CONTEXT AWARENESS AND MODELING IN SELF-ADAPTIVE GEO-INFORMATION VISUALIZATION

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Abstract: Self-adaptive system is an effective method to improve its usability to adapt to different individuals, user groups, surroundings and techniques. In the field of self-adaptive geo-information visualization (SAGVis), self-adaptive contexts mean various devices, different surroundings and individual requirements, etc. Context theory is a theoretic foundation for SAGVis, legible context awareness and analysis are the foundation of adaptation modeling, so this article brings forward new contexts categorization in SAGVis, and illuminates the detail elements of all kinds of contexts. Self-adaptation is achieved through user interface and visualization content which are both discussed in this article. Adaptive context models include: 1) task model, 2) user model, 3) domain model, 4) system model, 5) adaptive rule model. Both of the generic modeling and modeling are discussed, and the complementary of adaptability and adaptivity is suggested to be made full use of in SAGVis to satisfy users' requirements effectively.

Key words: Self-Adaptive, Geo-information Visualization, Context Awareness, Context Categorization, Context Modeling

INTRODUCTION

Self-adaptive system is an effective method to improve its usability to adapt to different individuals, user groups, surroundings and techniques **[1]**. In the field of geo-spatial information visualization, self-adaptive contexts mean various devices, different surroundings and individual requirements, etc. Reach on self-adaptive GIS and self-adaptive mobile service is ongoing, especially in mobile service, the contexts change constantly discussed by many researchers whose conclusions are typical and valuable.

Chinese researchers in SAGVis mainly study contexts from the point of self-adaptive structure and methods **[2]**, location based geo-spatial information service, modeling of self-adaptive mobile cartography **[3]**, map design and user interface design based on user cognition **[4]**, and so on. However, these are scatter, not demonstrating the importance and systematic category of contexts in SAGVis.

It's needed to point out that self-adaptation is a description of a system, but contexts are the real contents for a system to adapt to. We consider "context-aware" has the same meaning of "self-adaptive". Context theory is a theoretic foundation for SAGVis **[5]**. Context adaptation is an effective method to improve system usability **[6]**. Because of the dynamic factors of spatial data, calculation process, display devices, interfaces and users, contexts in SAGVis are multi-dimensional. Moreover, legible context awareness and analysis are the foundation of adaptation modeling, that is, inspecting and discriminating particular contexts, establishing relative knowledge database, so as to provide proper service according to contexts.

1 DEFINITION AND CATEGORIZATION OF CONTEXT

1.1 Definition of Context

Chen and Kotz**[7]** define context as "the set of environmental states and settings that either determines an application's behavior or in which an application event occurs and is interesting to the user". Dey **[8]** defines context as "any information that can be used to characterize the situation of an entity. An entity is a person, place, or object that is considered relevant to the interaction between a user and an application, including the user and applications themselves". Dey calls the system "context-aware" system which can offer users information and service according to these contexts.

1.2 Generic Categorization of Context

Context gradually categorized in detail. Schili [9] divides context into here categories: 1) Computing context, such as network connectivity, communication costs, and communication bandwidth, and nearby resources such as printers, displays, and workstation. 2) User context, such as the user's profile, location, people nearby, even the current social situation. 3) Physical context, such as lighting, noise levels, traffic conditions, and temperature. Chen and Kotz [7] add 4) Time context, such as time of a day, week, month, and season of the year, and 5) Context history, user an physical contexts recorded across a time span.

1.3 Categorization of Context in Mobile Map Service

Nivala and Sarjakoski **[10]** categorize the contexts and gave out their features for mobile map services, they are 1)System, such as size of a display, type of the display (black/color screen), input method (touch panels, buttons etc.), network connectivity, communication costs and bandwidth, nearby resources (printers, displays).2) Purpose of use, user, social, cultural, such as user profile (experience, disabilities etc.), people nearby, social situation.3) Location, physical surroundings, orientation, such as lighting, temperature, surrounding landscape, weather conditions, noise levels.4) Time, such as time of day, week, month, season of the year. 5) Navigation history, such as previous locations, former requirements and points of interest.

Reichenbacher **[5]** points out that SAGVis should be personalized, minimal intrusive, location-based, timely, context-aware, attentive, proactive, reactive, prioritized. He summarizes the contexts form the point of where, when, what else, what task, who, what conditions and what culture, and emphasizes the hierarchical levels of context.

Vasilios Zarikas**[11]** puts forward that the PALIO system (Personalized Access to Local Information and services for tOurists) pays great attention to the location and contexts and their modeling. The contexts include 1) Awareness of the environment where the user interacts (location, time, weather condition, noise, companions, description of the surrounding area). 2) Awareness by the system of the particular device in use and proper response/communication with the client application / platform that the tourist uses for the communication. 3) Awareness and reconciliation of bandwidths, of the status of wireless communication, of switching between different network providers, etc.

YAN Chaode**[3]** considers that adaptive elements of mobile maps come from the whole process of mapping and using, they can be classified into six groups, namely spatial elements (location, time, movement state, spatial relationship), operational elements (zoom in, zoom out, rotation, drag, etc.), technical elements (display, computation, orientation, communication, etc.), information elements (data format, date quality, data scale, themes, etc.), user elements (sex, age, preference, language, task, etc.) and elements usage context (weather, ray, season, etc.).

1.4 Categorization of Context in adaptive GIS

Mathieu Petit**[12]** points out that adaptive GIS automatically offer users the right contents and interfaces according to multi-dimensional contexts. So the multi-dimensional contexts should be clearly discriminated. He establishes a three level model for adaptive GIS: user, geographical and device contexts.

The user context reflects the way individual users are sorted into groups of similar behaviors according to the properties of the data usually requested, and the user interface usage. The appliance context characterizes the internal specifications (e.g. data transmission speeds and volumes, interface memory), output capabilities (e.g. display size and resolution) and input capabilities (e.g. mouse, touch screen, keyboard). Appliances are organized into groups of similar capabilities and can be even composed of several devices to support groupwork (mobile, desktop, web, composition).

1.5 Categorization of Multi-Dimensional Context in SAGVis

According to the related works and modeling requirements, the categorization of multi-dimensional contexts in SAGVis is shown in tab.1, this categorization is more systematic and the contents are more detailed, it is helpful for later context modeling.

Tab. 1 Categorization of Multi-Dimensional Context in SAGVis

Categories	**Contents**	**Feature**
User context	✧ User	✧ User's profile: career, age, preference, education level, culture and social background (faith, language, etc.), physical condition (disability or not, left/right hands, etc.), personality(introversive /extroversive), sensibility ✧ User's ability: computer operating ability, geo-information knowledge, spatial cognition and perception(memory, learning, problem solving, decision-making) ✧ User's experiences of operating this kind of system ✧ User's history of using this system ✧ The ability of user's partner
Activity context	✧ Task	✧ Geo-information service ✧ Locating ✧ Navigating ✧ Searching ✧ Planning and designing ✧ Analyzing ✧ Identifying ✧ Checking
	✧ Tool	✧ zoom in, zoom out, rotation, drag, etc.
	✧ Data	✧ Data format ✧ Data quality ✧ Data scale ✧ Map themes ✧ Others (data representation, such as multimedia)
Physical context	✧ Location	✧ Location(relative)
	✧ Orientation	✧ Position (absolute)
	✧ Physical surroundings	✧ Lighting ✧ Temperature ✧ Surrounding landscape(geography elements) ✧ Weather conditions ✧ Noise levels
	✧ Time	✧ Time of day, week, month, season of the year
	✧ Movement state	✧ Vehicles (walk, bicycle, car, etc.) ✧ speed
System context	✧ System style	✧ Mobile, desktop, web, composition ✧ Other assistant devises
	✧ System capability	✧ Display (size, resolution) ✧ Type of the display (black – color screen) ✧ Input method (touch panel, keyboard, mouse, buttons etc.) ✧ Network connectivity ✧ Communication costs and bandwidth ✧ Nearby resources (printers, displays, Communication devices, etc.)

2 ADAPTIVE THEMES OF SAGVis

SAGVis is dynamic mapping according to multi-dimensional contexts mainly through user interface and map visualization which come to be the two most important themes of SAGVis. Then the issues in adapting multi-dimensional contexts will be introduced.

2.1 Adaptive User Interface, AUI

Multi-dimensional contexts bring SAGVis AUI design and implementation a series of challenges: 1）The differences in computing power of multi-devices. 2) The input and output constraints of multi-devices. 3) Contexts change frequently while users are carrying out tasks. 4)User personality and cognition level are various, etc.

So, AUI should be sensitive to 1)devices: screen surface, color depth, screen resolution and network bandwidth, 2)interaction: remembering previously used interaction, windows sizes and locations, considering input and output constraints,3)users: adapting to user experience level, system and task experiences, skills, conventions, and preferences.

AUI design aims at 1) adapting to different users on similar devices, 2) developing multi-device user interface. It focuses on user characteristics to achieve the first purpose, such as user sex, age, personality, knowledge level, culture background, cognition capability, etc. according to which to design the elements of AUI (layout, color, functions, icons), to offer personal interface though adaptive mechanisms. Adaptive, multi-device user interfaces provide user interfaces that can be used across multiple platforms and/or display devices, and adapt to the characteristics of different users and user tasks. There is a growing demand for the development of multi-device, adaptive user interfaces, and the techniques are gradually perfect **[13]**.

User-interface modeling will be an essential component of any effective long term approach to developing UIs. User-interface modeling involves the creation of knowledge bases that describe various components of the user-interface, such as the presentation, the dialog, the platform, the task structure, and the context **[14]**. Adaptive mechanisms developed based on above knowledge can help UIs to match the requirements of each context of use.

2.2 Adptive Map Visualization

Doc. Ing. Václav Talhofer, CSc.**[15]** put forward the concept of adaptable maps. The set of characteristics related to the user, the environment, and the purpose of maps is called a context, and the maps which can dynamically respond to the context are called adaptable maps. They give out the themes of adaptive cartography (symbols, resolution, contents, and cartographic method) and the related cartographic contexts (action, technology, situation, and user). Consequently, SAGVis system should not only generate a huge quantity of cartographic representations of one cartographic data set in a short time, but the products should adaptive to different user requirements, so that the decision-making process of the user which is dependent upon the map information shall be facilitated as most as possible.

Reichenbacher**[5]** points out that adaptive maps produced by adaptive geo-visualization service should be simple and highly generalized based on cartographic principles, rendered fast, graphically concise, attractive, crisp, and legible. In addition their content should be flexible, i.e. the content should be dynamically updateable and linkable to other information. They should be adaptive to different users, activities, and situations and fit other web services. At least these services must be capable of displaying points of interest (POI) and landmarks, the geo-location of people, objects, and events, routes, and search results (i.e. people, objects, events). They should also visually emphasize order in relation to relevance, importance, priority, availability, time criticality, etc.

3 CONTEXT MODELING

Context-aware computing is the technical base for adaptive system, it consists three phases: Discovery – learning about entities and their characteristics. Selection – deciding which resources to use as the key concern of the context-awareness. The system should be capable to select entities based on the surrounding context. Use – employing the available resources.

Adaptive modeling can mainly be divided into outside context modeling (physical context, system context) and user modeling (user profile, tasks, activities). There are many differences between them with respect to data acquisition, coupling to applications, and representation, but it is crucial to model and considerate both in common **[16]**, for outside context and user always interact with each other.

3.1 Generic Context Modeling

In order to integrate the interaction between user and context, Zipf **[16]** gives out a method of generic context model (Fig.1); this model includes three components, namely the interaction of user, knowledge, and situation.

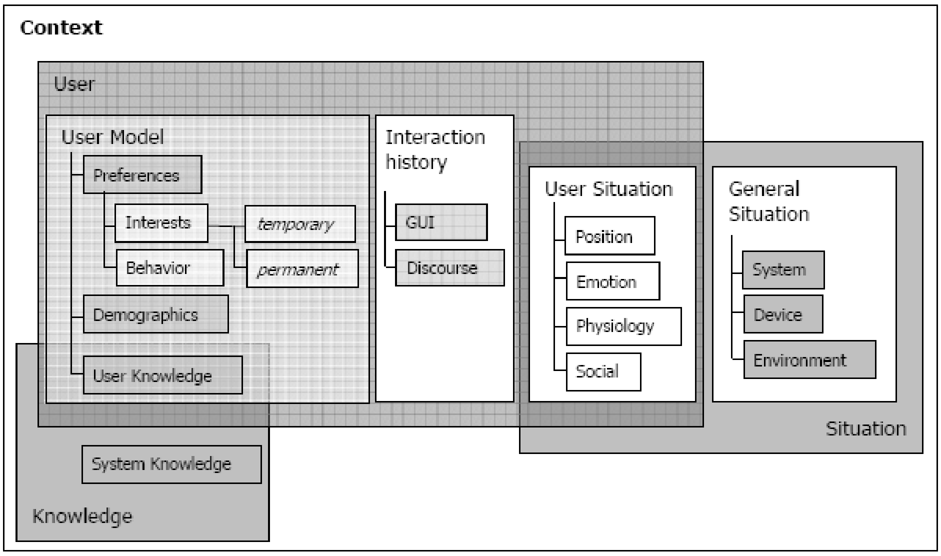

Fig.1: Context model including strong user model enhancements

Reichenbacher also points out that the mobile context dimensions are not independent, but have many and sometimes quite complex interrelationships as illustrated in Fig. 2.

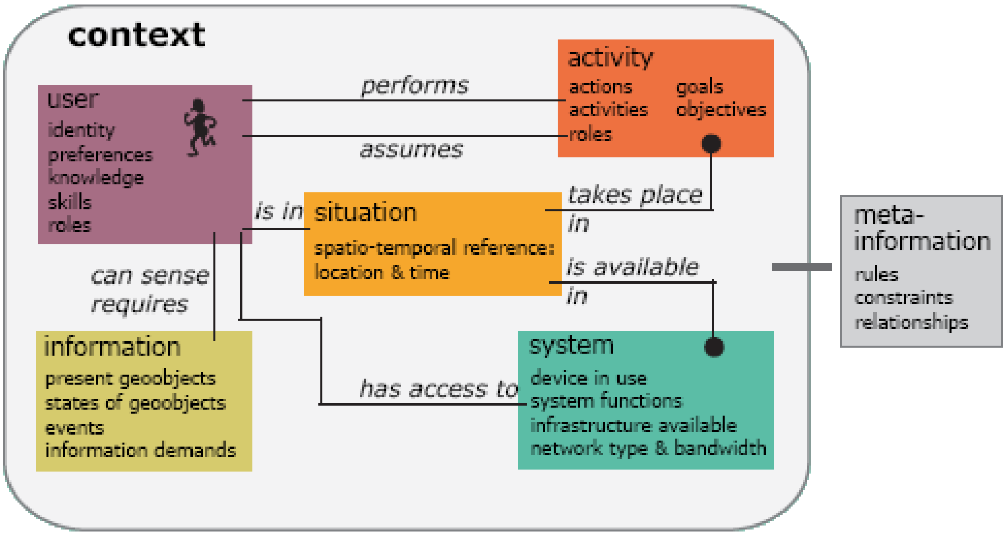

Fig. 2 Generic context model for mobile cartography

3.2 Taxonomic Context Modeling

As analyzed above, adaptation objects are contexts whose changes trigger adaptive events. According to the contexts categorization and themes of adaptive geo-information, although they are various, the adaptive context modeling mainly includes **[5]**:

1) **Task model**: this model describes the user tasks or activities and the changing needs of the user over time.
2) **User model:** this model addresses user roles and the belonging to a user group describing different needs for different user groups or roles.
3) **Domain model:** in this model knowledge about the real-world domain is captured. It is an

information model that could be treated as a geo-ontology.
4) **System model**: this model keeps the knowledge about the system, i.e. the capabilities of the device, the functions available, etc.
5) **Adaptation model**: the adaptation model consists of the adaptation rules that basically specify how the adaptation should be effected.

1）Task model

Task model includes task (objective) classification, process of accomplish tasks (thinking modes of different users accomplishing tasks, activity modes), dynamic requirements, accomplishment patterns of collaborative tasks. Reichenbacher**[5]** concludes mobile users' basic actions, questions, objective, operations, and parameters of spatial data, etc.

The purpose of users to use a system is to accomplish their desired tasks efficiently. Users establish their own thinking modes based on respective knowledge and experiences, if a system can automatically adapt to these modes to offer users appropriate guide or tools, then the service must be satisfying.

A task can be done with different tools in different manners, so in a sense, tasks and tools are relatively independent. No matter what kinds of tools and methods used, the comprehension and operation habit of tasks lie on users' thinking modes.

Task analysis data are always obtained from feedbacks of subjects in observation, discussion or questioning experiments, after concluding, and then further represented intuitively in words and charts.

User activity analysis is quite complex, because 1) different user roles use different functions in the same system, 2) different users' activities have some interdependence, 3) there are material and information flow during system using, 3) activity sequence is various, 5) activity strategy adjusts according to system feedback, 6) hiberarchy is a characteristic of activity, 7) activity is affected by outside situation, 8) usage always reflect users' personality, habit, and culture.

In a word, user activity should be depicted form multiple points. UML is an excellent tool, such as use case diagram, sequence diagram, collaboration diagram, class diagram, state transition diagram, component diagram, deployment diagram **[17]**.

2）User model

User Model is the core of SAGVis **[18]**, users' preferences and habits of interface, data, and representation are induced from users' profile and historical activity records, according to which users are divided into different roles and groups. User individual cognition system and map spatial cognition theory are theoretical foundation for geo-information visualization system, further more, they have the same effect for individual, adaptive service and adaptive map representation.

User modeling in SAGVis is different from user modeling in general adaptive systems, the former needs more user cognition experiments.

1) SAGVis system is a design system of geo-information which makes knowledge of geo-information visualization automatically adapt to user's needs and spatial cognition level. That is to say, it combines with cartography and GIS domain knowledge, and performs many functions in different manners on multi-devices.
2) SAGVis system is an active design knowledge service system, for which domain model, task model and user model are three important components. This user model is associated with domain model and process model, so it is more complex than the user model in usual information retrieval system.
3) SAGVis system includes interface adaptation, function adaptation, map data adaptation, usage context adaptation, and so on. So user cognitive characteristics associated with tasks, the matching between interface structure and cognition structure, data organization and cognition requirements, the matching between mental map and map representation, system evaluation, etc. are all need to be test. As a result, user activity cognition analysis and geo-information cognition are both included.

3）Domain model

Domain knowledge means the important issues or concepts in a special domain and the relationship between them **[19]**. Domain knowledge in SAGVis means dynamic semantic knowledge related to geo-information which is accumulated in a long time for users. The knowledge is diverse for different users' personality, experience, education level and preference, moreover, for a user, it is changeful, such as expansion and disappearance.

Domain model is the description of geo-information concepts and structure users prefer. It is an information model that could be treated as a geo-ontology; the model based on ontology is usually selected as an effective method to describe it. The advantages of this method lie in: 1) improving the shareability and reusability of domain knowledge, and depicting its structure, 2) improving the sustainability of the model, because entity changes more frequently than domain ontology.

Domain knowledge base (DKB) is not only the basement of domain modeling, but also a way of domain models storage. It may include domain ontology base, domain user base, domain preference base and domain requirement resource base. Domain ontology base is the support of domain knowledge representation and semantic searching, including entities (concepts) and relationship between them. Domain user base includes user types and possible relationship between them. Domain preference base includes user preference (with preference value) of concepts in ontology base. Domain requirement resource base includes reusable resources to be recommended to users, and any resource (entity) has one or several keywords represented by domain ontology **[20]**.

So the result of user classification in user modeling can be directly used into domain modeling and stored into domain knowledge base.

4）System model

SAGVis must adapt to system contexts, including various systems (mobile, desktop, web, and combination) with different capabilities (as shown in tab.1). System contexts affect the function service, data transportation, visualization and others in geo-information service.

Take display devices for example, there are multiple kinds of them, such as desktop devices (CRT, LCD, projector, television), mobile devices (portable computer, mobile telephone, PDA, vehicle navigation display), etc. SAGVis mainly offer users adaptive geo-information service through electronic maps and multimedia information in visualization interfaces, so the capability of display (size, resolution, color mode, contrast, luminance, visual angle, sunlight/moonlight definition) and difference of display environment will have a direct effect on interface, map and multimedia.

It determines the layout of interface, appearance of toolbar, design of icons, selection of input way, and determines map contents, Cartographic Generalization, symbol design, color design, determines speed, fluency, and definition of multimedia information.
System model is to describe the functions of systems and capabilities of devices, it stores the systems and devices types and related parameters in model data base, getting ready for adaptive service matching.

5）Adaptation model

Adaptive model is generally composed of two parts: adaptive rules and model matching.

Adaptive rules are principles of offering users proper information. Generally, according to theories of traditional cartography, map design, and human-computer interaction, etc, after several user cognition experiments, using clustering and reasoning methods, the process of geo-information visualization, the elements of map visualization, and user interface are divided into several levels or types, which are the actions system shall provide. Then according to user types in user model, domain knowledge in domain model, user tasks in task model and device capability in system model, which are the conditions system shall adaptive to, system offer individual information and visualization methods to users. For example, Yu Zhuoyuan **[18]** gives out some map visualization states and adaptive rules.

Model matching means the process of triggering the adaptive rules and matching conditions with actions. The ordinary method is production inference, its mechanism is *IF <condition> THEN <action>*, this easily achievable method gives a system adaptability to a certain extent. But as a method of rule-based reasoning (RBR), production inference can only make reference according to preconceived rules, not able to adapt to frequent changes of contexts. Furthermore, a real SAGVis system should have the ability of self-learning to complementary and modify its rules along with its experience accumulation.

Case-based reasoning (CBR) is to make reference according to experience knowledge represented as cases previous solved. It makes a system have the ability of self-learning, and the establishment and maintenance of this kind of system is relatively easy, also user's thinking process of association, intuition, analogy, learning and memory can be better simulated.

The integration of RBR and CBR can improve system ability of self-learning, their application in SAGVis is as following:
1) Using RBR to search case model in CBR to offer initial model——RBR is a assistant reference engine.
2) Using RBR to match user requirements based on elements of contexts in operation process——an adjustment process of service and case models.
3) Storing the new case models and related conditions in CBR case base——conditions in RBR become thorough and RBR is extended.
4) The system is improved in this volute process, conditions become thorough and case models turn to be excellent, the system's ability of self-learning and self-adaptation is improved.

4 CONCLUSIONS

This article shows out the categorization of multi-dimensional contexts, concludes the challenges adaptive user interface and map visualization have to face to. Then points out the importance of context modeling, it is needed to understand the complex relationship of various contexts in a whole, at the same time, it is necessary to improve the taxonomic context modeling. The rationality and efficiency of the models are crucial for SAGVis system. So far, fully self-adaptive system hasn't been achieved. Adaptation has two means——adaptability and adaptivity. Adaptable system generally needs to make some context models and several templates which are selected by users in operating process. But adaptive system needs to establish adaptive mechanisms following which the system responds automatically according to real-time dynamic changes of contexts. Out of question, adaptive context modeling is superior to adaptable modeling **[21]**. So now the complementary of adaptability and adaptivity is suggested to be made full use of in SAGIV to satisfy users' requirements effectively.

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