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Master's Thesis

Academic Year 2014

Relative Location Oriented Social Network

Graduate School of Media Design,
Keio University

Ruowei Xiao

A Master's Thesis
submitted to Graduate School of Media Design, Keio University
in partial fulfillment of the requirements for the degree of
MASTER of Media Design

Ruowei Xiao

Thesis Committee:

Associate Professor Kazunori Sugiura	(Supervisor)
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Abstract of Master's Thesis of Academic Year 2014

Relative Location Oriented Social Network

Category: Science / Engineering

Summary

Location based social network(LBSN), generally refers to networks that consist of both location information and social connections. Many LBSNs define locations as absolute coordinates, which only partially reflect locations' attributes and are far away from human cognition: Computers consider locations as sparse isolated spots, while we human beings connect them. Thus, the absolute location definition has led to many existing problems in current LBSN framework and can not better leverage the value of relative locatioins inside peoples's minds.

Therefore, this thesis proposed a complementary LBSN framework: Relative Location Oriented Social Network(RLOSN). The core concpet, "Relative Location", present a relatively comprehensive two-layer location model that consist of spatial attributes, conceptual attributes and the mapping between them. Based on this concept, we separated the relations into mainly four typical catogories, including: location-location relation, user-location relation, user-user location and temporal relation. We further established corresponding framework,data collecting and mining mechanisms.

To notice that the RLOSN was not directly targetting any end users. Rather than any concrete top-layer applications or services, our focuses were more on the network structure itself, as the middle layer infrastructure. However, in order to fully evaluate our proposal, we deviced an online hybrid application adopting RLOSN framework, ROSA, the Relative-location Schedule Assistant. Its main function was to assist general users to schedule all kinds of visit activities in their daily life.

The results showed that ROSA possessed a higher usability over alike traditional applications in both system and interface aspects. Moreover, it could better support users' spatial decision making seamlessly and lower down the operation overhead when compared to using ad hoc services. However, to further stretch the application senario of RLOSN, there is still much work left to be done in the nearby future.

Keywords:

LBSN, Relative Location, RLOSN

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Location Based Social Networks

1.1. What are Location Based Social Networks?

Traditional location based social networks(LBSN), generally refer to **online social networks with location information included**[13]. The pervasion of GPS built-in smart devices, location based services and the soaring application of online social networks have paved the way towards the birth of LBSN. As a result, we witnessed a booming of LBSN at the beginning of this century: Brightkite, Foursquare, Gowalla, and etc. Online social networks such as Twitter(founded in 2006), Factebook(founded in 2004) also have developed their own location related features.

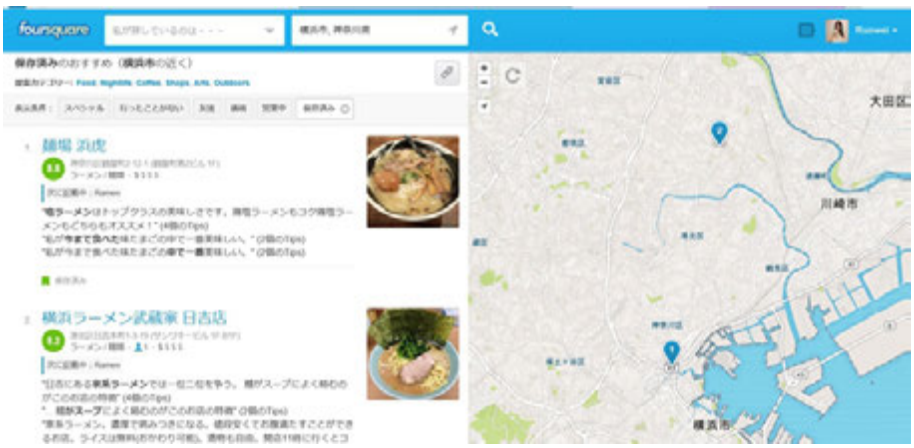


Figure 1.1: Foursquare Interface

- **Foursquare**. Founded in 2009 and claimed to have 45 million members by the end of 2013. On one hand, it allowed members to share their locations, tips, and likes with friends allowing the service to recommend places and ideas for activity to its members. On the other hand, it allowed businesses to benefit through information about potential customers, offer promotions, and snag and maintain customer interest in a product or venue.

- **Brightkite**. Founded in 2007 and already stopped their services. Brightkite was based on the idea of making check-ins at places, where users can see who is nearby and who has been there before. It primarily oriented for location sharing.

Figure 1.2: Brightkite Interface

- **Gowalla**. Founded in 2007, acquired by Facebook in 2011, and subsequently shut down. It was very popular LBSN that morphed into a service that supported curated city and location guides using information provided by its members. The primary objective of Gowalla was for the members to

explore interesting locations called "spots" and check-in at such locations, using categories such as nature walks, pubs, and landmarks. It was able to provide place recommendations for its members and anyone accessing the service with information, tips, photos, and other information about places, locales, and venues in a city.

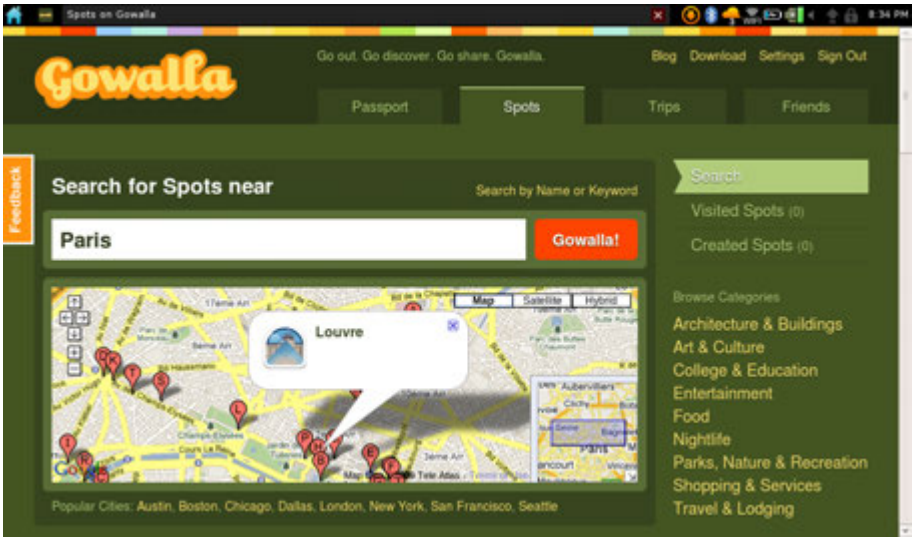


Figure 1.3: Gowalla Interface

With LBSN, personal users can be kept abreast of relevant information, arrange real-world meeting, explore one's current environment, participate in social gaming, and share locations and keep personal location history[18]. Besides, companies and enterprises also leverage the power of LBSN to "infer the habits and interests of particular demographics." and "project businesses into public conscious without the need for expensive advertising campaigns"[18]

As the objective of this thesis, however, we will expand the concept of traditional location based social networks to a broader scope: **networks that consist of both location information and social features, and any applications and services constructed on the basis of this kind of networks**. We don't actually care about any concrete top-layer applications though. Instead, our focus

Figure 1.4: Facebook Nearby Feature

is rather on the intermediate network structure, concept data model as well as upper-layer-oriented interfaces. Therefore, in order to distinguish from traditional location based social networks, we name our objective "location oriented social networks".

1.2. LBSN Related Research and its History

Related researches in early stage, way back to more than a decade ago, paid special attentions on the topic of **network topology and structure**. C Jiang et al. proposed a hybrid location model in [9], using an URL-like string to present physical locations, specifically the hierarchical structures of locations, e.g. "*ali://keio /hiyoshi/kyouseikan/floor3/C3S01*". The author argued that varied location models can be divided into either "hierarchical" class or "coordinate" class, and "neither model is by itself completely satisfactory". They claimed that "these two classes have **complementary** benefits and drawbacks", which could be respectively concluded as user-friendly and machine-friendly. However, the limitation of

this plot was apparent though, since these kinds of top-down methods could not capture other semantic properties, such as a place's functions, and were difficult to scale up. Actually, rather than hierarchical models, as we may find out later in this paper, correlated location models is more likely to be complementary to the absolute coordinate models, since hierarchy, functionality and other spatial relations can be all concluded as correlation between locations.

Almost at the same time, researchers became curious about users' motivation to share their locations and started to explore the area of **user behavior analysis**. S. Consolvo et al. conducted a series of user study by mainly questionnaire methodology and stated in [5] that what kind of location information and in which way it is shared depended primarily on the relationship between the sharer and recipient and the purpose of sharing. Users were likely to disclose the most useful information instead of the most detailed one about their locations. This conclusion was then further strengthened by the research of J. Lin et al.[11], in which they suggested that the relationship between familiarity and the choice of place names is not linear. A simple but interesting example from our daily life can illustrate this: when asked by an unfamiliar friend about our current location, we may simply replied with "at home"; the same goes with the occasion when asked by a close family member. Detailed geographic names, such as postal address, were most likely to be used when people of medium familiarity required our address. This phenomenon, in its deepest nature, reflected an innate asymmetry between the sharer's and the recipient's knowledge about locations. As a result, the same information became "no use to know" for some recipients, while "no need to know" for the other. While this kind of researches relied highly on users' subjective responding to certain hypothetical situations without actually sharing their locations, the result might be highly limited to the examinees' personal identities, experiences, moods and so on, while examinees' behaviors may differ when they were unware of the test purpose or their locations being actually shared.

Therefore, another branch of user behavior researchers began to collect and

study user data via commercial LBSN services, mainly the "check-in"s of a user. N. Li et al. took Brightkite as their data pool, from which they extracted and studied user features like social graphs, update pattern, mobility and etc.[10] S. Scellato collected check-ins from Gowalla and studied how location factor affected the accuracy of predicting a potential social friend[17]. They claimed that they were able to narrow the prediction space down to 15 times smaller while still maintain 66% of future social links discovery, since "30% of the new social links were among 'place-friends' ", in another word, people who shared similar location visiting patterns were more likely to become friends. Further in another research[16], S. Scellato made a transversal comparison among Gowalla, Brightkite, and Foursquare users properties and came to a general conclusion that LBSN's "social-spatial structure can not be explained by taking into account only geographic factors or social mechanisms." However, "check-in"s, or say data collected from LBSNs, not only identified the utilitarian aspect, but also the self-presentation aspect of users[12],[6]. By selecting to share which places they had been, most LBSN users were shaping their own social images either consciously or unconsciously. And to most people, checking in LBSN was something they would do only when they were not in a hurry or they felt themselves in their comfort zone. That could be an explanation that why we are more often to see check-ins at a restaurant during lunch time, than someone checks in at hospital while he or she was sick. Moreover, many LBSNs don't verify users' real geographical positions and allow users to modify the final location they uploaded. Therefore, check-ins may not necessarily reveal the whole, actual scenario of user activities, and by this kind of fractional, unauthentic data hardly can we infer a complete, correct model of user activity.

Based on the outcome of user behavior analysis, researchers further applied **machine learning** methodology to this topic. The main idea was to extract features of user behavior patterns, select the most prominent ones to feed machine learning models, such as support vector machine, decision tree and etc., and train these

algorithms to give pragmatic feedbacks in order to support users' decision making process. M. Ye et al. developed friend-based collaborative filtering approaches for location recommendations, based on the premise that social friends could provide more valuable location recommendations than non-friends[22]. Since the non-friends were ruled out, the computational overhead of the algorithms were lowered down in the price of accuracy. Later in another research, they applied support vector machine classifier to automatically attach semantic annotation to different places[21]. By observing users' check-ins patterns, they tried to extract features of places from both so-called "explicit patterns" and "implicit relatedness". Take restaurants as an example, normally we could infer a place to be a restaurant because it might have a bunch of visitors at around noon, which referred to the explicit patterns. Moreover, we could further suggest that different places that visited by the same person also at noon may be restaurants as well, which, respectively, referred to the implicit relatedness. As previously discussed, check-ins has its own limitations, since it cannot actually redraw users' activity trajectories. In places that people rarely check in, it will be a difficult challenge to distinguish what kind of place it is and give correct location tags. However, in Ye's paper we can see that there is a possibility that we can actually imply the similarities, or say, the relations between different locations that is hidden behind users' visiting patterns.

Among all the LBSN-centered researches, the project "Geolife" by Y. Zheng et al. from Microsoft Research Asia that worth specific attentions[23]. Based on the correlations between location-location, user-location and user-user, this project aimed at realizing a series of application scenarios. Main functions were concluded as: 1) To share and query trajectories, e.g travel routes and itinerary; 2) To recommend locations in either generic (calculating place popularity) or personalized (calculating social friends similarity) way; 3) To recommend friends based on similar location histories; 4) To query and recommend activities related to locations. This large-scale study touched all the three tracks of network topology,

user analysis as well as machine learning, and shared similar interests upon some topics with our studies. Up until now, this is the most related research to this thesis from the view of philosophy, goal and methodology. Despite that we don't actually involve the machine learning algorithms at current stage, this paper by Y. Zheng et al. gave us a good vision at this aspect.

1.3. Current Issues and Contributions

From last century to now, a lot of brand-new concepts have emerged, from "ubiquitous computing", "cyber physical environment", "web of things" to "contextual awareness". Most of these researches are conducted in order to involve cyber networks and physical reality together as a continuum so that the space environment around us can understand our needs more "smartly", support our decision making seamlessly, without actually interrupting our workflow. Locations, as the container of human activities and various devices and sensors, are always considered to be an important mesosphere interacting between users, physical and virtual resources, thus are given specific emphasis in aforementioned studies. However, after reviewing the history of LBSN research, we can see that current problems lies mainly in the following three issues:

- The **concept** of "location". In order to simplify geographical models and lower the computational overhead, "location" has been regarded equal to a pair of physical coordinates in traditional LBSN, consequently leading to an unclear and vague understanding about this concept for a long period in the past. This simplification may be beneficial to machine processing, however, seems to be meaningless to human beings, since it is usually the specific social meaning associated with the physical coordinates that people care about, for instances, someone's home, workplace, shopping place...and etc. While this kind of social meaning may not stay static, if not changing

all the time, hence once changed, it would be difficult to retrieve by only physical coordinates.

- The **presentation** of "location". Now that the drawbacks of traditional coordinate model has evoked studies on substitutive models, researchers started to realize that spatial coordinates are definitely not the only presentation of a location. A previous discussed example was the research by C Jiang et al.[9], which was constructed on the basis of location hierarchy. This kind of presentation partially revealed the social attributes of locations, while somehow incomplete. How to give an accurate presentation about location and its related attributes, has became the second dilemma that we have to face.

- The **methodology** of exploiting "location". In order to discover the social value that people attach to locations, recent LBSN study has shown a trend to mine users' activity data in depth, either by extracting check-ins from existing LBSN service like M. Ye et al.[22], [21], or by automatically collecting users' trajectories by built-in GPS like in the research by Y. Zheng et al.[23]. Whether and to which extent can this kind of backhanded data manifests the map in users' minds are still in need for further evaluation. Then how about directly asking our users to expose their thoughts directly? The incentives encouraging people to do so also remain a issue.

While the weak points of absolute coordinates model have long been criticized and make-up proposals have been made in academia, traditional map cartography and web search are still dominating most of today's LBSN user interfaces. In one of our previous papers, we concluded the loopholes of applications and services adopting absolute coordinates framework as: 1) Inadequate usability 2) Privacy concerns caused by disclosure of users' absolute position 3) Lacks of contextual understanding 4) Unable to support users in activity level[15]. All these problems above, strongly hampering the growth of LBSNs today, we believe in

their deepest nature are due to **the discrepancy lying between the different understanding of computers and human beings about the concept of "location".**

1.4. Summary

Chapter 1 breifly introduced the concept of location based social network: Online social networks with location information included. In a chronological way, the history of LBSN researches was discussed, mainly in three different tracks: network topology and structure, user behavior analysis and machine learning.

This chapter also defined the objective the whole thesis as: networks that consisit of both location information and social features, and any applications and services constructed on the basis of this kind networks. To notice that, the scope of this thesis does not include any concrete top-layer applications or services, instead, it focused on the network model itself, which was a big difference from traditional LBSN definition.

At the end of Chapter 1, current issues in LBSN researches were summarized respectively in the concept, presentation and methodology. As a conclusion, we argued that all the existing issues in their nature, were due to the discrepancy between the computers' and human beings' understanding about locations.

2. Relative Location: A Relation-Oriented LBSN Framework

2.1. What are Relative Locations?

As stated in Chapter 1, the research objective of this thesis will **not** be any specific applications or products. Instead, we would like to look at location oriented social network as a whole, the paradigm of which can serve as an intermediate layer to build up different sorts of top-layer services. To notice that unlike traditional LBSN and any other previous studies in this field, as important as its social feature, location information itself is considered rather a parallel main body in the network in this thesis, than just an inclusion attached to end users.

The reason to emphasize the independent status of locations lies in mainly three aspects: 1) Locations are carriers of human activities, specifically mass activities. 2) Locations are also physical space containing various sensors, infrastructures and devices. 3) Locations work as the hub communicating both the users, physical as well as cyber resources.

At the initial stage of this study, we conducted a series of preliminary user experiments applying "Think Aloud" strategy [19]. All 6 participators were separated into 3 groups, each group consisting of 1 females and 1 males, age ranging from 19 to 43. Each group was assigned a target location, at the order of measuring scale, from Hokkaido(50 km), Tokyo(3 km) to Akihabara(150 m). The task

was to ask single participator to create respectively a 7-day, 2-day and 3-hour visit plan in 1.5 hours and participators could use all the available resources including the Google map, online search engines, tour guidebooks or pamphlets, and etc. During the procedure, participators were required to speak out what was going on in their mind when doing the task. We arranged this experiment in this way in order to rule out the effects that distance, age, genders and personal experiences had on the subject itself to the least level, given the limited participator number and diversity.

The purpose of this user experiment was to observe and discover certain user behavior patterns related to spatial decision making, or more specifically, we want to know what users' "mental maps" exactly look like and how are they different from the actual maps or map applications we use in our daily life. And we did find some interesting features that we believe to be shared among general users.

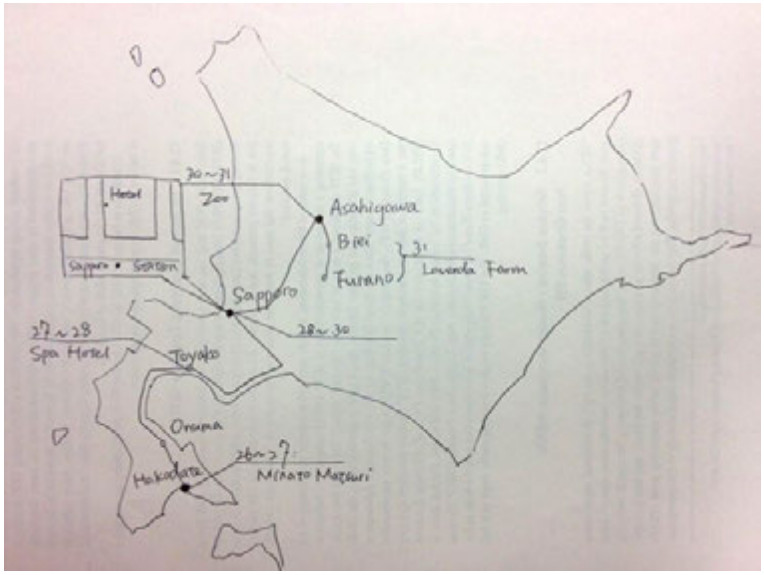


Figure 2.1: A User's Description about Her Mental Map

- Rather than isolated spots, users were more likely to treat locations in a **connected** manner. Figure 2.1 shown a typical mental map drawn by a

user. This could also be saw in users' oral descriptions about a location, e.g. "Hiyoshi campus is on the opposite side of Hiyoshi station.", in which the station was regarded as a spatial reference to the university campus. On the contrary, neither absolute coordinates nor postal addresses seemed to be understandable enough to be used in daily communication.

- In most of the occasions, users arranged the visiting sequence according to the **importance** of locations, instead of physical distances. We observed a common phenomenon in our experiment that when provided a list of view spots, users tended to first select a few major view points that were most attractive to users, organize the itinerary, then add some less attractive spots into the itinerary according to how much time was left and how far it was to the selected major view points.

- Users sometimes schedule their visit according to **special events**. Despite importance of locations, users would also shape their schedule according to special events taking places in those places. Take the Hokkaido group as an instance, during a one-week holiday from 20th to 26th, users could either plan a visit like as Hakotate-Sapporo-Asahigawa, or at a reverse sequence like Asahigawa-Sapporo-Hakotate. However, because there would be a special Matsuri in Hakotate on 20th, both of the Hokkaido group participators chose the former sequence.

- Naturally users were expecting a relatively **higher "information density"** around the places that users considered to be important. While on the other hand, users tended to erase irrelevant information or less important places from the map. Users often sought for extra information like nearby restaurants, transportation, etc. around places users planned to visit, however, ordinary map application, e.g. Google map, only provided a flat information interface and hence users had to frequently zoom in, zoom out or refer to other resources in order to get information they needed.

- Users' queries sometimes were rather **vague** without explicit keywords, such as a place name. It was not rare that we might know what kind of places to go without knowing exactly which place to go. For example, Akihabara was quite famous for its maid cafes. But a newcomer might become extremely confused and did not know how to choose from among varied maid cafes. That was something beyond the ability of current navigation applications, from where we could see a clear difference between users' mental maps and the actual maps. Therefore we were in need of others' opinions to help make our own decisions. That's one reason why public comments collecting services such as Taberogu became popular. "Wisdom of crowd", in the other words, also plays an important role in assisting spatial decision making.

- Ad hoc applications and sparse information sources **lower** users' efficiency and **increase** the total overhead. In total, users had spent much more time on seeking for location related infromation and switching from one tool to another(average time:51 min 23 sec), than on planning visit itinerary itself(average time: 22 min 41 sec). Just like the other human beings' activities, people's spatial decision making procedure involves multiple tasks as well as multiple processes. However, concurrent ad hoc applications and services support only specific single task, which, inevitably increases the total overhead, since users have to manually aggregate the outputs from different applications and services together[8],[3],[2].

We have reviewed many existing issues in current LBSN researches in Chapter 1 and strongly argued that they were caused by different understanding from the machine side and human side about locations: Computers consider locations as sparse isolated spots, while we human beings connect them.

In reality, varied relations widely exist among locations and locations, locations and users, users and users...we believe that if make good use of those relations, we could simulate a more natural, ideal model of the actual world, and further narrow down the gap between human beings and computers. Thus, we come up

with our main concept: Relative locations.

2.2. How to Define Relations?

Let's further elaborate the relations in LBSN from three different aspects.

Figure 2.2: The Mapping between Absolute and Relative Locations

Location-Location Relations

Today's LBSNs regard location more as a certain physical space defined by Cartesian coordinate system. However, in people's minds as well as in our daily conversations, a location is rather a concept space that defined by all kinds of "social coordinates", which refer to various relations, including but not limited to: 1) Spatial adjacency, e.g. "Hiyoshi campus is on the opposite side of Hiyoshi station." 2) Hierarchical affiliation, e.g. "Mita campus and Hiyoshi campus all belong to Keio University." 3) Function Similarity, e.g. "All the Ramen restaurants around Hiyoshi." 4) User customized relations, e.g. "home", "work", "places appeared in xxx anime/TV drama". Although current absolute coordinates based mapping and navigation have already become mature and acquired high precision

and efficiency by leveraging GPS and Wifi positioning, we believe that navigation based on social concepts as well as corresponding location recommendation system, still remain to be further exploited.

Location-User Relations

When we say exploiting users' "mental maps", we may notice that different users'cognition towards same locations are actually diverse, so are users' needs. If we keep tracing a user's daily trajectories during a long enough period, we may find some special locations emerge. Generally it may be a place that the user stays for a long time or frequently visits, e.g "home", "work", "school"; Or it may be somewhere that the user wants to visit, e.g a destination; Or it may be a place with special meaning to this very user. In the other words, some locations possess stronger social correlations to a user thus stand out among the other locations in the user's mental map. It is an intuitive implications that users will expect a relatively higher information density around these "important", e.g "A person cares more about the PM2.5 index around the places he lives and works than other irrelevant places." When single user's trajectories accumulate to group trajectories, we are able to obtain mass activities data that reflects public opinion relations between locations and users in a larger scope, which may provide a more interesting and valuable social mining perspective.

User-User Relations

Current social networks give us a mature paradigm of user-user relation model. Explicitly in our RLOSN, user-user relations are mainly represented by the query and share operation of users' trajectories, and the introduction of "wisdom of crowd" mechanism, which we will discuss in more details in the coming chapter.

Temporal Relations

The three kinds of relations mentioned above actually belong to horizonal relations, while there is also another kind of relations that we cannot ignore. Temporal relations, or event-event relations, particularly stress on the vertical correlations among locations, users and events. A typical example is the timeline feature of

locations in our RLOSN, which consists of a series of sequential events. The timelines of locations' and users' will intersect, and consequently form users' activity flow.

In pratical data processing, we model these intangible relations and the connected locations into a weighted, undirected graph for simplification purpose:

$$G = (V, E) \tag{2.1}$$

Where V represents locations, E represents relations between two locations. More specifically, $e_{i,j}$ represents a relation between location i and location j, and $w_{i,j}$ represents the weight of the relation $e_{i,j}$. $w_{i,j}$ is defined as the summary of spatial connection $w_{i,j}^{spatial}$ and social connection $w_{i,j}^{social}$ with corresponding coefficients:

$$w_{i,j} = c^{spatial} * w_{i,j}^{spatial} + c^{social} * w_{i,j}^{social} \tag{2.2}$$

$w_{i,j}^{spatial}$stands for spatial connection weight, which defined as how conveniently people could travel between location i and j. Because this convenience is mainly affected by both transportation cost and time consuming, and considering multiple transportation methods may exist between i and j, the convenience of kth transportation method (walk, bus, subway, etc) is defined as a function $f_k()$ of cost $c_{i,j,k}$ and time $t_{i,j,k}$, and $w_{i,j}^{spatial}$ as the value of the most convenient transportation method

$$w_{i,j}^{spatial} = min(f_k(c_{i,j,k}, t_{i,j,k}) \tag{2.3}$$

$w_{i,j}^{social}$ represent the social connection weight, which is decided by how many kinds of social relations exist between location i and j, and how much each relation would contribute to social connections.

$$w_{i,j}^{social} = sum(g_k(r_{i,j,k}, s_{i,j,k}, t) \tag{2.4}$$

Where $r_{i,j,k}$ represents the kth social relation exist between i and j, which includes similarity, sequence, subordinate, etc. $s_{i,j,k}$ represents the strength of kth

relation. And $g_k()$ indicates in what manner the kth relation will affect social connections between i and j. Since these social relations are usually time triggered or event driven in a certain point of time, the time variable t is included.

2.3. A Socio-Spatial Location Model

The modeling of location should well balance the machine utilization and human understanding, as well as the physical space and conceptual space. So we define elements as follows:

Identifier: machines could use this ID to find location accurately and quickly. ID may have no actual meaning to human, for example: Facebook use a string of numbers (id=557055802), www use 4 strings of numbers (divided by dot). However, most applications also use human understandable id for user's convenience, e.g. "www.facebook.com/kierdarby" refers to the same user as "www.facebook.com /profile.php?id=557055802", "www.keio.co.jp" refers to the same website as "68.23 2.45.253".

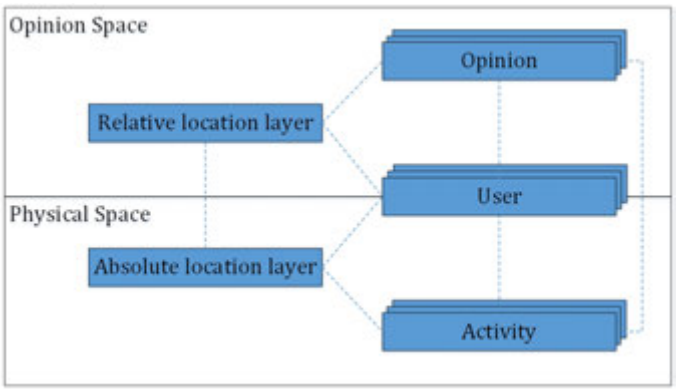


Figure 2.3: Two-Layer Location Model

Coordinates: physical space is defined by coordinates, they are identical, like most LBS do.

Address: Address is designed to be compatible to post address, they are also identical.

Location relation: In every user's thoughts, locations doesn't exist separately. On the contrary, they are related with each other and exist like a complex network. Relation is the core mechanism when users address location related problems in their opinion space.

Event: Event refers to human activity related to a certain location.

Opinion: Opinion refers to a certain user's thoughts when he or she take part in location related activities.

User: User mean a certain person who uses a certain LBSN application or service.

By using location as a bridge, we could easily weave space, users, activities and opinions together, which will better organize spatial knowledge to support decision making. However, this goal will not be achieved automatically, unless we use a complete model of both absolute location and relative location to connect physical space with opinion space. Hence, here we propose a two-layer location model, as shown in Figure 2.3.

2.4. A Relation-Oriented Framework

In a real application, the two layer location data model could be stored in a Relational database. And the database schema was shown in Figure 2.4.

Since the absolute location data as well as web map has already been supported by many LBS which are publicly accessible, such as: Google Map and Foursquare, there exists a necessary need to be compatible with these data sources. Hence we serve no map nor absolute location data from our database. In our framework, we retrieve absolute location data and user generated data to mine higher-level relative location data and provide them with Restful interface. Then, in a LBSA client, relative location data could be mixed with raw absolute location and map

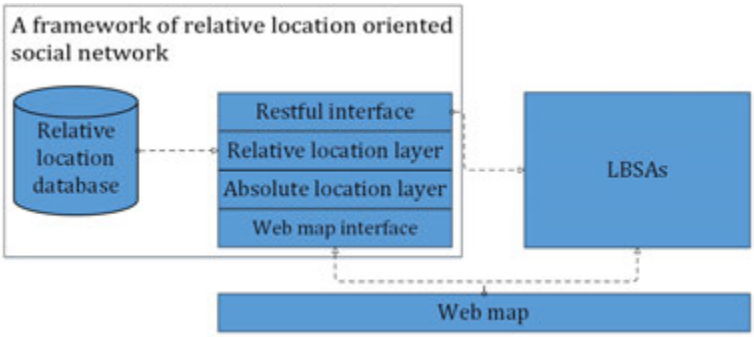


Figure 2.4: Database Schema

data to formulate an adaptive interface based on user request. Under this framework, developers could selectively combine several data-sources via standard programming interface, or hide unnecessary information by temporarily disconnect certain layers. Hence, the LBSA based on this framework could be very flexible, inter-operable and scalable.

To provide fundamental programming support for RLOSN framework, we hense developed an API Library. Thus, various relative location oriented applications could be quickly developed and deployed to gather user data. As an example of how to take use of this library, a paradigm application based on the API lib will be introduced in the following chapter. For API reuse purpose, this library used MVC structure to provide better flexibility and compatibility. MVC structure is a software development architectural pattern that divide a given software system into three correlated parts: Model, View and Control. In our Library:

Model: A mere data manipulation layer to query, manage and feed all kinds of data used in system, which contains various PHP functions to control SQL database and affiliated JS functions to temporarily create local copy of subsets of database in memory for fast visiting purposes.

The model part include two major classes: LocInfo and LinkInfo, which implementing two interfaces: AbsoluteLocation and RelativeLocation respectively, and three classes to implement these interfaces, as shown in Figure 2.6.

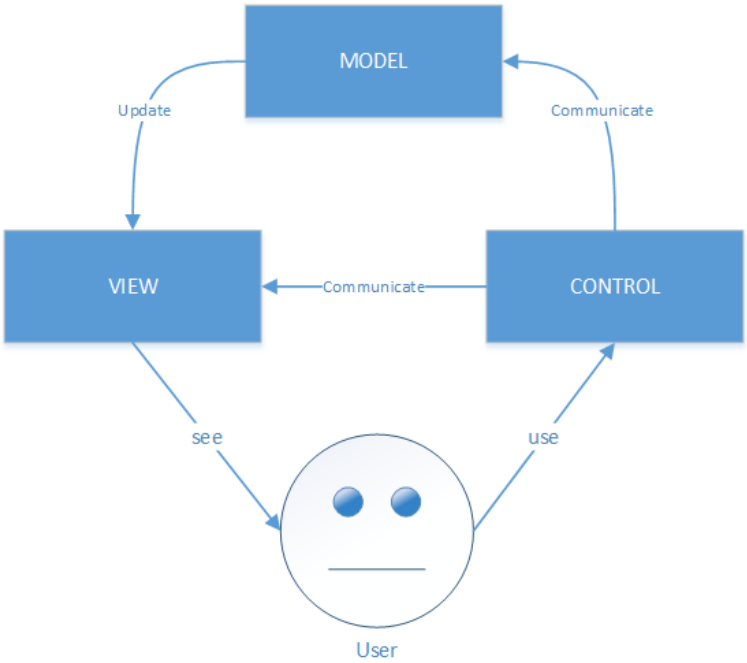


Figure 2.5: MVC Framework of RLOSN API Library

Each class have multiple related functions to handle attributes or communicate with other objects, for example, marker object in view part. To better manage an array of locations, we also provided easy-to-use functions to add, find, move or delete LocInfo in array. For fast-prototype purposes, we have not added those functions as member functions yet. However, this work could be easily done while we think everything is ready and a stable beta version will be released. Due to limited space, we could not give all the details of every classes and related functions. The class of LocInfo and part of related functions are given below as an example, anyone who have interest could contact authors for more details.

View: A mere presentation layer to render location data (both absolute and relative) on a map interface, which contains various HTML elements and JS functions to deal with data visualization. Users will not worry about transform between data and visual components. Just feed the data to desired service I/O interface, and everything will be there.

Figure 2.6: Class Overview of RLOSN API Library

The view part include four major classes: map, marker, infoBox, and line, which are used to create and update various view components. For example, a line object as an instance of line class handles a single line on the map view. Draw a line on the map is a simple task, however use lines to visualize various kinds of relation is a whole different story. To achieve this task, we wrapped various kinds of line implementations in the line class: straight or curve, continuous or dot, along the road or railway. Other features like: how to create, modify and delete lines, how to manage a line array, and how to visualize lines according to strength are also taken good care of. All kinds of features could be controlled by simple commands.

Event handlers to update view components according to certain event dispatched from control part are also well designed, such as: click, drag and drop. Considering the potential use in mobile devices, the tangible interaction events

Figure 2.7: Overview of Class LocInfo and Class Line

are also supported.

Due to limited space, details of other classes are not provided in this paper. They are also implemented in the same way and provide carefully designed functionality which suits our framework's requirements. For example, the infoBox are designed to be capable of displaying a whole other webpage in it, include: texts, pictures, videos, links, buttons, or even runtime variable elements. Thus one could better retrieve and represent location information in user's thoughts.

Control: A mere action layer to add listeners, such as user input or system events, and communicate with the other two layer, for example, tell view layer to update some visual elements.

The control part include three major classes: FB, FS, which are used to communicate with external api, such as Facebook and Foursquare; and DB, which are

used to communicate with internal database api provided by our own. All the data retrieval procedural could be called with the same process, either external or internal, which include four steps, while the last three may be executed as a loop for several times:

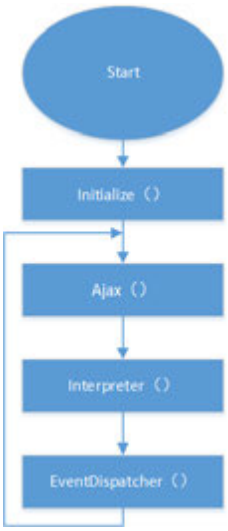


Figure 2.8: Distributed Data Retrieval Process

First, initialize(). In this step, parameters are set for next steps, such as: user name, password, remote call address.

Second, ajax(). In this step, a remote procedural is called asynchronously to retrieve data, which is implemented as an Ajax function. Ajax means Asynchronous JavaScript and XML, which is a set of standard web technologies to send data to, and retrieve data from, a server asynchronously in the background without interfering with the view part and control part. This feature makes it very suited for our distributed-services framework.

Third, interpreter(). In this step, retrieved raw data, most frequently wrapped in a JSON format, are interpreted into our own data model, which is defined in Model part.

Finally, eventDispatcher(). In this step, events are dispatched to corresponding handler to trigger data processing or view update.

2.5. Data Collecting and Mining Mechanisms

If all kinds relations weave together and hence construct the grand networks of relative locations, the core of them, in fact is user activity data. Therefore, it is the crucial challenge that in what way we collect and mine the data, and how we refine different relations out of this massive complicated data.

Data Collecting

There were actually three data sources for our research:

1) **Crawling from existing LBSNs**. Commercial LBSNs, e.g Foursquare, Instagram etc. Have already successfully gathered a large amount of user groups and by taking advantages of their open APIs we were able to obtain necessary data to build up our initial location relations.

The construction of initial relations highly relies on existing LBSNs, e.g. Foursquare, to obtain necessary absolute location data and compute desired relative location data. Although technically we could use a web spider to continuously crawl foursquare data and eventually make a local copy, this kind of large scale crawling will violate Foursquare's term of use. Hence, in our system, we didn't save any foursquare data (or other third-party data) in our database, instead we use a RESTful interface to retrieve foursquare data at runtime. Thanks to today's high speed internet and web service technology, this method could also provide acceptable performance. In practice, while the user send a query, the application will initialize a remote call procedure using Ajax to retrieve Facebook data on the background. The user will not notice the whole process, until the data is ready, the application will update the interface accordingly. For example, while the user query "keio university, yokohama, kanagawa prefecture", the application will automatically use "next venue" api to retrieve data from Foursquare. Retrieved data will be return in JSON format, and could be interpreted as an object array, like what we printed in the console of browser:

Here, an array contains 30 objects was returned (the array length is defined by algorithm, and may be tweaked to achieve better performance), each object con-

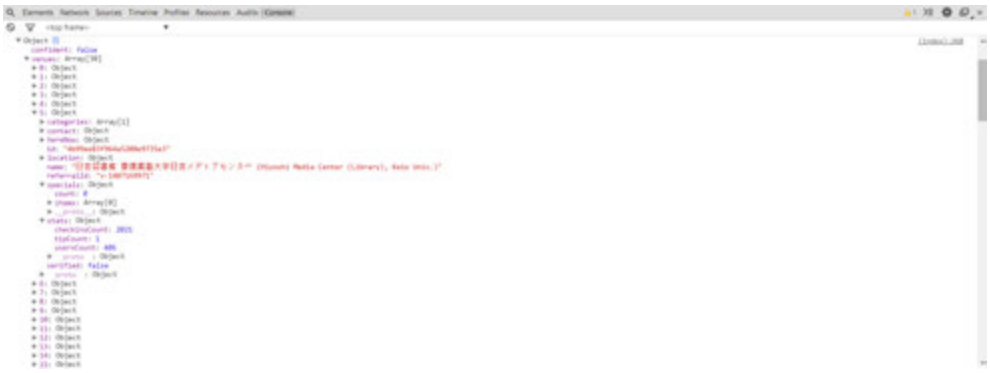


Figure 2.9: a sample data set retrieved from Foursquare

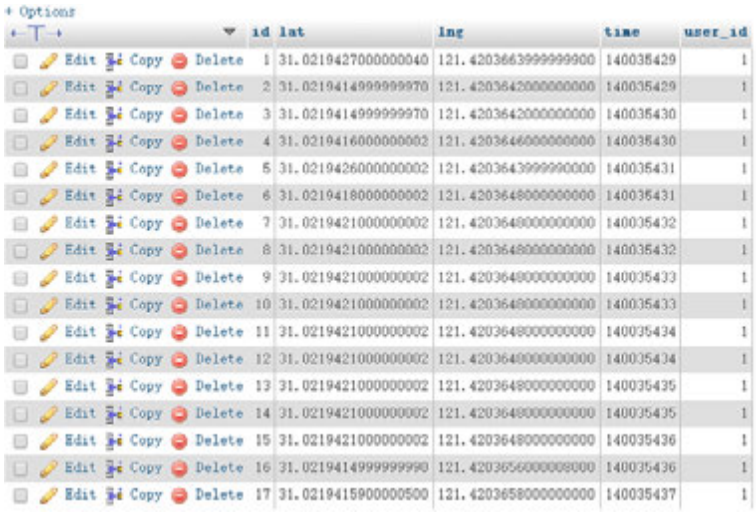
tains various location attributes retrieved from Foursquare data. Some important attributes, such as: referralId, which could be used to trace more related location; stats, which contains user statistics and used in our application to compute strength of relation. After computing, these data will influence the appearance of each location in main interface according to strength of relation, as shown below.

Figure 2.10: display location information according to relation strength

2) Recording massive users' activity data by our web applications, also called the

passively collected data. Despite users' instantaneous locations and speeds at any given time point, data passively recorded also include long-term features, such as user's dwell time in one single location, visit frequency to the same location, and etc. We believe this kind of long-term data is beneficial for revealing users' personal activity patterns and building up one's customized map interface.

By leveraging sensors within portable smart device, user's altitude and longitude coordinates will be recorded at a short time interval, e.g. 30 seconds, and uploaded to our SQL database. A sample record will looks like below. From these raw data, higher level activity data might be recognized, like: stay, walk, run, or take bus.



+ Options

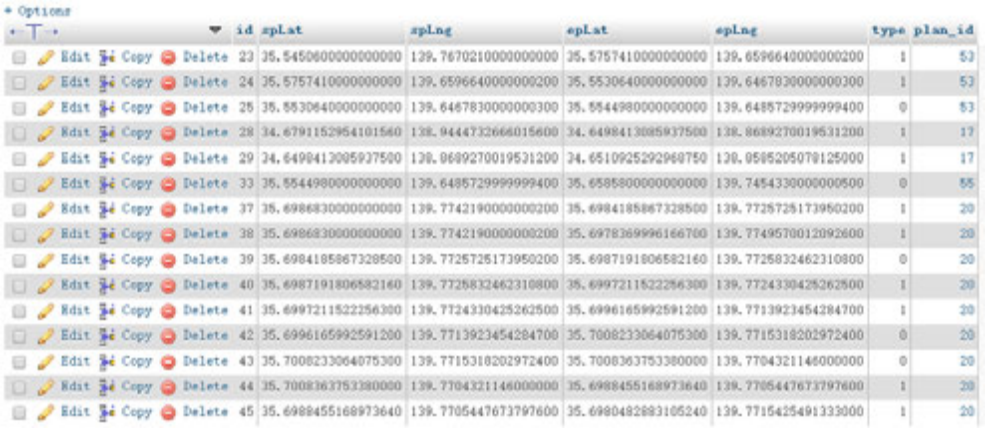
	id	lat	lng	time	user_id
Edit Copy Delete	1	31.0219427000000040	121.4203663999999900	140035429	1
Edit Copy Delete	2	31.0219414999999970	121.4203642000000000	140035429	1
Edit Copy Delete	3	31.0219414999999970	121.4203642000000000	140035430	1
Edit Copy Delete	4	31.0219416000000002	121.4203646000000000	140035430	1
Edit Copy Delete	5	31.0219426000000002	121.4203643999990000	140035431	1
Edit Copy Delete	6	31.0219418000000002	121.4203648000000000	140035431	1
Edit Copy Delete	7	31.0219421000000002	121.4203648000000000	140035432	1
Edit Copy Delete	8	31.0219421000000002	121.4203648000000000	140035432	1
Edit Copy Delete	9	31.0219421000000002	121.4203648000000000	140035433	1
Edit Copy Delete	10	31.0219421000000002	121.4203648000000000	140035433	1
Edit Copy Delete	11	31.0219421000000002	121.4203648000000000	140035434	1
Edit Copy Delete	12	31.0219421000000002	121.4203648000000000	140035434	1
Edit Copy Delete	13	31.0219421000000002	121.4203648000000000	140035435	1
Edit Copy Delete	14	31.0219421000000002	121.4203648000000000	140035435	1
Edit Copy Delete	15	31.0219421000000002	121.4203648000000000	140035436	1
Edit Copy Delete	16	31.0219414999999990	121.4203656000009000	140035436	1
Edit Copy Delete	17	31.0219415900000500	121.4203658000000000	140035437	1

Figure 2.11: passively collected data

3) Users voluntarily contribute and share their own data, which equals to **actively collected data**. For data collecting purpose, our application is also supposed to have certain mechanism to record users' active operations, e.g singe query operation along with keywords that users input, personal tags, following and sharing behaviors...This kind of active data can better show important relations between specific users and locations in their mental maps.

In our prototype application, which will be discussed in the following chapter, the system provids users a line connection function. While a user connects two

locations in a travel plan, data will be collected and stored in our database to indicate that these two locations have some sort of relation in this certain user's thoughts. Part of a single user's data may looks like:



+ Options

	id	spLat	spLng	epLat	epLng	type	plan_id
Edit Copy Delete	23	35.5450600000000000	139.7670210000000000	35.5757410000000000	139.6596640000000200	1	53
Edit Copy Delete	24	35.5757410000000000	139.6596640000000200	35.5530640000000000	139.6467830000000300	1	53
Edit Copy Delete	25	35.5530640000000000	139.6467830000000300	35.5544980000000000	139.6485729999999400	0	53
Edit Copy Delete	28	34.6791152954101560	138.9444732666015600	34.6498413085937500	138.8689270019531200	1	17
Edit Copy Delete	29	34.6498413085937500	138.8689270019531200	34.6510925292968750	138.8585205078125000	1	17
Edit Copy Delete	33	35.5544980000000000	139.6485729999999400	35.6585800000000000	139.7454330000000500	0	55
Edit Copy Delete	37	35.6986830000000000	139.7742190000000200	35.6984185867328500	139.7725725173950200	1	20
Edit Copy Delete	38	35.6986830000000000	139.7742190000000200	35.6978369996166700	139.7749570012092600	1	20
Edit Copy Delete	39	35.6984185867328500	139.7725725173950200	35.6987191806582160	139.7725832462310800	0	20
Edit Copy Delete	40	35.6987191806582160	139.7725832462310800	35.6997211522256300	139.7724330425262500	1	20
Edit Copy Delete	41	35.6997211522256300	139.7724330425262500	35.6996165992591200	139.7713923454284700	1	20
Edit Copy Delete	42	35.6996165992591200	139.7713923454284700	35.7008233064075300	139.7715318202972400	0	20
Edit Copy Delete	43	35.7008233064075300	139.7715318202972400	35.7008363753380000	139.7704321146000000	0	20
Edit Copy Delete	44	35.7008363753380000	139.7704321146000000	35.6988455168973640	139.7705447673797600	1	20
Edit Copy Delete	45	35.6988455168973640	139.7705447673797600	35.6980482693105240	139.7715425491333000	1	20

Figure 2.12: actively collected data

While data from a crowd of users are collected, data mining may reveal some human spatial behavior pattern and result in a wisdom of crowd, which could be used to teach computers more about human spatial behavior and build better recommendation system accordingly. Currently, this kind of data is still very limited because only a few users have tried our application. We are managing to recruit more participates to gather data in a larger scale and design data mining method to validate our proposal based on the data sets collected.

Data Mining

We aimed at mining two sorts of data in total: 1) Physical signals. 2) Concept information. The former can now be attained in high precision by physical sensors, e.g built-in GPS, Wi-Fi hotspots etc. As the latter one, however, there does not exist such kind "social sensors" that can directly read concepts and opinions from users' minds at current stage. Therefore, how to imply social concept information from user activity data has became a hot issue under this research topic. There were two kinds of errors commonly appeared, as mentioned in Chapter 1: The

source data, as the primary prerequisite, was incomplete or not accurate at the first place, consequently the inference resulted in fallacy, e.g mining "check-ins" data to attach sematic tags to locations. Or even the source data was correct, errors were inevitable when mapping the physical signals into concept space. Therefore, it might be a more efficient and precise solution, or at least a valuable compensation, to introduce user control into machine computing, allowing our users to describe their own thoughts. The issue was how to provide an encouraging mechanism to give users incentives. We argue that to motivate ours users, by providing concept information users can: 1) increase the system usability, as a result extra operations can be saved and the total overhead lowered; 2) provide others, e.g users' family or friends, conveniences so that users' emotional as well as social demands can be satisfied; 3) obtain economic repay.

Moreover, current location-based data mining are mostly targeting a single location. While under the framework of RLOSN, different locations are connected to form a hive-structured network, thus existing network analysis methods can also be applied to study the location features in network level, and researches in larger scale can be carried out. One possible proposal is to apply "Pageranking" algorithms to study location significance.

2.6. Summary

The main idea of this chaper was to describe the basic concepts of "relative location" and RLOSN. A few interesting findings from the preliminary user experiment of this study led to discrepency between users' and machines' understaning about locations. Then, four different sorts of relations were discussed, namely the location-location relations, location-user relations, user-user relations and temporal relations.

Based on the four kinds of relations, a double-layer location model that consisted of social as well as spatial space was constructed and corresponding relation-

oriented framework was brought out.

Finally, we talked about the data collecting and mining mechanisms of RLOSN. In conclusion, This chapter provided a theoretical blueprint for implementing RLOSN.

3.
ROSA: A Paradigm Implementation of RLOSN

3.1. Relative-location Oriented Schedule Assistant

As readers might already know, the proposed RLOSN is **not** directly end-user-oriented in this thesis. It exists only as a mesosphere beyond the physical and the network layers, while beneath the application layer. However, in real implementation, we have to create an original application on the basis of RLOSN. As we stated in Chapter 2, data processing is one of the crucial part in RLOSN, so a pragmatic application acting as a "data collector" is indispensable if we want get actual user activity data as much as possible. Of course, as a holistic network proposal, many of RLOSN's functions and interfaces can be tailored to be adaptive to user-customized services or demands. However, in order to evaluate our proposal comprehensively, we had been always seeking for an explicit application or service that able to carry full features and functions of RLOSN. Moreover, one of our core values, "relations", we believe widely exist among locations, users and themselves. In order to better practice this philosophy, we carefully devised our prototype in a bottom-up method accordingly. User interface, as the top layer directly interacting between users and RLOSN, is also an important carrier to convey our value about "relations". As a result, we came up with ROSA.

ROSA, short for Relative-location Oriented Schedule Assistant, is an online hybrid application adopting RLOSN framework, whose main function is to assist

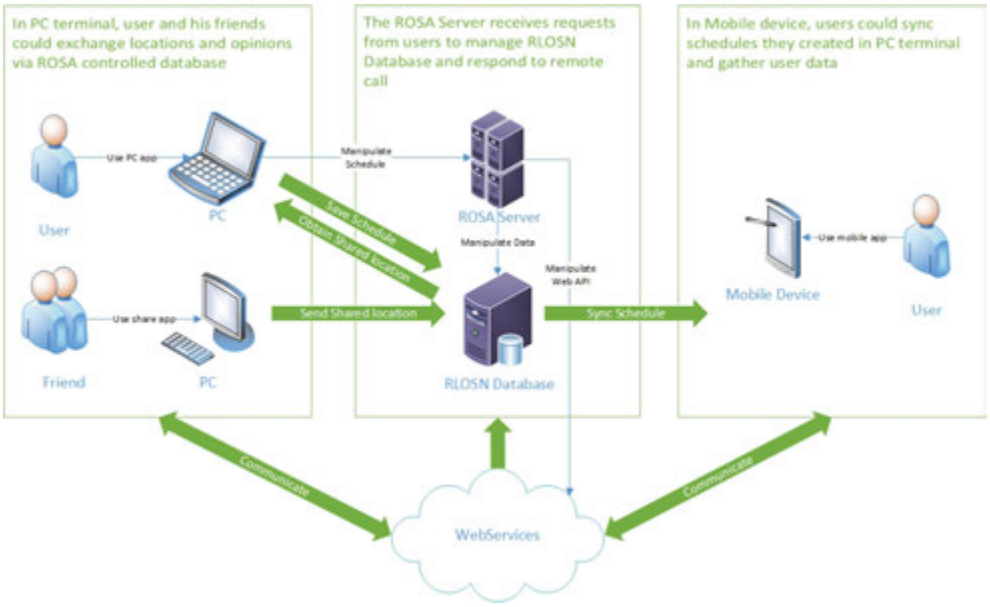


Figure 3.1: User Case Graph

users to schedule their daily visit. The primary innovation is leveraging location-location, user-location, user-user, as well as temporal relations in support of users' spatial decision making. The main purposes of developing this application is to evaluate two major aspects of the "relation" idea:

First, by supporting location-location relation in LBSN, this prototype will better help users to make spatial decision, which means relative location oriented framework have potentials to improve system usability and thus attract more users.

Second, by supporting location-person relation in LBSN, this application will better help users, as well as computing system itself, to collect friend's opinion, which means relative location oriented framework have potentials to gathering opinions together and thus generate better solutions by wisdom of crowd.

Figure 3.1 and Figure 3.2 respectively illustrated the typical user case and data flow of ROSA.

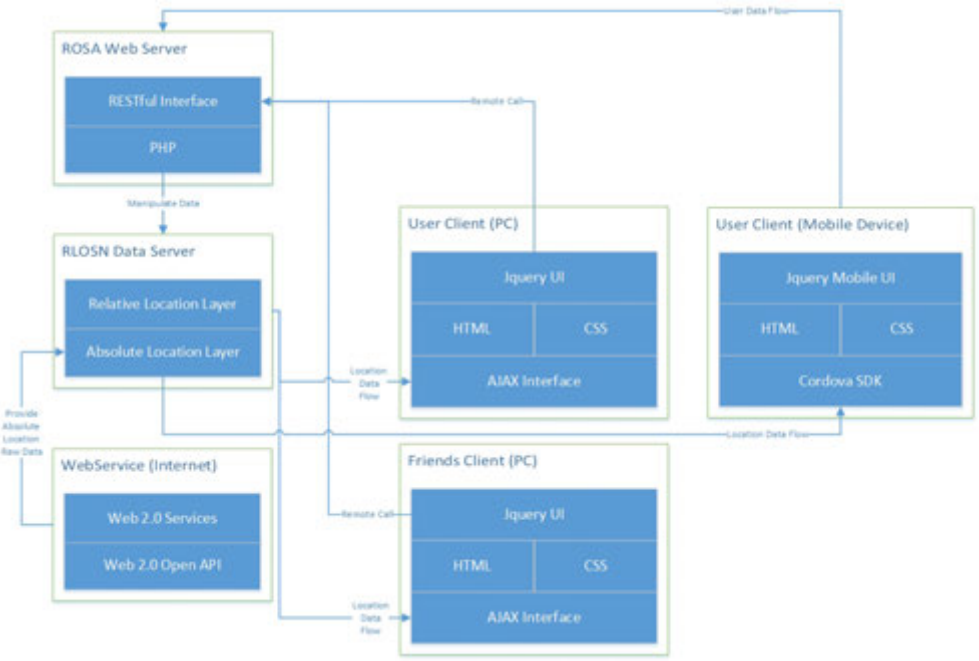


Figure 3.2: System Components

3.2. System Design

Since the ROSA is developed based on RLOSN-API lib, to better summarize the system structure and illustrate the interior mechanism under the interface, database model, work flow, data flow as well as state machine diagrams are presented here to give a better overview.

In this prototype, we used a relational database to handle raw data, include: absolute location data from web services and relative location data from our users. The database could be defined by UML model as Figure 3.3:

More specifically, two major tables: relative location and absolute location is given as below:

Relative Location

{

Figure 3.3: UML Model Graph

Integer Location_ID as primary key, foreign key; //idendifier of location

String Location_Name; //one absolute location may have multi names

Integer Address_ID; //a reference to accurate address

Integer Absolute_Location_ID; // a reference to location coordinates

Integer Timeline_ID; //a reference to timeline of activities

Integer User_ID; //a reference to users

}

Relation

{

Integer relation_ID as primary key; //the relation of two locations

Integer location1_ID; //one location

Integer location2_ID; //another location

Float relation_strength; //strength of relation

Integer relation_type; //reserved, type of relation

}

The level 1 data flow diagram using Gane-Sarson methodology is provided below to show the major sub-system blocks (procedures, interfaces, and databases), and how they are connected with each by various kinds of data flow.

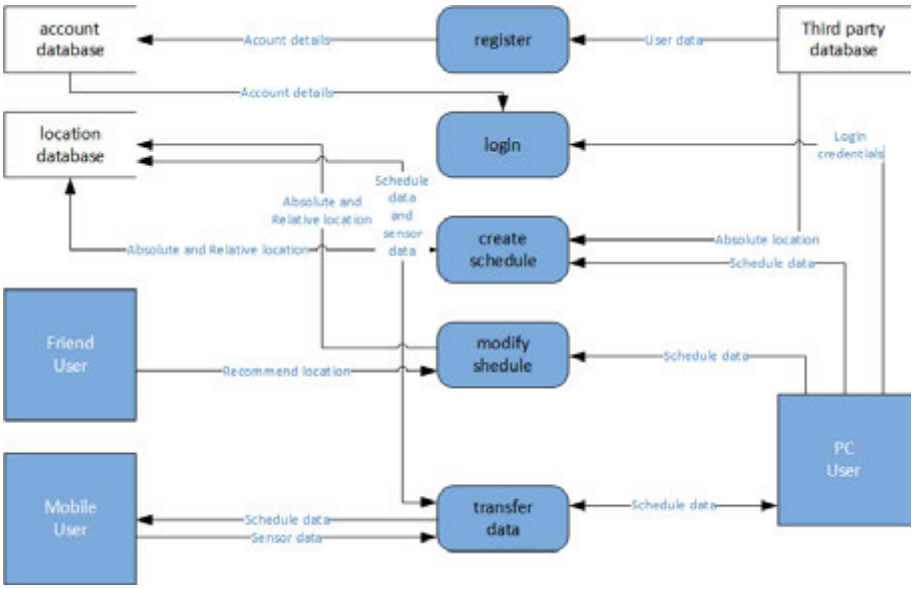


Figure 3.4: Level 1 Dataflow Diagram

According to Gane-Sarson methodology, the whole ROSA system could be divided into three kinds of sub-system (level 2): procedure (process data), interface (input/output data), and database (store data). Each sub-system consists of multiple components, both API and system specific. For example, "create schedule" sub-system contains five components: search absolute location, search relative location, add marker, add route, save schedule. A level 2 data flow diagram of "create schedule" sub-system is provided in Figure.

Each component may use several API functions in RLOSN lib which related to model, view or control separately. Functions are executed according to certain

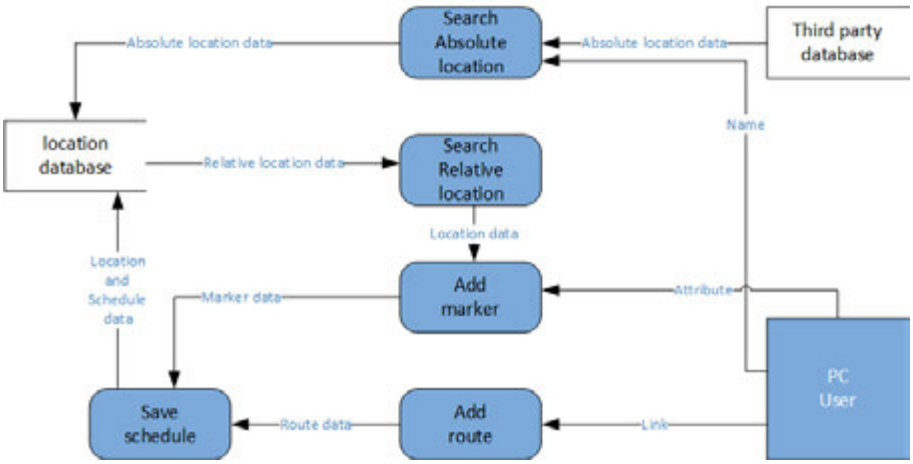


Figure 3.5: Level 2 Dataflow Diagram

events, and cause corresponding state transition, such as: view update or data change. Take component "add marker" for example: First, mouse-click event listeners and key-down event listeners are added by calling the API function addListener() of the map class in APP initialize stage; Second, while a user input is received, the corresponding event will be dispatched to certain function and the related data will be changed (here new location data will be added and pushed into the array); Finally, View will be changed (here an infoBox will be created and displayed to user) as a feedback. A UML state machine diagram is provided in Figure to describe this situation.

3.3. Server-Client Architecture

Server Side

Our prototype requires syncing data between Heterogeneous devices, so the server side technology should provide connection with various terminals and operating systems. To provide compatibility and scalability as much as possible, it's better to use standard web technologies which include: Java, ASP, PHP, Ruby, node.js, etc. After a serious comparison, we decide to use PHP as our major

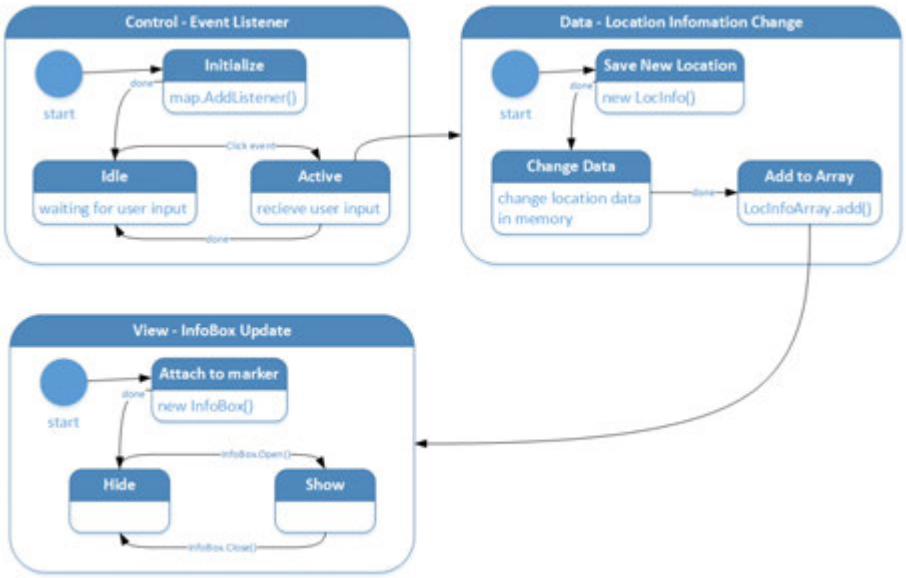


Figure 3.6: UML State Machine Diagram

server-side development tool, the reason include:

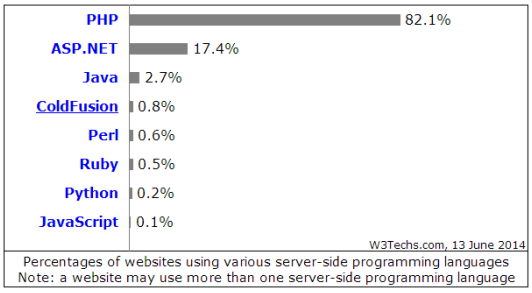


Figure 3.7: Server Side Programme Language

First, most websites use PHP to develop server-side application, sum up 82.1% as statistics by w3Techs.com. Also, PHP's success in Facebook development proved its capability to satisfy the requirements of developing large scale social network application.

Second, PHP could co-exist with many other developing tools, such as: python, or node.js.

Client Side

This prototype has two kinds of clients: PC and mobile device. Their functions and requirements are quite different:

- PC client aims to provide a productive tool to help user connect with various location data sources, include: physical spatial data provider like Google Map, and opinion spatial data provider like friends or websites. Hence, App in PC should: Be capable of providing quick response to large data flow; Be compatible with most existing LBSN web APIs (Google Map, Foursquare, Facebook, etc); Be user-friendly to support spatial decision making; AJAX is a web technology meets our requirements.

- Mobile client aims to provide relatively simpler functions, merely sync data from database server that generated by PC, record user data (such as sensors, camera, or user input) on the way, and upload data occasionally. However, because of various mobile platform existed today and they are all incompatible, such as: Android, IPhone and Windows Phone, mobile app should take a technology framework that could easily porting from one platform to another and automatically adapt to various hardware specifications, such as screen resolution.

Several cross-platform library could support our requirements, such as: Cordova, Xamarin, Unity. In this prototype development, we selected Cordova because it is: Lightweight; Easy to use; Compatible with mainstream web developing tools, like: html5, CSS, Javascript, JQuery Mobile, etc.

3.4. Web Service Interface

In case some procedures may need remote call functions of our application, we are managing to provide a RESTful interface to provide service addressing. This will help us to better integrate with distributed services seamlessly.

To retrieve data from database, one could use a traditional Ajax-PHP remote call which may looks like:

```
$.ajax({

        type: 'post',
        async: false,
        url: 'php/sqlAddUser.php',
        data: userName: window.userName,
        dataType: 'json',
        success: function(data)
        {
        //codes to realize program logic
        }
});
```

Or, many developers may prefer a routine closer to HTTP web standard, which is called REST. REST means Representational State Transfer, which refers to an architectural style that use mere HTTP manipulator such as: GET and POST, and hide the details of implementation and protocol syntax in order to focus on the roles of components. Our RESTful api use four methods to manipulate remote data, which include:

GET to retrieve data,

POST to add data,

PUT to update existing data,

DELETE to delete data

The same function as remote call shown above, while use RESTful interface in curl may looks like:

curl -X POST -H "Content-Type: application/json" -d '"userName": "xxx"' http://reloc-rosa.com/user

As an example, our RESTful API interface used to manage user accounts are listed below:

Table 3.1: User RESTful API

URI	Method	Parameters	Description
/user	POST	name	Add user
/user/:id	GET	-	Get user info
/user/search/:query	GET	name	Search user by name
/user/:id	DELETE	-	Delete user
/user/:id	PUT	name	Change user name

3.5. Interactive Design

Since the main purpose of this prototype is to show "relation" as a core idea in relative location oriented system with its benefits to improve system usability and wisdom of crowd, the interface design should center on these two major tasks.

How to use "relation" idea to design more usable interface comes from two guidelines:

First, cognitive fit theory suggests, the outcomes of spatial decision making depend on the fit between information presented by computing system and information presented in decision maker' thoughts[7]. Judging from this theory, the more a map-based interface fit user's mental map, the more usability it will provide.

Second, according to cognitive load theory, human working memory capacity has inherent limits[4]. Avoid loading users with unnecessary information will greatly improve their efficiency. By examining the relation weight between the target location and other locations, we could develop an adaptive method to

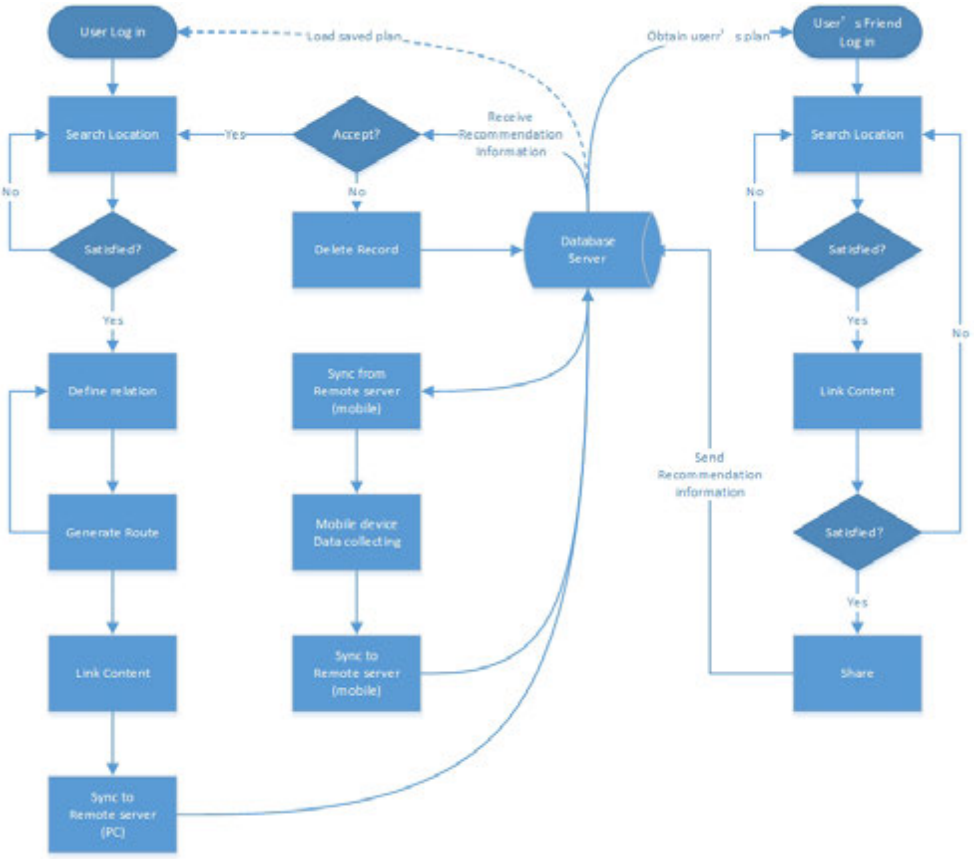


Figure 3.8: Interaction Flow Diagram

dynamically change information density on the map. This method will emphasis on necessary information and hide unwanted to reduce cognitive burden.

Hence, our design objects includes: First, to design an interface that closer to user's mental map; Second, to design an interface that adaptively changes information density; Third, to design an interface that is capable of promoting users' opinion sharing.

The whole working flow of user interaction is displayed by Figure 3.8. Following with the graph, let us look at some specific details that worth of attentions out of the whole blueprint.

- **Mental-Map-like Interface**. In a preliminary study, we asked partici-

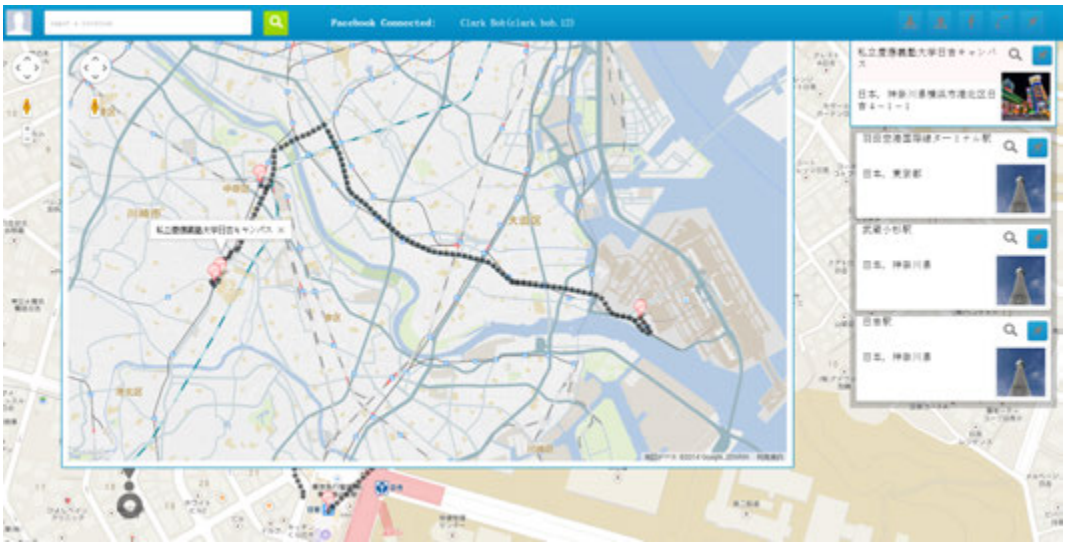


Figure 3.9: Mental Map Like Interface

pates to describe the location of their home and then draw the image that displayed in their thoughts while they were answering the question. A typical image looks like in Figure 3.9. From this study, we confirmed that user's mental map consists of multi-layers from global to local. All the layers and locations in mental map are connected by certain relations, users may instantly jump through these relations from one layer or location to another.

To simulate mental map as close as possible, we designed a two-layer map to show global map and local map simultaneously. The global map could be temporarily hidden to switch to local map immediately. Links between locations are also displayed as visual cue and provide quick access.

- **Adaptive Information Density**. Information density change automatically based on relation with target location to reduce. For example, while searching for "Keio university", unrelated map information will be hidden, locations related to "Keio university" will be emphasized based on relation strength, as shown in Figure 3.10.

As a comparison, the lower of Figure 3.10 is a result image while searching "Keio university" in Google Map. Our interface is considered to be more "readable" by users.

- **Easy-to-Share Interaction**. In our preliminary study, we confirmed that users have requirements and willing to share spatial information. However, difficulties in sharing with today's LBSN usually reduced their efforts.

  To address this problem, we designed: 1) A one-click interface to share schedule easily; 2) A SNS integrated interface to send invitation to social friends; 3) And a map visualized interface to sync opinions.

Figure 3.11 shown a typical user's travel plan. He sent his plan to his friends by this prototype application and asked for points of interest on the way. His friends immediately gave feedbacks and displayed in user's map interface (shown as green dots). The user could click "accept" button to save recommendations and comments from friends or "refuse" button to delete them. The whole opinion gathering process could be completed in several minutes with a few clicks, no extra typing or drawing was required, and the communication is very intuitive.

3.6. Summary

Chapter 3 was the specific implementation of RLOSN. In order to collect user data, fully evaluate all features and functions, and apply the relation oriented design philosophy to the user interface, a top-layer web service named ROSA was devised and introduced in this chapter.

ROSA standed for Relative-location Oriented Schedule Assistant, an online hybrid application mainly used for assisting users to schedule all kinds of visit activities in their daily life. In the coming sections, ROSA's database design, server-client architecture,web service interface and interactive design were discussed in details. The three most prominent features of user interface: mental-map-like

interface, adaptive information density,and easy-to-share interaction were introduced in depth.

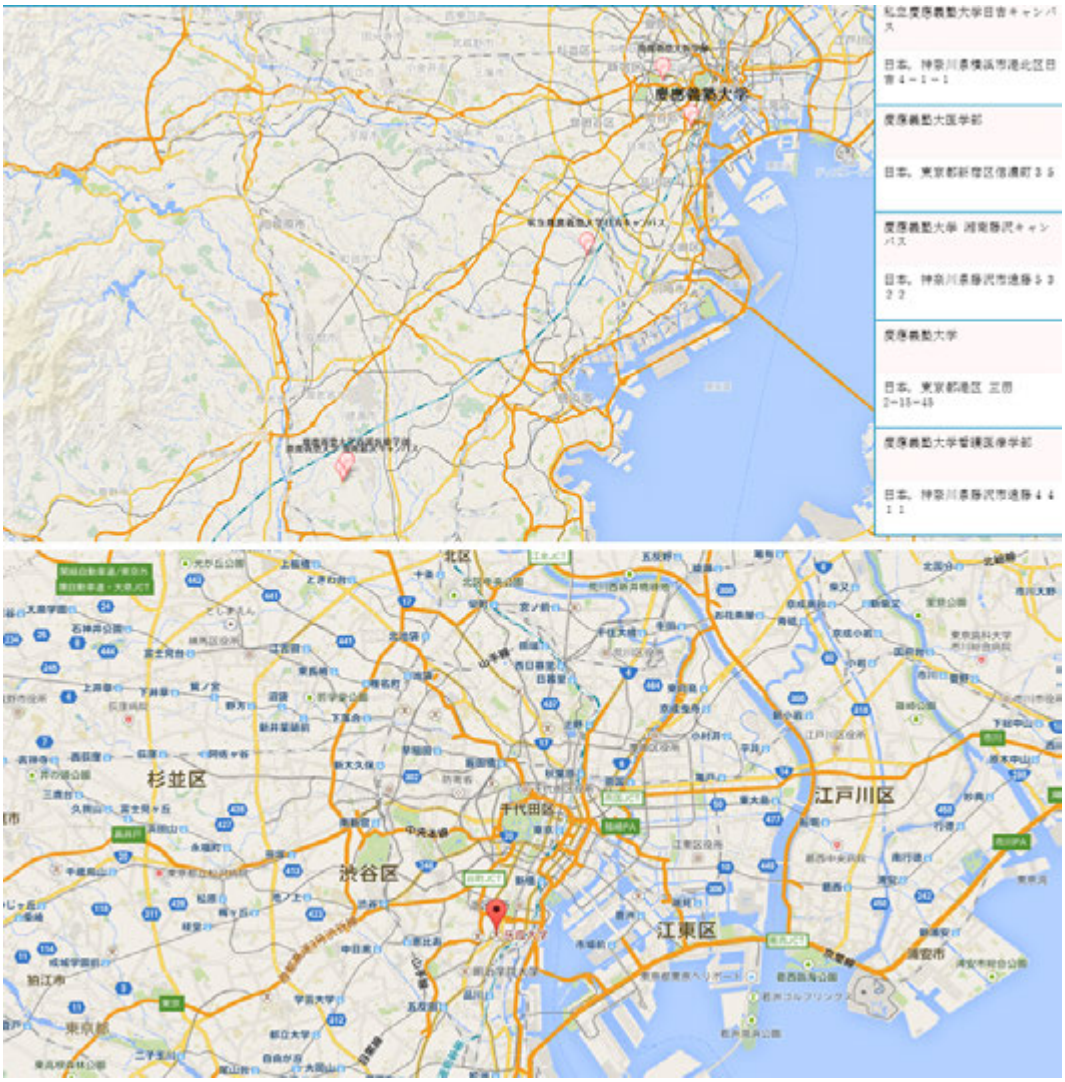


Figure 3.10: Information Density Contrast between ROSA(upper) and Google Map(lower)

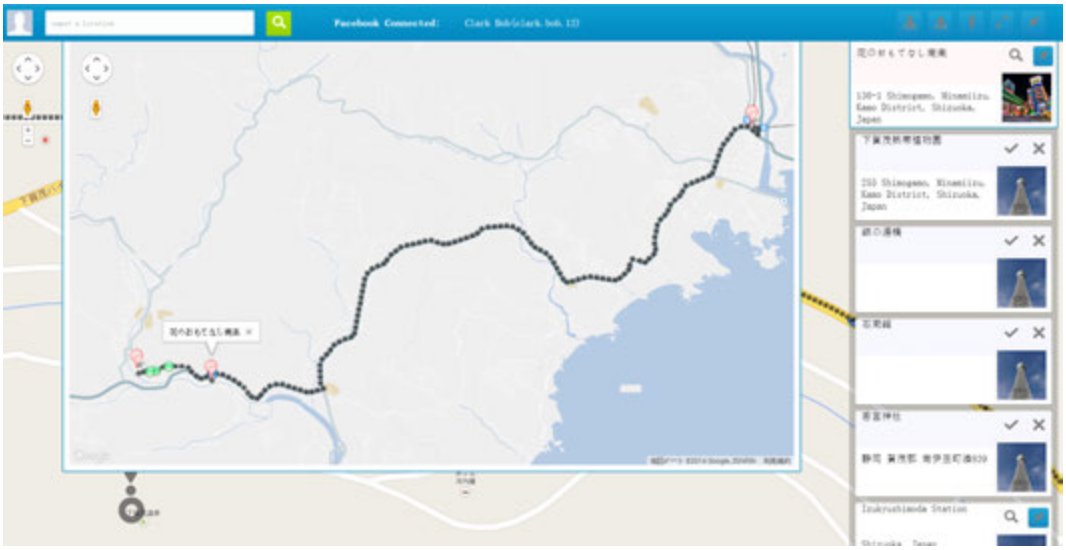


Figure 3.11: A Typical User Travel Plan

4.
Evalutaion

4.1. Concept Usability

To discuss the potential use of relative location and how it may influence user's spatial decision, since it's actually an abstraction of historical data of other users ¨ spatial behavior, a preliminary user experiment was conducted using our specifically developed web map interface. In this interface, when user search a certain location or place a marker on the map (to simulate user's current location), the interface will switch to relative location mode. To better explain this mode, imagine a traveler plans to have a travel to Hokkaido. If he decided to begin his travel in Sapporo, the biggest city in Hokkaido with an international airport. By searching "Sapporo" in today's web map, he will get a result like the Figure 4.1 below.

Figure 4.1: Absolute location oriented interface shows every location equally

Though many locations are shown in this map interface, the users could hardly

decide where to go because every location is equally displayed. They will have no idea about the difference between those locations. While in our relative location oriented interface, location information will be displayed according to the relation with current location: lower-related locations, which also means fewer travelers will visit them from the current location under this circumstance, will be weaken or hidden to simplify the interface, while information of higher-related locations will be strengthen. This will help users to focus on potential destination from the current location, by indicating other user's choices.

Figure 4.2: Relative location oriented interface shows locations differently based on relations

How to decide the relations of locations and their strength is a core problem of relative location oriented application, like app mentioned above. In real life, there exist various kinds of relations between locations which reflect different human knowledge and activities regarding related locations. For example, a similarity relation between two book stores may means there are similar people have similar activities on these locations; a collaboration relation may mean people living in these locations have many communication and cooperative activities. All these relation information are stored and used by human brain to support decision-making process in spatial related tasks. However, it's quite difficult for computers to handle so many kinds of relations, not to mention many relations used by human are very difficult to give a clear definition. Considering the complexity, we

could not process all these kinds of relations in one application. On the contrary, desired relations should be chosen wisely on different situations. In this test, only "route" relation are used, which means two locations are related with each other because they are contained in the same route of a certain user's travel. Here, a 3-stage strategy is designed to find relations of locations and their strength.

First, attractions and landmarks are collected as much as possible from human knowledge (travel website, blog and magazine) by student volunteers. Because this work is quite time-consuming, only those locations in Hokkaido are collected.

Second, initial strength of relation are calculated based on data from several selected trip advisor websites. In those websites, travelers usually post their travel notes which describe in detail where have they been during the trip. For each time two locations are found in a travel note simultaneously, we add up the strength of relation between these two locations. Data from different websites are normalized to avoid bias.

Third, students are invited to design their own travel plans using this web-map interface and other information they may found. Strength of relations are recursively calculated based on each user's feedback to simulate how users' activities could be reflected in the relation of locations dynamically. In the test, 20 students in the same class were invited to take part in an asynchronous remote testing and give subjective feedback. Students were divided randomly into two groups. Every student in each group were asked to design a 7-day travel in Hokkaido. The only difference is: group A use the relative location oriented interface described in this paper, while group B use Google map. Students could also use any other information source to help make decision. All students have never been to Hokkaido before.

Findings include:

First, Relative location oriented application could help users to make decision faster and better, which result in a reduction of task time consumption.

Second, Relative location oriented application could influence user's decision,

since most participants in group A reported that they cared more about locations that had higher relation strength with the current location, since it reflected other users choices.

More detailed information about test design and outcomes could be found in our conference paper. Though this test have shown just one potential benefit of using relative location, we believe further studies will confirm our hypothesis that taking relative location into consideration could help us to address many problems exist in today's LBS application, such as: usability improvement, privacy preservation and better social mining. However, because of the heavy workload of the whole research field, we could not finish all the system building and validation works in a short period. Until now, our work are mainly focusing on:

Provided a usable and flexible framework (RLOSN) to collect and handle relative location data, as the basement for further research.

Developed a base API library (RLOSN API library) to support agile development of relative location oriented application for future research.

Evaluated some use case by developing prototype applications (ROSA, mainly to show how to attract users to contribute their data about relative location by providing a more useable relative location oriented schedule application).

The usefulness of our framework and prototype will be shown by the next two usability evaluation in this chapter. We are managing to develop more application and further study what advantages and disadvantages will relative location oriented application bring to user's spatial behavior issues, include: privacy preserving and collective spatial intelligence.

4.2. System Usability Test

To test scalability of our system, two web load testing were conducted.

First, we programmed a test unit to simulate one user that continuously sent requests in 30 minutes. Results shown, during the 30 minutes test, no error

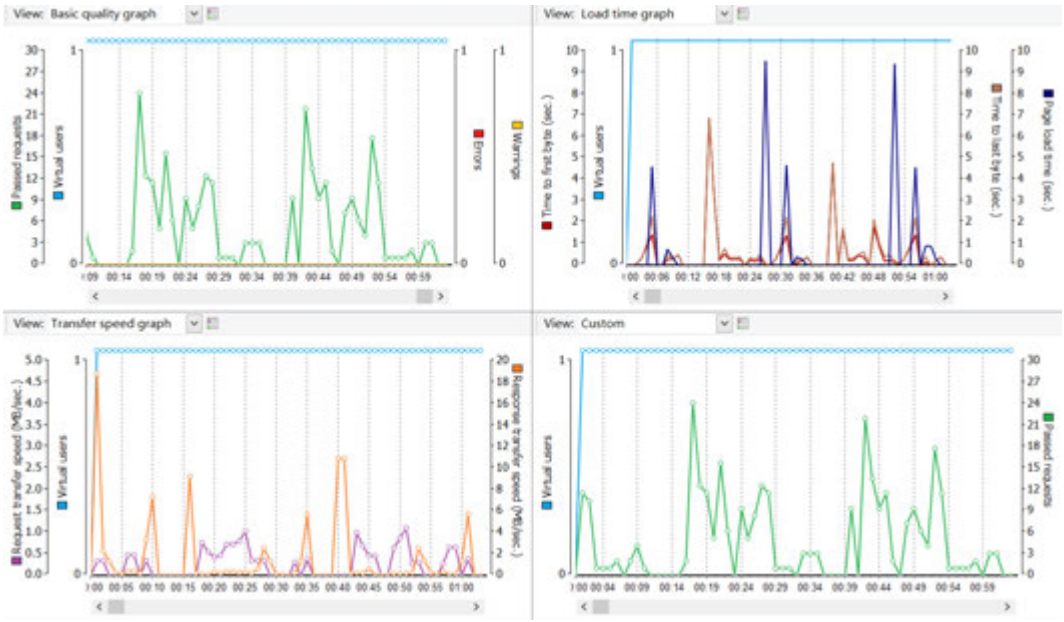


Figure 4.3: Web Traffic Result

occured, and the web traffic was show in Figure 4.3.

Then, we deployed a multi-thread testing program to simulate X (from 1 to 100) users that simultaneously send requests in 1 minute. We counted page load time, response time and errors as shown in Figure 4.4.

Results shown, while user count continuously added and sent request without interval, the page load time, server response and error number are all increasing. While simultaneous visiting users is less than 50, no error occurred. Then, error increased according to the visitor's number linearly. After divided by total user request, the error rate is relative low and very stable (less than 1%), which proved the robustness and scalability of our system. The reason why request error will happen when user counts more than 50 is mainly because Google limited the concurrent connection from the same website. This will be shown in the next test where we use merely our own database. To exceed concurrent connection, we may have to pay Google for extra connections or add more servers to support extreme cases and bypass the network flow.

Figure 4.4: Load Test Results

Finally, we tested our RESTful interface with the same method. In this test, we simulated multiple users sent request to obtain a 8K byte dataset from RESTful interface, codes that retrieve data from web APIs are excluded to avoid interrupting. Results shown, while using merely our own data, the system runs more effectively and stable. Results listed in Figure 4.5 and Figure 4.6.

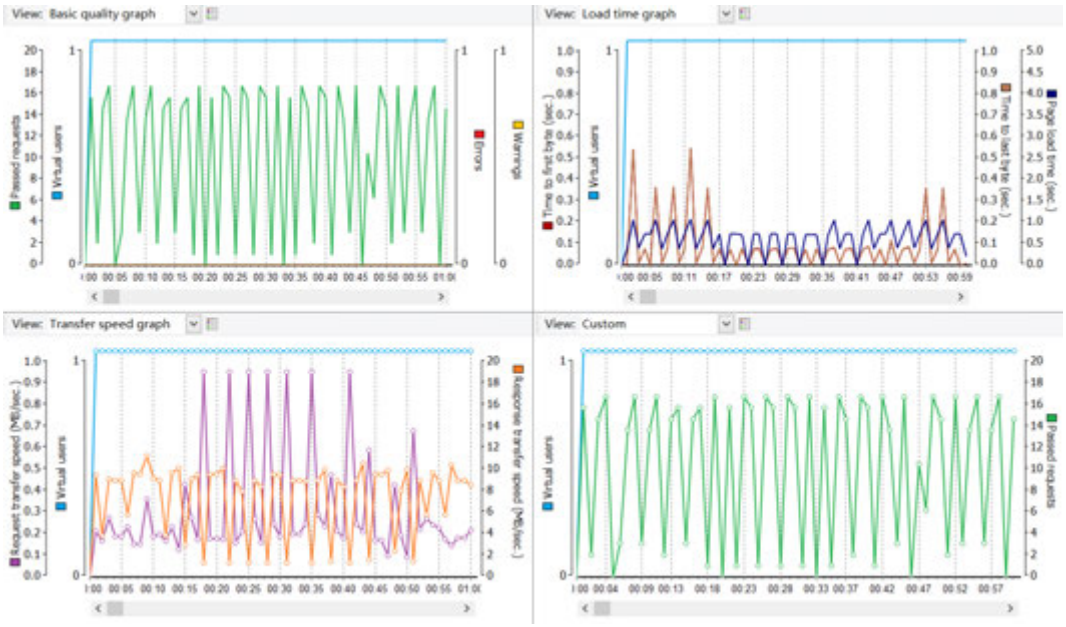


Figure 4.5: Scalability Test

4.3. Interface Usability Test

6 users (3 male, 3 female) are divided into 3 groups (1 male and 1 female in each group) to complete tasks. 3 groups are required to use different applications to complete same tasks:

Control Group 1, Use Foursquare;

Control Group , Use Roadtrippers;

Experimental Group, Use Our Prototype.

Time to complete tasks were recorded and compared(see below). Survey and Focus group were organized to obtain further information.

Tasks are given as:

Task1. Suppose you are an international exchange student in keio university(hiyoshi campus) who decided to have trip to Tokyo in a weekend. Your locations of interest are listed below, find them on the map, remember their locations.

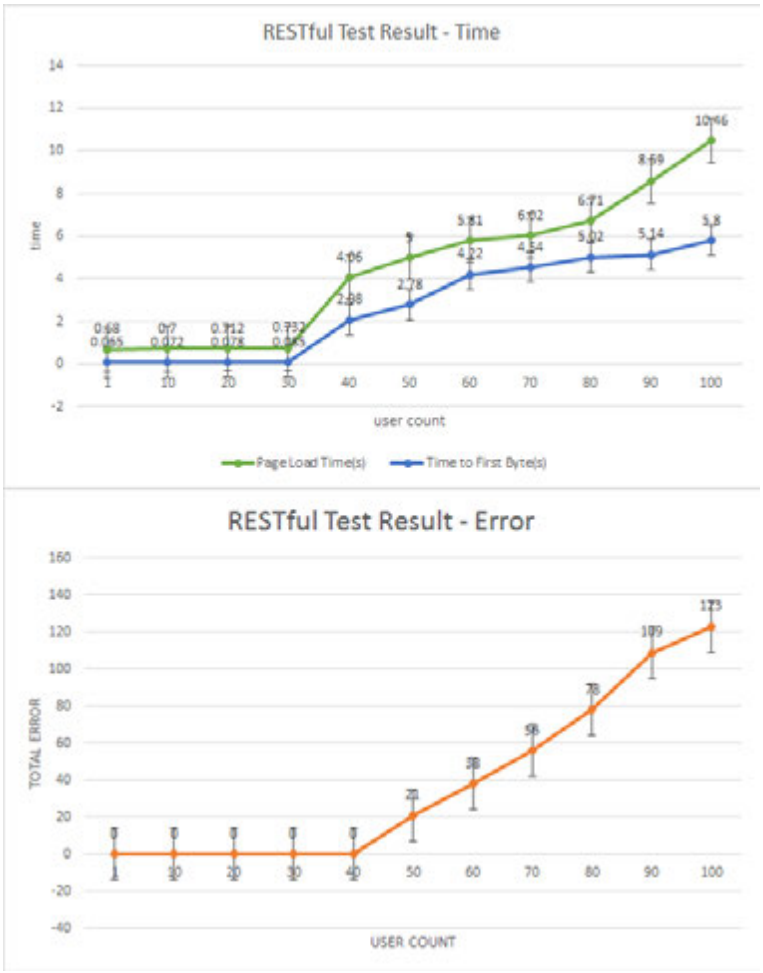


Figure 4.6: RESTful Test Results

Task2. Select places where you want to visit and arrange them in your travel plan (introduction of these locations are provided as webpages, time consumed in browsing those pages are not counted). You are planning to start your journey from Keio University, Hiyoshi campus at 9 am, and get back at 9 pm, please take transportation time into consideration. (Approximate transportation times between each two locations are provided). Participates can give up at any moment.

Task3. Suppose you are going to have lunch around Akihabara, because of the time limitation, you decided to select the nearest restaurants to the subway

station. Confirm the location of restaurants in the list below and add the nearest one into your travel plan.

Task4. Share the travel plan with your friend (the friend is assigned by researcher)

Task5. Your friend recommended a restaurant (Musashiya, Hiyoshi) for you, however, neither google nor foursquare could tell you where this restaurant is located. Ask your friend for information to find it on the map and add it to your travel plan. (The participates and their friends sit in the different rooms, to simulate their daily communication scenes, they could use an instant messaging software to chat with each other).

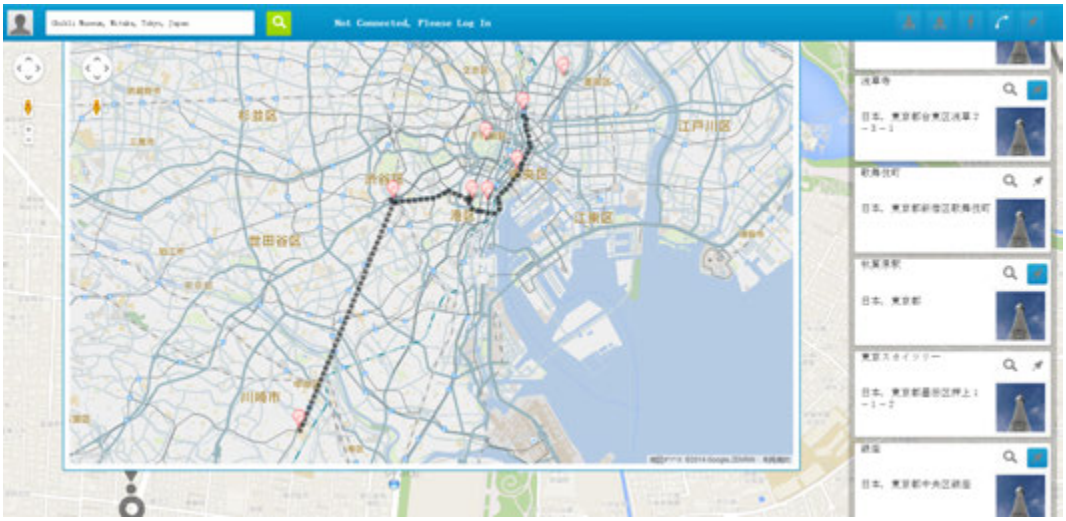


Figure 4.7: Interface Usability Test

Results are shown below:

As a summary, experimental Group completed the same task with better quality and few time, which proved the advantages of using our prototype.

Table 4.1: Interface Usability Results

-	Control Group 1	Control Group 2	Experimental Group
Task 1	8m39s	6m22s	5m48s
Task 2	16m10s(2 gave up)	18m34s(1 gave up)	14m27s
Task 3	5m32s(2 gave up)	8m14s	3m41s
Task 4	46s	9s	14s
Task 5	5m52s	1m49s	2m24s

4.4. Summary

In this chapter, evaluation part actually were divided into concept, system and interface usability test.

The concept usability test is a preliminary study validated our hypothesis that taking relative location into consideration will bring us some potential benefits.

The system usability test consisted of a series of web load testing, respetively testing the error rate, web traffic, load time and response time, given multiple users and consecutive requests.

The interface usability test were conducted among 6 participators and each of them were given a seres of spatial tasks. The time used to complete each task, the degree of task to be finished as well as user feedback were recorded.

To give a conclusion, our prototype generally maintained a positive performance in comparison to any other like products and hence the advantages of adopting RLOSN famework were proved to some exent.

5. Conclusions

5.1. Contributions

This thesis contributed several unique attempts that are exclusive from previous researches, mainly in the following three aspects:

Concept/Model

This thesis established a comprehensive socio-spatial location model, consisting of both the physical coordinates space and the social conceptual space. In order to distinguish from traditional concept as well as underline the social connectivity aspect of locations, we brought out a new concept called "relative locations".

Methodology

Derived from the core value of "relative location", the methodology adopted in this thesis shifted from geographical mapping to conceptual mapping, driven by user activities, and centering correlations between location-location, user-location and user-user. We applied this methodology to build a series of compatible data models, network structures and interaction mechanisms.

Implementation

To further prove and evaluate the usability and efficiency of "relative locations", this thesis devised a novel but pragmatic prototype that can be used in planning daily visit scenario.

5.2. Limitations

During the implementation of RLOSN, we adopted a relatively mature solution and the results were inspring somehow. However, due to limited working time, there were also obvious limitations in both the width and depth of our research.

As most commercial LBSN services today, we adopted the relational database technology. It was pervasive, popular, somehow limited. Especially when dealing with highly connected data,such as social graphs, or the location network that we proposed. It would face larger and larger efficiency and cost challenges along with the increase of network scale and query depth.

Also, our system is able to collect varied raw data by both sensor side and user side. However, in order to better understand and infer users activity pattern, further data process and analysis were necessary. Therefore we may need to consider machine learning.

Moreover, to integrate physical and virtual space, sensors are considered to be a possibility. We had always been conceived to involve the sensor network, or in a more popular saying, IoT(Internet of things) into our framework, which was closely related to, however, beyond the scope of this thesis. But we found it a valuable attempt to strech out for this possibility.

5.3. Future Work

Graph Database

The concept, "graph database" was first systematically elaborated in the book Graph Databases by Ian Robinson et al. and raised to help "manage and query highly connected data"[14]. Readers with knowledge about "graph theory" may know that a graph is just a collection of vertexes and edges, or a set of nodes and the relationships that connect them. In Graph databases, graphs represent entities as nodes and the ways in which those entities relate to the world as relationships.

Since data in our two layer model could be divided into two categories: nodes and relations, we seek to use a database that provide fully support for both data types. However, today¨ s mainstream database solutions, both relational database and graph database, could not complete this task alone.

Though the name of "relational database" suggests relation plays an important role in this kind of database, it's actually very limited. "Relational database" only maintain relations between structural elements (table), not node elements (record). "Graph database" solved this problem by maintain relations between every nodes. This feature makes graph database especially suited to handle relation data from various network-structured applications, such as: social network.

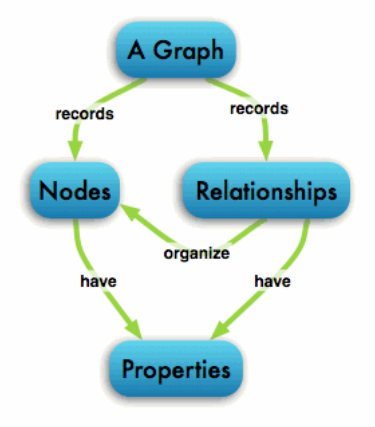


Figure 5.1: Graph Database

However, comparing to relational database, graph database also have some important disadvantages:

First, graph database is much slower when operating on huge numbers of structured records. In a graph database, each record has to be examined individually during a query in order to determine the structure of the data, while this is known ahead of time in a relational database. Second, graph databases use less storage space, since they have to store extra data of relation between every two nodes.

Considering those advantages and disadvantages respectively, a better solution

may be using relational database and graph database simultaneously. In practice, we use relational database to store raw data, because raw data are usually big scale highly structured data. Then we mining high-level data from raw data, which has more irregular and complex structures, and store them in graph database.

Machine Learning

The second future mission is to involve machine learning methods into RLOSN. The main challenge we face today in LBSN is actually how to teach machines to understand human knowledge about space, such as: location naming or labeling, location searching or recommendation, and spatial intelligence. Machine learning researches will help to address this problem. Some classical classification methods have already been tried with or without modification, such as: Decision Tree, Artificial Neuro Network and Support Vector Machine. For example, Agrawal et al. used a Gradient Boosted Decision Trees in local search to disambiguate location queries[1]. Yamamoto et al. used a probabilistic model to classify locations related to certain historical event[20]. However, most attempts nowadays treat locations as isolated nodes, which exist in two aspects: first, researches usually retrieve date from public accessible data sources, such as Foursquare, Brightkite, and use them as separated records to train classifiers; second, Methods are usually proposed to deal with every single location's attributes, without considering their relations with other entities. However, we argued that, many locations are related with each other directly or indirectly. As shown in this paper, if well designed, these relations could be collected while users interacting with computing systems. After taking relation data into consideration, the previous isolated location nodes could be connected into a graph which could be further analyzed by many graph mining technologies. For example, today's POI recommendation algorithm merely take data from every single location into consideration. As a comparison, with a graph based algorithm, data from adjacent node in the graph will also be considered, such as pagerank method. We believe, it will introduce some new ideas into machine learning process and result in better performance.

Wearable Devices

Finally, we want to prospect for the possibility to combine wearable devices with RLOSN together. One commonly acknowledged technology trend is that within the next 2 or more decades, the boundary between virtual and physical world will become more and more vague, and the way that users gain, exchange and operate information more natural and intuitive.

Wearable device, as one of the key revolutions that engine this tide, is a promising area that has not yet been fully exploited. Some IT scrutators have predicted that in the coming future, wearable devices, e.g smart glass, smart watch etc, will gradually replace portable devices like mobile phones that we used to be so familiar with. While hidden behind this change, we can see an immanent transition taking place in the traditional way that people get information.

Since the first computer ENIAC born in 1946, this great invention has dramatically changed human being's lifestyle ever since. With the evolution of personal computing devices from desktop computers, laptop computers, PDAs, to tablets, smart phones today, modern people are getting more and more used to relying on them to get information once needed, which has almost formed a path dependence: Rather than actually being at somewhere and getting to know the place, it is more likely for modern people to first search on the Internet and find a destination. This kind of information flow from virtual data to real location, of course, can bring us some advantages and conveniences. However, we human beings are born to be sensitive to certain kinds of information, like distance, position, and etc. Thus we are able to capture the spatial relation to environment around us rapidly. Unfortunately, once we try to digitalize this information, we will lose a considerable amount of it, which is usually crucial in support for spatial decision making, if not dispensable.

To be complementary to the particular path "virtual data to real location", it is necessary to have some mechanism to provide a reversed flow that is "real location to virtual data", while wearable smart devices make it become possible. Products

like Google Glass, Galaxy Gear, Nike FuelBand etc, integrating with abundant sensors, enable us to extract varied information from the environment around us.

In order to truly make the vision "seeing/being is knowing" come true, more external information is needed to support functions like real-time indoor navigation, local and community services etc.Your Google Glass by itself can hardly tell you whether there is still any slot left in the parking lots before you actually drive your car in, but the sensors or the cameras in the parking lots can. What we lack is some kind network infrastructure that can integrate the environment information, physical as well as virtual resources as a whole so that your smart devices can get prompt feedbacks from the environment to support your activity in real time. And RLOSN is one of these attempts. In the coming few decades, our mission is to extend RLOSN to a level that is correspondent to and in support of wearable devices, so that the hardware potentials can be fully exploited.

5.4. Summary

As the ending of this thesis, last chapter concluded both the contributions as and the limitations of this thesis. Exclusively, we made innovative progress in concept/model, methodology and implementation of LBSN. While there are still some remained issues in this area and gave us the prospects in the potential development of the proposed RLOSN in the future. Three promising new technologies, namely graph database, machine learning and wearable device, shed the lights on the future vision of RLOSN.

Acknowledgements

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Appendix

A. Application Manual for ROSA: PC

In PC, ROSA could help users to quickly find spatial objects, arrange schedules for spatial behaviors, such as: travel, share spatial objects with friends in a relative location format, or ask for recommendations.

Interface Overview

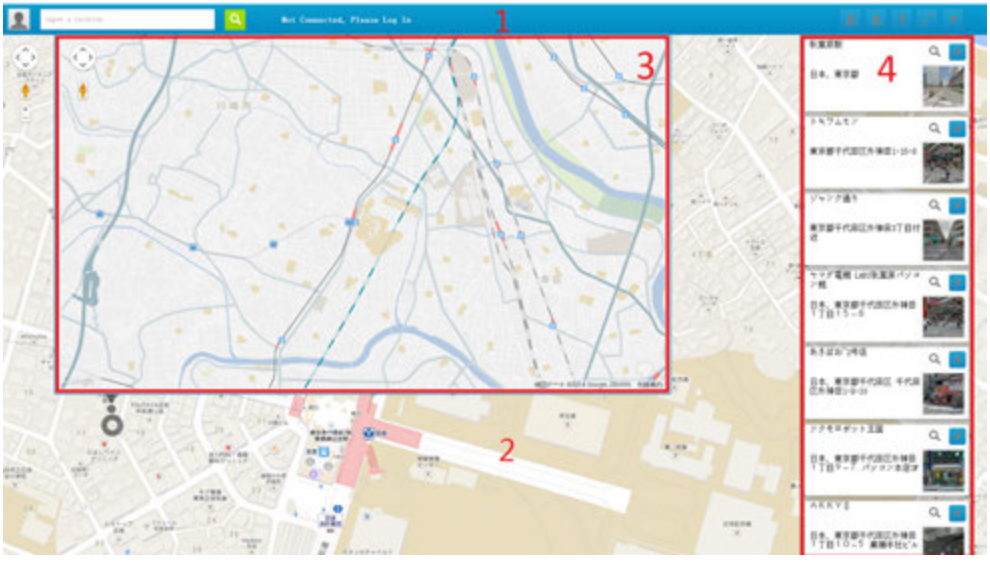

Figure 5.2: The Initial Interface of ROSA

The whole interface could be divided into four areas:

1. The tool bar area

Displayed in graph A as area 1. Here, main functionality of this application are provided by using various controls with label 1 8 in the graph below, including:

Figure 5.3: Toolbar Area

Control 1 - login with Facebook ID

Control 2 - input location name for query

Control 3 - query absolute and relative location information

Control 4 - save schedule

Control 5 - load schedule

Control 6 - share with friends

Control 7 - link locations in schedule

Control 8 - add locations into schedule manually

Detailed information about each control will be introduced in functionality sub-section.

2. The actual map area

Displayed in graph A as area 2. Here, an actual web map (using data from Google map) are displayed.

3. The mental map area

Displayed in graph B as area 3. Here, the mental map area could be fold/unfold by clicking the circle-shape control on its bottom. Comparing with the actual map, the mental map is simplified and emphasis on key information to be closer to the map in user's thoughts, which is: simpler but more effective, less accurate but link spatial information better.

4. The location list area

Displayed in graph C as area 4. Here, all the locations added by user will be displayed as a card with two controls:

Figure 5.4: The Location Card

Functionality and Operations

1. User login

Currently, users need not to register in our system. All functionality could be accessed by using Facebook ID. One could also use this application without login. However, some functionality (such as: save, load) may be disabled because they are user dependent.

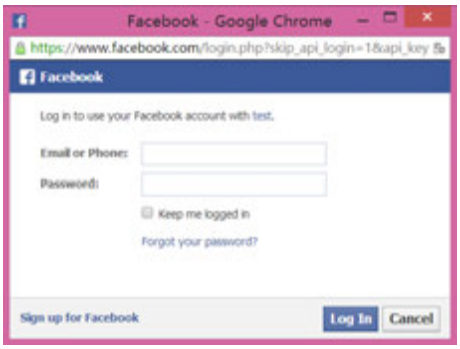

Figure 5.5: User Login

2.Manage locations

Users could input keywords in control 2, such as “keio university”, then click control 3 to query locations they need. A certain query may returns several locations, user could select some and dispose others. The selected locations will be added into location list.

User could manually add location by using control 8, then clicking on map and providing necessary information. This function could be useful especially

Figure 5.6: User Defined Location

when certain locations could not be found on Google Map or Foursquare. Added locations will also be displayed on the map as markers (red pin). Left-click on the marker will open the infoBox to show information about current location, which provided by the system or inserted by user. Right-click on the marker will show relative location (blue dot) related to user-defined locations.

Figure 5.7: Show Defined Location Information

3. Manage relations

In relative location paradigm, locations are linked with each other with one of more kinds of relations. Users could define relation between two locations by using control 7. To achieve this goal, user should: first, click control 7; second, click two locations (displayed as markers on the map) in sequence.

Currently, there are only two kinds of relation are visualized by the system, which could be switched by left-clicking the line that represent this relation. The first kind is "general", which show a direct line between two locations; the sec-

Figure 5.8: Add General Relation

ond kind is “route” which show a path between two locations. Relations could also be deleted by right-clicking the connection line. Other relations may also exist between two locations, such as: identical, parent/child, alternative. We are managing to develop functions to support those relations.

Figure 5.9: Switch To Route Relation

5. Save/Load schedules

Users could use control 4 to save schedule and control 5 to load schedule. Only users who create and save the schedule could load it again. So users must login

before using this function. A loading page from a test user are shown below, click "load" button will load the corresponding schedule and visualize all its data onto the interface.

Figure 5.10: Load Schedule

6. Share with friends

Users could use control 5 to generate a URL (red text) that contains exactly the same location information with the saved schedule, and share with friends. A dialog with pop up after clicking control 5, users could click "OK" to share the URL on the Facebook, or click "CANCEL" to send URL by their own.

Figure 5.11: Create URL for Sharing

If User choose "OK", a list of his friends on Facebook will pop up. He could choose those friends that he would like to share, and send the requests.

7. Take recommendations from friends

User' friends could use URL to access the share page, which contains all the spatial information provided by the user. The share page have the similar interface like the home page that the user used to create his schedule, without operations save, load or delete locations. However, besides viewing the schedule, share page provide a recommend control that friends could use it to add new locations as recommendation, and send them back to the user instantly.

If recommended locations was sent by a friend, user will see them after reload

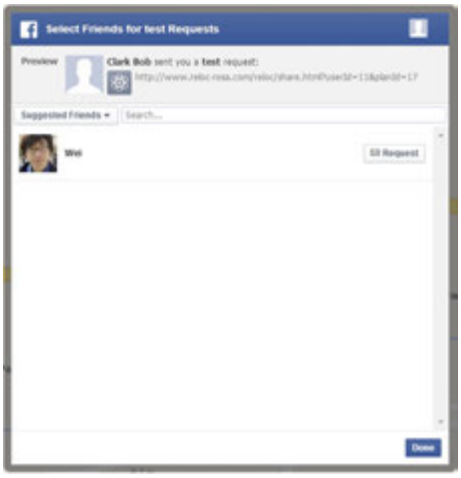

Figure 5.12: Share Schedules on Facebook

the homepage. The recommended locations are shown as different cards in the location list comparing to normal location card, where the control 11 and 12 have taken the place of control 9 and 10. Click control 11 means the user accept the recommendation and turns it to be a normal card, while click control 12 means user refuse it and the recommendation will be disposed.

Using this functionality, a group of users could easily sync their recognition about a spatial activity, such as travel. And the data behind this will provide us many useful evidences about how human beings take spatial actions under social environment and "wisdom of crowd". We are managing to collect data and further study this mechanism.

B. Application Manual for ROSA: Mobile

The mobile app is relatively simple in this application, its main function include:

First, view saved schedules on the mobile platform.

Second, collect user data (mainly physical coordinates) on the move and upload to the server.

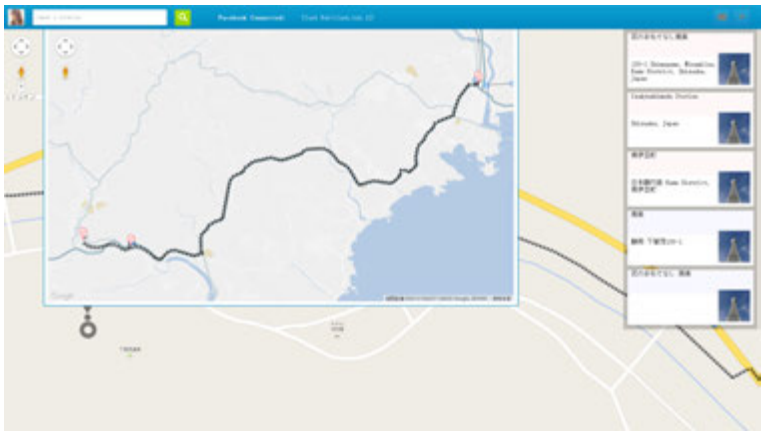

Figure 5.13: Recommendation Interface

Figure 5.14: Handle Recommendation

The main interface are shown below with a map area, a scroll-bar area and a control-bar area.

In map area, users could zoom, pan map to get proper map area. In scroll-bar, users could slider finger to switch locations in the list. In control-bar, users could use 3 controls to switch different views.

For example, touch the “plan” control will bring users the list view of current saved schedules (as shown in graph 2). Touch one schedule in the list will download this schedule, then automatically jump back to map view and display all the data onto the map area (as shown in graph3). Touch the marker loaded on the map will pop-up the detailed infoBox to show related information.

While users walking along the way, their location data will be recorded and stored in mobile platform. Visited location will be displayed in the list view.

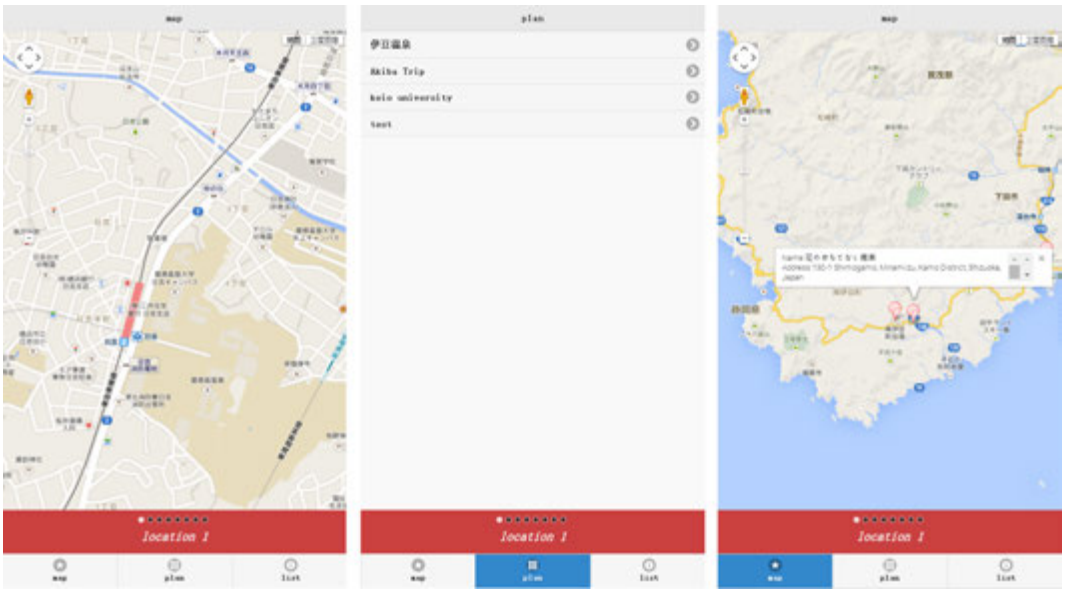

Figure 5.15: Mobile Interface

C. PhP Code Sample

```
<?php header('Content-type: text/plain; charset=utf-8'); ?>
<?php
//write locations to database
  include 'dbPass.php';

  $planName = $_POST['planName'];
  $userId = $_POST['userId'];
  $locInfoArray = json_decode($_POST['locInfoArray']);
  $linkInfoArray = json_decode($_POST['linkInfoArray']);

  $status = 'success';
  $runtimeInfo = '';

  $length = count($locInfoArray);
```

```
  $length2 = count($linkInfoArray);
  if($length<=0){
        $status = 'warning';
        $runtimeInfo = $runtimeInfo.'
|writing is no performed, travel plan contains no place.|';
        echo json_encode(array('status'=>$status,
 'runtimeInfo'=>$runtimeInfo));
        exit();
  }

  $mysqli = new mysqli($host,$user,$pass, $dbName);
  if($mysqli->connect_errno) {
        $status = 'error';
        $runtimeInfo = $runtimeInfo.'
|sql database connection failed.|';
        echo json_encode(array('status'=>$status,
 'runtimeInfo'=>$runtimeInfo));
        exit();
  }

?>
```

D. JavaScript Code Sample

```
/////add a marker on the map, and append to array
//contain two click event call-back function
function addMarker(locInfo, map, icon, zIndex, markerArray)
//locInfo: instance of LocInfo class
```

```
//map: instance of google map class
//icon: user-defined marker icon
//zIndex: z-depth
//markerArray: array to store markers
{
        var position = new google.maps.LatLng(locInfo.lat, locInfo.lng);

        var marker = new google.maps.Marker({
 //create a marker to represent the user-defined location
                map: map,
                icon: icon,
        zIndex: zIndex,

                position: position,
                lat: locInfo.lat,
                lng: locInfo.lng,
        title: locInfo.name,
        html: locInfo.desc,
                type: locInfo.type,
                pin: locInfo.pin
        });

        if(map == window.map)
        {
        google.maps.event.addListener(marker, "rightclick", function () {
        //use right click to search relative location
                        var locInfo = getLocInfoFromMarker(this);
                        locInfo.type = 'search location';
                        clearTempMarkers();
```

```
                        searchRelativeLocation(locInfo);
                });
        }

//add line on the map to represent location relation
function addLine(startPoint, endPoint, type)
{
        //logVariable(startPoint,'startPoint');
        //logVariable(endPoint, 'endPoint');

    var request = {
      origin:startPoint,
      destination:endPoint,
      travelMode: google.maps.DirectionsTravelMode.DRIVING//TRANSIT
    };
    directionsService.route(request, function(response, status) {
      //logVariable(status, 'DirectionsStatus');
          if (status == google.maps.DirectionsStatus.OK) {
                //logVariable(response, 'DirectionsResponse');
                //mapDirectionDisplay.setMap(window.map);
      //mapDirectionDisplay.setDirections(response);
                //infoMapDirectionDisplay.setDirections(response);
                var myRoute = response.routes[0].legs[0];
      points = [];
                if (status == google.maps.DirectionsStatus.OK)
      {
          for (var i = 0; i < myRoute.steps.length; i++) {
                for (var j = 0; j < myRoute.steps[i].lat_lngs.length; j++) {
                    points.push(myRoute.steps[i].lat_lngs[j]);
```

```
                }
            }
        }

google.maps.event.addListener(routeLine, 'click', function(){
var i = findLineIndex(routeLine.startPoint, routeLine.endPoint);
        changeLineType(i,'straight');
        });
google.maps.event.addListener(infoRouteLine, 'click', function(){
var i = findLineIndex(infoRouteLine.startPoint, infoRouteLine.endPoint);
        changeLineType(i,'straight');
        });
google.maps.event.addListener(straightLine, 'click', function(){
var i = findLineIndex(straightLine.startPoint, straightLine.endPoint);
        changeLineType(i,'route');
        });
google.maps.event.addListener(infoStraightLine, 'click', function(){
var i = findLineIndex(infoStraightLine.startPoint, infoStraightLine.endPoint);
        });

        });

                window.startPoint = null;       //clear variables
                window.endPoint = null;
      }
    });
}

////////////////search relative location
```

```
function searchRelativeLocation(locInfo)
{
        clearRelInfoBoxes();
        simplifyMapStyle();
        relArray = [];
        locInfoArray = [];

        var lat = locInfo.lat;
        var lng = locInfo.lng;

        var position = new google.maps.LatLng(lat, lng);
        if(containMarker(position, window.markers) === false)
//if current search location is not contained in window.markers, add it
{
var marker = addMarker(locInfo, window.map, 'img/search_pin.png', 3,
 window.markers);
var infoMarker = addMarker(locInfo, window.infoMap, 'img/search_pin.png', 3,
 window.infoMarkers);
        }
        else    //else change type of corresponding marker to search location
        {
                var index = findMarkerIndex(lat, lng);
                window.markers[index].type ='search location';
                window.infoMarkers[index].type = 'search location';
        }}
////////////////update location list on the right accroding to
data from window.markers
function updateLocList()
{
```

```
        $("#curLocContainer").html('');
        $("#locList").html('');
        logVariable(window.markers, 'window.markers');
        logVariable(window.recommendMarkers, 'window.recommendMarkers');

        //add cards fro recommend Locations
        for(i = 0; i < window.recommendMarkers.length; i++)
        {
                var info =
getRecommendLocInfoFromMarker(window.recommendMarkers[i]);
                //logVariable(info,'info');
                var recommendLocCard = createRecommendLocCard(info.lat,
info.lng, info.name, info.desc);
                $('#locList').append(recommendLocCard);
        }

}
/////////////////stylizing relative location display according
 to relation strength
function showSearchArray(locInfoArray, ratingArray)
{
        simplifyMapStyle();
        clearRelInfoBoxes();
        //logVariable(ratingArray, 'ratingArray in showSearchArray');

        var maxRating = Math.max.apply(null, ratingArray);
        var minRating = Math.min.apply(null, ratingArray);
        var ratingRange = maxRating - minRating;
```

```
        for(var i = 0; i < locInfoArray.length; i++)
        {
                var lat = locInfoArray[i].lat;
                var lng = locInfoArray[i].lng;

                var position = new google.maps.LatLng(lat, lng);}
}
```