

An Approach to Creation of Smart Space-Based Trip Planning Service

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Abstract—Trip planning is among important and complex problems in tourism industry. Trip plan preparation requires data analyzing from a substantial number of services. Usually, service or standalone application provides limited functionality, which can be used only in trip preparation and for basic scenarios. This paper provides an approach to creating Smart Space-based Trip planning service. The Smart Space technology allows to create proactive services with context-based scenarios and multi-service usage. The paper describes trip planning problem as a list of possible tasks and presents mathematical model for common task. The presented approach includes high-level architecture of Smart Space-based service, scenarios usage and possible data sources from existing third party services and used algorithms for data transformation.

I. INTRODUCTION

Tourism industry is evolving rapidly in the world as a whole. According to the world tourism organization, "International tourist arrivals worldwide grew by 5%, the same rate as during the full year 2013" [1]. It should be noted that the share of individual tourists grows and comes to the fore. However, the increase of "organized" tourism (i.e. aware about existing regional infrastructure and services) requires easy access to complex information about the destination.

The organization of individual tourist trip requires recommender systems to solve the following tasks: gathering information about attractions, which the tourist wants to visit; planning the trip, and organizing the trip environment (e.g. transportation, accommodation, etc.). Each task requires analysis of a large number of external sources and reviews, which for ordinary tourist is quite a serious problem [2].

In this paper we focus on the trip planning problem, which can be divided into the following tasks:

- 1) Selection of attractions to visit. Commonly, it is based on descriptions, images and reviews.
- 2) Selection of the route. It depends on selected means of transportation.
- 3) Definition of the timetable. It commonly depends on distances between attractions and their operation schedule.

4) Selection of stops and places of accommodation. If tourist relies only on the nearest gas stations, hotels and cafes, in practice they may be unavailable for various reasons.

5) Selection of optional attractions, which can be visited in case of free time.

In this paper we provide an approach to creating proactive service based on Smart Space technology [3, 4]. This service can provide combination of various services.

The rest of the paper is organized as follows. Section II presents related work and examples of related services. Section III describes trip planning problem as a list of possible tasks and presents mathematical model for common task. Section IV presents the idea of using Smart Spaces technology for creating the trip planning service and introduces service architecture based on Smart-M3 platform. Section V describes possible data sources from existing third-party services. Section VI presents common usage scenarios with service interactions through smart spaces. Section VII introduces multi-user model for trip planning service with various user relations. Section VIII summarizes the contributions of this paper.

II. RELATED WORK

Galavas et al. [2] describes classifications of recommender systems, and proposes typical scenario of tourist trip design problem. Also the paper presents various applications and services for solving this problem.

Vansteenwegen et al. [5] presents mathematical formulation of team orienteering problem with time windows, which is close to the problem, considered in this paper. Also the paper presents an algorithm for finding optimal route.

Smirnov et al. [6] presents smart space-based tourist recommendation system that allows acquiring information about places of interest around the tourist from different Internet sources.

Quite many services can be used to trip planning. The first group are the trip planning services, using public transport or motor roads [7, 8]. Commonly, they work in

closed area and do not provide up-to-date information about recent changes.

The next group of services provide trip plan for local area [9, 10]. They are based on predefined guides and can't be expanded to the full route from tourist's home to the attraction.

The next group are the services with manual trip planning [11]. They are helpful for advanced tourists, who can take into account all details.

The last group are the services with user trips and reviews [12]. These services are similar to services with trip plans for local area, but don't have any area restrictions. Also these services present well-trying routes and trip plans.

III. THE TRIP PLANNING PROBLEM

The mathematical model of common trip planning problem is based on the model from [5] with additional conditions. Let A be the set of admissible points, which can be visited, T be the set of trip days, $K \subset A$ be the set of required points. The objective function maximizes trip benefits:

$$\sum_{i \in A, t \in T} a_{it} c_i \rightarrow \max, \quad (1)$$

where a_{it} is a binary variable equal to 1, if the point i was visited during day t , and 0 otherwise; c_i is the benefit from visiting point i .

The conditions of route connectivity:

$$j: \sum_{t \in T, i \in A} b_{ijt} - \sum_{t \in T, i \in A} b_{jit} = 0; \quad (2)$$

$$t \in T, i \in A: \sum_{j \in A} b_{ijt} - a_{it} = 0, \quad (3)$$

where b_{ijt} is a binary variable of used route between points i and j in day t (equal to 1, if the route was used, otherwise 0).

The next condition adds required points to route:

$$k \in K: \sum_{t \in T} a_{kt} > 0. \quad (4)$$

All specific requirements like attractions choice or necessary food stops can be easily added as separate conditions. For example, the next condition adds constraint on the maximum busy time in each trip day:

$$t: \sum_{i \in A, j \in A} b_{ij} B_{ij} + \sum_{i \in A} a_{it} f_i \leq W, \quad (5)$$

where W is the maximum time, B_{ij} is the driving time between i and j . This feature allows to solve trip planning problem iteratively by adding specific restrictions.

The trip planning problem is a combination of a classic traveling salesman problem [13] and multiple knapsack problem [14]. The free space in a knapsack is the free time for tourist, which can be spent during the day. Therefore, trip planning problem belongs to the class of NP-complete problems.

This class of problems requires large computation resources and special algorithms. In this paper we propose a heuristic algorithm, which adds constraints and improves solution at each step, and can be terminated after any step, if required.

The trip planning starts from definition of start and end points and target of the trip. Quite often, trips start and end in the same point and can be represented as a cycle. Lets assume, that tourist knows the start/end place and the attractions, which should be visited.

The first step is route preparation. For this tourist should select the list of possible transports (airplane, train, car, bus, etc.). After that the route between the starting point, attractions and the finish point could be constructed. If the route includes a point, which can not be reached using selected transports (e.g., access to an island only by car), an error message is given.

Most services only calculate the route, but in practice other trip conditions, like stops for sleep, can force to change to route and sequence of visited attractions.

So, the next step of trip planning is route modification based on these conditions. At this step the route is divided to parts, and ends of these parts are added to the route as new points. E.g., long drive by car is divided to several parts with stops. The main problem of this step is to reasonably select such points, as they can significantly affect the route. E.g., the nearest hotel may not be the best place for sleep, as the tourist may have more requirements for it.

The next step is time planning. Commonly, attractions, transport and other objects have schedule of operation, and also may depend on weather conditions. At this step the trip plan can also be reorganized. E.g., if the next attraction along the route will be closed for the next few days, then the tourist may want to visit other attractions.

The last step is to select attractions. Most tourists don't know all attractions, events or other places of interest in the

visited region. At this step some attractions, which can be interesting for the tourist, are added to the trip plan. The core problems at this step are to identify tourist preferences, and to find nearest attractions, which can be added to the trip plan without major overhaul of the route.

The route planning algorithm must be performed before the trip and also several times during the trip, because of occurrence of various "disturbances" during the trip, e.g. closed road or broken car.

Also the algorithm currently ignores other conditions, e.g. joint trip or choice of activities as most of these conditions require additional information from other tourists. However, in many cases the route planning algorithm will work also in the common information space.

IV. SMART SPACE USAGE FOR TRIP PLANNING

Smart Space technology is a one of possible ways for solving the trip planning problem. Common information space, proactive concept and flexible connections to external sources help to get the most accurate plan under lack of knowledge. This technology provides seamless integration of different devices and services into common information environment, where each service can share information to each other, make computations and interact for join tasks solving [3, 4].

Smart-M3 platform is an open-source project, which implements Smart Space technology [15, 16]. The Smart-M3 platform is based on semantic information broker (SIB), which collects and distributes information, and knowledge processor (KP), which represent external information sources or consumers and perform operations on the knowledge.

The comparison between standalone application, web-service and smart space service implementations is shown in Table I. The standalone mobile application has higher privacy, but restricted access to computational resources and Internet. The web-service avoids most restrictions, but reactive approach also reduces access to frequently changing information. The Smart Space technology provides proactive approach and flexible connections to external sources.

The general reference model of the smart space-based trip planning service is illustrated by Fig. 1. Each third-party service with tourist information (e.g. attractions, accommodation, weather) located at separate physical device or server. The knowledge processors (KPs) for these services can be located on several physical devices or several KPs can be located at the on physical device. The KPs are communicates through SIB, which can be located at separate physical device. The User agent represents mobile application with user interface at user's physical device and communicates with services through SIB. The Route planning algorithm is a consuming process, generally located at separate physical device and gathering required information through SIB.

TABLE I. SERVICE IMPLEMENTATIONS COMPARISON

Indicator	Client application	Web service	Smart space service
Internet connection	Unstable Internet connection, mainly mobile Internet	Single point high speed Internet	Multi point high speed Internet
Computing resources	Mainly mobile device	High-performance server	High-performance cloud
Access to external service	Direct access to personal data, service limits	Indirect access to personal data, service limits	Indirect access to personal data, reduced service limits
Dynamically changed data	Static slice, manual updates	Static slice, periodic updates	Proactive service, dynamic updates
User relations	Manually	Can be implemented	Can be implemented
Privacy	High	Medium	Medium-High
Extensibility	Low	Medium	High
Trip plan updates	Dynamically	On request	Dynamically

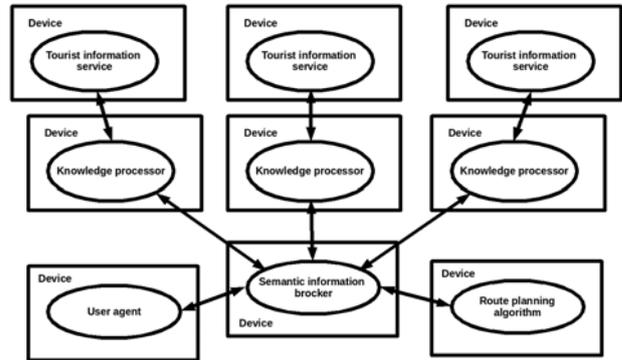


Fig. 1. Reference model of the trip planning service

The high-level architecture of Smart-M3-based Trip planning service is presented in Fig. 2. The service is based on distributed architecture and each unit commonly works on separate device. The SIB is a semantic information sharing service, providing semantic level communication channel for KPs to interact with each other.

User KP run on tourist physical mobile device and represent user's positions and core attractions and planning restrictions. Also User KP provides result of route planning algorithm to tourist. The User KP includes 3 modules: user interface (UI) for interaction with user, authentication module (Auth) for performing authorization on the third-party services such as Geo-information services (GIS) or Booking services; and knowledge processor interface (KPI) for performing interactions with SIB.

E.g., Weather KP provides current and future weather for requested coordinates from third-party weather service e.g. weather.com. Unfortunately, most weather services provide weather only for larger cities. Therefore, Weather KP requires information about nearest cities and calculates average weather. This information is provided by GeoPosition KP.

GeoInformation KP provides information about attractions (position, description, images, etc.) from third-party services. Also route planning algorithm requires estimations for attractions (e.g. schedule, inspection time or attraction size). This information can be estimated or provided from other tourists. The Review KP provides required estimations, which can be evaluated using internal Evaluative service or obtained as the average value from third-party Review service.

The Event KP provides information about events (position, description, schedule, etc.) from third-party

services. The core feature of Event KP is that information about events has a short cache time and usually event service provides events only for closed region. Therefore, Event KP should detect region for required position and provide to SIB up-to-date events, as the route planning algorithm should not consider past events.

The Booking KP provides information about hotels and other accommodations (name, place, photos, price, availability, etc.) from third-party services. The core information about accommodation places can be cached, but price and availability are changed dynamically and can't be cached reliably.

The Transport KP provides information about transport: schedule for public transport (e.g. bus, ship, train), routes from third-party services, internal road map and other conditions for selected transport (drive time, stops, etc.). The Transport KP provides optimal route for required set of points and options for each part (time, speed, distance).

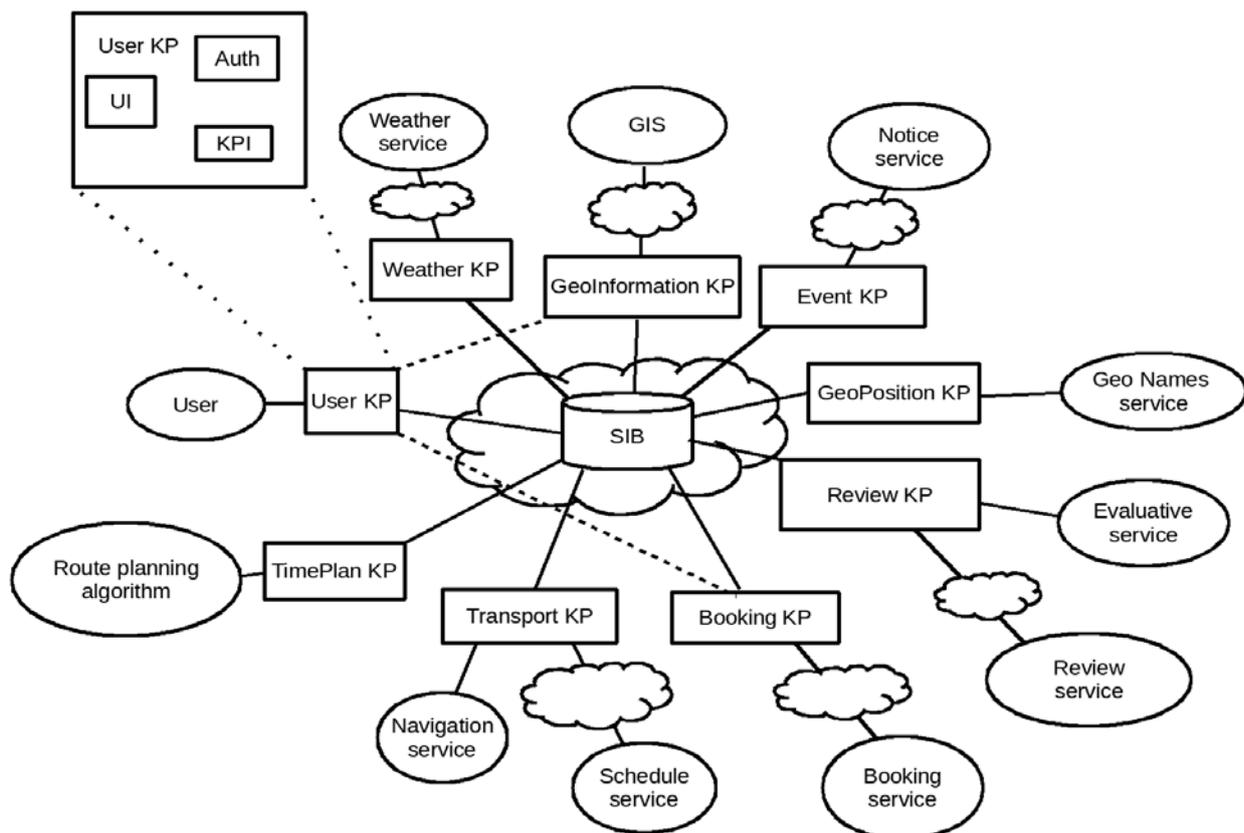


Fig. 2. Route planning service architecture in Smart Space technology

The TimePlan KP is a mediator and implements Route planning algorithm. It uses information from other KPs and provides to User KP route plan.

This architecture can be changed by adding or removing KPs and services. The minimal configuration (service core) includes User KP, GeoInformation KP, Transport KP with Navigation service and mediator TimePlan KP.

This set of KPs provide solution to problem (1)-(4). Other KPs can be added for more accurate planning and provide solution to problem (1)-(5).

V. DATA SOURCES

The implementation of Weather service and Geo Names service can be based on M3-Weather service [17] and use weather.com service for weather and off-line copy of GeoNames.org service for city detection.

There are plenty of Geo-information services, which can be used as a source of attractions: Foursquare, Wikimapia, etc. Unfortunately, most of them forbid data caching and limit the number of requests. Therefore, geo2tag-based services are preferable for using in Trip planning service, because geo2tag is open-source LBS platform [18, 19] and doesn't have restrictions by default. Another solution is to use distributed list of GeoInformation KP. It can increase the number of requests, but does not eliminate all limitations.

The Booking.com service [20] can be used as a Booking service, because it is a popular world-wide service. The Graphhopper library [21] with OpenStreetMap service [22] can be used as a navigation service.

There are no unified services for Notice service, Review service and Schedule service. All required information is distributed between various local services. For example, Russian Railways service (<http://rzd.ru>) has information about train timetable for Russia. Therefore, the algorithm for finding events, reviews and transport is as follows:

- 1) Service defines required coordinates in SIB;
- 2) GeoPosition KP detects the region for required points;
- 3) Event KP detects web-services for the region;
- 4) Event KP provides retrieved information to SIB.

The evaluate service based on 2 sources:

- estimated duration of the visit from other users;
- based on indirect evaluations.

The data for the first source can be easily obtained by User KP through SIB. The second source requires complete information about attraction and provided evaluation may be inaccurate.

The Route planning algorithm may recalculate the trip plan for each user relocation, or arrival of new information. It requires resources and can be run on server or in the cloud.

VI. USAGE SCENARIOS

The usage scenarios in this section illustrate the heuristic algorithm from Section III.

In the first scenario the trip planning service provides available attractions and events to a tourist for the target region (see Fig. 3). The User KP inserts search request into SIB. The GeoInformation and Event KPs are subscribed to user's search requests and SIB sends notification for new requests. When GeoInformation KP finds required list of attractions, this list will be published on SIB. The Event KP works similarly. The User KP is subscribed to this list and provides found items to the tourist.

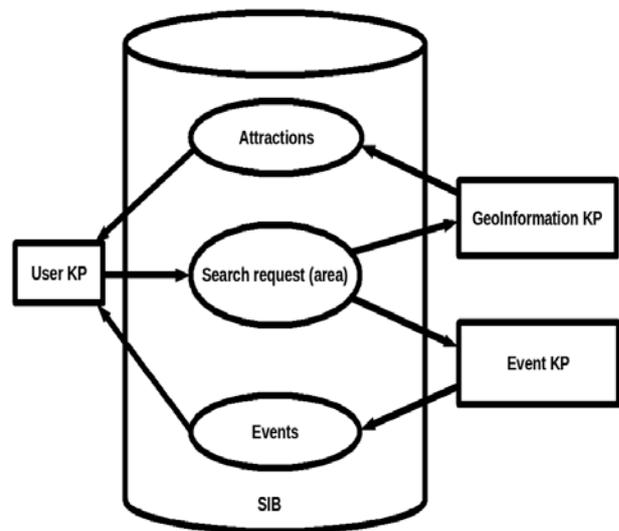


Fig. 3. Scenario of gathering attractions and events for the target region

The next scenario shows interaction of the service core (see Fig. 4). The User KP inserts list of required attractions and events with user's restrictions to SIB. The Transport KP is subscribed to these objects, creates route and publishes it to the SIB. The route includes distance and time for each road section. The TimePlan KP is subscribed to the route object and creates schedule. Also TimePlan KP checks restrictions like (5) from the model in Section III and if schedule is impossible, then TimePlan KP inserts additional restrictions to SIB. If restrictions are modified by TimePlan KP then Transport KP get notification and recalculate the route. If schedule is published to SIB by TimePlan KP, then User KP gets corresponding notification and shows schedule to the tourist. The schedule includes found route and required breakpoints.

The next scenario describes use of additional sources like weather or duration of visit (see Fig. 5). User KP insert attractions, events and restrictions to SIB. When attraction was published, the GeoInformation KP and Review KP get notification and estimate duration of the visit. Also GeoPosition KP gets notification, when attractions and/or events was published and insert corresponding cities to the

SIB. The Weather KP is subscribed to the cities and publishes current weather for new cities to the SIB. The TimePlan KP is subscribed to the weather and additional attraction info (e.g. duration of visit) and recalculates schedule when notified.

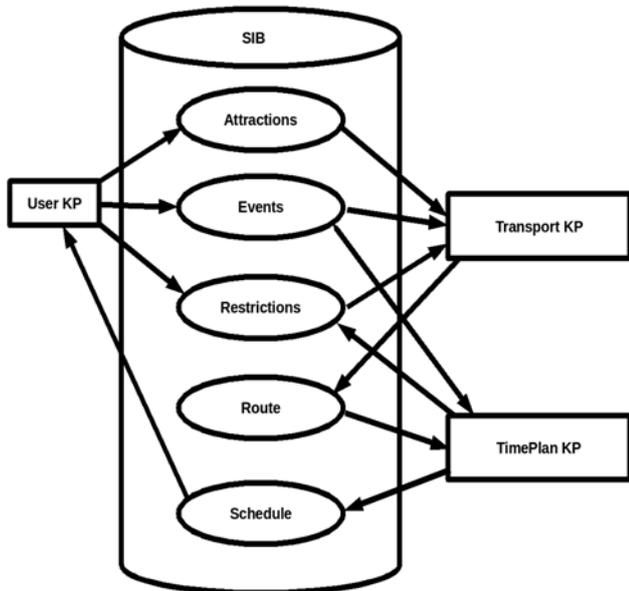


Fig. 4. Scenario of schedule preparation using service core

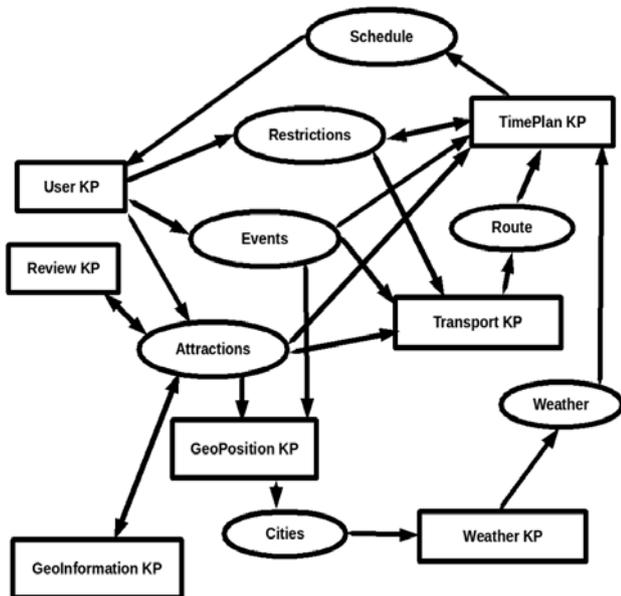


Fig. 5. Scenario of usage additional data sources with KPs

The other KPs like Booking KP work similarly: the get notification and provide additional information for TimePlan KP. The bottleneck of this architecture extensibility is

subscription – each additional KP provides own information and TimePlan KP should know how to process it.

VII. INTER-USER ITERATIONS

The described above scenarios by default are available for single users. The multi-user access requires user identification and data binding. It can be easily solved by adding unique identifiers for each user and binding data to each user's trip.

The Smart-M3 architecture provides easy way to organize inter-user iterations. The following scenarios describes common cases occurring in tourism.

The first scenario is to organize trip for users, who are unwilling to share their plans. The privacy is provided by organization of user space in SIB and anonymous data presentation for KPs. For example, start point and list of required attractions are stored on user device and provided to SIB through random user ID. Each KP except TimePlan KP process independently and can't detect user. The TimePlan KP provides trip plan for generated User ID and also can't detect user.

During the trip user may provide some information, for example, current position or estimated durations of the visit to an attraction. This information is provided anonymously and can't be used for user detection.

The next scenario is tourists meeting at some of the attractions. This scenario requires defined relations between tourists in SIB and both trip plans. The easy way to define relation in SIB is to provide additional information about tourist and its friends. If strict confidentiality is required, then the relation can be provided by common unique key from these users.

The TimePlan KP creates trip plans for these users and find intersections, if they are possible. In simple case the meeting does not require changes of trip plans, but in general case the nearest meeting point should be added to both trip plan.

The last, but not least, scenario is to create trip plan for a tourist group. In this case each tourist provides own start point, list of required attractions and time interval for the trip. The TimePlan KP combines and arranges attractions by priority, and creates common trip plan. The frequently required attractions will have a high priority and be obligatorily included to the trip plan. Other required attractions can be visited in parallel or during free time.

Figure 6 shows user spaces in SIB for this scenario. User 1 has private space, identified by User ID. The space of other KPs has intersection with User 1 space.

The spaces of User 2 and User 3 have common intersection provided by a key. Using this intersection User 2

can access to space of User 3 and vice versa. Also KPs has access to spaces of both users and their intersection.

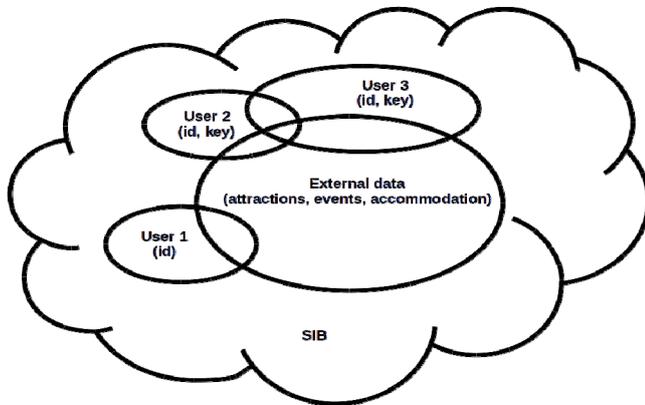


Fig. 6. User's spaces in SIB

VIII. CONCLUSION

The trip planning problem is a complex problem, as the trip plan often depends on a large amount of diverse and dynamically changing information from a large number of external sources, and is subject to updates during the trip.

The presented approach to use of Smart Space technology is one way to improve solution of this problem. The use of Smart-M3 platform can move complex calculations from user's mobile device to servers or cloud. Also, data gathering can be distributed. Smart-M3 platform can easily organize user context and its changes using relations between user spaces. Smart-M3 platform can proactively provide changes for uncached data like weather or available hotels.

The Smart-M3 based architecture also can flexibly change corresponding list of available services. The core services provide sufficient functionality and adding a new service does not require significant changes of the architecture.

The presented results are work-in-progress. The future work will include design data model and trip planning ontology. Also presented approach evaluation requires development smart space-based trip planning service using Smart-M3 platform and testing through a case study.

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