Toshimitsu Takagi in 2004 (Wiemker et al., 2015). The feature of the game is that it is no longer a single puzzle to be fixed, but there will be several different types of puzzles waiting for players to solve. Often a level of the game provides an overall backstory. Players will move to a closed environment to start the game after understanding the background of the story. Unlike many traditional puzzle games, Escape Room allows and supports multiplayer co-op. Players need to find useful information in the environment provided by the designer and use this information to connect with the puzzle. The blue crosses in Figure 15 are some possible clues. Due to the emphasis on the possibility of cooperation, some puzzle solutions even require two or more people to work together. This greatly enriches the playability and richness of the overall game.

Figure 15: Room Escape (https://insomniaescaperoomdc.com/the-alchemist-2-0-virtual-escape-room).

5. PUZZLE-MOPSI

Puzzle-Mopsi is a puzzle game based on image location information. The player needs to match a set of images given by the system with the location on map corresponding to the image. The way to match is to drag the image into the slot on the map. These slots are the actual geographic locations of the images. This game is web based and can be played at: cs.uef.fi/o-mopsi/PuzzleGame.

5.1 MOTIVATION

In the review of the previous two chapters, it is not difficult to find that there is the possibility and significance of fusion between LBGs and puzzle games. Not only that, Puzzle-Mopsi can also try to overcome or avoid problems that still exist in many LBGs and puzzle games. Below we will discuss the LBGs and puzzle games separately.

LBGs

In the current game field, many game designers choose to release LBGs on mobile platforms alone. This is not only because of the dependence on location, smartphone penetration also makes it more convenient to promote LBG. However, the result of focusing on mobile and publishing only on mobile has indirectly led to the development of LBGs on the desktop and laptop far less than on the mobile side. On the other hand, in the process of players experiencing LBGs, the overall experience of the game may be very different due to many external factors (Figure 16). The presence of these potentially unpredictable data (location-based data) makes the player's gaming experience very inconsistent (Jacob & Coelho, 2011). Not only that, but privacy concerns, location uncertainty, cultural barriers, and even player fitness and speed can all have an impact on expected game outcomes (Ferreira et al., 2019).

Figure 16: The effect of having GPS position (left), losing GPS (mid) and losing internet connection for a Pokémon player.

Puzzle games

For the puzzle game, the following points are hindering its development to some extent. On the one hand, because the puzzle game appeared very early, people have long been accustomed to trying these games offline. Many people tend to invest less energy in online puzzle games than other types of games as their familiarity with offline puzzle games. On the other hand, paper puzzle games tend to be less popular than video games among children and young adults, but these age groups do form the most critical stage of a person's potential interest in an academic career (Johnson, 2019). The decrease in demand and interest in puzzle games has affected the further development of puzzle games to a certain extent.

Puzzle-Mopsi

For the problems that LBGs and puzzle games may face, Puzzle-Mopsi tries to make change in the following aspects. First, Puzzle-Mopsi needs to access the database according to the user's demands and does not need to retrieve user's location in real time. This can avoid differences in user experience caused by untimely communication or failure of real-time GPS information. Second, the images used by Puzzle-Mopsi are all taken by users about their daily life. These photos are often interesting and can help us discover some points in life that are not often found. Compared with many puzzle games, especially jigsaw puzzle games, the Puzzle-Mopsi composed of these pictures with geographic information is likely to provide players with a new option. Third, compared with many papers puzzle games, Puzzle-Mopsi as an online game has advantages in broadcast and updated version. Puzzle-Mopsi combines the advantages of some LBGs, and puzzle games and hopes that through a new form, users can better understand their surroundings or any place they are interested in.

5.2 GAME RULES

Based on the discussion for the preliminary analysis and design of Puzzle-Mopsi we describe here the main rules. The primary purpose of Puzzle-Mopsi is to match photos with locations in the form of a puzzle to increase players' knowledge of the game area and stimulate players' interest in exploring. The player's goal is to place a set of photos provided by the system to the correct location on the map. In Puzzle-Mopsi, all game content comes from O-Mopsi. Including, but not limited to, curated collections of images and information (images, names) in collections. All the player needs to do is select a one of the games they are interested in and start the game. After the player selects, the page will display the layout shown in Figure 17.The interface mainly consists of the following three parts: draggable image, slot and exit button.

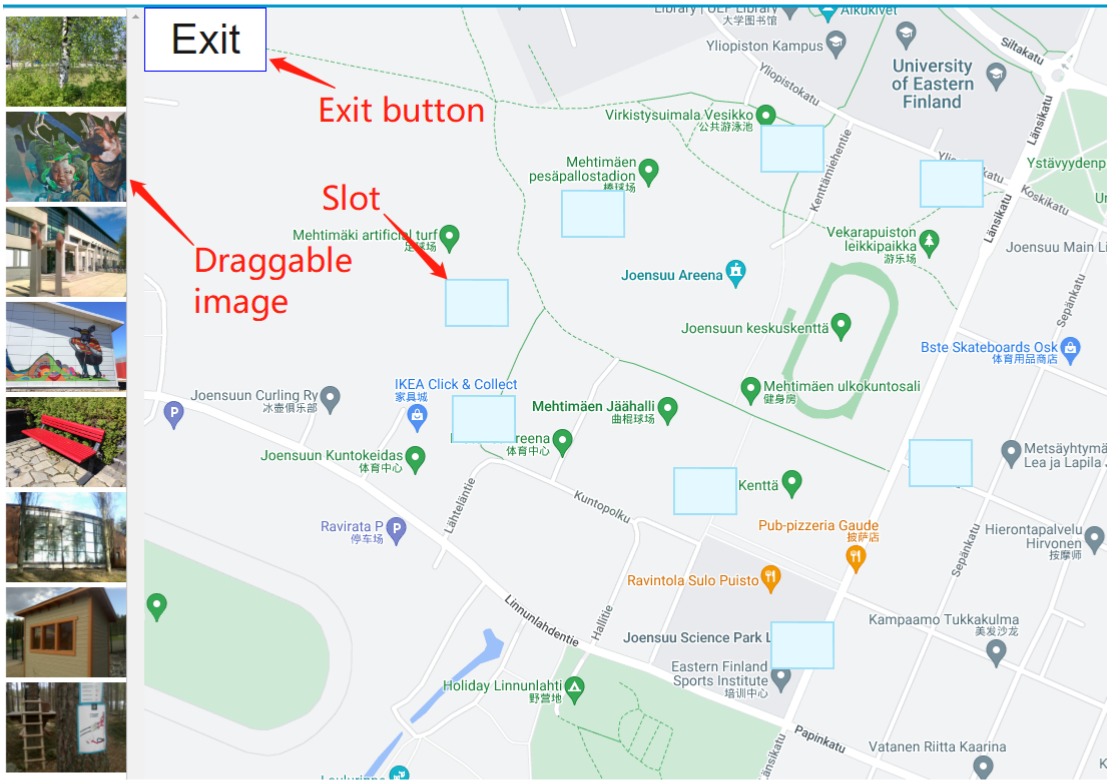

Figure 17: Screenshot for game interface.

Draggable image is mainly arranged on the left side of the page. The player is free to choose a draggable image and drop it anywhere he wants. If the target location of the drop is not close enough to any slot or there are other images in the slot, an animation effect will be triggered to move the image back to the same position in the list shown on left bar.

Each slot can receive only one image. When the player tries to drag the image close enough to the slot, the slot will prompt the player to drop into the slot by changing the color of the border. If the player chooses to release the mouse at this point, a successful drag and drop will complete. If the player needs to adjust the image in the slot, any drag from the slot is acceptable. Not only that, if the player wants to move the image that is in the slot out of the slot and return to the list, it can be done by right-clicking on the image or left-clicking dragging the image to any non-slot area.

The role of the Exit button is more direct. Players just could click it whenever they want to go back to the main screen, whether they finish the game or not.

On one hand, compared with traditional jigsaw puzzles, Puzzle-Mopsi no longer restricts the order of puzzles. The basis for players to retrieve each 'fragment' is no longer dependent on the shape of other nearby 'fragments', but the possible geographic information hints near the slot and their own knowledge of this area. This may be harder for some players in some ways.

For example, some players may not have been to the actual destination. But think about it from another angle, or it's a good way to get to know a new city, a new neighborhood. On the other hand, Puzzle-Mopsi tries to add more logical elements to the game than many other LBGs. The puzzle mode allows players to try more and think about the rationality of the location where these images should be located. The free drag-and-drop and result settlement methods also meet the player's needs for operating space as much as possible.

5.3 PUZZLE-MOPSI PLAYING

For players who are new to Puzzle-Mopsi, they may be curious about how to solve the puzzle of each game quickly. Here we would like to share some possible ways. Let us to use 'SciFest 2018' as an example (Figure 17).

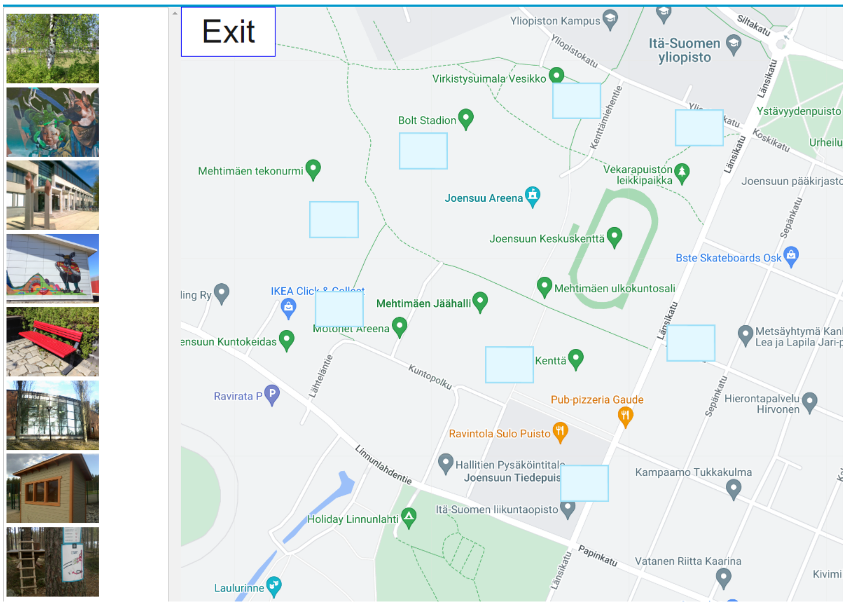

Figure 18: 'SciFest 2018' game screenshot.

Before starting to experience the game, we recommend that new players, especially those who are not very familiar with the geographical location of the target game, may consider switching the map type (from roadmap to satellite). See Figure 19 for the switching method. Compared with the concise and clear information provided by roadmap, satellite can provide users with more detailed, real and rich geographic information of target locations and nearby locations. This may reduce the difficulty for users to find the correct target to a certain extent. Relatedly, we have disabled browse street view and click on a place to see details, which comes from the google maps API. This can effectively avoid the problem that the difficulty gap is too large when different users experience the same game.

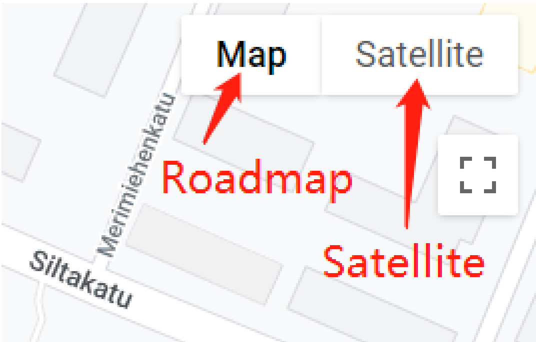

Figure 19: Switch between roadmap and satellite**.**

Before we analyze the type of each picture, we can actually divide the pictures in each level into three categories: Images that know the location for sure, images that are not so sure, and images that have no clue at all. We could first try to put a fully positioned image into the slot. For example, as in SciTest 2018, I am sure that there is a picture of the SciencePark building that I go to every day, and the other is a side shot of the swimming pool that I go to every week. After this screening, the actual images we need to analyze have been reduced from eight to six (see Figure 20).

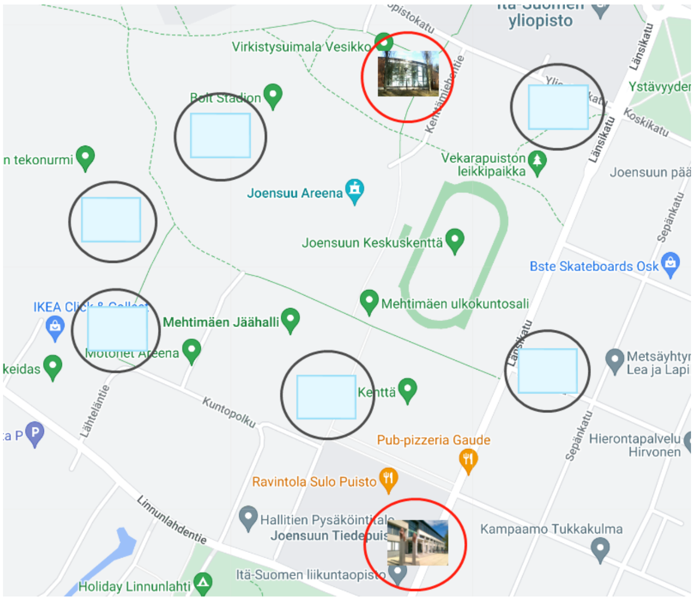

Figure 20: Existing image slot (red circle) and the empty slot (black circle).

In the remaining six images, we can simply classify them. Figure 21 is a possible classification idea.

Figure 21: One possible image classification.

The main purpose of classifying these images is to analyze where they might be on the map. For example, the two images indicated by the ‘nature’ in Figure 21 mainly contain some green plants and trees. Although there are still some man-made objects, such as ladders and posters, the location of these two images is much less likely to be located near the downtown construction area or large open space. Based on the above reasonable speculations, we can temporarily exclude several possible smaller slots (Figure 22). In the remaining two slots, it could not be difficult to find that the two selected images and the slot may match each other because of the difference in the surrounding environment of the slot (Figure 23). In the same way, we can also obtain information from the map, such as some slots are close to roads, or some slots are next to buildings. According to this information and the possible classifications we have made before, the image can be dropped to some possible slot positions correspondingly.

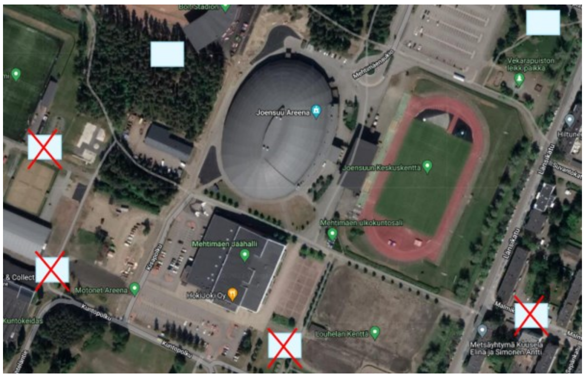

Figure 22: Eliminate possible wrong options.

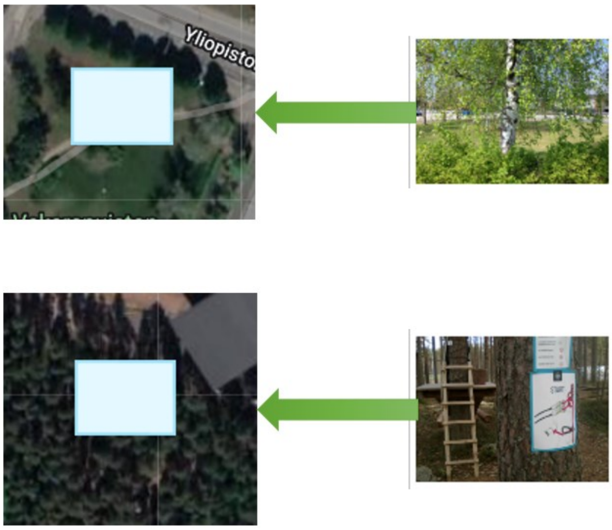

Figure 23: possible two sets of matches.

In addition, we can also further infer the possible location of the image through the geographic information given on the map. Looking at the image on the right side of Figure 24 reveals the following features: the exterior walls of the house are painted, the roof of the house is not flat, and the house as a whole may be relatively large. In the game, only the area on the left side of Figure 24 meets the above conditions.

Figure 24: Infer the location based on the image details.

After a reasonable guess, we can drag the remaining pictures that cannot be guessed into other slots, and the system will display whether it is completely correct or if there are several errors that can be adjusted. If there are wrong targets, in addition to transposing and adjusting the possible positions of the previous analysis, we can also consider the position of some images should be correct and others need to be adjusted by the number of errors displayed each time. As shown in Figure 25, the screenshot in the lower-left corner shows two errors. We swapped image 1 with image 2 and found one more error. Then it can be inferred that one and only one of 1 and 2 are correct before the permutation. After swapping image 2 with the image below it we found that the number of errors reached 4. We can also use this to conclude that there is an image that is correct before image 2 is swapped this time. Removing the variable, we can conclude that the position of image 1 is wrong and the position of the other two images is correct. So, we have completed a successful inference. After a finite number of inferences, we could get the true correct answer.

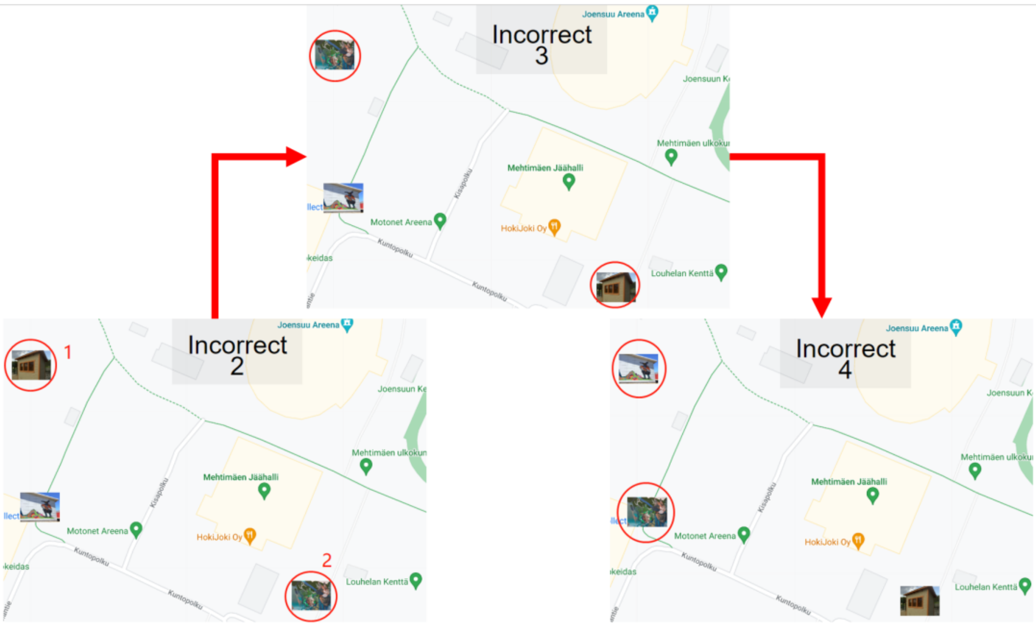

Figure 25: Adjust image order.

According to the above example, Puzzle-Mopsi can find that in addition to testing the user's understanding of relevant geographic information, Puzzle-Mopsi can also exercise the user's logical thinking ability, information induction and classification ability, and observation of things. In the following chapters, we will describe how to design and implement the Puzzle-Mopsi.

6. DESIGN AND IMPLEMENTATION

This section will mainly discuss some design ideas for the game and how to implement them.

6.1 GAME DESIGN

The user interface in Puzzle-Mopsi is mainly divided into two: the main interface (welcome interface) and the game interface. In the main interface, players can log in to their accounts, freely browse and select all list of games currently provided by Puzzle-Mopsi. In the player interface the list on the left shows all the draggable images and the map on the right shows the same number of slots as the images on the left. Figure 26 shows the actual structure of the slot on the map.

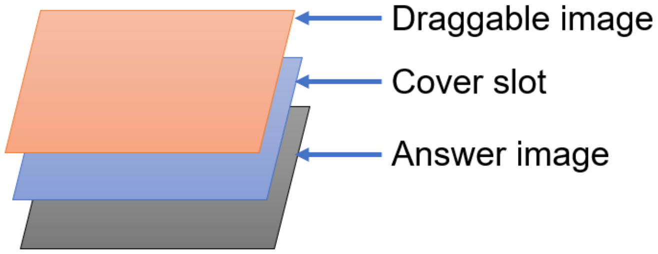

Figure 26: Image layer structure.

On the map of the game interface, what we see by default is a light blue slot in the middle of the blue border. In the subsequent player's operation, the slot may become the appearance of the picture due to the player dragging the picture. The real slot structure is divided into three layers. The bottom is called 'Answer image'. All information about the draggable image that should be placed in this slot is stored in this layer. Such as the image itself (the size is compressed to the same size as the slot), image ID, location information, etc. The middle layer is called the 'cover slot'. It covers the bottom image information and listens to see if a draggable image is close enough to it. When the distance is less than the threshold, it will change its color to prompt the player.

The top layer is the draggable image itself. When the image is dragged into the slot, all its information will stay in this layer.

When a player tries to drag an image into a slot, there are several situations that need to be analyzed differently. The first is the source of the drag. There are two possible sources in Puzzle-Mopsi, the picture list on the left and other slots that have been dragged into (Figure 27). If the source of the dragged image is the left image list, the map offset needs to be considered during the dragging and subsequent drop process. After offsetting the map offset, it is possible to place the image in the slot as expected by the operation. This is mainly due to the interaction of external elements with the google maps API (see Section 6.2.3 for details). If the source of the drag is a slot in the map, there is no need to consider the processing of the offset.

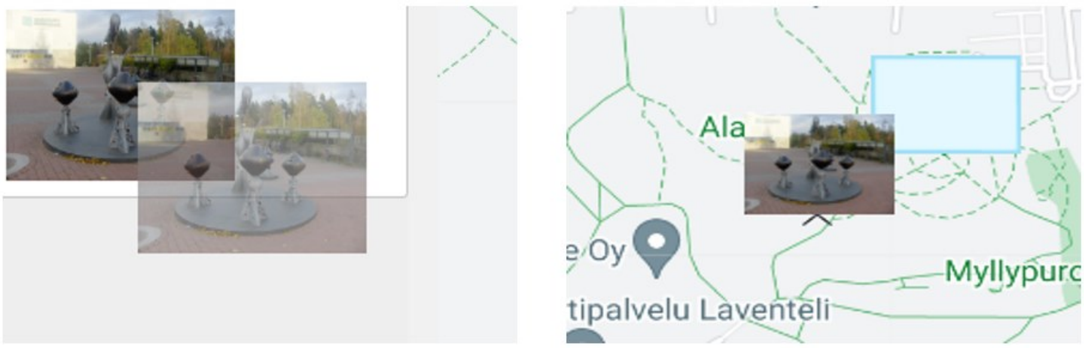

Figure 27: Two possible sources.

After all the images are dragged into the slot, the settlement will be carried out. If all the targets are dropped into the correct position, there will be a prominent font showing 'congratulations' to celebrate the completion of a Puzzle-Mopsi. If any image is not in the correct slot, it will display the incorrect number of image locations. Players can choose to re-drag images they think are wrong to where they might be right. The result will be displayed the next time all images are placed in the slot.

6.2 HOME SCREEN

On the home page, Puzzle-Mopsi is mainly divided into the following parts (see Figure 28): the game logo and login button are displayed at the top; the left side of the page displays all list of games currently published and the basic information corresponding to each one (such as thumbnails, game name) and the changelog so far; the right shows where all the games are currently on the map.

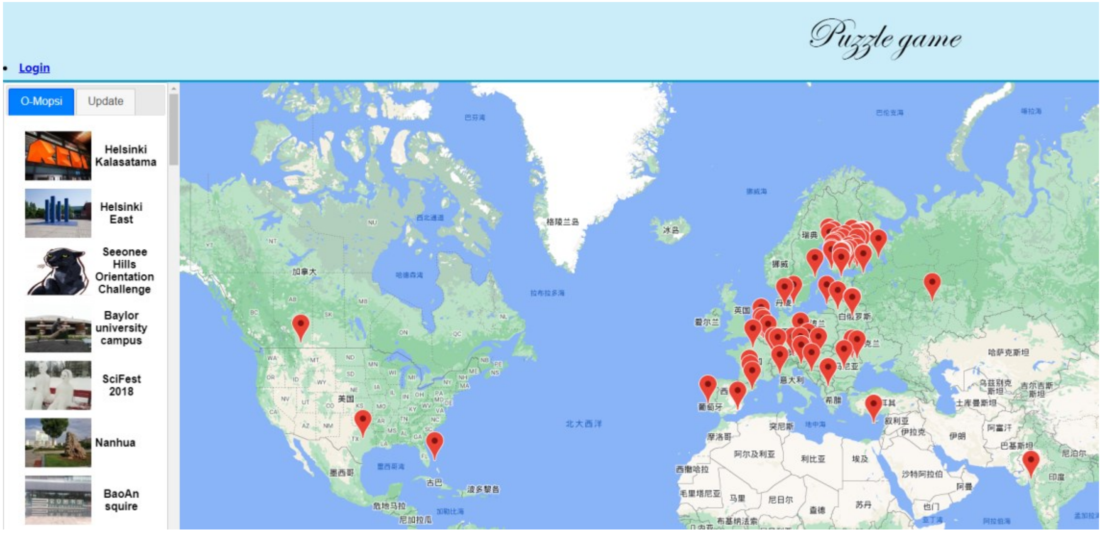

Figure 28: Home screen.

Players can log in with their Mopsi account by clicking the login button above. Players who did not have an account before can also create a new account after clicking. After a successful login, the player's name will be displayed in the upper left corner of the page.

The game hall part includes two things: All of the publish game (below the O-Mopsi label) and Update.

6.3 MAP OFFSET CONTROLLER

During the experimental phase, we found that the image will offset in some cases. To be precise, if the image itself belongs to google maps (as in Puzzle-Mopsi in the form of google Marker) then there won't be any unreasonable offsets. But if the source of the image is an external UI, then there will be a certain degree of offset stably (see Figure 29).

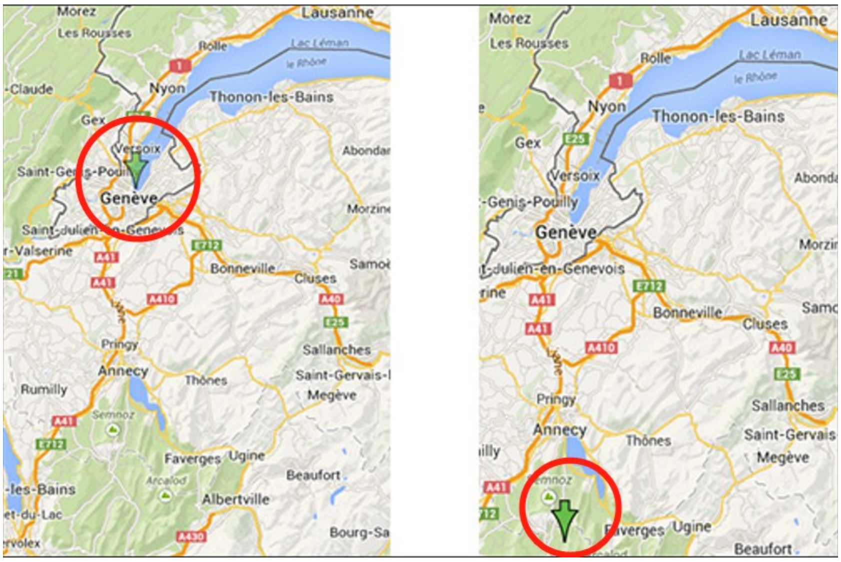

Figure 29: The sample for expectative location (left) and real location (right).

After analysis and data review, we have concluded two possible reasons:

1. The default boundary of the bounding box of google maps is the overall page and the coordinates of the upper left corner are used as the reference value. when the map is not placed at the top left corner of the page, the offset of the map probably is used inside the calculation.
2. The anchor of the marker by default is the bottom center, but the script simply takes the position provided via the event argument, which may give different results and it is depending on the point inside the image where the player gripped it.

We analyze the possible solutions according to the reasons as follows:

```
var mOffset=$($map.getDiv()).offset();
    var point=new google.maps.Point(
        ui.offset.left-mOff-
set.left+(ui.helper.width()/X),
        ui.offset.top-mOffset.top+(ui.helper.height()/Y);
    var ll=overlay.getProjection().fromContainerPix-
elToLatLng(point);
```

The logical idea of the main body is the reference offset value at the upper left of the UI minus the reference offset value at the upper left of google maps and add a certain proportion of the size of the dragged object itself. The values of X and Y are respectively related to the size of the dragged object itself. The size of the picture dragged in Puzzle-Mopsi is uniformly 120×90 pixel. In order to achieve the effect of offset, we set the values of X and Y to 2 and 1.8, respectively.

6.4 DISTANCE JUDGEMENT

In the previous section we solved the problem of offset. Then the next problem to be solved is how to judge whether the image meets the conditions that can be put into the slot. As shown in Figure 30, in the image on the left the picture may not be close enough to the slot, so we tend not to consider it to fit in the slot. In the picture on the right, the distance between the image and the slot looks likely enough to fit into the slot. It can also be noted that the color of the slot in the left and right pictures is different. The purpose of this is to prompt the player if the distance is close enough.

Figure 30: Detecting whether the distance meets the conditions:
No (left) or Yes (right).

In the process of dragging, player can freely choose the right time to drop. If the distance between the picture and the nearest slot is greater than a given threshold value (this value will change dynamically with the zoom level, see Table 1) then the picture will be returned back to the left picture list. Conversely, the image can be successfully dropped into the slot. This rule applies when the image source is in the list on the left or in the slot on the map. Due to the existence of the offset, when the image source is the left image list, the distance between the image and the slot we used the comparison between latitude and longitude. In the map slot, the distance judgments directly use the actual distance (unit: meters) as the judgment standard. In order to facilitate the conversion, we refer to the following conversion formula:

$$d = \sqrt{\left(\Delta\varphi^2 + (\frac{\Delta\varphi}{\Delta\psi})^2 * \Delta\lambda^2\right)} * R \qquad (1)$$

where $\Delta\psi$ can be obtained from this formula:

$$\Delta\psi = \ln\left(\frac{\tan\left(\frac{\pi}{4}+\frac{\varphi_2}{2}\right)}{\tan\left(\frac{\pi}{4}+\frac{\varphi_1}{2}\right)}\right) \qquad (2)$$

In the above formula φ is latitude, λ is longitude, *Δλ* is taking shortest route (<180°), *R* is the earth's radius, *ln* is natural log. It is worth noting that the data in Table 1 are not entirely derived from the formula above. In the debugging phase of the project, due to some settings of the google maps API and the slight gap between the theory and the actual test, we simplified and adjusted the data to a certain extent.

Table 1: The relationship between zoom level and distance.

Zoom level	Distance by meter	Distance by LL
12	4	0.00006
13	7	0.00012
14	15	0.00025
15	30	0.00050
16	60	0.00100
17	120	0.00200
18	240	0.00400
19	480	0.00800
20	960	0.01600

When the distance between the image and the slot during the dragging process is less than the value in Table 1, it will be judged, and the slot border will change color to make it brighter. In this case, if the player releases the mouse, it will enter the next judgment. If there is no other image in the slot, the picture will be put into the slot smoothly, otherwise, the image will be moved back to the image list.

In addition to the situation shown in the figure above, we also need to consider two possibilities:

1. How to design the distance judgment between image and slot to make the user experience more comfortable.
2. For two very close slots, how to put the image properly.

Users often expect to have a reasonable distance between the drag and drop target and the drag and drop destination(Doeweling & Glaubitt, 2010). This reasonable distance often means that the user wants the distance to be sufficiently tolerant within a suitable distance range. Not only that, the distance determination in all directions of the target slot should be kept exactly the same.

This can prevent users from suddenly feeling inexplicable confusion during the experience. In the specific practice of Puzzle-Mopsi, we set this distance as shown in Figure 31.

Figure 31: Image satisfies the condition of the limit distance from four directions.

Before determining the distance between the image and two close slots, we need to confirm a concept. Is this distance really the distance between the two images? In fact, in actual operation, whether it is the image in the list on the left of the source, the image in the slot and the slot itself are actually counted as a point. This means that these images and slots do not have a so-called bounding box. Calculating the distance between the two is not a comparison between the two bounding boxes but a more direct point-to-point. At this time, it is not difficult for us to find that the distance between the image and 2 or even more slots only needs to be traversed at any time as the drag position changes to determine who is the closest to the image. The below code for the specific practice method.

```
Compute distance compute distance between slot and image

Define shortestDistance = MAX_SAFE_INTEGER
Define nearestSlot = null
Foreach slot
    If distanceImageToSlot < shortestDistance
            shortestDistance = distanceImageToSlot
            nearestSlot = slot
```

6.5 DRAG AND DROP

After ensuring that the image does not have a strange offset and determining the distance between the image and the slot, we can finally fully implement the drag and drop function. First, there is a problem worth considering: Due to the different sources of images (in the external UI or map slot), we also need to discuss drag and drop separately. Figure 32 shows the difference between the image source is a slot or a list during the dragging process.

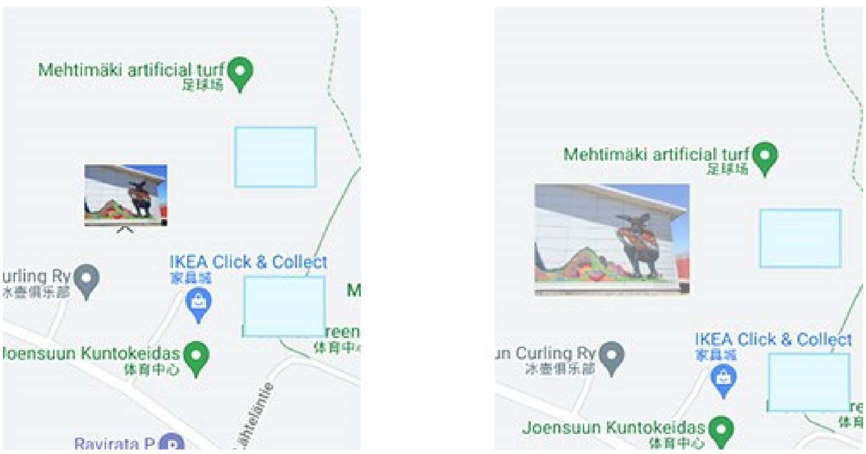

Figure 32: draggable image from the slot (left) or list (right).

6.6 THE RESULT

In Puzzle-Mopsi, the possible outcomes are shown in three cases (Figure 33): prompt the incorrect number, hide, and game success.

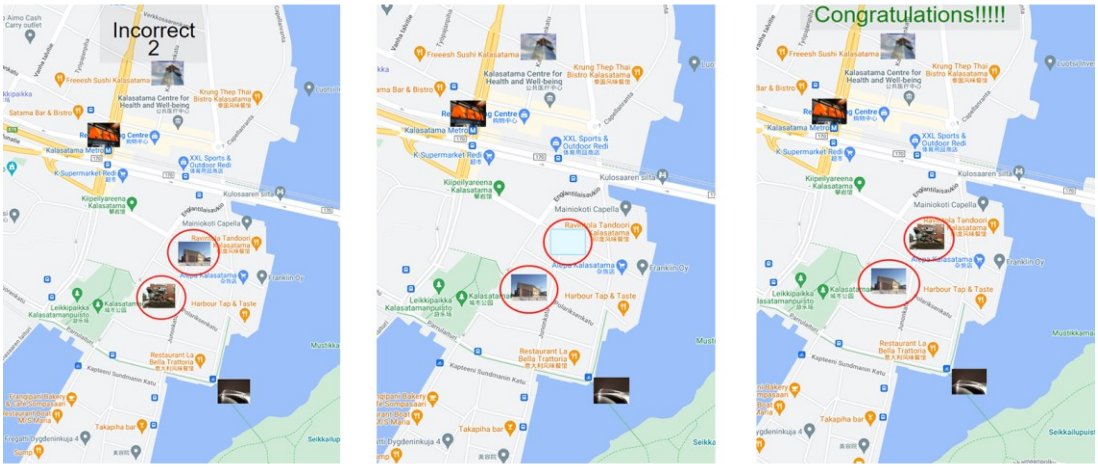

Figure 33: Display of results in different situations.

As shown in the left part in Figure 33, if player drop all of image to the slot but still has few mistakes, the result will display the incorrect number of images. The player could continue to consider if there have been some images at incorrect location. In the process of adjustment, we could see the result will hiding as mid part of the Figure 33. On the one hand, it can provide the player with a free field of vision to the greatest extent and minimize the interference of various controls to the player. On the other hand, this can also make the outcome of the game more mysterious and valuable. The player must finish the complete puzzle through his own thinking to get the possible results instead of constantly moving and receiving timely feedback of right/wrong. This also makes it much more difficult to get the correct answer through the exhaustive method. After the player has successfully dropped all images to the correct position, the 'congratulations' will celebrate the player's victory. At the same time, all images and maps themselves will be disabled from dragging, and players can click 'Exit' to return to the main menu to browse more games.

7. EXPERIMENTS

The next part is the experimental report on the game. We invited group members of our group to play this game and collect their datasets and feedback. We recorded the player's actions and time for each game. Not only that, but players also rated the difficulty of the game from 1 (very easy) to 5 (very hard) in their feedback, as well as how well they knew local knowledge and how interesting the game was to them.

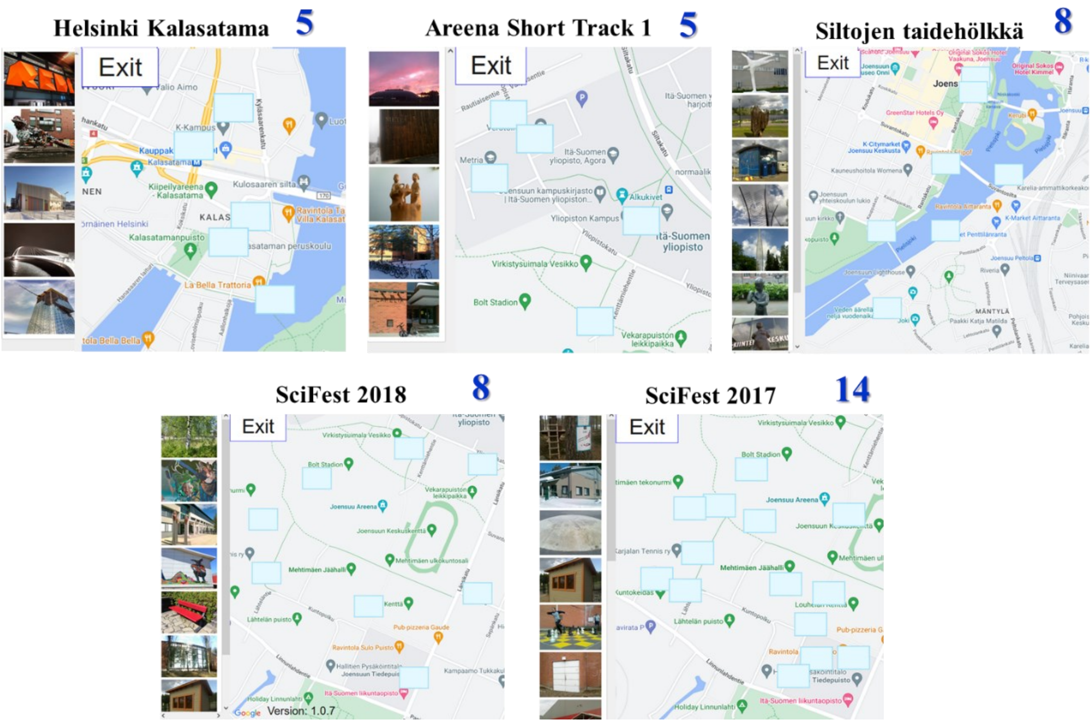

Figure 34: Five games for experiments

In the experiments, we selected five games from the O-Mopsi database (Figure 34). Four of them are in Joensuu (three used for SciFest event, one from downtown) and one in Helsinki. Since the daily work area of the testers is in Science Park, we have selected three games (SciFest 2017, SciFest 2018, Areena Short Track 1) in this vicinity. They have similar game area but the number of targets is divided into 5, 8 and 14 three intervals. Other parameters of the game are the estimated difficulty as an instance of TSP (Sengupta & Fränti, 2021).

We summarize the information collected, as shown in Table 2. Through the data in the table, we observed that there is a significant correlation between game properties and game time (Pearson=0.62). Local knowledge depends mostly how far the game is from the location our school (Joensuu Science Park) coded as: neighborhood (***), same city (**) different city (*). Minimum spanning tree (MST) branches refers to the difficulty of the problem as TSP instance according to (Sengupta & Fränti, 2021). Difficulty refers to players' opinion (on average) using scale 1=very easy, 2=easy, 3=normal, 4=difficult, 5=very difficult. Time and moves are the average time and moves required by the player to find the solution.

Table 2: Summary of the games and their properties

Game			**Properties**		**Results**		
Name	Year	Knowledge difficulty	Targets	MST branches	Difficulty	Time (s)	Moves
Helsinki Kalasatama	2019	*	5	0	2.75	184	13.00
Areena Short Track 1	2011	***	5	1	1.50	73	7.25
Siltojen taidehölkkä	2015	**	8	1	2.50	231	24.50
SciFest 2018	2018	***	8	0	2.38	140	17.75
SciFest 2017	2017	***	14	3	3.25	350	67.75

From the data in the table, we found that there is a positive relationship between the number of targets with the difficulty of the player's decision, as well as time and moves. Helsinki Kalasatama is an exception. This is mainly due to the fact that players don't know much about this game area. Although the targets are only 5, its average difficulty factor (2.75) even exceeds the two games in Joensuu with targets of 8 (2.50 and 2.38). Differences in game area with player outcomes can also be reflected in Siltojen taidehölkkä and SciFest 2018. They have the same number of targets. Due to the difference in location (the former is in the city center and the latter is around the school), players generally feel that the former will be harder. From the results, it can also be found that the average time and moves will be more. Figure 35 shows the relationship between the difficulty of the user evaluation and the actual time spent.

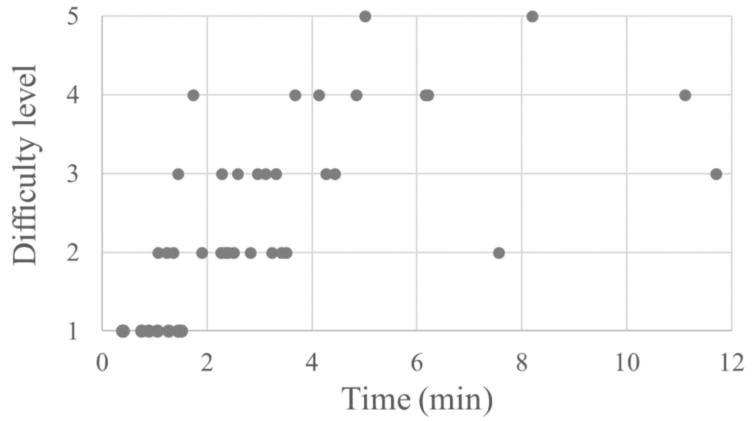

Figure 35: The difficult of the games (as reported by the players) versus the time taken to solve the game.

Judging from players' feedback on the game, most players prefer games in a familiar environment. Players are often confused when the game is in a completely unknown environment. While a small number of players will take the unfamiliar environment as a point of interest. How to solve the puzzle in an unfamiliar environment through the geographic information on the map and switching between different types of maps will make them feel very interesting. At least two types of players exist from player records. Most players choose each move through careful observation. But a minority of players will choose to focus on quick matches and rule out wrong options. Their moves will also increase significantly compared to other players. Most reported issues have focused on some deficiencies in the game interface. Other minor issues are the possible deviation between the location of individual targets on the map and the actual location.

8. CONCLUSION

In this thesis, we propose a location-based puzzle game: Puzzle-Mopsi. It combines the features of puzzle game and location-based game. The main purpose of the Puzzle-Mopsi is to test the player's observation and logic between image and position. Unlike most LBGs, puzzle games do not require players to provide real-time GPS data. All location-related information is pre-stored in the database. This reduces the demands on the player's hardware and the impact of the environment on the player's experience. Compared with many puzzle games, Puzzle-Mopsi's game sources are freer. All puzzle images are derived from the player's life and travel records. While experiencing the game, players can also learn some information and knowledge that they may not have known before. This can also promote a better understanding of the community/city they live in and encourage them to explore the actual location after experiencing the game.

All current Puzzle-Mopsi games are derived from the O-Mopsi image set. This means that Puzzle-Mopsi has room for improvement in many ways. For example, the difficulty classification of the game. For Puzzle-Mopsi, clearer and more recognizable pictures can make the game easier. Not only that, but the overall size of the object depicted in the photo also has an impact on difficulty. Things that are too small compared to buildings or sculptures are more difficult to analyze in relation to other information on the map. Finally, since there may be very clear and very fuzzy pictures in the same set, this also makes the difficulty determination in Puzzle-Mopsi difficult. Another example is the creation part of the game. Currently Puzzle-Mopsi does not support new game creation. All game items correspond to O-Mopsi's image set. This limits further development of the game.

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