Research on Holographic Location Map Cartographic Model

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Abstract. With the widely application of mobile internet, map becomes an important portal of location-based services. This article introduces a new kind of map named Holographic location map (Ho-lo map). Firstly, the concept and characteristics of Ho-lo map are given. Secondly, this article gives emphasis to the cartographic model of Ho-lo map. The algebraic form of this model is explained. And the context model, relationship computational model and representation model being parts of cartographic model are expatiated then. As the basis of cartographic model, the knowledge database of Ho-Lo map is presented. Finally, the cartographic process of Ho-Lo map is analyzed. An example of Ho-Lo map in the context of airport is showed. Compared with traditional map, Ho-Lo map has significant differences in drawing objects, drawing main body, drawing patterns and drawing technology. The cartographic mode will change from static to dynamic, and then to real-time. This will lead to many changes in cartographic techniques.
Key words. Holographic location map, Cartographic model, Context model, Relationship computational model, Representation model, Semantic similarity

I. Introduction

Along with technology of internet, mobile communication, mobile positioning, and the widespread use of smart mobile devices,

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Location-based Service (LBS) has become an important infrastructure of maintaining national security, improving military execution ability, constructing smart city, and realizing intelligent transportation. Especially, it has become necessary foundation of human dealing with natural disasters and safety incidents. While one key point of which is the need for high-precision, multi-perspective map for location-based services (Zhou et al. 2011).

Since 1994 Bill etc. proposed the concept of location services (Schilit et al. 1994), more and more attentions have paid for map which is an important basis of location-based service. Many companies launched their own map platform for location-based services, such as Street View of Google, Open Street Map of Microsoft, UpNext of Verizon and AutoNavi Map. At present, location data is mainly used for navigation and monitoring. Map for location-based services is mainly displayed in the form of 2D or 3D. Although some simple attribute information can be drawn on the map, it cannot provide on-demand, dynamic information and near real-time mapping, not to mention uniform standards and technical approach. It is still far from ubiquitous spatial information intelligent service which means people can access spatial information service whenever, wherever and whatever needed (Zhou et al. 2011).

In 2011, the concept of holographic location map (Ho-Lo Map) was proposed by the Chinese academy of sciences Zhou Chenghu etc., and it has aroused widespread concern in academic circles and become the major map form of ubiquitous spatial information intelligent service.

As closely related to user's context, the information and representation of Ho-Lo map are nearly real-time and dynamic, this will put forward stricter requirement about map design and production. The traditional, static, experiential mapping mode does not apply to Ho-Lo map. So this article takes cartographic model of Ho-Lo map as the object of study. Through analyzing the concept and characteristic of Ho-Lo map, the cartographic model is established in an algebraic way and each of process of this model is described in detail. This model illustrates the dynamic mapping mode and process of Ho-Lo map in theory. Because the phase of mapping is delayed to using so it will achieve truly near real-time mapping.

2 Current research of cartographic model

Research on cartographic model had lasted for many years. Many experts and scholars recognized that geographic information and visualized maps were different in the principle of data representation (Li et al. 2011), then they studied the conversion process of geospatial data to map data from different perspectives. For example, Aileen Buckley etc. put forward the concept of digital landscape model and digital mapping model, defined the cartographic data model from three layers of concept, logic and physics. And he elaborated the conversion process of GIS data to cartographic data (Aileen et al. 2005). Andrew U. Frank distinguished the difference between cartographic data model and GIS data model from the design viewpoint of cartographic database and pointed out the difference between them: cartographic data model was aimed at mapping, while GIS data model was aimed at geographic reality (Frank, 1991). Paul Hardy expatiated the conversion process of GIS data to map for the high quality graphics and illustrated the method of applying cartography rules to produce map in detail (Paul Hardy, 2009).

Chinese scholars have studied cartography model deeply for a long time too. Professor Li Lin and his team of Wuhan University had researched map symbolization and graphic expression model for a long period of time (Li et al. 2011, Yin et al. 2006, 2007). They proposed topographic mapping model based on the algebraic structure (Li et al. 2011). This model revealed the transformation mechanism of geographic spatial information, and provided a good theoretical basis for functional design of mapping system driven by database. Researcher Wang Yingjie and Professor Chen Yufen researched on self-adaptive map visualization and proposed automatically generated method of visual display mode based on state space (Wang et al. 2012). These studies have laid good foundation for this article. However, as a new type, the mapping process of Ho-Lo map will transform from traditional static mode to dynamic. We must research on its cartographic model according to its characteristics, and the model will provide a reasonable reference for Ho-Lo map producing.

3 Ho-Lo Map and its cartographic model

3.1 The concept and characteristic of Ho-Lo map

Zhou Chenghu etc. defined that Ho-Lo map was a kind of digital map based on location which can fully reflect location itself and various location-related features, events and things. It was a new type of map adapting to the needs of modern location-based services development (Zhou et al. 2011).

Using the term ‘holographic’, there are two meanings: ① we want to satisfy the location services at anytime, anyplace about anything for anyone, so the whole information of geo-features should be gathered, processed beforehand. The prefix ‘holo-’ has the meaning of ‘Whole, entire’. ② To holography, interference formed by a split laser beam is the key; while to Ho-Lo map, people, geo-features and event will interference by location. So it is the similar course to holography.

In this article, from the perspective of cartography, the Ho-Lo map is defined as follows: based on ubiquitous networks such as various positioning systems, sensor networks, internet and telecommunications networks etc., Ho-Lo map is a kind of digital map with uniform semantic relationships and space-time geographical correlation referred to location, and it can satisfy all kinds of demands by obtaining and merging multi-source heterogeneous dynamic information such as location coordinates, property, relationships, moving etc. in real-time. Being visualized, it can fully display various relevant features, events and things around the location.

Compared with traditional map, the Ho-Lo map has two major characteristics: all-inclusive and dynamic.

①All-inclusive: one meaning is all kinds of information will be integrated together, including directed association and implication relation based on location among users, objects or between users and objects, then the space-time location information frame with coherent and explicit semantic location will be made; the other meaning is that visualized form of Ho-Lo map may be 2D, 3D, panorama, augmented reality and their combined forms.

②Dynamic: to different users, their activities and preferences in different place at different time are different, Ho-Lo map will confirm the information needed dynamically, and merge the information dynamically in real-time. So the process of map producing must be dynamic and in real-time.

3.2 Geographic relevance

The concept of Geographic Relevance (GR), proposed by Raper first, can be defined as a relationship between the user's geographic information needs and the spatio-temporal expression of geographic objects in the user's surrounding environment(Tumasch Reichenbacher et al., 2009). Tumasch Reichenbacher etc. pointed out that the idea of current LBS is extended by shifting the location-based perspective to a relevance based perspective, including time, topic, and motivations(Tumasch Reichenbacher et al., 2009). According to the above analysis, the relationship among users, objects or between users and objects associated by location is the focus of Ho-Lo map. Stefano De Sabbata etc. analysed the criteria users apply when judging the relevance of geographic entities in a given mobile usage context(Stefano De Sabbata et al. 2009). Obviously, the cartographic model of Ho-Lo map and GR are very close. The cartographic model of Ho-Lo map is the special case of GR in location map. So we can use the criteria of GR, such as spatio-temporal proximity, hierarchy, cluster, co-location and association rule etc., to deliver location-related information to mobile users.

3.3 The cartography model of Ho-Lo map

Seen from the above definition and characteristics, the cartographic process of Ho-Lo map is an expression process of dynamic relevance of people, objects and things in a visual form. From reference 3, we can define reality expressed by Ho-Lo map as follow algebraic form:

$$\Omega = (T, C, R, u); \quad (1)$$

Here, Ω is the reality expressed by Ho-Lo map; T is element in Ω. T contains not only geographic features but also dynamic targets such as persons, vehicles, and aircrafts etc. R is the relationship of elements in T. u is the computational model of above relationship.

For the relationship R, along with the real-time changes of users' locations, time, goals, it can be further described as follows:

$$R = u(T, C); \quad (2)$$

Here, C is the context when Ho-Lo map is drawn.

The map space of Ho-Lo map is defined as:

$$\phi = (F, SR, v); \quad (3)$$

Here, ϕ is the map space of Ho-Lo map; F are the cartographic elements; SR is the spatial relationship of cartographic elements;v is a visual model to describe SR.

The cartographic model of Ho-Lo map is to establish a mapping relationship between Ω and ϕ. It can be described as follows:

$$\phi = f(\Omega); \quad (4)$$

Since the spatial relationships of map elements are attached on the geographic features, so the above equation can be rewritten as

$$F = f\left(T, C, u(T, C)\right); \qquad (5)$$

Here, f is a function or procedure, which enables the geographic features meet the requirements of map expression. C can be described by a number of factors, namely:

$$C = g(t, l, p, e, \ldots\ldots); \qquad (6)$$

Here, t is the time for mapping, l is the location of user, p is current user, e is the goal event of user, g is a function or procedure, which will convert single context factor into a comprehensive formalized context description. Simultaneous formula (5), (6) we can obtain:

$$F = f\left(T, g(t, l, p, \ldots), u\left(T, g(t, l, p, \ldots)\right)\right) \qquad (7)$$

As t, l, p, e are all variable, the cartographic process of Ho-Lo map is a real-time, dynamic process, the key of which is to determine the three functions or processes f, u, g.

3.3.1 The Context model of Ho-Lo map

As viewed from technology, context is useful for representing and reasoning about a restricted state space within which a problem can be solved (Cristiana et al. 2009, 2011). In the linguistics view, context is the combination of situation and context. It represents the situation of real world and the background knowledge which what one says can be understood. A group of related contexts constitutes the cognitive model of the human brain. In formula 7 mentioned above, the function or procedure g will form comprehensive formalized context description. This description can be further analyzed as independent variables of relational computational model and representation model. Due to the instantaneous variability of the context, g is also required to have behavior prediction. So it can be characterized as follows:

$$g = \left(form(t, l, p, e, \ldots\ldots), reason(act_c, form)\right) \qquad (8)$$

Here, $form(t, l, p, e, \ldots\ldots)$ represents formalized context description; $reason(act_c)$ represents predicting the next behavior according to current behavior.

①Formalized description of context factors

The independent variables of context model g are the data that sensors access and users input. The form of data is maily numerical value and informal description, and the number of independent variables may be very large or very small. It is necessary to convert to the form which meets the requirements of the context description. Such as, convert the time value to the period of time (ex. convert at 11:30 to lunch time); convert the weather and traffic crowded information into the driving speed information, and so on. This kind of transformation is close to the specific context and the regular knowledge of human behavior in the context, requiring the support of knowledge base of Ho-Lo map. Of course sometimes, the independent variables can't be converted to corresponding, normalized, descriptive information. For example, to the user's taste preferences, it's ok to describe using Sichuan cuisine or Guangzhou cuisine, as well using fresh, salty, sweet, spicy tastes and so on. This requires relationship computation according to semantic similarity, in order to meet the cartography's need.

To make the context description satisfied with the requirements of following relation computing and expression templates selecting, we need to organize the context factors according to certain logical form. For different contexts, the basic factors needed to be described and the roles of the various factors in the process of reasoning are different. So this article defines an abstract description method of context factors, which has the characteristics of openness, self-descriptive and formalized.

The formalize description of context can be described as:

$$C_1 = \{TYPE(M), NAME(n), SUB(num|S_1, S_2, \dots\dots, S_{num})\}; \quad (9)$$

$$S_1 = \{TYPE(L), NAME(n_{s1}), VALUE(v_{s1}), POWER(p_{s1})\}; \quad (10)$$

In the above formula, C_1 are the description styles of context factors which have sub-items; S_1 are the description styles of situational factors which have no sub-items.

Telling from the form, the above description way converts the context factors into tree structure. The nodes and depth of the tree are all alterable, and it suits the different demands of description in different contexts.

②Logical reasoning between behaviors

In the process of modeling and reasoning, people behaviors are the key. As the abstract tools for interpreting the close connection between the objective world and people behavior, activity theory solve effectively the hard problems in context information communication and sharing through action layering. Combining with the particularity of Ho-Lo map, this article constructs the following behavior related models:

Suppose one context can be divided into n behaviors, there are m contextual factors affecting these behaviors. Set the action as A, contextual information as C, the behavior related model a is expressed as follows:

$$\mathrm{a} = (\mathrm{A}, \mathrm{C}, \mathrm{r}); \quad (11)$$

Here, $A = (A_1, A_2, \ldots\ldots, A_n)$, $C = (C_1, C_2, \ldots\ldots, C_m)$. r represents the relationship between the elements in A. Picture 1 describes the logic structure of behavior reasoning.

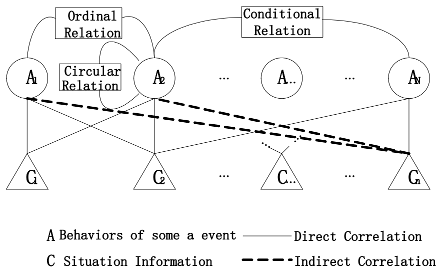

Figure 1. The logic structure of behavior reasoning.

3.3.2 The relationship computational model of Ho-Lo map

Formula 7 above, function or process u will calculate the relationship of features in T based on reasoning results of context, and choose a collection of features which meet the requirements of g.

Features relationship in T are divided into two categories: one is spatial relationship which mainly lies on features' geometry data; the other kind is the semantic relation which mainly lies on features' attribute data.

Therefore, the function or procedure can be expressed as follows:

$$u = \left(u_{spa}(T), u_{sem}(T)\right); \qquad (12)$$

①Computation model of spatial relation

To Ho-Lo map, the purpose of spatial relationship computation is to extract the features within a certain spatial and directional range. The features mainly reflect Euclidean distance and direction relation between features and location of users, viz.:

$$u_{spa}(loc, T_i) = \{\, T_i \mid dis\ (T_i, oc\ ) \leq \delta, \alpha \leq dir\ (T_i, oc\ ) \leq \beta, T_i \in T\} \qquad (13)$$

Among them, loc is current user's location.

②Computation model of semantic relation

Semantic relation $u_{sem}(T)$ can be used to select features according to matching degree of the features attributes and contextual demands. That means semantic similarity computation based on the knowledge database of Ho-Lo map.

Calculative process of the semantic relation is as follows:

- Make the description $D_1, D_2, D_3 \dots\dots$in the context correspond with Objects' attributes $A_1, A_2, A_3 \dots\dots$;
- For each attribute, compute similar degree $S_1, S_2, S_3 \dots\dots$ between attributes and context demands.

$$S_1 = \alpha \times DisSim(D_1, A_1) + \beta \times DepSim(D_1, A_1) + \gamma \times ConSim(D_1, A_1); \quad (14)$$

Among them, $DisSim(D_1, A_1)$ is semantic distance; $DepSim(D_1, A_1)$ is node conceptual depth. $ConSim(D_1, A_1)$ is semantic overlap ratio.

- Sort and valuate weights for each attribute, and a weight matrix is obtained:

$$E = [\alpha \quad \beta \quad \gamma \quad \dots](\alpha + \beta + \gamma + \cdots = 1) \quad (15)$$

- Compute semantic similarly for the whole question:

$$S = \alpha S_1 + \beta S_2 + \gamma S_3 + \cdots \quad (16)$$

- Through calculation of semantic similarity of targets meeting the requirements of spatial relation, we can get a sorted sequence of similarity, which can provide quantitative basis for 'finding the most comfortable target'.

3.3.3 The representation model of Ho-Lo map

The above formula 7, function or process f will make the extracted elements mapped to graphic symbols of Ho-Lo map based on g and u according to different applications, contexts and users to achieve different maps display. Therefore, the expression model of Ho-Lo map should contain two parts:

① Semantic description of expression template

Give a normative explanation of basic constraint when designing the expression template. It can be described as:

$$\mathrm{M_1} = \left\{ \begin{array}{c} \mathrm{PURPOSE(p_1), STYLE(s_1),} \\ \mathrm{CONTEXT(num|time_1, place_1, people_1, event_1, device_1, \dots\dots),} \\ \mathrm{GEOFEATURE(num|geoType_1, geoType_2, \dots\dots)} \end{array} \right\} \quad (17)$$

Among them, $PURPOSE$ says the cartographic purpose of the template, such as navigation, POI display, information indicating etc.; $STYLE$ says the style of the template, such as the cheerful, sedate etc. $CONTEXT$ says the context's description which suits template. When there are some difference between the description and the context model, we still can find the similar degree between the templates and the contexts by calculation of semantic similarity. This method can avoid a large increase of expression templates because of the context slightly change. *GEOFEATURE* says the geographic features expressed in this template and it is convenient to match the geographic features coming from relationship computation.

②The expressive template

It contains the instruction of expressive methods, methods of the data classification, symbol forms; visual variables, such as color, transparency, dynamic and static state, size etc.; and auxiliary tools when reading the map, and so on. The template design is closely related to the display engine, such as the data classification methods are corresponding with the methods provided by display engine.

3.4 The Knowledge database of Ho-Lo map

In the cartography model mentioned above, the establishing and arithmetic of context model, relationship computation model and expression model are all based on knowledge database. Therefore, knowledge database should contain at least three aspects (Figure 2):

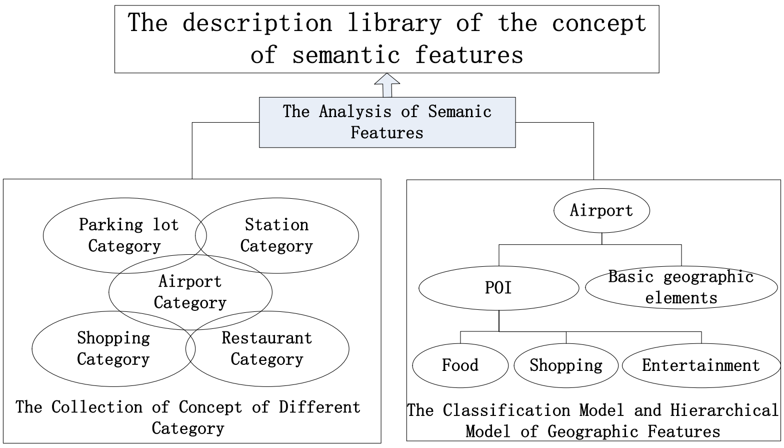

Figure 2. The knowledge database's structure of Ho-lo map.

①The conceptual collection of situations in different categories.

Ho-Lo map takes the relevance among people, events and things as map content, which will vary with the changes of context such as persons, locations, time, events etc. The change is due to variety of people thought essentially. Thus, only the concepts involved in people thinking are extracted, and the relevance among these concepts is established, can we meet the need of cartography. Human cognition is based on experiences, beginning with categorization and forming concept. Categorization is the basis of the category and concept. Therefore, we believe that Ho-Lo map should establish different categories of context collection based on prototype category theory. And in accordance with the far or near to central concept, a quantitative relationship can be established. These scenarios concepts and description of their quantitative relationship will become the fundamental basis for extracting the geographic information required for mapping.

Extracting context concepts and quantifying their relationship is the core and most difficult contents in the drawing of Ho-Lo map. We think context concepts should be constructed by top-down and bottom-up processes boundmutually . By means of questionnaire and talk to a sample of small number of people, the top-down process constructs concepts set and their relation. By analyzing the big data such as user path and user behavior in a certain place, the bottom-up process revises and supplies the above model. This process will continue in the real time cartographic process, in order to achieve the objective of constructing a whole context concepts set which complies with the rules of human cognition.

②Semantics aggregation model of geographic concept

The purpose of the knowledge database of Ho-Lo map is that we can reason out the geographic information and its means of expression needed in the mapping according to current context. Therefore, in the knowledge database, semantic aggregation model of geographical concept become the basic reference when selecting geographic information.

In this article, the geographical concepts are divided into basic geographic information and POI information according to the background and the subject, and then can be further divided into detailed aggregation relationship models. Semantic aggregation model of geographical concepts has a direct connection with the database of Ho-Lo map. Classification and coding mode of geographic data are based on this database.

③The description library of concepts semantic features

The above concept set of context makes it possible to find the largest correlated concepts set based on context information. But the concepts set of context can not be equated with geographical features. It is needed to establish incidence relation between the concepts set and semantic aggregation model of geographical concept.

From a cognitive perspective, the above concepts set reflect the cognitive mode of common users. But semantic aggregation model of geographical concepts partly reflects the cognitive mode of geography information professionals. The two models are not equivalent.

Therefore, we need to draw lessons from the theory and technology of ontology modeling method, establish the concepts set of context and the semantic features of geographical concept, and form the semantic features database to provide the basis for computing semantic similarity.

4 The Example of Ho-Lo map mapping

4.1 The cartographic process of Ho-Lo map

According to the above cartographic model, this article makes the cartographic process of Ho-Lo map specific. The process is a dynamic mapping information transfer process, which a previously established model as its foundation, real-time reasoning and calculation as its core (Figure 3).

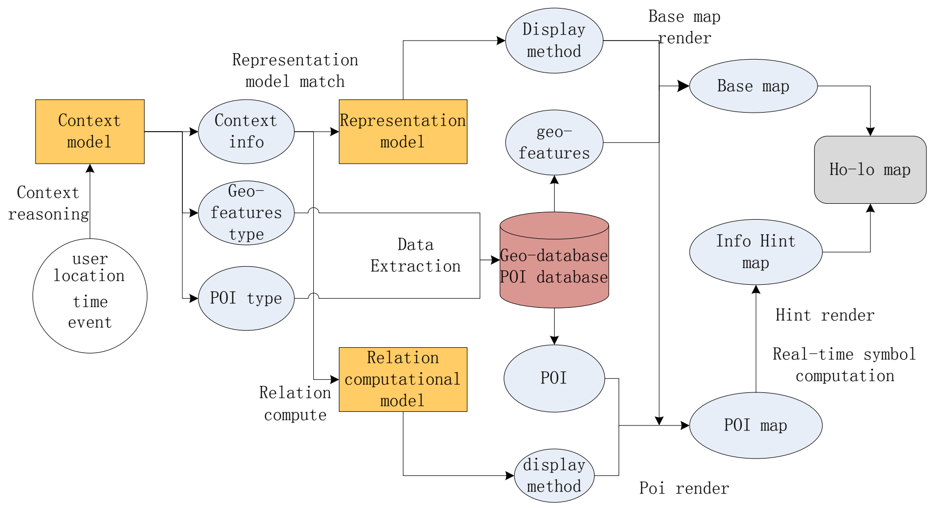

Figure 3. Cartographic process of Ho-Lo map.

In the pre-modeling stage, according to the specific application, establish context model, calculation model and expression model of Ho-Lo map. And each model should be abstracted from the real world to abstract concept, and then the concept is formalized to digital expression. In the real-time drawing stage, its process is as follows:

①Current information such as user, location, time and event as the input, through the reasoning process of context, find the matching context from the context models, so as to obtain the formal description of current context.

②According to formalized description of current context, obtain geography features by relationship computational model.

②According to required geography features, extract corresponding data from Ho-Lo map geographic database.

③Make the formal description of the current context as input to match cartographic express model of Ho-Lo map, in order to obtain map expressive template.

④Drawing base map of Ho-Lo map according to expressive template.

⑤ Make the formal description of the current context as input to relationship computational model, and obtain POI features.

⑥According to required POI features, extract corresponding data from Ho-Lo map POI database.

⑦Drawing thematic map of Ho-Lo map according to expressive template through real-time symbolic computation.

⑧Integrate the base map with the thematic map and eventually we can get a full holographic location-based map.

In the above process, there are many procedures of the transfer of cartographic information, which proposes the severe challenge to the real-time making of Ho-Lo map.

4.2 Cartographic example of Ho-Lo map in the context of airport.

① Establish the knowledge database of ho-lo map

- According to prototype category theory, establish a collection of concept of basic scenarios.

Conduct a survey of 13 people in the way of questionnaires and talking. Through extracting the concepts in the result, collection of concepts and their relationships are initially formed in airport category(Fig 4).

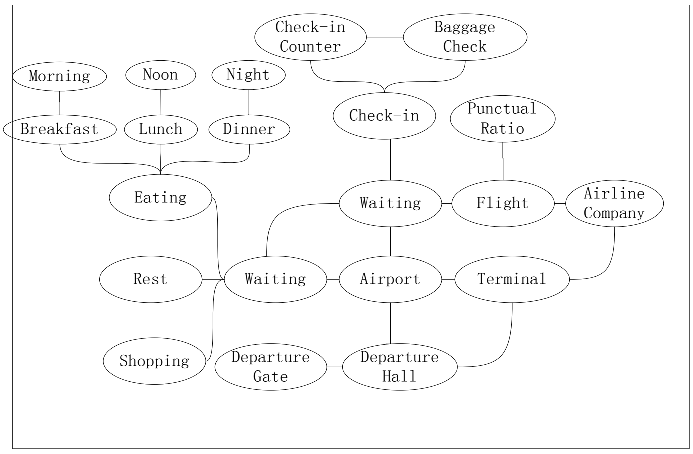

Figure 4. Collection of concepts in airport category.

- Establish classified model of geographical features in airport(Fig 5).

Confirm geographical features classified model of airport according to the relevant standards.

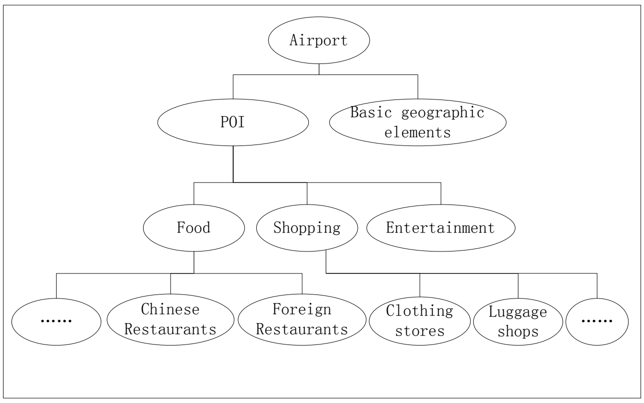

Figure 5. Classified model of geographical features in airport.

- Analyze semantic characters of concepts and classification mentioned above.

Analyze the semantic characters of concepts in the category using "Ontologic level" concept presented by Guarino, etc.

Ontologic level	Type	List of semantic characters
Social level	property	Military, civil, all
Social level	Arrival region	International, internal, provincial,

		extensional
Social level	rank	VIP、common、first-class、business class、tourist class、……
Functional level	function	Waiting, rest, food, shopping, medical, treatment, register, check……
Static level	reference	number of persons, speed, punctual rate, delay rate, number of departure gates, ……
Static level	state	open, stop, damage, close, ·····
atic level	space-time information	Time, location, floor, ……

Table 1. Semantic characters of concepts in the category using "Ontologic level"

For example, when analyze semantic characters of the concept 'airport lounge', we can get formalized description as follows:

<airport lounge> ::= <civil> | <domestic> |< common > |< waiting > |< 1000 persons > |< open>.

② Compute context description by sensors' information and users' input.

Let the information acquired by sensors as a time of 11:30, the place as relative coordinates in some coordinate system. The information corresponds to the airport lounge and user Mr. Zhang, who will take the plane flying off at 2:30 pm to Beijing.

According to context model, calculate and reasoning the formalized description of the context (taking the description of time, place as example):

$$C_1 = \{TYPE(comp), NAME(airport\ ), SUB(3|T, P, U)\};$$

here, $T = \{TYPE(comp), NAME(time), SUB(2|T_p, T_l)\};$

$$T_p = \{TYPE(ind), NAME(period\ of\ time), VALUE(midday), POWER(0.5)\};$$

$$T_l = \{TYPE(ind), NAME(remain\ of\ time), VALUE(2.5), POWER(0.5)\};$$

$$P = \{TYPE(comp), NAME(location), SUB(2|P_t, P_e)\};$$

$$P_t = \{TYPE(ind), NAME(type), VALUE(airport\ lounge), POWER(0.7)\};$$

$$P_e = \{TYPE(ind), NAME(func), VALUE(rest), POWER(0.3)\};$$

③ Calculate appropriate geographic features according to the description of context.

According to the keywords described in the context, such as ‘midday’, ‘airport lounge’, ‘rest’, etc., we choose the closest concept in the category: eating. Then we calculate semantic similarity of the concept of eating and geography to find the appropriate geographic features type: eatery.

④ Select the appropriate expressive template to mapping according to the description of context and semantic description of expression template

Select the expressive template which semantic description is similar to the semantic of the words ‘midday’, ‘airport lounge’, ‘rest’, and draw the map in accordance with the expressive template.

5 Conclusions

Ho-lo map is a new type of map which is constructed based on mobile internet. Compared with traditional map, it has significant differences in drawing objects, drawing body, drawing patterns and drawing technology.

Firstly, it is a kind of dynamic thematic map which regards the correlation, associated with persons, events, things based on human behaviors as its core. The representation contents of Ho-lo map are varying with user, environment, location and time.

Secondly, in order to achieve generated real-time, used once (Yan et al. 2006), the drawing objects of Ho-lo map is changed from experts to mapping system which having certain intelligent processing capabilities and supporting real-time mapping.

Thirdly, only the cartographic mode of Ho-lo map is from static to dynamic, and then to real-time, it can meet users’ demands in the process of moving. This change will lead to many changes in cartographic techniques.

By studying the cartographic model of Ho-lo map, this article reveals basic process and dynamic mapping procedure from theoretical level. However, the mapping process of Ho-lo map requires highly real-time and dynamic, and its drawing foundation is knowledge database. These put forward higher cartographic preparation request to Ho-lo map

Therefore, based on the cartographic model proposed in this article, the important task for the future is gradually improving and practicing to test each process of the model.

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