UNIVERSITY OF
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University of Eastern Finland

School of Computing

Master's Thesis

O-Mopsi: Location-based Orienteering Mobile Game

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CONTENT

Abstract

Location-based (mobile) game combines gaming and player's physical location. We have developed a game O-Mopsi (cs.uef.fi/o-mopsi), which is based on the concept of classical orienteering. O-Mopsi can be played on mobile phones with GPS receiver and Internet connection. It requires players to move around in the real world. An O-Mopsi game consists of targets, which are geo-tagged photos. In order to finish the game, player must visit the set of targets in free order. The player with shortest time is the winner. Game creation, game management, game result, online player tracking and social networking functionalities can be found on the O-Mopsi web site. Games can be played at any time using O-Mopsi application, which currently exist for Symbian, Windows phone and Android platforms. The game has also been arranged as continuous workshop three time (2012, 2013 and 2014) at an annual international festival (SciFest). SciFest is aimed at introducing science and technology to school children. The overall feedback received from the players has been positive.

In this thesis, we describe the O-Mopsi game in detailed. We study how it has been technically built and study the algorithms used in the game creation. We present the targets on the Google map, and analyze game results. Specific attention is paid to the calculation of reference route, which is NP hard optimization problem, a variant of travelling salesman problem. We compare three algorithms: Tabu search, ant colony optimization and greedy algorithm with the O-Mopsi game data and with larger scale data taken form Mopsi (cs.uef.fi/mopsi).

Keyword: Location-based aware, mobile gaming, orienteering, GPS, social network.

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1. Introduction

Mobile devices that are aware of their location have become increasingly ubiquitous over last few years. Nowadays, there are at least ten different systems in use or being developed that a phone could use to identify its location. In most cases, several are used in combination, with one stepping in when another one becomes less effective[1].

Here we briefly introduce four most common ways which Smartphone use to detect the location:

- GPS;
- Cell ID;
- Network;
- Wi-Fi.

***G**lobal **P**ositioning **S**ystem* (GPS) was developed by the U.S Department of Defense and was first included in cell-phones in the late 1990s. It is the best-known way to identify the user location outdoors. A constellation of satellites is used to send location and timing data from space directly to the user phone. If the phone can pick up signals from three satellites, it can detect where you are on a flat map, and with four it can also detect your elevation.

There are two other GPS-based technologies which could help to improve the accuracy. They are *Assisted GPS* (A-GPS) and *Synthetic GPS* (S-GPS). GPS works well if phone finds three or four satellites, but it may take a long time or even no signal at all if you are indoor or in an "urban canyon" of buildings which reflect satellite signals. A-GPS describes a collection of tools that help to solve the problem. For example, in indoor situation, phone may use Wi-Fi or network to get data until full GPS service starts. But this still requires an available data network and the time to transmit the satellite information. S-GPS uses computing power to forecast satellites' locations days or weeks in advance in order to help phone to identify its location in two seconds or less.

GSM *Cell ID* (CID) is a generally unique number used to identify each *base transceiver station or sector* (BTS) within a *location area code* (LAC) if not within a GSM network[2]. This system tends to be more aware in urban areas with more smaller cells than in rural areas, where cell may cover an area of several kilometers in diameter.

Network and *Wi-Fi* do much the same thing as Cell ID, but with greater precision because their access points cover a smaller area. The most common way how Wi-Fi determines location is called *received signal strength indication* (RSSI). It takes the signals your phone detects from nearby access points and refers to a database of known Wi-Fi networks. Using signal strength to

[1] http://www.pcworld.com/article/253354/ten_ways_your_smartphone_knows_where_you_are.html
[2] http://en.wikipedia.org/wiki/Cell_ID

determine distance, RSSI determines the location in relation to those known access points (see Figure 1, 2).

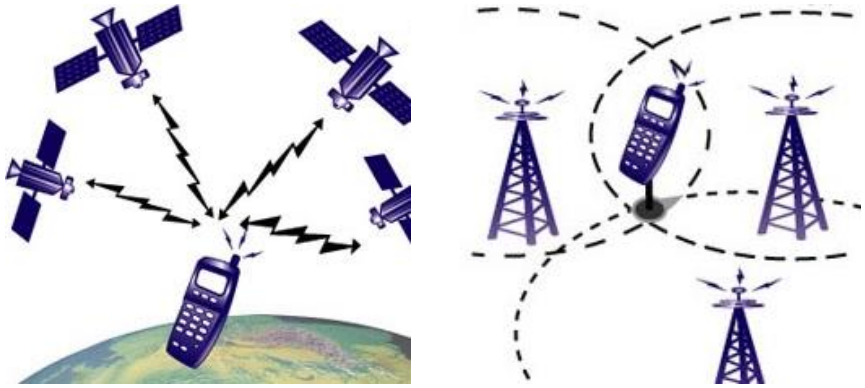


Figure 1: GPS positioning & Network / Wi-Fi positioning

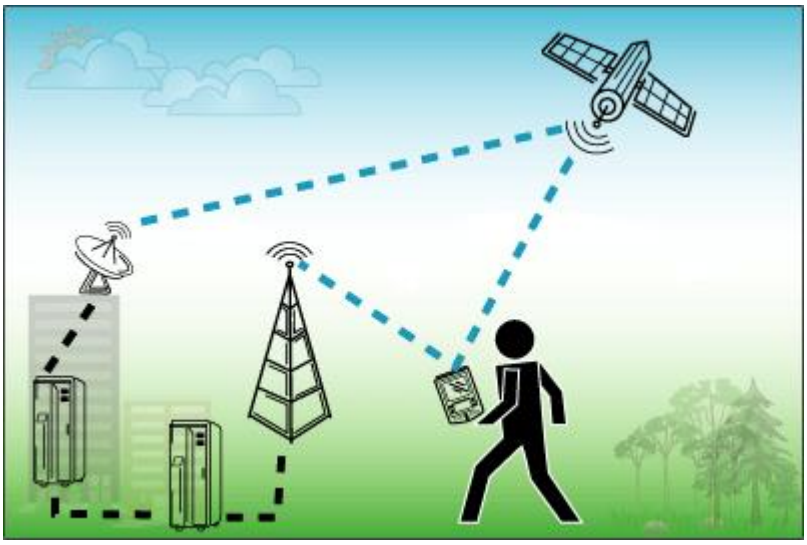


Figure 2: Communication and positioning as location-based service components

Location-based game (LBG) is a type of pervasive game in which the game-play evolves and progresses via a player's location[3]. In most cases, a location-based game uses GPS to determine the location. We have developed a location-based game called O-Mopsi[4]. It is based on the classical concept of orienteering and exploits the data available in a geo-tagged user generated photo collection[5]. A game is created by defining a set of targets so that players must visit all the targets in order to complete the game [1]. So far, we have developed O-Mopsi on three different

[3] http://en.wikipedia.org/wiki/Location-based_game
[4] http://cs.uef.fi/o-mopsi/
[5] http://cs.uef.fi/mopsi/photos/

mobile platforms, Nokia Symbian, Windows phone and Android platforms. The mobile client has functionalities such as plotting targets on the map, displaying compass data and giving audio clue with varying pitch and sound frequency about the distance to a target. Photos are used as an additional aid for identifying a target. The web interface allows game management, real-time players tracking, post-game trail analysis and suggesting tours calculated by Tabu search algorithm [1]. Calculating reference routes as a study topic, we also developed a TSP page[6] for testing different algorithms and allowing access to more data from Mopsi[7] user collections. O-Mopsi was designed for the annual SciFest Festival[8] which brings together thousands of school kids, high school students, and teachers to learn about science and technology. O-Mopsi was presented during 2012, 2013 and 2014.

For having a better understanding of O-Mopsi, we take a look on classic orienteering first. Orienteering is a family of sports that requires navigational skills using a map and compass to navigate from point to point in diverse and usually unfamiliar terrain, and normally moving at speed (see Figure 3). Participants are given a topographical map, usually a specially prepared orienteering map, which they use to find control points[9]. Control points are placed on features on the map that can be clearly identified on the ground. Control points are marked in the terrain by white and orange "flags" (see Figure 4, 5). Each competitor receives a *control description sheet*[10] or *clue sheet* which gives a precise description of the feature and location of the control point, e.g., boulder, 5m, north side. For experienced orienteer the descriptions use symbols (pictorial).

Figure 3: Orienteering race (*left*) and compass (*right*)

[6] http://cs.uef.fi/o-mopsi/tsp/
[7] http://cs.uef.fi/mopsi/
[8] http://www.scifest.fi/
[9] http://en.wikipedia.org/wiki/Orienteering
[10] http://en.wikipedia.org/wiki/Orienteering#Controls_and_control_description_sheet

Figure 4: Control points[11]

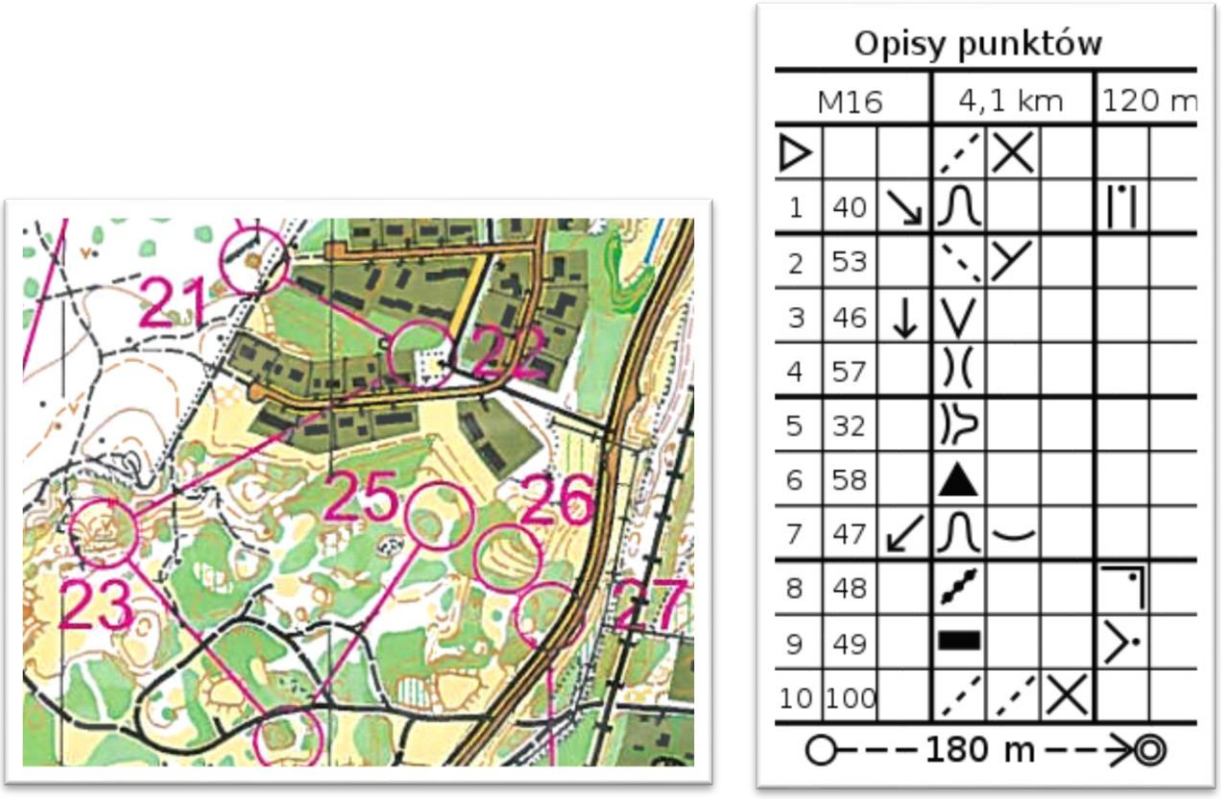


Figure 5: Example of control points marked on the map & control description sheet

Orienteering has many variations. *Foot Orienteering* (foot-O) is one of the oldest and most popular one. Usually, a foot-O is a timed race in which participants start at staggered intervals, are individually timed, and are expected to perform all navigation on their own. The control

[11] http://en.wikipedia.org/wiki/Orienteering#Competition_and_results

points are shown on the orienteering map and must be visited in specified order. Standings are determined first by successful completion of the course, then by shortest time on course[12]. Orienteering has been included in the programs of world sporting events including the World Games[13]. The rules and guidelines[14] of orienteering are defined by the International Orienteering Federation (IOF)[15].

Classic orienteering[16] is a race between controls in a preset order. The winner is the person who completes the course in the shortest time. This is usually cross-country. Courses are normally designed so that the fastest route is not straightforward to find on the map, and not easy to follow on the ground. The classic orienteering has a typical winning time of 75 - 90 minutes. Classic orienteering are usually held in forest to increase difficulty level (see Figure 6).

Another type of orienteering is called *sprint orienteering*[17]. It is described by much shorter races, with winning times in the region of 12 - 15 minutes, often held in city parks and other more urban settings (see Figure 6). Control sites can include benches, litterbins, sculptures, and other objects common to urban parks. Usually one needs to visit all targets but there are variations where the aim is to visit as many as possible within a given time.

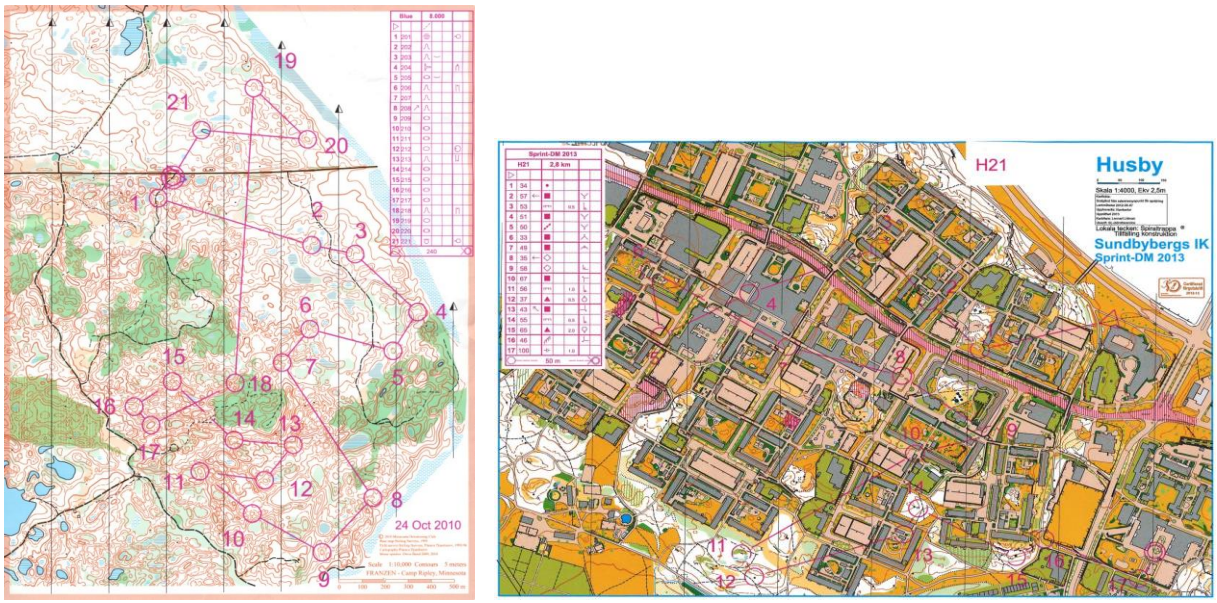


Figure 6: Example of classic (left) and sprint orienteering (*right*) map.

[12] http://en.wikipedia.org/wiki/Foot_orienteering
[13] http://www.theworldgames.org/
[14] http://orienteering.org/foot-orienteering/rules/
[15] http://orienteering.org/about-the-iof/the-iof/
[16] http://en.wikipedia.org/wiki/Orienteering#Classic
[17] http://en.wikipedia.org/wiki/Orienteering#Sprint

For example, in 2013, there was *Cycling Joensuu*[18] orienteering races held by University of Eastern Finland Students Unit. The *rules*[19] state that there are two people in a team and each team will get a map (see Figure 7) with legend describing tasks. The aim is to find the control points and fulfill every task correctly. Each task is worth different amount of points. The team with the biggest total amount of points wins the race. In case of equal points, shortest time wins.

The inspiration of O-Mopsi game is classic orienteering but there are differences. In O-Mopsi, there is no fixed visiting order, but the player can freely choose the order to visit the targets. All player uses GPS and mobile phones instead of a map and compass.

Besides orienteering aspect, O-Mopsi can combine educational and travelling aspects. For example, selecting tourist attractions as targets would create a sight-seeing tour, instead of a racing game, and users might just tour the targets without competing who is the fastest. For educational purposes, each target should have some educational motive depending on the subject.

The remainder of the thesis is structured as follows. In Section 2, we give an overview of location-based services and location-based games. In Section 3 we show how one plays O-Mopsi games. In Section 4, we study what O-Mopsi application consists of. In Section 5, we study the algorithms in O-Mopsi. User feedback from SciFest 2012 and 2013 are given in Section 6, and conclusions drawn in Section 7.

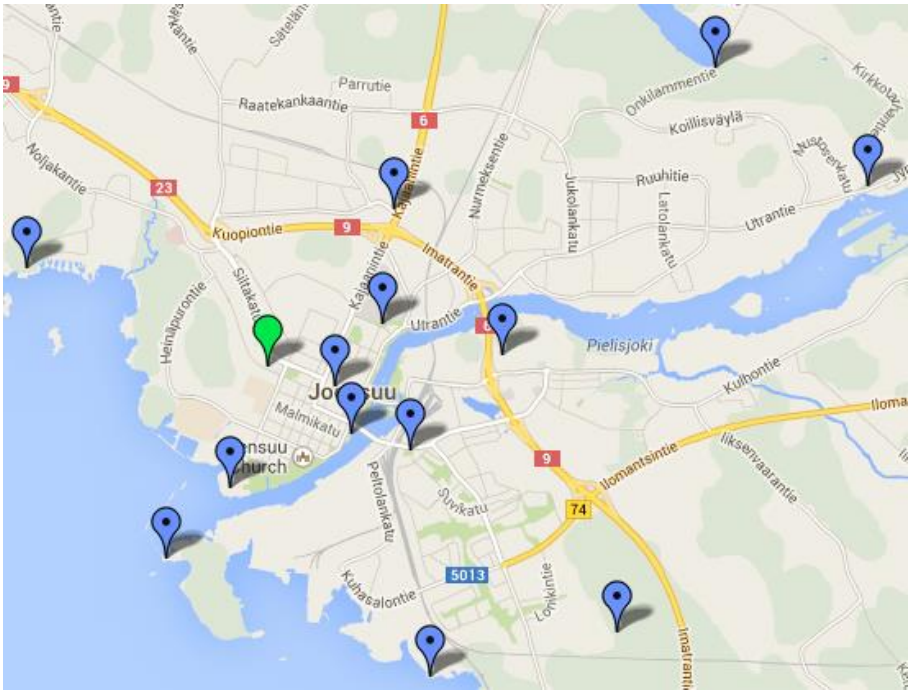


Figure 7: Example of Cycling Joensuu map - Bike

[18] http://isyy.fi/en/events/cycling-joensuu/
[19] http://vladt89.com/files/runcity/Cycling_Joensuu_rules.pdf

2. Location-based Applications

2.1 Location-based Services

A ***L**ocation-**b**ased **S**ervice* (LBS) is defined by the *CTIA*[20] as "any wireless service or application that uses the geographical position of a wireless device"[21]. According to a *GSMA*[22] study, the most commonly used location-based services are practical services, such as weather information or maps, and users of these services value them highly. For example, Figure 8 shows Joensuu city on OpenStreetMap and Figure 9 shows the weather of different cities in Finland[23].

Currently, many location-based applications are available in the market, and one can use these applications with a smart phone with GPS inside. Foursquare[24] is one of the most well-know location-based social networking service for mobile devices. By using *Foursquare* (see Figure 10), people can share and save the places they visit. Users "check-in" at real-world venues, and with each check-in, they are awarded points and sometime "badges" or "venue mayor ships". Foursquare had over 40 million users worldwide as of September 2013 [2].

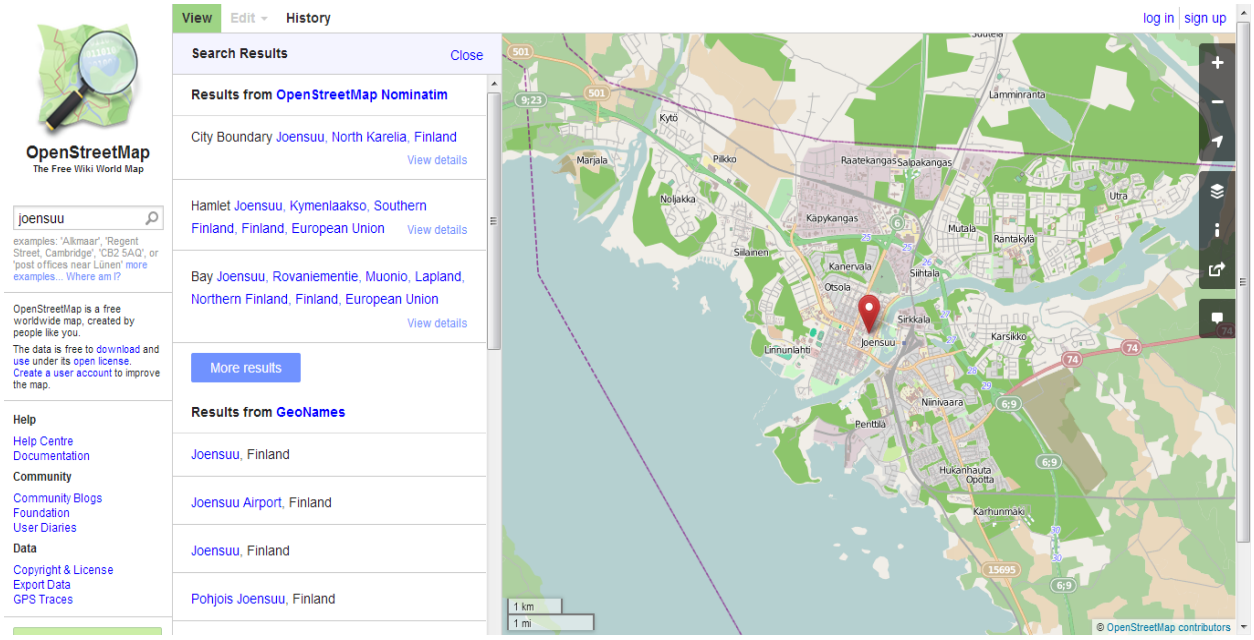


Figure 8: Example of a location-based map service called OpenStreetMap

[20] http://www.ctia.org/
[21] http://www.fosigrid.org/family-online-safety/content/location-based-services
[22] http://www.fosigrid.org/companies/gsma
[23] http://en.ilmatieteenlaitos.fi/weather/Joensuu%20
[24] https://foursquare.com/activity

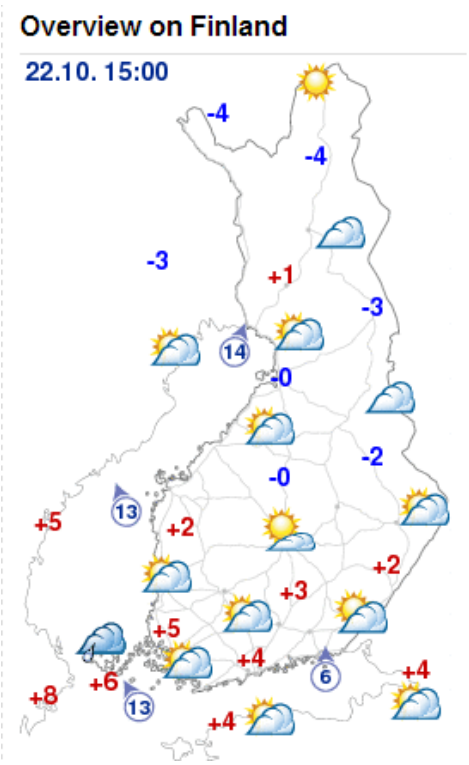


Figure 9: Example of location-based weather services.

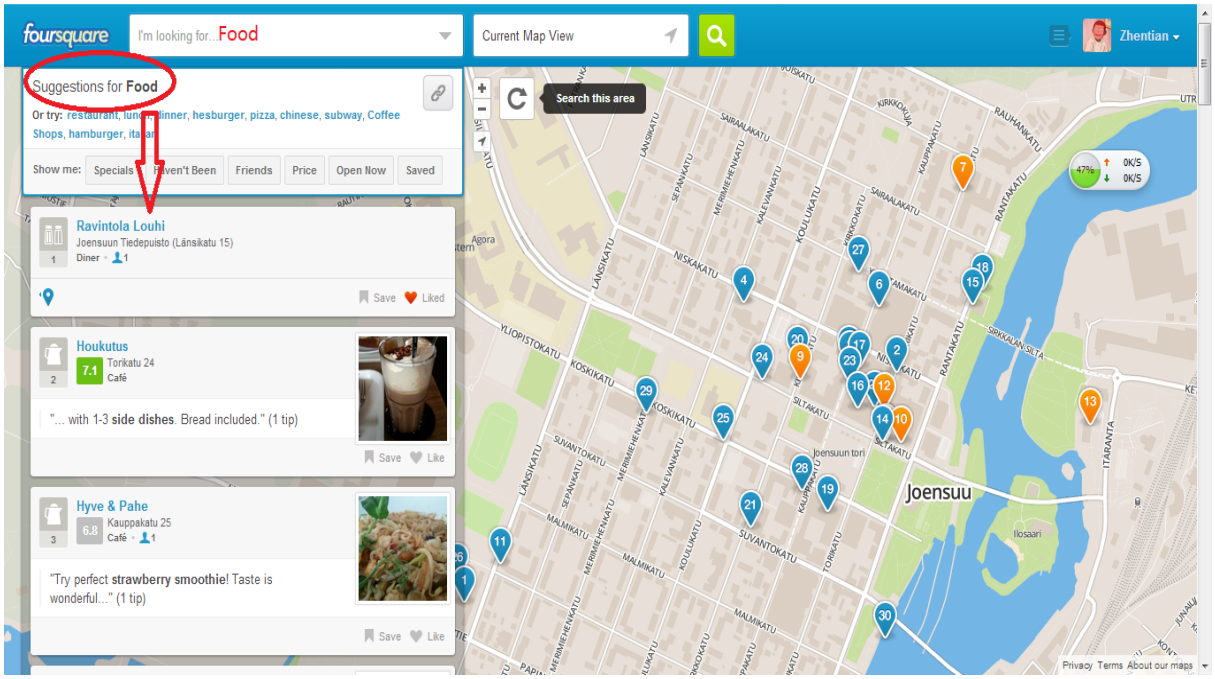


Figure 10: Searching for food in Joensuu city with Foursquare

The "check-in" functionality is quite popular nowadays. On Foursquare, there is over 4.5 billion check-ins in total, and millions more coming every day (see Figure 11).

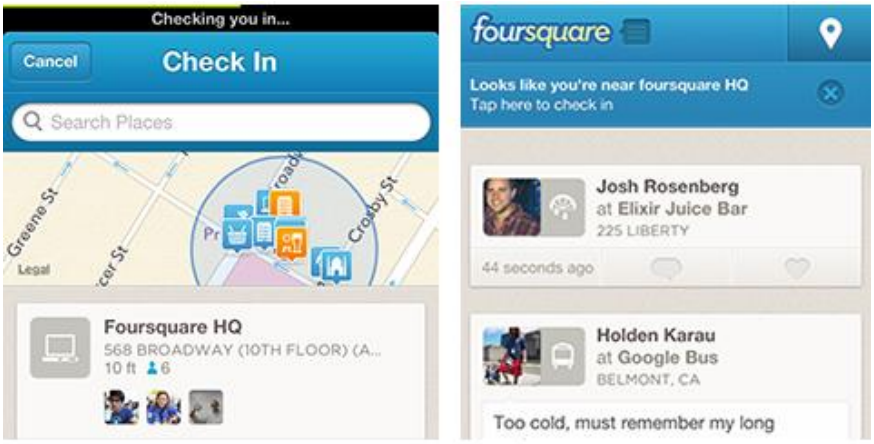


Figure 11: Foursquare, mobile client, check-in

In China, there is a very popular LBS application called Jiepang[25] (Chinese: 街旁), with almost the same functionalities as Foursquare. Users can use Jiepang application to track and share life moments with friends. It is one of the leading location based services for "check-in" in china. Currently, it has more than 5 million registered users.

2.1.1 Mopsi Application

Mopsi[26] is a location-based service [3]. It is a locator assistant that helps individuals to know where the other users are and what is around them. It supports photo sharing, tracking and chatting. It has applications integrated both on web and in mobile phones. Mopsi contains service, photo and route databases. The latter two are collected by users via mobile applications. User profile database is used for giving personalized recommendation containing data about activities of Mopsi users within the area [4]. Figure 12 shows the web interface of Mopsi.

Mopsi data collection

In Mopsi, there are two kinds of user generated data that can be uploaded and saved on the Mopsi server: *geo-tagged photos* and *routes*. Mopsi users can review their data collections, and also view other Mopsi users' collections. Photo may have an associated description which user can type when the photo was taken. Once photo is uploaded to server, the location (latitude and longitude) and Unix timestamps is also sent and stored in the database. A route is a sequence of points recorded at a fixed interval. The system distinguishes the following mode of transportation: *walk*, *run*, *bicycle* and *car* [5].

[25] http://jiepang.com/
[26] http://cs.uef.fi/mopsi/

Figure 13 shows both photo and route results for a selected user, *Pasi*. He has over 1000 routes consisting of over 2 million points in total until 5.7.2014. To display such a massive amount of data the system uses polygonal approximation and bounding box solutions as described in [6]. There are 2341 photos took by Pasi in a year. They are placed on the map at the locations they were taken. For displaying the large photo data on the map and avoid overlapping elements, a grid-based clustering algorithm[27] is applied. Photos appear also in the timeline view, on the top of the web page, clustered by time[28].

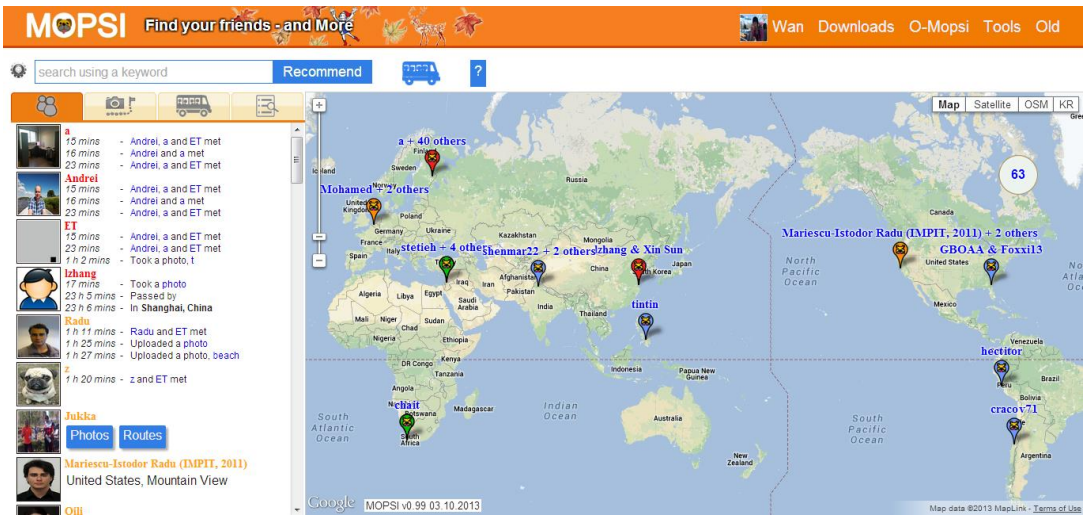


Figure 12: Example of Mopsi web interface

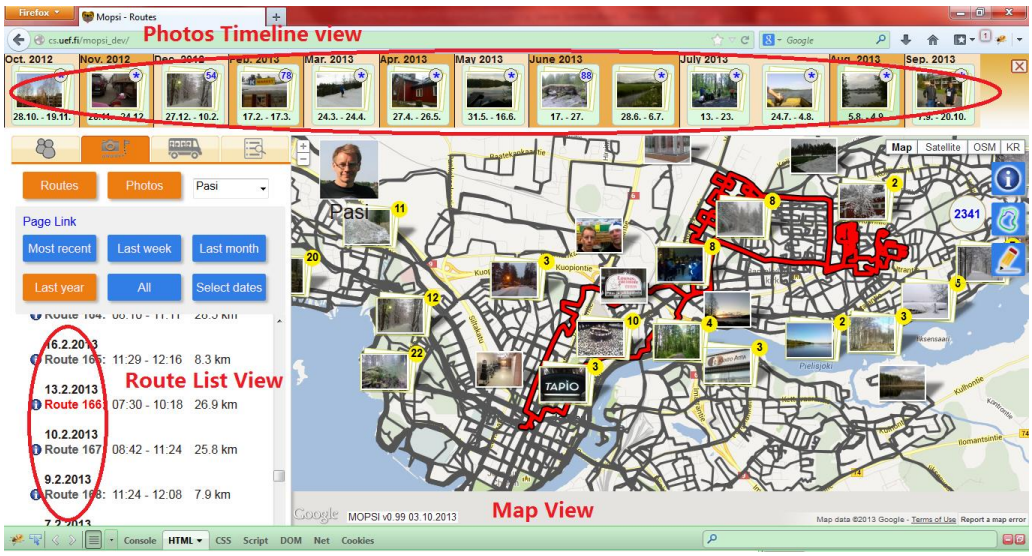


Figure 13: Example of photos and routes collections from Mopsi user

[27] http://cs.uef.fi/o-mopsi/Document/ClusteringMopsi_logic.pptx
[28] http://cs.joensuu.fi/~radum/master_thesis/Detecting%20user%20actions%20in%20MOPSI.pdf

A route is analyzed by automatic segmentation, and detection of the movement type is done for each segment [5]. Figure 14 shows a route belonging to user *Pasi*. The route is segmented and classified mostly as running activity with one stop.

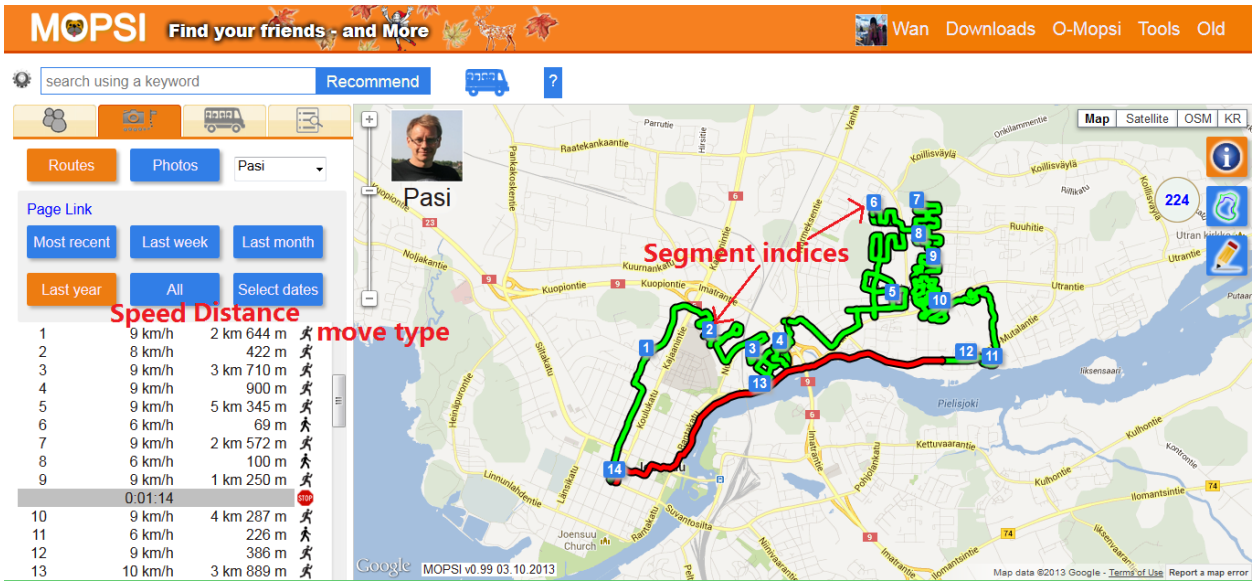


Figure 14: Analyzed route containing mostly running activity

On the mobile client, a user can view other users' collections. Linear access by time is implemented, and the most recent photo or route is being shown first. Figure 15 shows how a photo and route from *Pasi's* collection appear on Mopsi for Windows Phone.

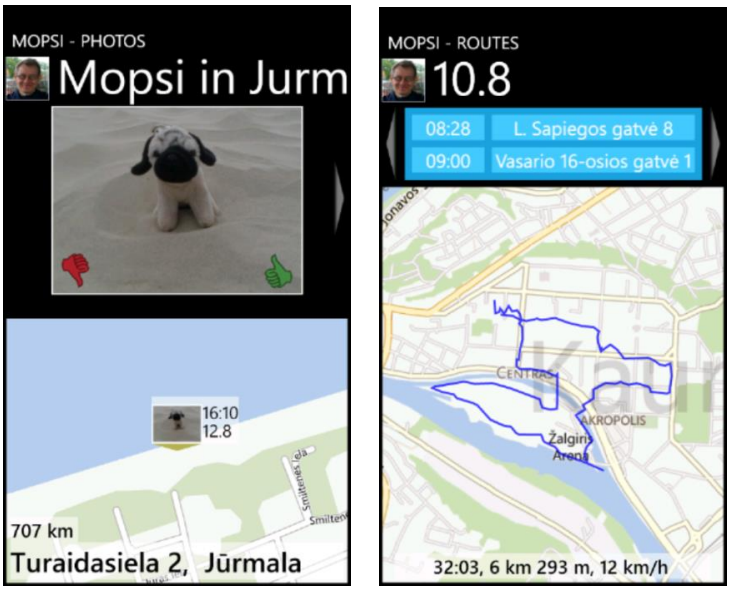


Figure 15: Mopsi on mobile (Windows Phone) showing a photo (*left*) and a route (*right*)

Location-based Search

Normal search engine like Google, Bing and Yahoo provide fast and relevant information. However, they don't utilize one important aspect of relevance: the location of the user. One reason for this is that location was not as widely available in the past as nowadays when GPS technology is integrated in most smart phones. Another reason is that web pages are rarely attached with location information [7].

Location-based search according to location information and keywords can provide relevant results in the user's area. Some famous applications like *TripAdvisor*[29] and *Booking*[30] provide tourist information, hotel information and reservation system. For example, a user wants to spend holidays in Hallstatt, Austria and needs to find a hotel on Booking. Given location and time information, Booking will provides the results (see Figure 16).

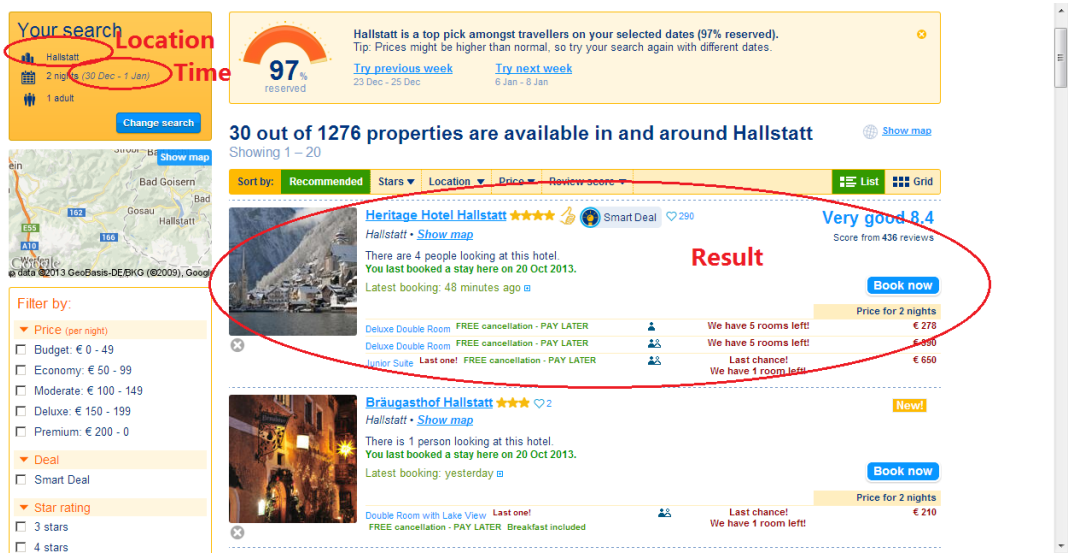


Figure 16: Booking search hotels in HallSatt from 30.12.2013 - 1.1.2014

Mopsi search combines traditional location-based service and search engine. It retrieves data from a local database, then queries relevant data from the user collections and finally performs location-based search from web as originally proposed in [8], and later implemented as summarized in [9]. The key idea is to use ad-hoc geo-referencing of the web page based on address detection within the body text [10], rather than relying on geo-tags or address tags which rarely exist.

[29] http://www.tripadvisor.com/
[30] http://www.booking.com/

A user may access Mopsi search from the web[31] as illustrated in Figure 17. Location can be selected by dragging the marker to the desired place on map or by typing an address in the appropriate field. Keyword must also be specified. The Mopsi mobile solutions[32] also provide access to the search. Figure 18 shows this feature on Windows Phone. Here location information is automatically detected by the phone. The only needed input by the user is the keyword [11].

Mopsi search engine allows the user to find nearby *services* and photos from user collection. *Services* represent a variety of categories such as restaurants, bars, cafeterias, grocery stores, museums, pharmacies and ATM machines. They are verified by administrators and are illustrated with green color coding. The information associated with them contains a title, location, photo, description, web link, keywords and user ratings. Photos are part of user collections and are marked with yellow coding [11].

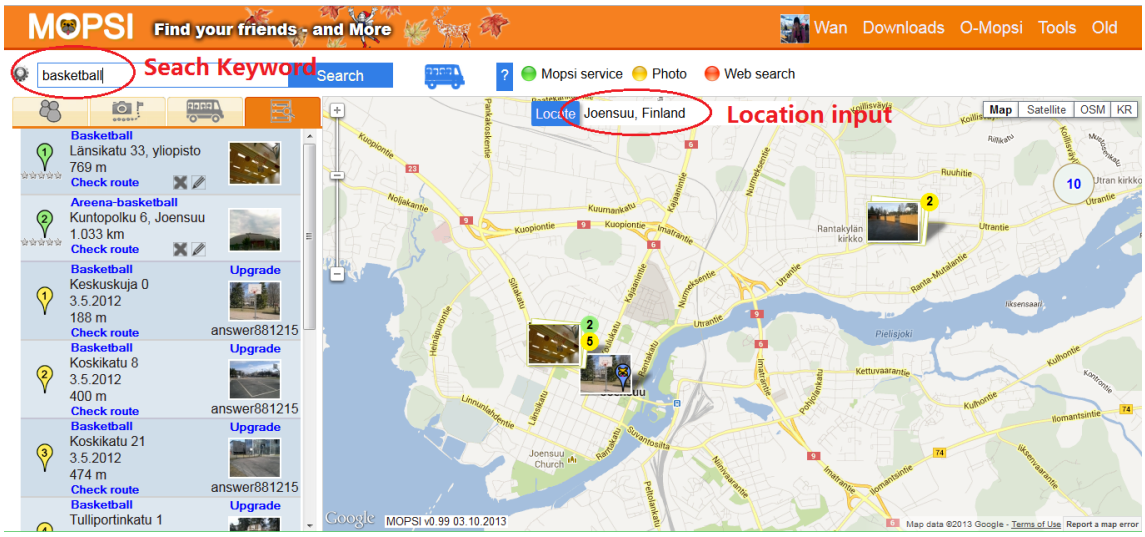


Figure 17: MOPSI web - searching for *basketball* in *Joensuu*

Location-based Recommendation

A common scenario for modern recommendation systems is a Web application with which a user interacts. Typically, a system presents a summary list of items to a user, and the user selects among the items to receive more details on an item or to interact with the item in some way [12]. For example, *YouTube*[33] is one of the largest video-sharing website in the world. YouTube can recommend users videos according to what they watched in the past.

Location-based Recommendation (LBR) is almost the same as other recommendation system, the main difference is that LBR system take location as input, and give the relevant result based on

[31] http://cs.uef.fi/mopsi
[32] http://cs.uef.fi/mopsi/mobile.php
[33] http://www.youtube.com/

this input. For example, *Tripadvisor*[34], if a user wants to spend holidays in Wien (Austria), then giving Wien as search input, the results are shown in Figure 19. These are recommended based on the ranking by all users, your *Facebook*[35] friends, and other relevant information such as hotels.

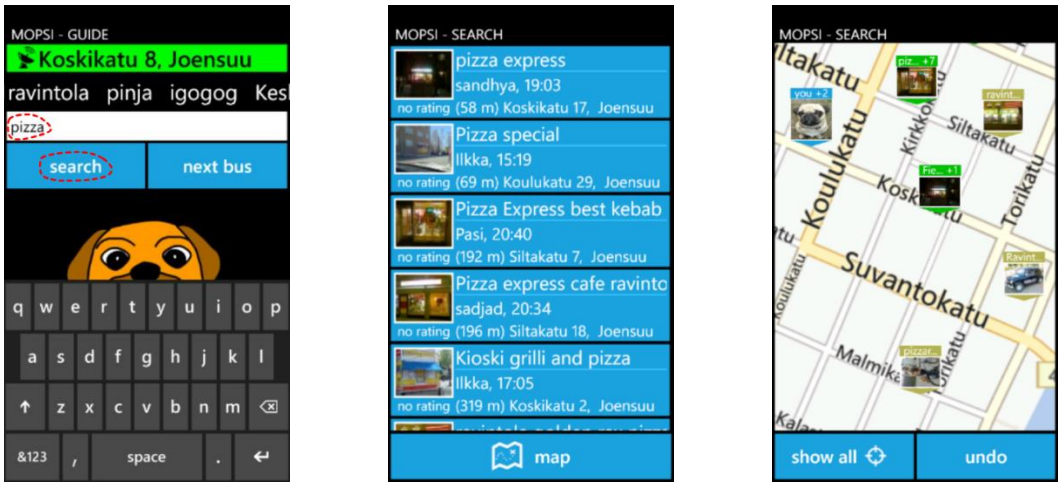


Figure 18: Searching for *pizza* in *Joensuu* using MOPSI for Windows Phone **[11]**

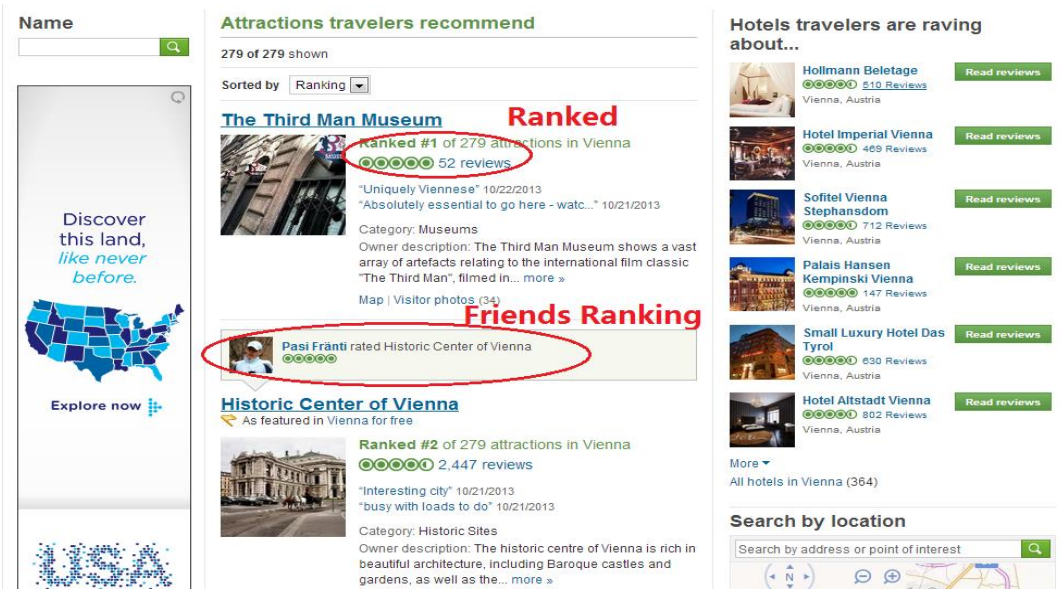


Figure 19: Attractions and hotels recommended by Tripadvisor

[34] http://www.tripadvisor.com/Attractions-g190454-Activities-Vienna.html
[35] https://www.facebook.com/

Four aspects of relevance are [3]: *content*, *time*, *location* and *user social network*. The system recommends trusted services, geo-tagged photos and routes. The goal is to offer personalized recommendations [4] by combining the three different data sources as described in the last two subsection. Binary search is used by doubling or halving the radius depending if too few or too many results are found. The process continues until enough results are found. A minimum of 10 results is the threshold for stopping the search (see Figure 20).

A user may ask for recommendations using the Mopsi web page (see Figure 21). In addition to time and location, the results also depend on the user profile and automatically obtained preferences. If the user is not logged in, user interests are excluded from the search criteria. Recommendation does not require additional user input, as opposed to the keyword required by the Mopsi search [11].

Recommendation can be used on the mobile trough a single tap of a button (see Figure 22). Location is automatically detected from the GPS sensor. Time and user identity are directly available in the application [11].

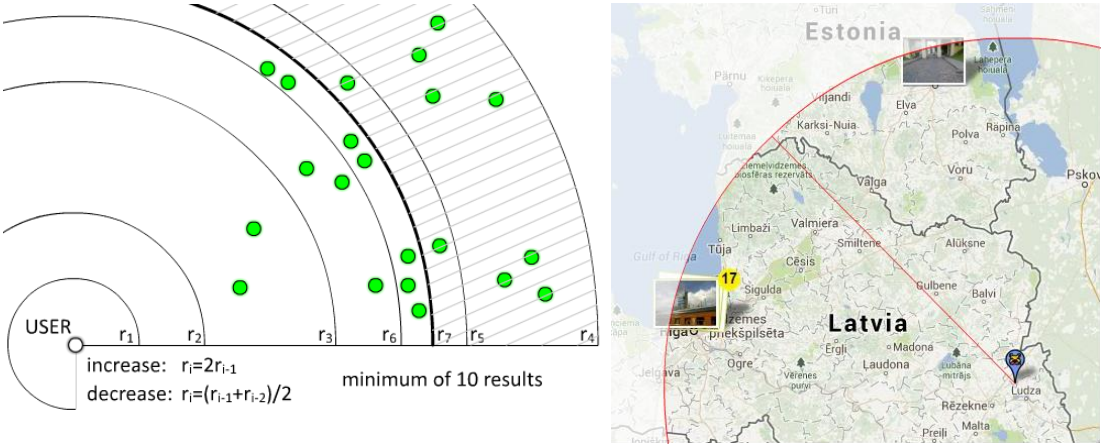


Figure 20: Changing radius to find results when nothing is close **[11]**

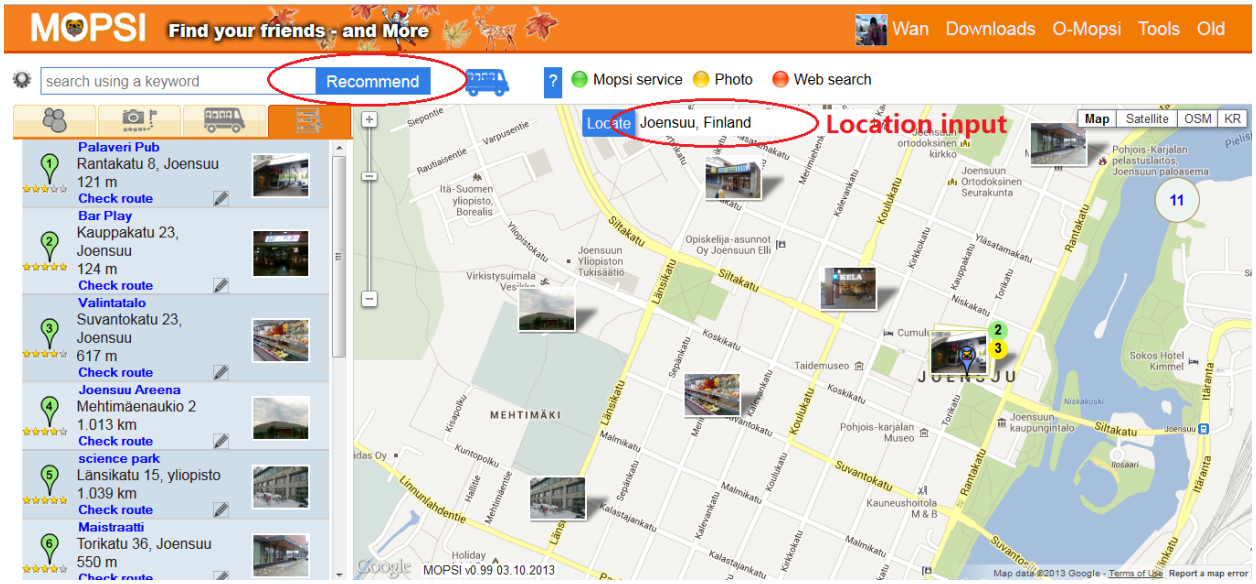


Figure 21: Mopsi web showing recommendations in *Joensuu*

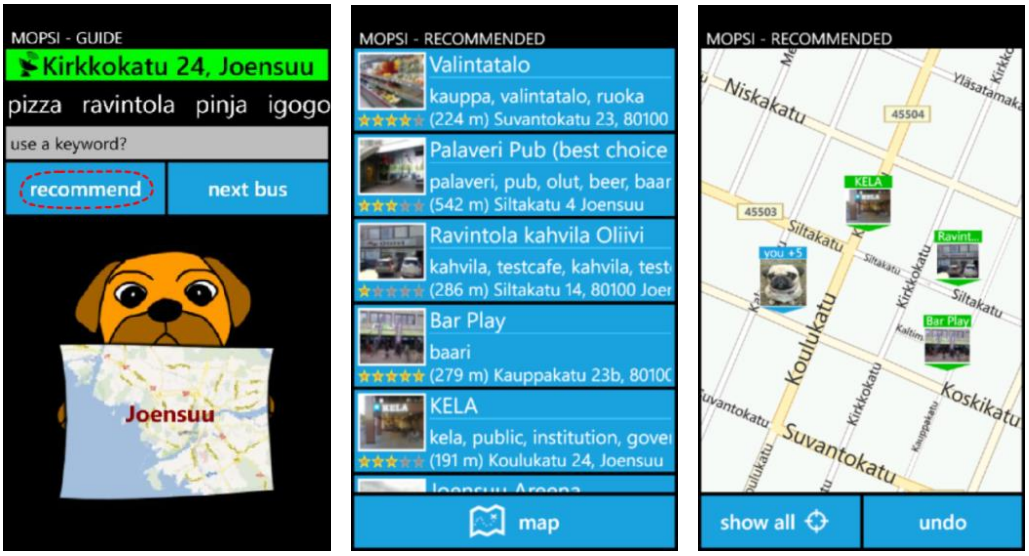


Figure 22: Mopsi for Windows Phone showing recommendations in *Joensuu* **[11]**

2.2 Location-based Games

What can be called a game? "*The game is one of the innate expressions of the human being. It is born with our abilities to move our bodies, and since then, has evolved through connections with dance, music, mimiryc and the exploration of the senses. It is one of the first manifestations of sociability, because even though it can be played alone, the game's full achievement is in the*

interaction with others" [13]. From the given definition, we know that a game can mix different physical realities, entrainment and communication.

2.2.1 Location-based mobile games overview

Location-based game experiences extend digital media out into the physical world – be it across a campus, the city streets or into remote wilderness. User with mobile displays move through the world. Sensors capture information about their current context, including their location, and this is used to deliver them an experience that changes according to where they are, what they are doing, and maybe even how they are feeling. As a result, the user becomes unchained form their PC and experiences digital media that is associated with the everyday world, and that is potentially available in any place at any time [14]. Location-based experiences aim to provide the user with a richer experience that extends across a series of locations. Perhaps the most compelling - and commercially promising – example is location-based games.

One good example for a location-based experiences game which catching most people eyes is a TV show called *The Amazing Race*[36]. It pits 11 teams, each comprised of two members, against each other on a trek around the world for approximately 25 days. At every destination, each team must compete in a series of challenges, some mental and some physical, and only when the tasks are completed they will learn of their next location (see Figure 23). Teams who are the farthest behind will gradually be eliminated as the contest progresses, with the first team to arrive at the final destination winning $1 million. Most of participants expressed their deep appreciation for this game, no matter whether they won the price or not, but because the experiences they got from this kind of game touched them much and gave them a different experience from other kind of games.

Figure 23: one team (left) was on the way & one team (right) was trying to complete their task

[36] http://www.cbs.com/shows/amazing_race/

2.2.2 Motivations for Location-based game

Physical reality

According to Maged and Stephen's article [2], there are large numbers of children and adolescents who are not getting their recommended daily dose of moderate to vigorous physical activity, and are thus more prone to obesity and its ill health effects. Therefore, more physical realities are needed in people daily life. *Exergames* are video games that require physical activity to play or moving one's body. For example, *Kinect* [37] is a full body gaming, no controller, no remotes, developed by Microsoft, see Figure 24. It has already attracted lots of users, but it requires to have Kinect device.

Location-based games can be considered as physical reality when this game is played outdoor and combine physical activity. However, some location-based games, for example *shadow city*, can be played even at home, and therefore, lacking the physical activity.

Education

Games are traditionally not associated with learning, but can arouse the intrinsic motivation of the learner [15]. Computer games in particular have been shown to raise students' intrinsic motivation to learn [16]. However, games on a desktop computer in the classroom mostly present the learning material in an artificial context and, more often than not, provide a very passive, repetition-based experience for the user, failing to appropriately raise motivation [17]. This is where mobile games in general, and pervasive games in particular, offer advantages. For example, *Savannah* [18], is a game for children in which one can learn how lions live and hunt in the African savannah. In the first part of the game the children play outside and move their character, a lion, on the virtual game field, by moving themselves in the real world. After the hunt, they return to the classroom to discuss the events of the game.

[37] http://www.xbox.com/en-US/KINECT

Figure 24: Two persons are playing volleyball game on Kinect

Tourist & Culture

Location-based game can also be used for learning culture and get tourist information about one city. *Learning culture* [19] is a game in which a story is given and a player should find the object (building, landscape and museum) according to the clues provided in the city of Matera. When the player gets close to this object, its historic story and culture information will be shown on the mobile device and next clue will be given. In this way, players can tour around the city and learn its culture. The information about the artistic and cultural heritage of the city Matera is provided by city tourist center. Another example is GUIDE project [20], which provides city visitors with a hand-held context-aware tourist guide.

Data Acquisition

Location-based games can also be used for real world data acquisition. With the help of the users, data can be collected about the real world to create more accurate or more detailed maps. For example, a building can be marked as a church or as tourist attraction. This data can be integrated in a map to allow better navigation.

2.2.3 Location-based game patterns

A *location-based game* (LBG) is here defined as a form of play that is designed to be played on a device in motion and changes the game experience based on the location [21]. There are four common game patterns which are analyzed [21] (see Figure 25).

1. Search and find
2. Follow the path
3. Chase and catch
4. Change of distance

Search-and-Find

In Search-and-Find, the basic concept is that player has to reach a destination. This location of destination is fixed. The most famous LBG game using this pattern is *geo-caching*[38]. In this type of games the player has to find an object which is hidden at certain location with only its GPS coordinates are given. The object is usually a real world box containing various items. The aim of the game is to find this box using the GPS coordinates, choose one of the items stored in the box, and in turn put a new item into the box (see Figure 26).

O-Mopsi belong to this category also. Different from geo-caching, O-Mopsi requires players to visit many places to find certain objects (building, signpost, land marker and so on) in order to finish the game.

[38] http://www.geocaching.com/guide/

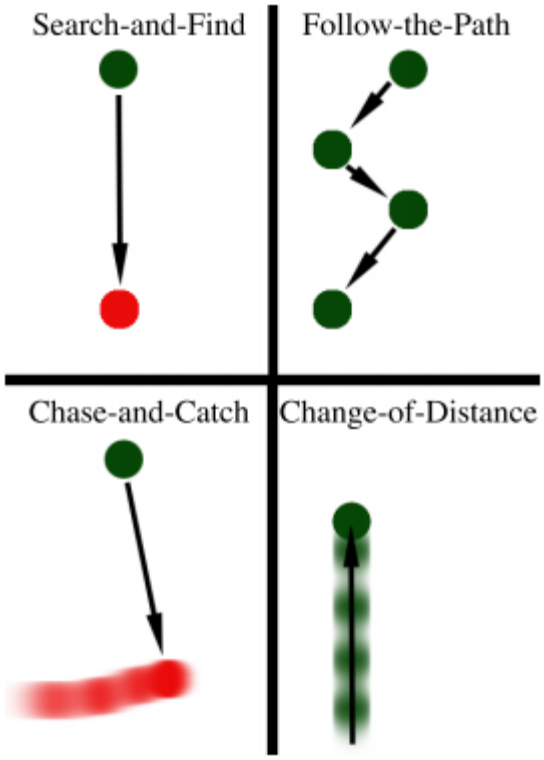


Figure 25: Graphical overview over the analyzed game patterns

Figure 26: Main components of Geo-caching, treasure box (*left*) and GPS device (*right*)

Chase-and-Catch

In *Chase-and-Catch* [22], players hunt a moving object, which can be another player or a virtual target existing only in the game world. The basic concept here is that the destination changes frequently. This pattern can be used in a single player environment with one player chasing one object, such as a hunter chasing a fox [22], or in a more complex multiplayer environment. For example, in *Shadow Cities* (no longer available) where two groups of players try to catch each other with every player chasing and being chased at the same time (see Figure 27).

Figure 27: Example of Shadow cities

In Botfighter [23], the player takes control of a robot with the mission of destroying other robots, controlled by other players. The players wander around the streets in order to find and destroy their enemies, while being on their toes as the other players might have them on their sights. Each kill provides the executioner with credits that can be spent at the game's website to improve the robot's capabilities further.

Follow-the-Path

Follow-the-path pattern is similar to *search-and-find* because the main goals in both of them are reach a destination, but *follow-the-path* asks a player to follow a given route. This is like classic orienteering, where all players must visit each targets in order. Besides a given route, it is also possible not to give any path to follow, but to track the other players movement [21]. For example, *CityExplorer* [24] is a game that aims to produce geospatial data to be used for non-gaming applications like a location-based service. In the game, players explore a city and take

photos by their smart phone about objects in different categories (see Figure 28). Another example of this kind of game is called *Tourality*[39], which has following game modes:

1. *Race*: Reach all targets faster than your competitors by reaching the targets in the given order (A-B-C-D).
2. *Chase*: All targets are active when the game starts. Reach more active targets and dye them in your color before the others.
3. *Rush*: Reach all targets in the game faster than your competitors. The sequence of reaching them is up to your strategy.
4. *Act*: At the beginning all targets except one are deactivated. As the only active spot is reached it gets deactivated, and another Spot is activated randomly. Reach more active targets than anyone else.

Race belongs to the class of *follow-the-path*, *Act* and *Rush* belongs to *Search-and-find*, and Chase belongs to the class of *chase-and-catch*.

Change-of-Distance

In *change-of-distance*, the main goal is to get closer to a geo-location or further away. The location itself is not important; it is just the movement that matters. Another distinction is that the direction is not important either. One example game in this pattern is *The Journey*[40], an adventure game where the player can read the next part of the story only after having moved a certain distance.

Figure 28: Example of user collection of CityExplorer

In Table 1, we list some games and show in which game category it belongs to, with its motivations listed as well.

[39] http://www.tourality.com/
[40] http://journey.mopius.com/

Table 1: Summary of LBGs

Game	Game Patterns				Motivations			
	Search & Find	Follow Path	Chase & Catch	Chang Distance	Physical Activity	Education	Tourist & culture	Data Acquisition
O-Mopsi[41]	X	-	-	-	X	-	X	-
Geocaching[42]	X	-	-	-	X	-	-	-
Tourality[43]	X	X	X	-	X	-	-	-
FoxHunt [22]	-	-	X	-	X	-	-	-
Shadow Cities	-	-	X	-	X	-	-	-
Botfighters [23]	-	-	X	-	X	-	-	-
Savannah [18]	-	-	-	X	X	X	-	-
CityExporer [24]	X	-	-	-	X	-	-	X
Business education [17]	X	-	-	-	X	X	-	-
AnswerTree [25]	X	-	-	-	X	X	-	X
GUIDE [20]	X	-	-	-	X	-	X	-
Learn culture [19]	X	-	-	-	X	-	X	-
The Journey[44]	-	-	-	X	X	-	X	-
Foursquare[45]	X	-	-	-	X	-	X	X
RunAway[46]	-	-	X	-	X	-	-	-
Ingress [47]	-	-	X	-	X	-	-	-

[41] http://cs.uef.fi/o-mopsi/
[42] http://www.geocaching.com/
[43] http://www.tourality.com/
[44] http://journey.mopius.com/
[45] https://foursquare.com/
[46] http://runawayapp.com/
[47] http://www.ingress.com/

3. O-Mopsi Game

O-Mopsi is a side-project of Mopsi. It is a game based on the classical concept of orienteering. A game is created by defining a set of targets. The player needs to visit all the targets in order to complete the game. The player spends shortest time is the winner. The game is played with a smart phone equipped with GPS and internet connection. Currently, there are three O-Mopsi versions available: one is for Nokia Symbian phone, Android and Windows Phone platforms (see Figure 29).

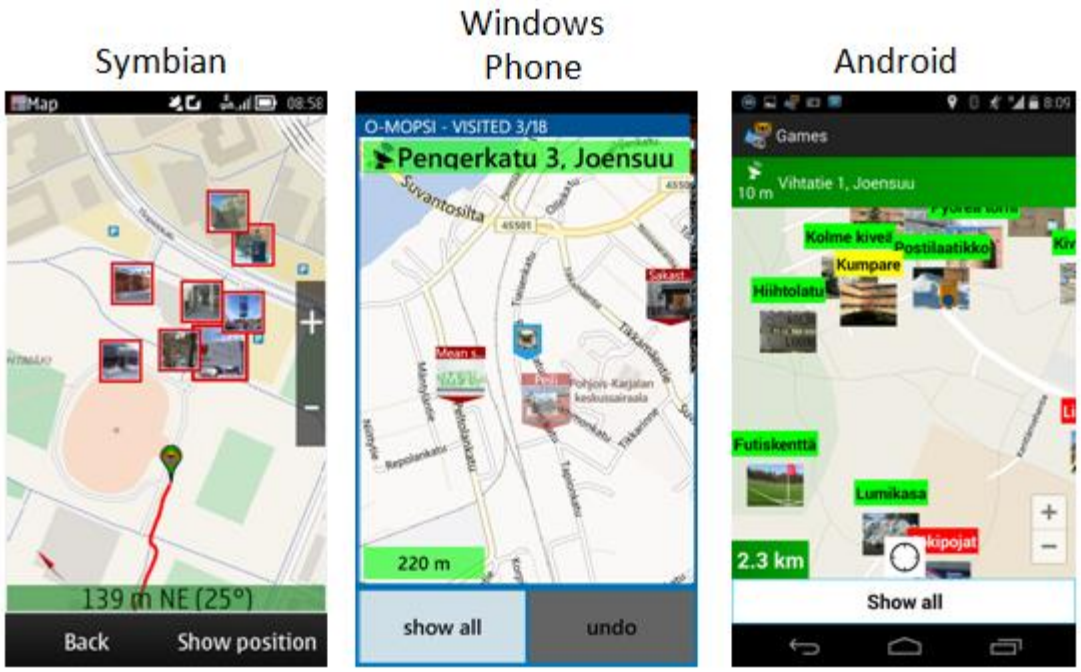


Figure 29: O-Mopsi version in three platforms

3.1 Game Rules

A game starts when player opens the game if GPS signal is available. Player needs to press the start button as well. The visiting order of targets is free and it gives extra challenge to the player to find the best order. To visit a target, a player must be closer than 20 meters to its location. This threshold was chosen considering GPS inaccuracies that occurs in the mobile device. For a good game, the creator should make sure that all targets have accurate location. A game ends when all targets have been visited.

Game results and players' progresses can be monitored real time using O-Mopsi web page, which also includes tools for game analysis including calculation of the shortest tour for reference. Players are ranked by time of completion. A player can also pause the game and continue it later,

but the time keeps running and added to the player's total time of the game playing. The player's route is recorded and stored on server.

3.2 O-Mopsi Game Playing

To play a game, user must login to Mopsi first. Internet connect is needed. After logged in, the player will get a list of games, from which he can choose to join a new game or to continue an existing active game. New and active games are marked differently (see Figure 30). The games that the player has already completed will not appear in the game list. Thus, players can play a certain game only once. In Windows Phone, players can review their finished games (see Figure 30).

Figure 30: The game list in three platforms

Before the game starts, a player should make sure that GPS is turned on. If a player is in a building or a place where GPS signal is weak, the player location will not be updated. To help a player make sure whether he has got the GPS signal, we show GPS status (see Figure 31). If GPS signal exists, the address has green background. Otherwise, it is yellow meaning that only less accurate location by network is known. The accuracy estimation is provided (in meters). In Windows Phone, the source of location is not known by the software, and the accuracy estimation is provided in meters. If the accuracy is less than the certain number of meters, yellow color is used.

Figure 31: Check GPS signal (O-Mopsi Symbian)

Once game starts, player will access the game screen. The interface of the Symbian and Windows Phone versions is slightly different, however, they both has the following six components (see Figure 32):

- Current Location
- Game statistic
- Goal details
- Closest goal
- Game results
- Exit

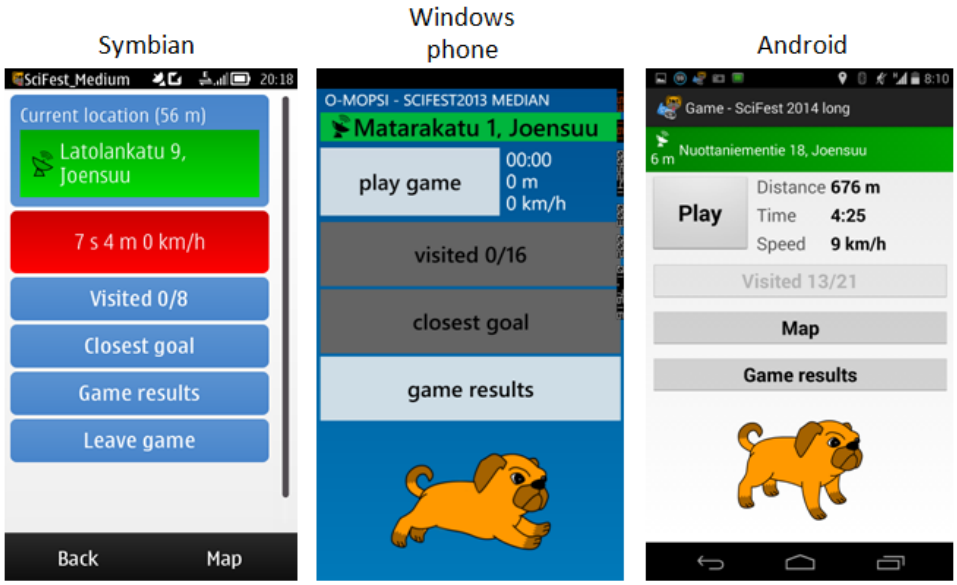


Figure 32: Game screen in three platforms

First component displays current location with the accuracy estimation in meters, and GPS status by the background color. The second component displays game statistic including the total time spent, the moved distance and the current speed. The third component shows the visited and total number of targets. By clicking this button, user will access the targets list screen (see Figure 33). It displays targets with photo thumbnails and the distance to the target location with direction. The photo which is surrounded by green border or background means this target has already been visited, whereas the red border or background means it is unvisited. When player clicks any target in the list he will navigate to the target detail screen in Symbian version. In Windows Phone version, it will open the map. There are four main components in target detail screen (see Figure 34):

- Distance & direction
- Photo
- Target description
- Back & Map buttons

The number like 1.6 km, NE shown in Figure 34 tells the distance and direction between the player's location and the target's location. A player can see a larger photo to help to identify the target and the description is given below. Here player can click map button to see the target on the map or return back to the target list screen.

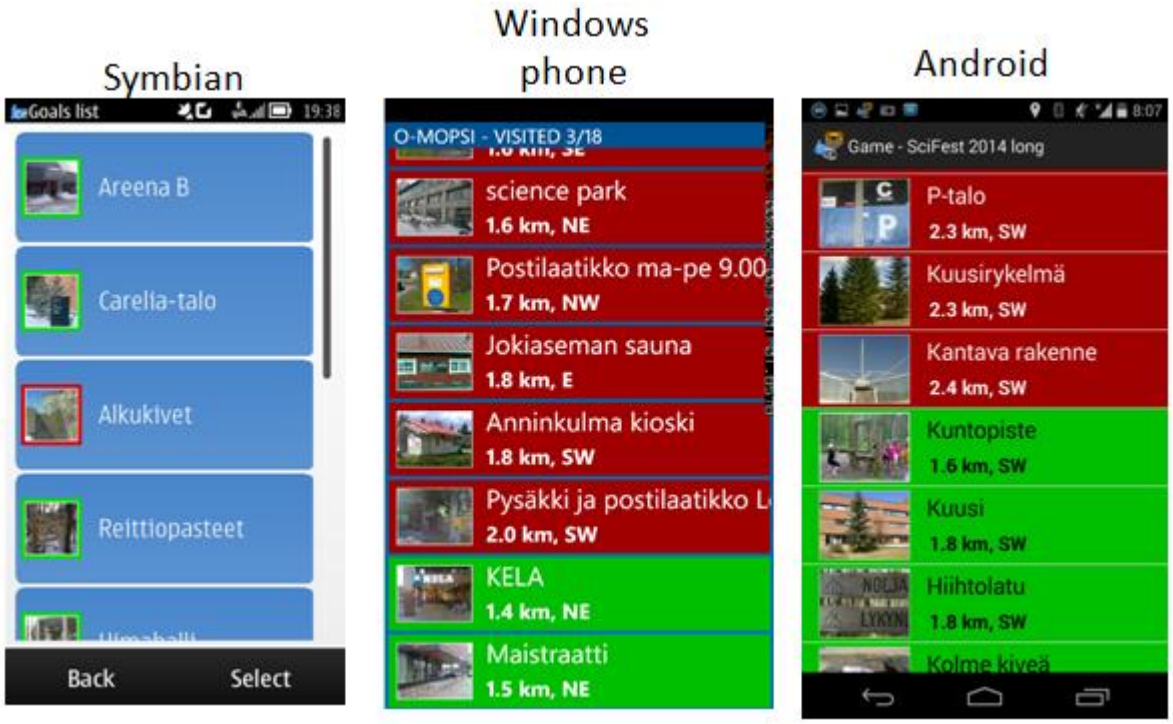


Figure 33: Target list screen in three platform

In O-Mopsi, both OpenStreetMap and Nokia map are available in Symbian version. For Windows Phone version, Bing map is used. On the map, it shows all targets and the location of player is updated in real time. If a target has been visited, the border of this target is marked by green color, otherwise by red. The route of the player is also drawn on the map. The closest target to player position is demonstrated by blinking until player visits it or another target is clicked on the map (see Figure 35). Blinking is helpful especially when there are lots of targets on a map close to each other. The distance to this target is also shown.

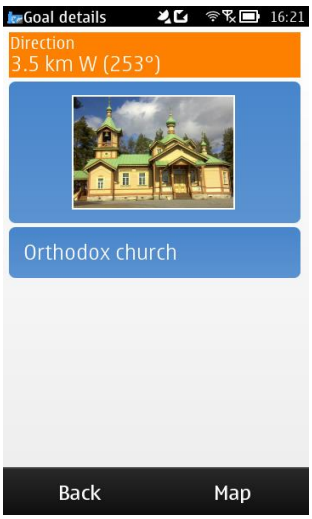


Figure 34: Goal details screen in Symbian version

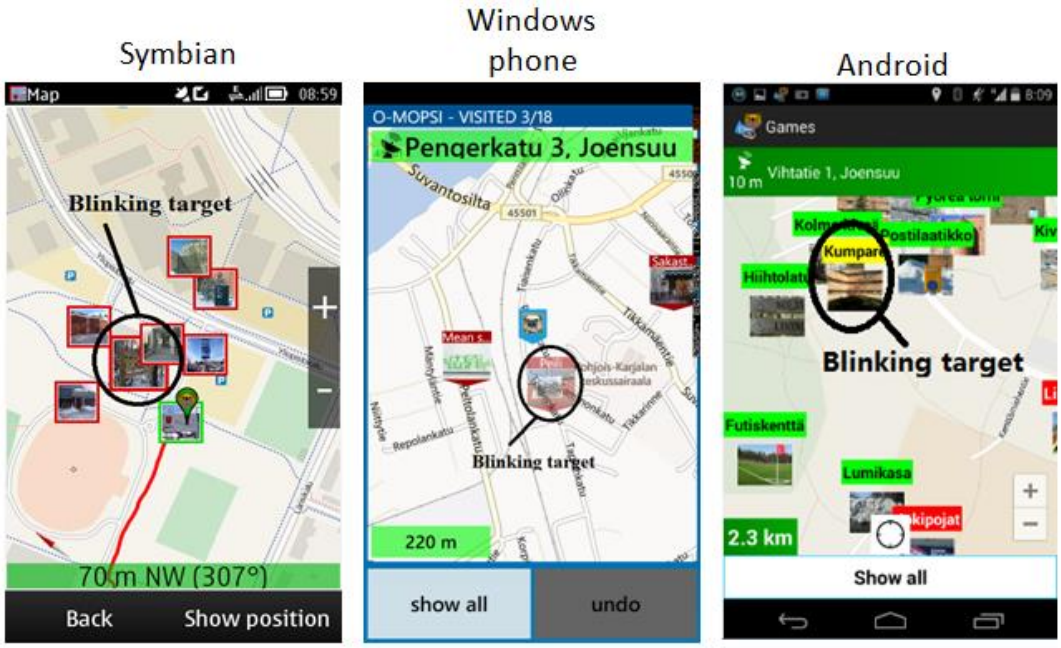


Figure 35: Map view in three platforms

For approaching a target, player is guided by sound. When distance is closer than 500 m, a beeping sound is played at fixed intervals. The interval between sounds is inversely proportional to the distance, starting from 2 seconds (500 m) and decreasing by 0.5 second every 100 m. The sound frequency increases or decrease depending whether the player becomes closer or further away from the target (see Table 2). After visiting a target, the approaching sound is stopped and a different sound is played to tell the player that he has reached the target. This sound would be played no matter on which screen is open in the game.

Player finishes the game immediately after he has reached the last goal. He can then check the results by clicking the game result button and see his rank and total time spent. The results of the other players (see Figure 36) are shown also.

Table 2 : The distance sound interval for different distance levels

Distance	Sound interval
> 500 m	no sound
400-500 m	2 s
300-400 m	1.5 s
200-300 m	1 s
100-200 m	0.5 s
60-100 m	0.3 s
20-60 m	0.2 s
< 20 m	"found" sound

Figure 36: Game result screen in three platforms

3.3 Workshop in SciFest festival

O-Mopsi has been presented in SciFest festival 2012, 2013 and 2014 (see Figure 37 and 38). The overall feedback is positive, we attach the questionnaire in the appendix A. There are more than 20 players played O-Mopsi each year.

Figure 37: Our staff helping children to set up O-Mopsi Game in SciFest2012.

Figure 38: Our staff presenting O-Mopsi to children in SciFest2013.

4. O-Mopsi Web

O-Mopsi web interface can be used for viewing the games, displaying the proposed shortest tour of a game, displaying game results and viewing players progress real-time. After logged in, user can also create new games or manage the games he has created earlier. User can publish his game result and his created games to the Facebook if he has connected his Mopsi and Facebook accounts. Figure 39 shows the use cases of web client.

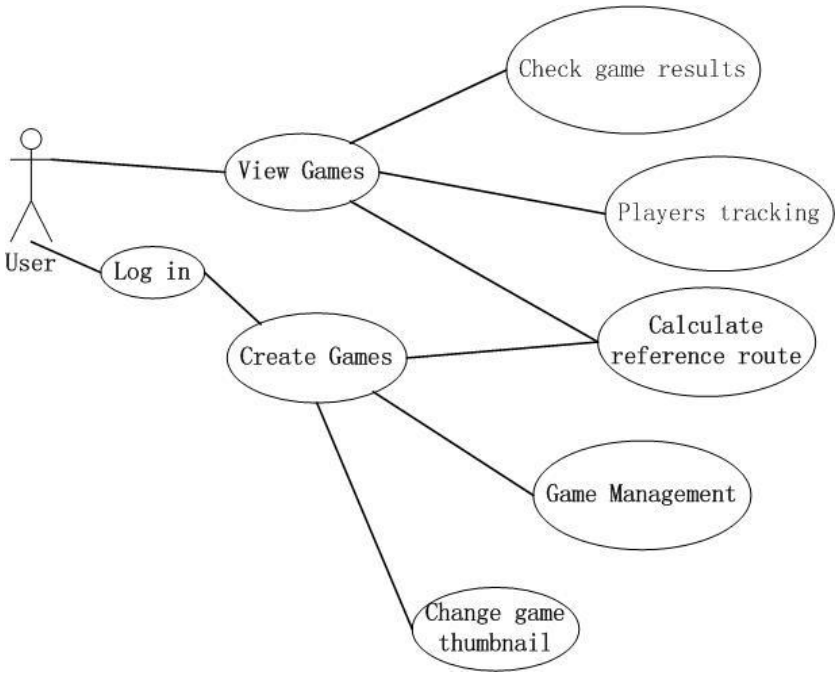


Figure 39: O-Mopsi web use cases

4.1 Game Hall

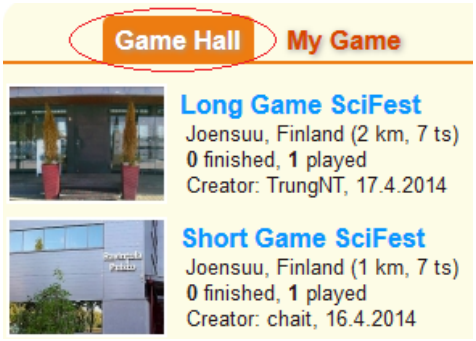


Figure 40: Game Hall

Game Hall (see Figure 40) in O-Mopsi acts as a welcome interface. It shows all games published with information such as the *description*, *thumbnail*, *creator*, *creation time*, *player statistics*, *game location* and *game level*. Game description and thumbnail can give a clear indication whether the game is sight-seeing tour or normal game. Game thumbnail is generated automatically using the photo of the first target, or it can be uploaded by the game creator. Thumbnail are shown on the map as well.

Player statistics contains information such as the number of players who have started the game and who have finished the game. Other O-Mopsi players can use this information to decide whether to join this game or not. For example, if a game has many players joined but only a few finished it, this can indicate that this game may be quite challenging or the targets were not well selected by the creator. Similarly, many players joined and finished the game may indicate that is a good game, or too easy. Game location is calculated by the average coordinates (latitude and longitude) of the targets (see Figure 41).

Figure 41: Average location of the game (Around Science)

On the map, there are seven targets marked in red and one as game thumbnail in yellow. The first target is chosen as game thumbnail by default. Creator can also change game thumbnail by uploading photo from desktop. We parse the coordinate by using Google maps API to get the city and country information. Other players can have a rough idea where those targets are located. The game level including reference tour length and number of targets. Reference tour length is

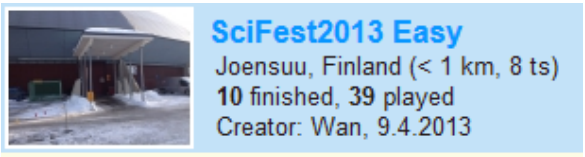
measured by Euclidean length of the shortest available tour in kilo meters for reference (see Figure 42). According to this information players can consider his / her physical ability to decide which game to play.

Game Hall provides the following functionalities:

- Showing targets on the map
- Online player tracking
- Analysis and simulation
- Game results

Figure 42: Game location, tour length, thumbnail and number of targets

These functionalities will be introduced in detail in the following sections. *Online player tracking* shows players real-time while they are playing. Users can also simulate the progress of all players who has finished the game. In the result list (see Figure 43), user can click each player to see his route.



Player	Start	Time
Wana	11.4.2013 12:01	7:06
Juhisterus	11.4.2013 11:06	11:03
karol	10.4.2013 15:02	14:15
IiVee	12.4.2013 10:40	15:52
Allusara	12.4.2013 10:08	17:50
Tytsyt	10.4.2013 12:05	18:49
Alypaat	11.4.2013 11:58	22:54
Pihla	13.4.2013 11:10	23:53
Panda	12.4.2013 13:29	28:22
Matomi	11.4.2013 11:55	29:41

Figure 43: Game results of SciFest2013 Easy

4.2 Creating a game

Game creation is one of the challenges which exists with many location-based games. By creation, we mean the construction and placement of game content [26]. If it is done poorly, players may not enjoy the game or may be at risk. In O-Mopsi, user can create new games and manage all the games that he has created. There are four main steps for creating a game:

1. Click *Create New Game* button
2. Give a name to the game
3. Add targets
4. Publish the game to game hall

If a game has been played by others, it will be locked so that the creator cannot add or delete targets from the game anymore. Therefore, the creator needs to make sure the game is ready before it is published to game hall. If creator does not choose to publish the game, other players cannot see this game in the game hall. An empty game cannot be published to the game hall. A playable game should have at least three targets not to be too trivial. Currently, O-Mopsi does not set upper bounding for the number of targets, and creator can add as many targets as he wants to. System shows the number of targets and reference distance for the game (see Figure 44). The reference distance is updated when creator adds or deletes a target. Tabu search algorithm is used for calculating the distance of the reference route. Those information are given and it is up to players to decide whether to join the game or not (see Figure 44).

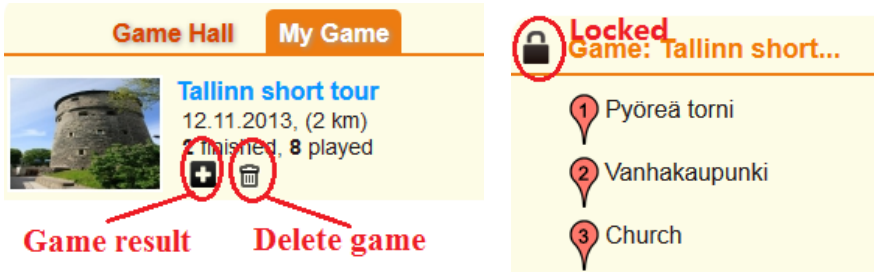


Figure 44: Single game view in *My Game* mode and its target list with a lock

There are three ways creator adds targets (see Figure 45):

1. Using Mopsi photos collection
2. Using Mopsi services
3. Uploading photos

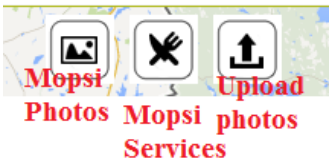


Figure 45: Tools for creating a game

Easiest way is to take targets from Mopsi, because they have location included, and usually description is already given as well. When using this tool first time, O-Mopsi detects user location by IP address thought HTML 5 or PHP, and shows a Mopsi marker on the map. Creator can then drag the icon or type the address in the search box to navigate to the place he wants. Mopsi photos are shown around the desired area. Creator can select the Mopsi users whose photos are searched by changing the user name on the top left of the map (see Figure 46). Selection of all users is also possible.

Targets are added by right clicking the mouse on a single target, or on a photo cluster. The border of selected photos will change color. Another way is to left click the photo (or photo cluster) and the press the "Add Goal" button. If the right click is repeated, the selected photo is unselected and removed from the target list. This tool is useful when a user collects photos by himself and choose them as targets. He can simply access his own photo collections at the selected location. It is also convenient to view friend's photos in the desired area, or even any other Mopsi users' photos.

Figure 46: Tool to show friends photos around the desired area

Using Mopsi services is similar to using Mopsi photos, but the targets are limited to the objects in the service collection. This avoids selecting people or animal which are not suitable as a target. There is also a location marker on the map and a location search box on the top. Creator can switch city by those tools. Mopsi services includes photos such as landmark, cafes, restaurants, museums and shops which are suitable as O-Mopsi targets.

Uploading own photos allows creator to add any target not existing in Mopsi. However, creator should then also give description and location. Creator can type location in the search box or drag the marker on the map (see Figure 47). This tool is useful when creator wants to make a tour game in a city where his friends have not yet been. After user clicks the "*Save*" button, the photo will be added on the map. User can still update the photo location or edit the description later.

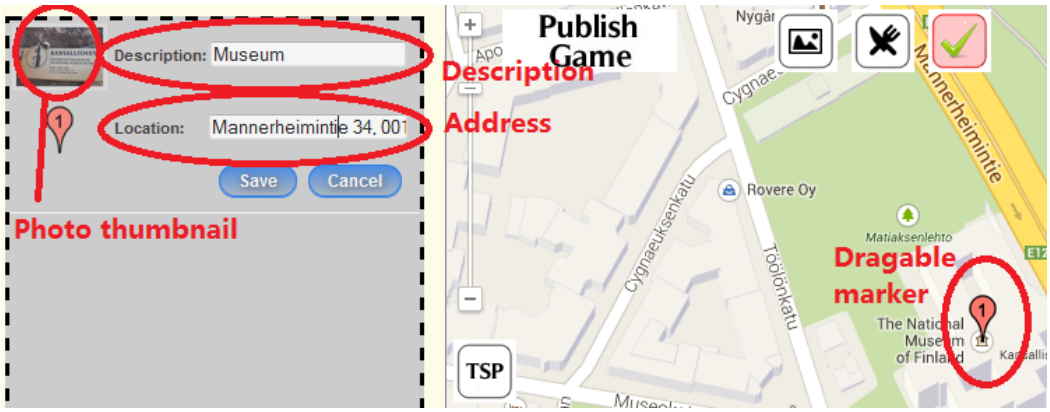


Figure 47: upload user own photo

Publishing game to the game hall allows creator to share his / her games with other O-Mopsi players. Creator can publish a game by clicking the "*Publish Game*" button on the map (see Figure 47). A game when first created is not listed in the game hall, they are still in editing model until this button is pressed (see Figure 48). Therefore, other players cannot yet join the game. Once the game is published, other players can see and join this game. Creator can also close this game later from the game hall, after which other players cannot see it.

Figure 48: Game Science Park - Utra is not published

4.3 How to Create Good Game

For a playable game, the quality of targets is important. Therefore, we list some rules for creators to follow.

1. Outdoor targets only
2. Reachable and clear target
3. Accuracy of location
4. Permanent targets
5. Distance between the targets
6. Number of targets
7. Short but descriptive name for a target
8. Descriptive name for the game
9. Language

Outdoor targets only. Targets can be small, like logo on door, small detail on building or big like Riosk, shop or other easy to find place. Selecting people, animals and indoor objects as targets is not good.

Reachable and clear target. Figure 49 (a) shows an example, both photos were taken in forest, but left one has an control point. It is good when players have a certain object to look for.

Targets permanent. Figure 49 (a) shows a control point in the forest, it is good during the SciFest (we set up control point for each target during the SciFest 2014), but it is not good after the SciFest because we took those control points back. Also, if you choose flowers as targets, they may not be found in winter.

Accuracy of location. Bigger target only if location can be identified reasonably well (see Figure 49 b). Right one is taken far away from the object, the location is not accurate. Choose close distance picture is better.

Figure 49: Example for choosing a target

Consider the distance between each targets. If two targets are far from each other, it will lose the interests for finding it. According to the feedback we got from SciFest, most of the players give comments that finding targets is the most interesting thing during the game. Players enjoy the feeling of achievement.

Number and length of targets. A game should have at least three targets. It is up to creator to decide how many targets he wants to add into the game, there is not up bounding limit. Creator can use TSP tool to check the reference route length. Sight-seeing tour can be more trivial to solve, like clear circular tour (see Figure 50).

Figure 50: Sight-seeing tour game in Singapore

Short but descriptive name for a target. Target name should be short because mobile screen cannot fit long names. It should give a hint for players to locate the target. Try to avoid using names like "Target 1", "No.1" or even empty name.

Give a depictive name for your game. A suitable game name can attract more players come to play your game. For example, game name can be: Postbox maniac, Joensuu Cafes or Niinivaara sightseeing. Players might be aware they need to find yellow box in a given area; all cafes in downtown; includes worth to see places in Niinivaara area.

Last but not least, it is about language. Using local language or English preferred is easier for people to adopt it.

4.4 Game Simulation

User can select a single or multiple players in the players list, and show their playing route on the map. *Animation tool* uses an icon of mopsi with different transportations which is determined by the player moving speed. When the simulation starts, the icon will move according to the route. When a target is visited, it's border will turn from red to green (see Figure 51). We also show speed and elevation charts to show detail movement information.

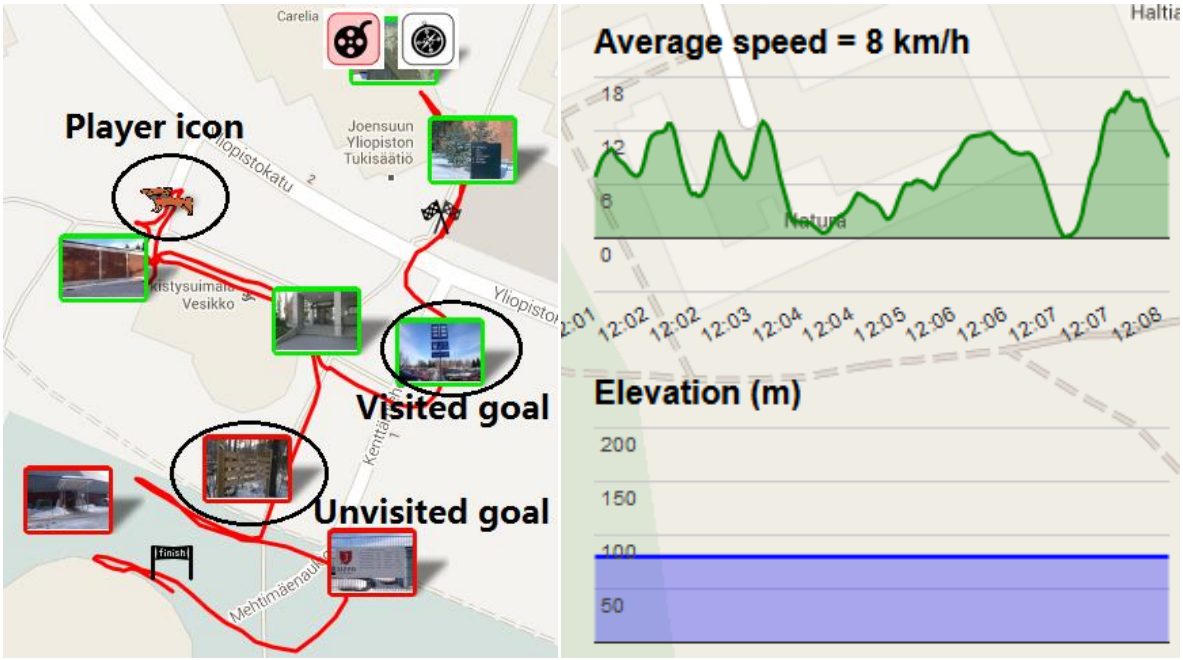


Figure 51: Game simulation

If multiple players are selected, then all selected players will move synchronously according to their routes. This simulates their playing supposing that they started at the same time. A score box is shown to display the progress of finding targets. After completing the game, numbers will be shown to indicate the rank of the players (see Figure 52).

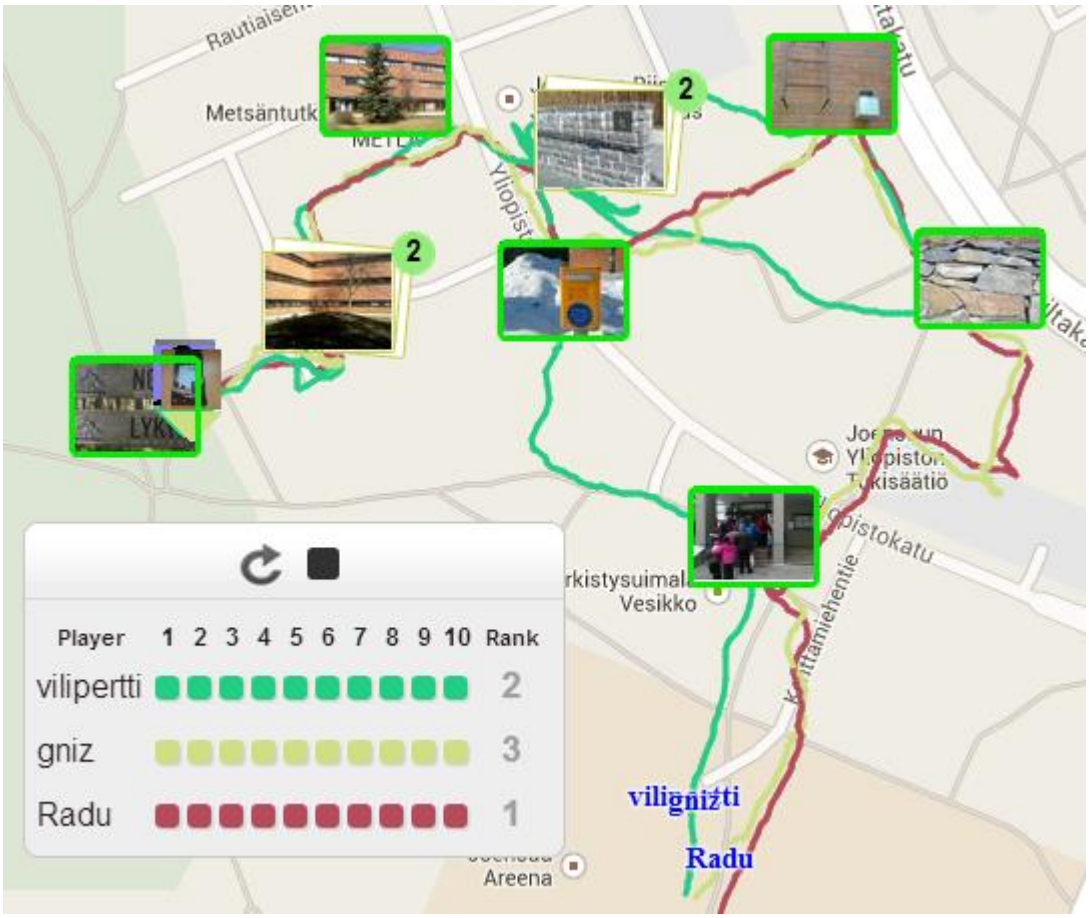


Figure 52: Multiple players simulation

Player tracking can also be monitored in real-time. When users enter the '*Online player tracking'*, player list (see Figure 53) is shown, including online players. The page is refreshed every 8 seconds. The players' routes are also drawn on the map.

Figure 53: Online players list

4.5 Facebook Publishing and Game Events

User can publish a game he created or completed in Facebook. Publication shows the game thumbnail, title, number of targets, estimated length, total number of games in the city and the number of games created by user. Publication of a completed game shows game title, time spent, distance, player rank and a map with the goals and player's route drawn on it (see Figure 54).

If user has linked Mopsi account with Facebook, the game result will be automatically published to the Facebook when he completes a game. It can also be done on O-Mopsi web by pressing a button on the game review page.

Mopsi has "*Events*" which includes users' activities like *take a photo*, *pass by a service*, *complete a tracking* and *meet friends*. One can see the events on Mopsi home page or on user's profile page[48]. O-Mopsi has four kinds of events (see Figure 55):

1. game creation

[48] http://cs.uef.fi/mopsi/profile/index.php?id=158

2. game participation
3. game completion
4. record breaking

A user can create an O-Mopsi game by selecting a set of targets from the Mopsi photo collections , the trusted services or uploading his photos. The *game creation* action will be triggered when he publishes the game to the Game hall. A player can choose to play any games from the database, once he joins the game, the *game participation* action will be triggered. *Game completion* action will be triggered when a player completed the game, if he broke the record at the same time, *record breaking* action will be trigged also.

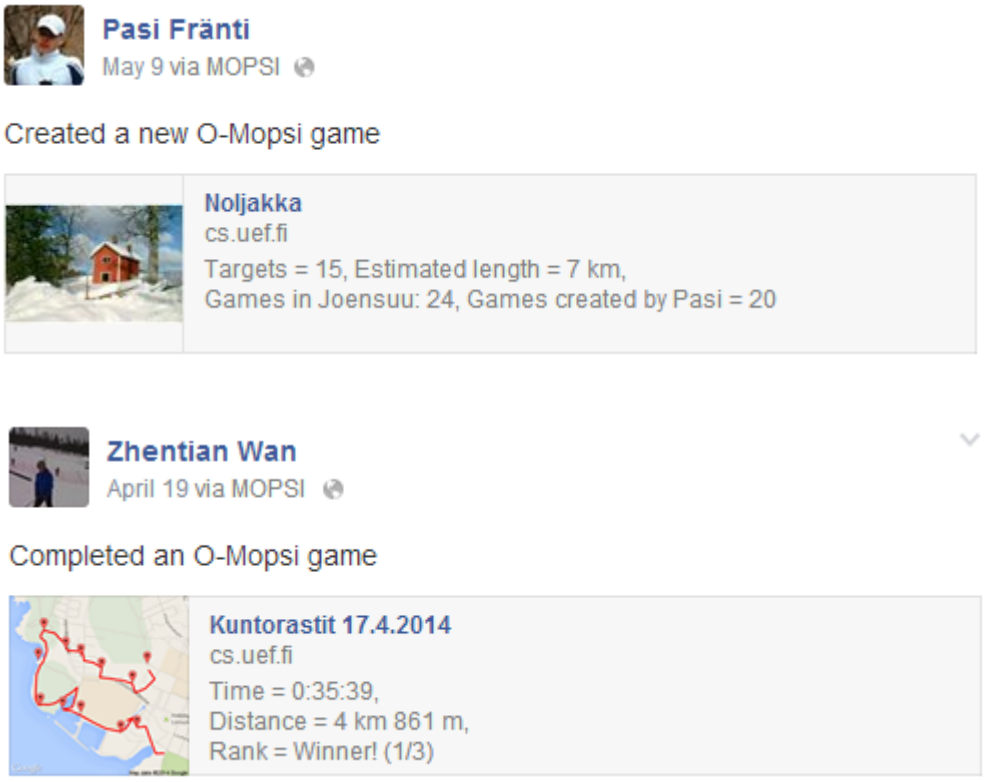


Figure 54: Publishing a created or completed game to Facebook

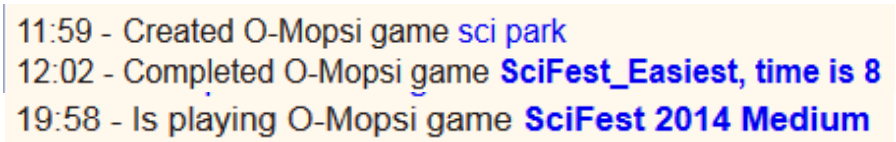


Figure 55: O-Mopsi game events

5. Further Improvements on Game Design

O-Mopsi has been presented in SciFest 2012, 2013 and 2014. We received 68 players feedback in total, of which 59 players (87%) gave a positive feedback. In 2014, positive feedback was 27/30 (90%) which indicates that O-Mopsi is an enjoyable location-based game. In this chapter, we will introduce further ideas of possible new game patterns for O-Mopsi. We study two location-based application, of which one is Geocaching and the other one is Foursquare. We try to learn from well-established applications how to further improve O-Mopsi.

5.1 New Game Patterns

Many of the alternative game patterns requires more users playing at the same time for a single game. Players can form teams to play against each other, which would increase the enjoyment of the playing. However, we also consider other single player game patterns.

Monopoly

When I was a child, I liked playing board game. One of my favorite board game is called Monopoly. Players move around the game board buying or trading properties, developing their properties with houses and hotels, and collecting rent from their opponents, the ultimate goal being to drive them into bankruptcy [49]. It would be fun if monopoly game can be played in the real world. The idea of applying Monopoly for O-Mopsi is that each players should visit as many targets as possible before other players visit them, and once a player visits a target, this target belongs to him. In the end, the player with the largest number of targets in shortest time is the winner (see Figure 55). This game pattern can be multi-players individually or played by teams.

Classic distance order

O-Mopsi ranks each player according to the shortest time currently. Alternative ranking could be used on shortest distance travelled. In this patterns, player should not only be fast but also smart as winner should visit all targets optimizing the total distance.

Sprint

Players are required to visit as many targets as possible in a given time. The player who visited most targets is the winner (see Figure 56). If two players come up with the same number of targets, then the player who spent shortest time is the winner.

Sprint with check point

[49] http://en.wikipedia.org/wiki/Monopoly_(game)

There are a series of targets in a game, each with different points. When a player visits this target he will get the amount of points accordingly. Players are required to get points as much as possible in a given time.

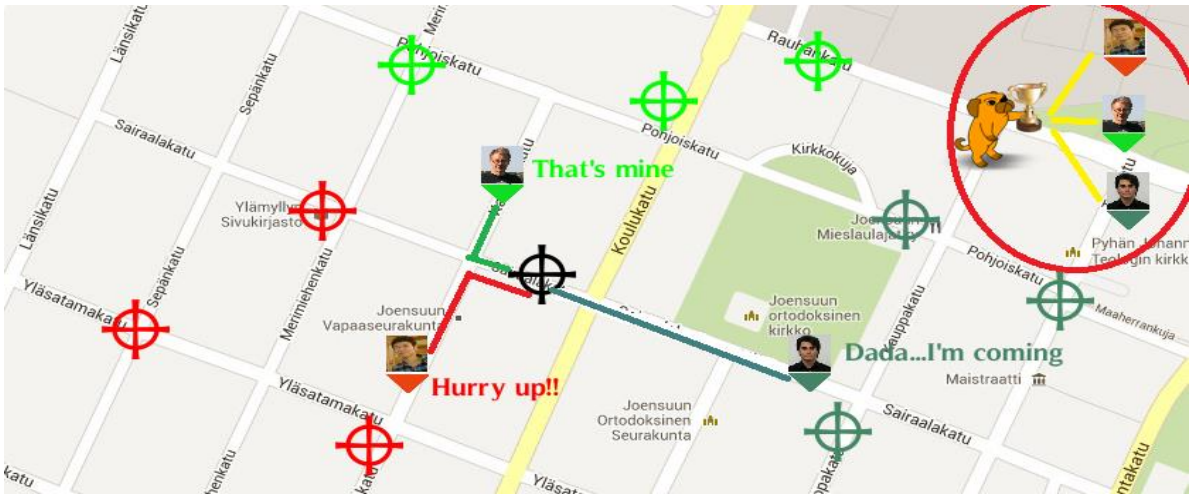


Figure 55: Monopoly game pattern

Rank	Name	Number
1	Pasi	6
2	Andrei	5
3	Karol	4

Figure 56: Sprint game pattern

5.2 Badges

The study of *Foursquare* [27] show that Badges is one of the reasons why users like Foursquare. People enjoy the feeling of achievement. Badges give people a reason to continue using the application. *Tripadvisor* also uses badges (see Figure 57). Inspired by those two applications, we design Badges for O-Mopsi for three achievements as well: number of games created, completed and won -- creator, orienteer and winner. Player can earn those badges by creating and playing games (see Figure 58).

Figure 57: Badges from TripAdvisor

Figure 58: O-Mopsi badges

6. Calculating Reference Route

We provides *reference route* for each game. This reference route indicate the potential minimum distance for completing the game. We use Euclidean distance when calculate the distance among targets to targets, therefore, real playing distance is often longer than the reference route.

Calculating reference route belongs to *Travelling salesman problem (TSP)*, which was first formulated as a mathematical problem in 1930 and is one of the most intensively studied problems in optimization[50]. The goal of TSP is that a salesman must travel through *N* cities. All the cities must be visited once and return to the starting city. TSP is a NP-complete problem[51].

In O-Mopsi, the goal of a player is to finish the game in a shortest time. This implies finding the shortest route, which usually reduces the travel time. The problem in O-Mopsi is slightly different because player does not need to return to the starting point. Otherwise, the problem is the same as TSP. In this thesis, we study *Tabu search* algorithm (TS) to solve TSP. The algorithm was programmed as a student project on *Design and Analysis of Algorithms course* [52] organized by University of Eastern Finland. O-Mopsi web page uses the algorithm to give a reference route for a game. TS algorithm does not guarantee an optimal solution.

The input of the algorithm is from a text file that contains the distance matrix of all possible routes between every target. The algorithm is based on the idea of swapping every path node that is not in the tabu list, and then keeping the best solution. The process is then repeated for the new solution by generating all possible swaps. The tabu list is updated by adding the pair of nodes of the best swap, and by removing the two oldest nodes form the list. The pseudo code for the algorithm below:

```
Algorithm tabu seach

bestSolution: = initialSolution;
for trials = 0 TO MAX_TRIALS DO
 for gap = 0 TO sizeOfTargets DO
  for q =1 TO sizeOfTargets -gap DO
    trialSolution = bestSolution;
    swapSolutionNodes(q, q+gap);
    if validateSwap() && Distance(trialSolution) < Distance
(bestSolution)
    then bestSolution =tempSolution;
         updateTabuList(q, q+gap); //the pair which have been
swapped
```

[50] http://www.princeton.edu/~achaney/tmve/wiki100k/docs/Travelling_salesman_problem.html
[51] https://gcu.googlecode.com/files/Exploring%20Algorithms.doc
[52] http://cs.joensuu.fi/pages/franti/asa/

We first initialize the solution by greedy algorithm. The greedy algorithm starts from the first target and selects next target as the closest to it. This is repeated until all targets are visited. We store the order and the total distance generated by the greedy algorithm. Then we use this result as the starting solution for the swapping stage (see Figure 59).

The idea is to swap though all possible solutions by increasing the gap. In this way, all pairs of nodes will be tried. Before swapping, we check if the pair is not recorded in tabu list and if not then we do the swap. After each swap, we check if the new solution gives a better result, and if yes, we accept the new best result and update the tabu list. Tabu list keeps track of the swaps that has caused improvement in the solution. The idea is to prevent falling back into old patterns and getting stuck into a local maximum. The algorithm end when a preset number of trials (MAX_TRIALS equals 100) have been used.

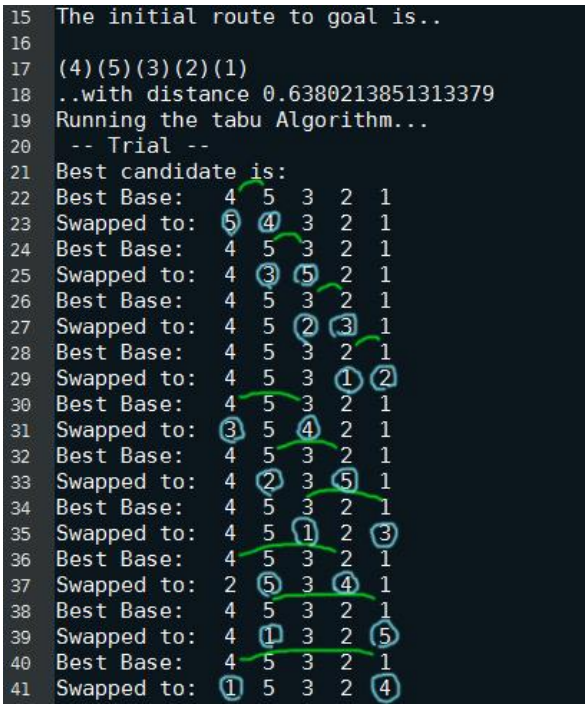


Figure 59: Swap mechanism[53]

[53] http://tonis.comli.com/index.php?page=tsp

7. Experimental Results

For testing purpose, we have developed a website *MOPSI TSP*[54]. We consider two main characteristics of the algorithms: processing time and tour length. Currently, four algorithms implemented:

1. Tabu search (TS), by Toni Sanio based on Design & analysis algorithm[55]
2. Ant colony optimization (ACO), by Hamid Behravan based on Ant Colony Optimization, The MIT Press Cambridge[56]
3. Dynamic programming with brute force (DYN), by Emmanuel Kolog based on Design & analysis algorithm[57]
4. Greedy Heuristics (GRE), by the author of this thesis based on Design & analysis algorithm[58]

In this thesis, we will focus on TS and ACO. Algorithm DYN can guarantee optimal result but it takes too long time, normally, it is suitable for less than 10 targets and algorithm GRE cannot give good result every time. We evaluate those two characteristics within O-Mopsi.

We selected O-Mopsi games to test the processing time of TS and ACO. In these games, the number of targets varies from 6 to 25. As we can see from the results in Table 3 and Figure 60, TS works well for smaller number of targets but it does not guarantee optimal solution. Starting from *Noljakka* game (N = 15), TS works worse than ACO. For *Barcelona Grand Tour* game, the difference between those two algorithms is up to 1 km. On the other hand, ACO consumes about 4 seconds or more for calculating reference route when the number of targets is greater than 15. For *Luxembourg Ville Haute game* (N = 25), it takes 10 seconds which is not user friendly in real-time application. TS only takes always less than 1 second (see Figure 61). In summary, TS cannot guarantee as good result as ACO if number of targets getting larger but it is fast and the difference is smaller than 10% or less. The corresponding results are plotted in Figure 62.

[54] http://cs.uef.fi/o-mopsi/tsp
[55] http://tonis.comli.com/index.php?page=readArticle&aId=9
[56] http://mitpress.mit.edu/books/ant-colony-optimization
[57] http://cs.uef.fi/o-mopsi/Document/DynProramming.pdf
[58] http://cs.uef.fi/pages/franti/asa/

Table 3: Result of the points number from 6 to 21

No	Game name	Number of targets	Time		Length	
			TS	ACO	TS	ACO
1	SciFest Easy	6	0.3 s	1 s	922 m	922 m
2	SciFest2013 Easy	7	0.3 s	1 s	484 m	484 m
3	SciFest Medium	8	0.4 s	1 s	516 m	505 m
4	Mekrijarvi Easy	10	0.4 s	2 s	5.2 km	5.2 km
5	Manneken Pis	11	0.3 s	2 s	1.3 km	1.3 km
6	Kowloon Park	12	0.5 s	3 s	844 m	815 m
7	Jokiasema	14	0.5 s	3 s	2.2 km	2.2 km
8	Noljakka	15	0.5 s	4 s	6.5 km	6.3 km
9	Rantakylä Tour	16	0.4 s	3 s	5.2 km	5.0 km
10	Barcelona Grand Tour	18	0.5 s	4 s	15 km	14.0 km
11	SciFest2013 Hard	19	0.5 s	4 s	2.1 km	2.1 km
12	SciFest 2014 long	21	0.7 s	6 s	3.1 km	3.0 km
13	Luxembourg Ville Haute	25	0.7 s	10 s	2.2 km	2.0 km

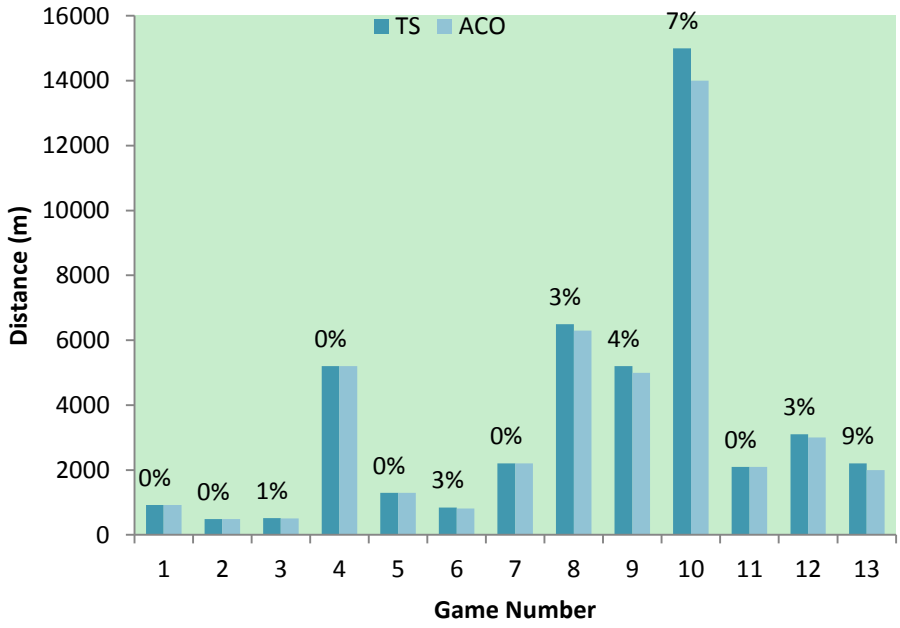


Figure 60: Distance comparison between TS and ACO for O-Mopsi games

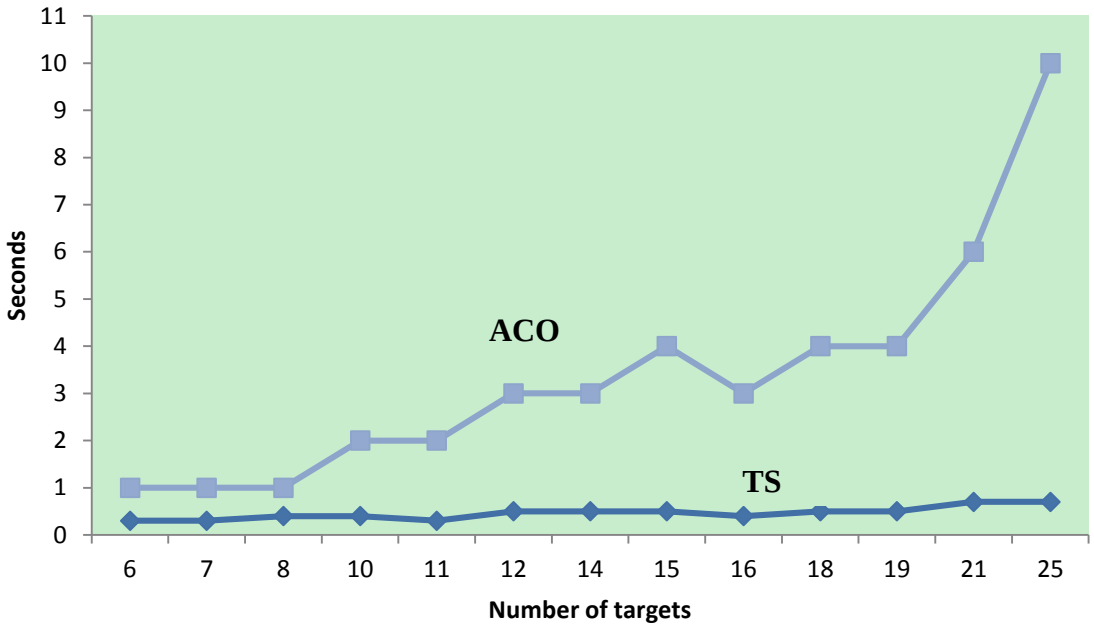


Figure 61: Time comparison between TS and ACO for O-Mopsi games

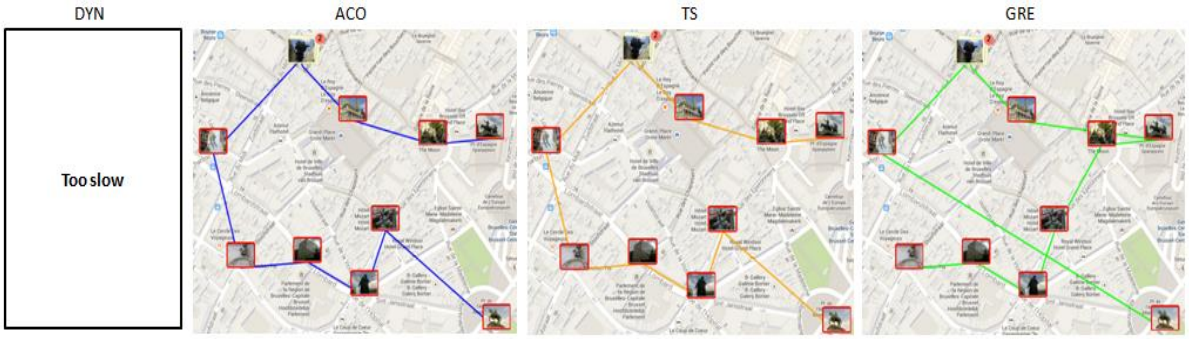
SicFest Easy:

SciFest2013 Easy:

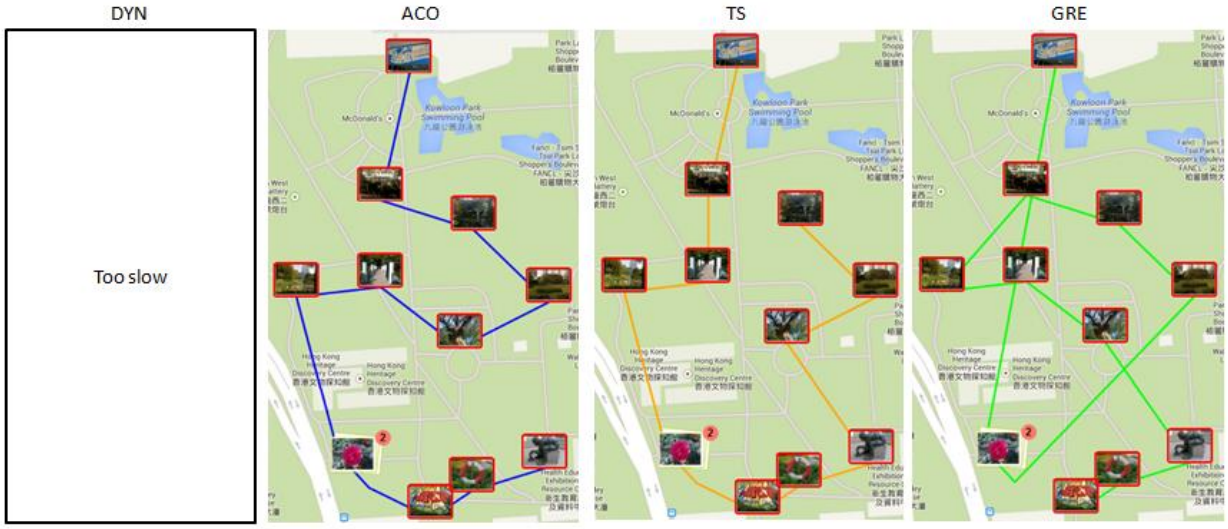
SciFest Medium:

Mekrijarvi Easy:

Manneken Pis:

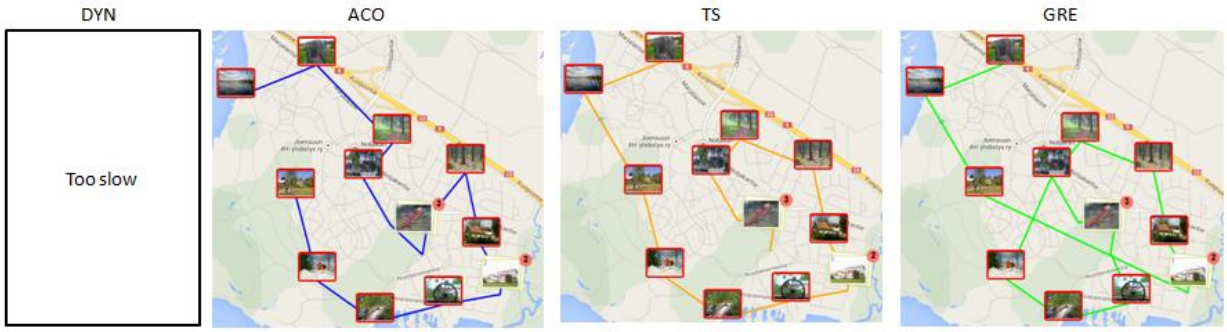


Kowloon Park:

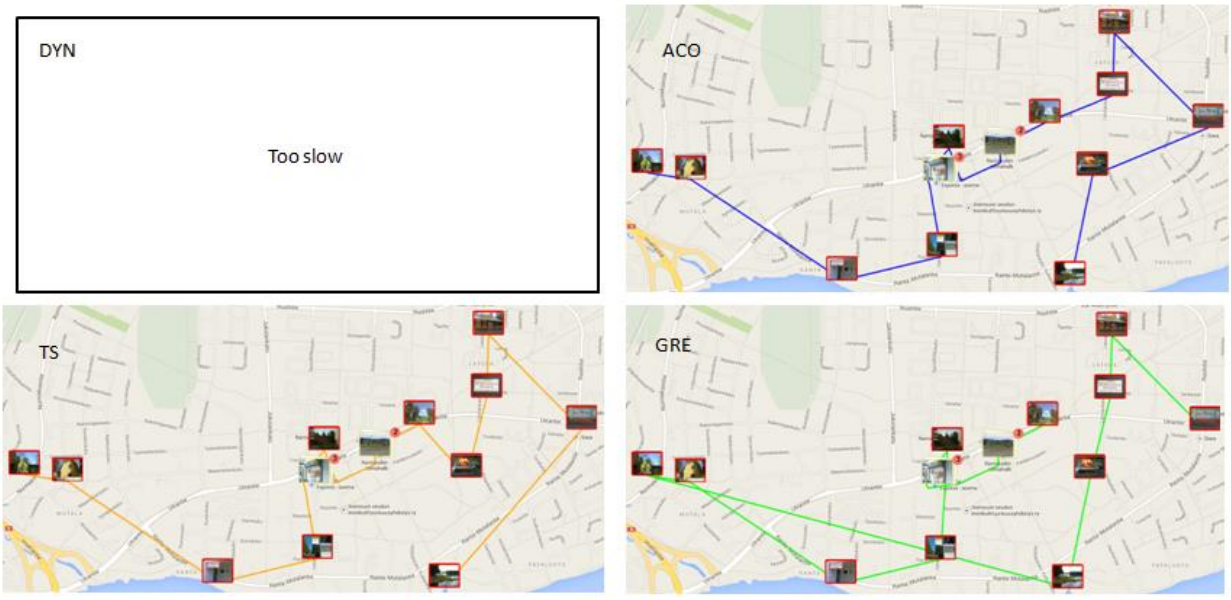


Jokiasema:

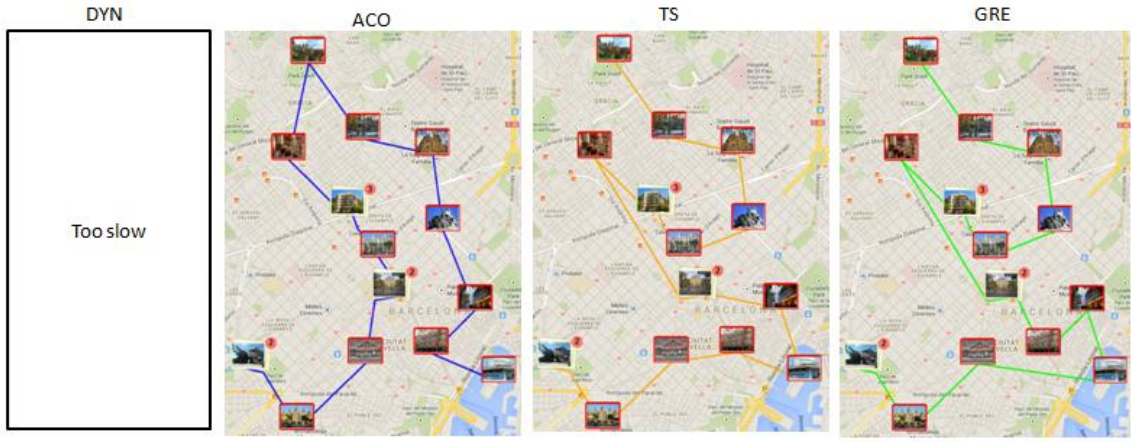
Noljakka:



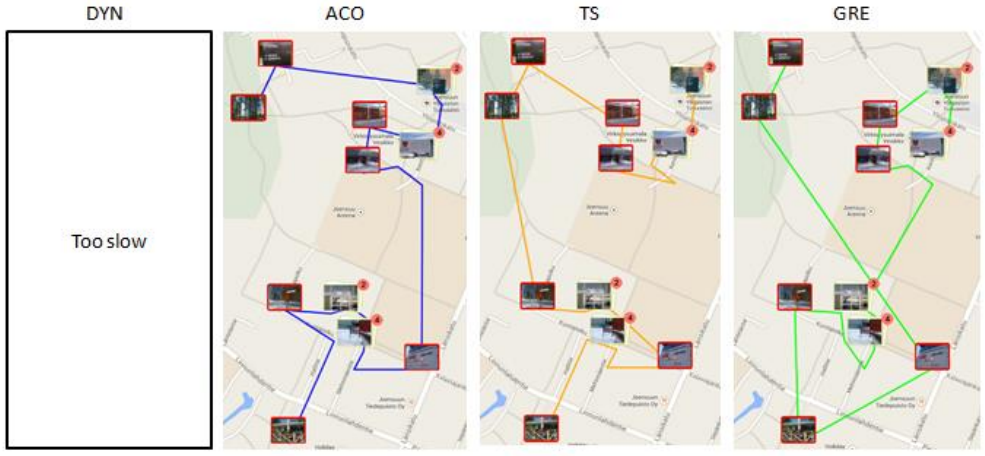
Rantakylä Tour:



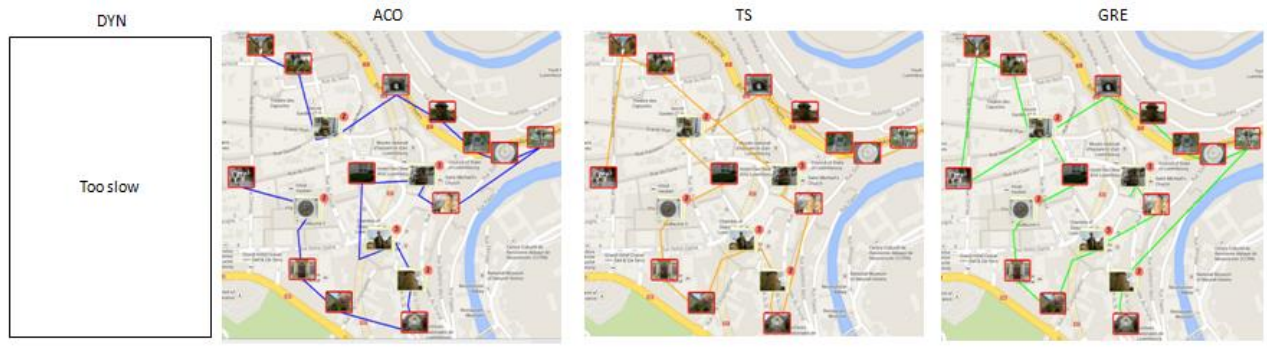
Barcelona Grand Tour:



SciFest2013 Hard:



Luxembourg Ville Haute:



SciFest 2014 long:

Figure 62 : TSP results for O-Mopsi games

8. Usability Feedback

O-Mopsi was originally developed for the *SciFest festival* (www.scifest.fi), which is an annual international science festival which brings together thousands of school kids, high school students, and teachers to discover new experiences and learn about science, technology and the environment [59]. SciFest is organized in the city of Joensuu, Finland in April.

O-Mopsi workshop was organized during the 2012, 2013 and 2014 editions of the festival. O-Mopsi Symbian Java version was used in SciFest 2012, Symbian Qt version for 2013 and Symbian Qt, Android and Windows phone version for 2014. Because of limited availability of mobile phones with GPS and data connection, the players were organized into teams. After the game, a short feedback survey was filled by the playing teams (see Table 4). Feedback shows that the players rated the game mostly as being good or very good. According to the players, game rules were easy to understand and playing the game was enjoyable. Negative feedback was

[59] http://www.uef.fi/en/edtech/past-projects/scifest

caused by software problems, or problems finding GPS signal in some case. We list detailed comments and user feedback in Appendix.

Table 4: Players' ratings of the game in SciFest

Year	Rating / Software	Very good	Good	Adequate	Bad	Total
2012	Java (V 0.10)	3	6	0	0	9
2013	Qt (V 0.6)	3	7	0	2	12
2014	Android (V 0.04)	4	8	1	0	13
	Windows phone (V 0.13)	4	4	0	0	8
	Qt (V 0.10)	0	2	2	0	4
	Not specified	0	5	0	0	5
2014 Total		8	19	3	0	30

9. Conclusions

In this thesis we present a location-based mobile game. O-Mopsi, which is based on the classical concept of orienteering. O-Mopsi game can be played by mobile application available for Symbian, Android and Windows phone platforms. It offers functionalities such as plotting the photos on map, displaying compass to indicate the direction and navigate to the selecting target by sound. In SciFest 2012, 2013 and 2014, we presented O-Mopsi game to the public. The overall feedback was positive. In 2012, there were 9 players, of which 33% of them gave best feedbacks and 66% rated it as good. In 2013, 29 players, of which 79% rated it as good. In 2014, 30 players, of which 90% players rated it good or very good.

We also developed a web server for O-Mopsi, in which users can create new games, view game results, see reference route and watch game simulation. Player can share the game and results with his Facebook friends. The O-Mopsi web page was developed mostly by the author of this thesis funded by MOPSI project during the years 2012-2014.

Calculating reference route was one of our study topics, for which we built a web page for testing different TSP algorithms. Currently, we have got 4 algorithms: dynamic programming with brute force (DYN), ant colony optimization (ACO), Tabu search (TS) and greedy heuristic (GRE). DYN grantees optimal result but with extremely high time complexity, which means it only works for ten targets or less. We compared ACO with TS, and found out that ACO gives slightly better results in general but it is significantly slower than TS. With 20 targets, ACO takes 5-6 seconds which is not user-friendly. As GRE did not give accurate results, we chose to use TS as a default algorithm in O-Mopsi to calculate the reference route.

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Appendix A: User feedback in SciFest 2014

Q1: In general, how do you like the software O-MOPSI?

Rating / Software	Outstanding	Good	Some chronic issues	Poor
Android	4	8	1	0
Windows phone	4	4	0	0
Nokia Qt	0	2	2	0
Not specified	0	5	0	0
Total	**8**	**19**	**3**	**0**

Q2: Do you think the training beforehand is useful?

Rating / Software	Yes	No
Android	11	0
Windows phone	6	1
Nokia Qt	4	1
Not specified	5	0
Total	**26**	**2**

Q3: Do you have difficulties on understanding the game rules?

Rating / Software	Yes	No
Android	1	11
Windows phone	0	8
Nokia Qt	0	3
Not specified	1	5
Total	**2**	**27**

Q4: Do you think the software is easily started?

Rating / Software	very easy	Level 2	Level 3	Level 4	Level 5	Level 6	very difficult
Android	4	4	2	2	0	1	0
Windows phone	1	4	1	2	0	0	0
Nokia Qt	0	2	0	0	1	0	0
Not specified	0	4	1	0	0	0	0
Total	**5**	**14**	**4**	**4**	**1**	**1**	**0**

Q5: How do you think of the interface?

Rating / Software	Outstanding	Good	Adequate	Needs improvement	Poor	N/A
Android	1	6	4	2	0	0
Windows phone	1	2	4	0	0	1
Nokia Qt	0	1	1	0	1	1
Not specified	0	2	3	0	0	0
Total	**2**	**11**	**12**	**2**	**1**	**2**

Q6: Do you enjoy the game?

Rating / Software	Outstanding	Good	Adequate	Needs improvement	Poor	N/A
Android	3	6	4	0	0	0
Windows phone	4	2	2	0	0	0
Nokia Qt	0	3	1	0	0	0
Not specified	2	1	2	0	0	0
Total	**9**	**12**	**9**	**0**	**0**	**0**

Q7: Would you recommend this software to your friends?

Rating / Software	Yes	No	N/A
Android	11	0	2
Windows phone	5	0	3
Nokia Qt	2	0	2
Not specified	4	0	1
Total	**22**	**0**	**8**

Q8: Which part(s) of the software did you like the best?

Item / Software	Login automatically	Interface	Game rules	Map	Find a goal	Tracking
Android	1	0	2	5	8	3
Windows phone	1	0	2	2	5	2
Nokia Qt	0	1	0	2	3	1
Not specified	1	0	0	1	4	2
Total	**3**	**1**	**4**	**10**	**20**	**8**

Text comments from Android users:

1. Quite good game.

2. It would work better and would find the place better. Did not work in the beginning. (Samsung S3 Mini).
3. It would work in iPhone too. So that it would not quit working when route has gone through. (Samsung Gal S3 4G)
4. Goal icons have the property that they shutter own position. (Nexus)
5. Some goals were found from really far away (distance even 50m), once I did not see the goal behind the corner before fanfares. Quite nice game for a person who has ordinary orienteering as a hobby. (Zte)
6. The program did not work Samsung Galaxy X2 GT-19100 Android 4.2.2 kernel. Outlook could be also improved.
7. A possibility to cancel game or at least stop time, instructions (time starts when game started), Finnish language. Norm thing! Android leaves program on. (Huawei)
8. The route length could be even shorter. Real time route display would have been helpful (bad net in own phone). Beep sound good, nearness information good. Goal finding sound good. Aplodes were a nice surprise. (Samsung XCover)
9. In mobile, in results list, the traversed length should read 1 km 500 m, not 1 km 500.

Windows phone users:

1. No need for image page. Just map! (Lumia 620)
2. Accuracy! Some time the connection broke, and all the goals were not seen.(Lumia 720)
3. Panning of map was not working properly, but that could be phone's problem. Good exercise.
4. It would be good to have a game for iPhone too. Good game. Worked well. It was nice that I could go outside.
5. The program was falling at some times. Could repair. Thanks.
6. Faster.
7. Officer's comment: Niko made short track. Web shows end time 1h33min. Real end time approximately 40min.

Nokia Symbian users:

1. Better phones! Did not work. Lags! Otherwise nice workshop, especially in the beginning ☺.
2. In the beginning could tell that orienteering goal's mark is not the same as the goal. Even if the mobile was inside the mark it did not give label. (for example Vesikko's entrance is better place to find)

iPhone users:

1. No need for ingame page. Just map!

Appendix B: User feedback in SciFest 2013

Using Nokia Qt O-Mopsi version only this year.

Q1: How would you rate o-mopsi program?

Rating	Excellent	Good	Something to improve	Bad
Total	2	21	6	0

Q2: Did you find the guidance given useful?

Rating	Yes	No
Total	27	2

Q3: Was it hard to understand the rules of the games?

Rating	Yes	No
Total	3	26

Q4: How would you describe opening of the program?

Rating	Very easy	Easy	Ok	Hard	Very hard
Total	4	16	7	2	0

Q5: How was the user interface?

Rating	Excellent	Good	Ok	Improvements needed	Bad
Total	3	16	3	7	0

Q6: what is your general opinion of the game?

Rating	Excellent	Good	Ok	Improvements needed	Bad
Total	3	19	5	2	0

Q7: Would you recommend this game to your friends?

Rating	Yes	No	Maybe
Total	13	3	2

Q8: What was your favorite part of the game?

Item	Login automatically	Interface	Game rules	Map	Find a goal	Tracking
Total	1	1	2	4	13	2

Q9: Was it useful to see the recommended route?

Rating	Yes	No
Total	13	5

Q10: How was the animation of the route? (Web)

Rating	Excellent	Good	Ok	Improvements needed	Bad	Did not see
Total	2	7	6	2	0	1

Written comments:

1. Pictures could be easier to see.
2. Saving the route should be improved - nothing was saved.
3. Bigger images.
4. Keep it simple that kids can play as well.
5. I was afraid many times that I will be thrown away from the program. However, that did not happen, program worked nicely.
6. Get better navigators in order to avoid bugs.
7. Time should start immediately - There should be a marker and when we go close it should convert into a photograph. Possibility of getting bigger photograph would be good.
8. There should be an arrow which would tell into which direction I am moving.
9. Confirmation should be asked before really closing the program.

Appendix C: User feedback in SciFest 2012

Using Java O-Mopsi version only this year.

Q1: What did you think about O-Mopsi?

Rating	Excellent	Good	Improvements needed	Bad
Total	3	6	0	0

Q2: Did you find guidance useful?

Rating	Yes	No
Total	9	0

Q3: Was is hard to understand the rules of the game?

Rating	Yes	No
Total	0	9

Q4: Was is easy to start the game?

Rating	Yes	No
Total	9	0

Q5: What do you think about the user interface?

Rating	Excellent	Good	Sufficient	Bad
Total	3	6	0	0

Q6: What do you recommend the program to your friends?

Rating	Yes	No	N/A
Total	8	0	1

Q7: What do you think about the game?

Rating	Excellent	Good	Sufficient	Bad
Total	4	5	0	0

Q8: What part of the program did you like the most?

Item	Login automatically	Interface	Game rules	Map	Find a goal	Tracking
Total	0	0	0	4	5	0

Written comments:

1. Route could be longer
2. Different sound would be nice.