Activity-oriented Context-aware Adaptation Assisting Mobile Geo-spatial Activities

Guoray Cai
School of Information Sciences and Technology
Pennsylvania State University
University Park, PA 16802
cai@ist.psu.edu

Yinkun Xue
Dept. of Computer Science and Engineering
Pennsylvania State University
University Park, PA 16802
yxue@cse.psu.edu

ABSTRACT
Human geospatial activities often involves the use of geographic information in mobile environment where the context of technology use is dynamic, complex, and unstable, creating unique challenges in designing effective mobile mapping applications. Enhancing the context awareness of the computing device can improve the usability of mobile map applications, but the potentially large number of contexts (physical context, computing context, human factors, and time) are not easily managed without a workable organizing structure. This paper proposes an activity-oriented context model that establish late (run-time) binding of contexts to the ongoning avtivity according to how they contribute to the success of the activity. Using this context model, adaptation of mobile map display to the changes of other contexts is based on the knowledge of ongoing task (within an activity) rather anticipated tasks. We discuss advantages of such an approach over traditional template-based model of context models in mobile computing applications.

Categories and Subject Descriptors
H.5.2 [Information Interfaces and Presentation]: User Interfaces—interaction styles, theory and model.

General Terms
Design, Theory, Algorithms, Human Factors.

Keywords
Context-awareness, activity model, collaborative plans.

1. INTRODUCTION
Geo-spatial information services are increasingly offered through mobile devices to augment human's mobolity while engaging spatial tasks. Examples include mobile tour guide systems, such as GUIDE[4], Tour Digital Assistant[2], Dynamic Tour Guide[8],and others[1]. Designing for usability of such systems must explicitly take into account the need for tailoring the presented information to the physical, cognitive, and social contexts that define the situation of use. Context awareness and context-adaption are especially important for mobile applications because contexts of mobile computing usage are extremely dynamic due to user's multitasking, switch of working environment, and shifts of user's internal goals[5]. As a consequence, it is often hard to prescribe what contexts are relevant and what to adapt to at the design time[6]. One way to overcome such difficulties is to build into the mobile application a degree of consciouseness about its changing contexts and a degree of autonamy in choosing a proper adaptation strategy on-the-fly. This motivates our interests in establishing a sound model of contexts that guides the context-aware behavior of mobile applications.

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2. ACTIVITY AS CONTEXT
This paper establishes a computational model of actvities that includes diverse sets of contextual factors as the ingradients of the ongoing activity. An aspect of the environment or situation becomes a relevant context when it defines (or helps to define) certain contextual states that have predicative power on how information services and presentations are provided. We follow those views of contexts taken by Activity Theory [9] and Situated Action[10]. An acitivity is the fundamental, meaningful unit of analysis to understand the interacting relationships among human minds, artefacts, and the environment. Activity includes not only external resources (people, artefacts, settings) but also internal mental processes (goals and beliefs). Such constituents of activity are not fixed but can dynamically change as conditions change. Context-awareness means that the system actively constructs and updates a model of the ongoing activity by sensing, communicating, and interpreting changing conditions, resources and processes. Context adaptation takes the activity as the context to infer what actions to be taken in order to ensure the success of the overall activity.

2.1 Modeling the Activity
Consistent with the above view of contexts, we have developed a model of context based on the computational theory of collaborative plans[7]. A collaborative plan is a moment-to-moment representation of an unfolding activity and includes not only a hierarchy of actions and recipes but also the knowledge and physical pre-conditions (modeled as parameters of recipes) as well as the set of mental states (beliefs, intentions, and commitments) that the participating agents have established towards the plan and its subplans (see Figure 1 for the structure of a collaborative plan). A collaborative plan can be partial (if there are un-instantiated parameters, un-executable leaf actions, or insufficient mental states), meaning that the activity is still ongoing and unfolding. Otherwise, a fully developed activity corresponds to a full collaborative plan. Human-computer joint activity can be modeled as the process of evolving a collaborative plan from partial towards a full plan.

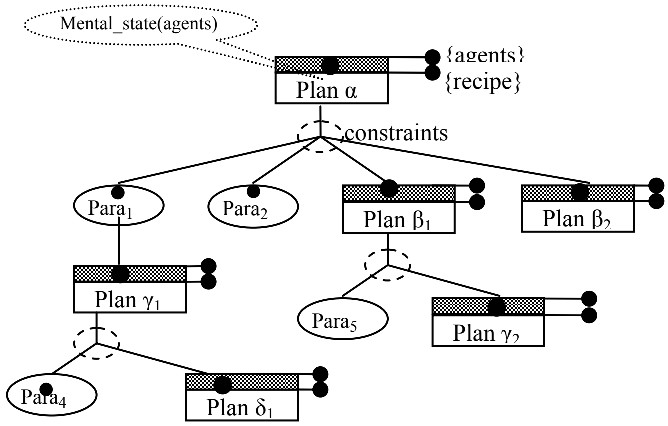

Figure 1. Collaborative plan as model of an activity

2.2 Model of Context

When a collaborative plan is established for an activity, various contextual factors can be associated with the activity based on how such factors contribute to various components of the collaborative plan as it evolves towards a full plan. The black dots (•) in Figure 1 indicate where computational, physical, cognitive, and social contexts can be pluged into the activity.

2.2.1 *Social contexts as 'agents' of a plan*

The "agents" attached to a plan node within a collaborative plan indicate who are the participants of that plan. The set of 'agents' for a plan is commonly negotiated within the social contexts of an activity. *Social contexts* include people, groups, organizations, and computer agents that have a degree of conscious about the collective activity and their roles, responsibilities, and cooperative relationships.

2.2.2 *Cognitive contexts as 'menta- states' of a plan*

'Agents' of a plan hold certain mental states towards the plan. For example, agent 1 may hold an intention to work on plan α, and believe that other agents will copperate with it. In the sametime, agent 1 may have committed in doing plan γ. Such cognitive states (*intentions*, *beliefs*, and *commitments*) exist internally in human minds, but they are important constituents of a collaborative plan.

2.2.3 *Contexts provide 'recipe' for plans*

A plan on a complex action requires a piece of knowledge, called "recipe", which specify one way of accomplishing the complex action. A recipe decomposes a comlex action into subactions with (optional) knowledge pre-conditions (i.e. parameters). Recipe knowledge may come from the mind of human particpants (i.e. *cognitive contexts*) or from the knowledge-base of a computer system (i.e. *computing contexts*).

2.2.4 *Contexts as parameters of plans*

A plan on a complex action often involves the identification of one or more parameters as knowledge pre-conditions to the execution of the plan. Such parameters may be obtained by sensing the physical environment, by communicating with human who are believed to have the knowledge, or by consulting a knowledge-base. For example, user's physical location may be a parameter for the plan to in a way-finding task. Similarly, time can be another parameter that could be read or sensed from the physical contexts.

2.3 Context Adaptation Mediated by Activity

By using the activity as a 'lens' to view mobile contexts, all the contextual factors are intimately and explicitly related through the collaborative plan of an activity. The importance of any contextual factor is easily interpreted using our model. Now we show how a mobile information service can adapt to the changes of the activity / contexts. Suppose that a mobile device serves as provider of geographical knowledge (parameters) to some of the actions in the plan. Among many cases of context adaptation, two of which are given below.

2.3.1 *Shifting focus-of-attention of the activity*

Agents of an activity do not attend to all part of the activity at the same time. Generally, there is always one action (plan node) that is the focus of the current activity at any given moment. What are considered relevant contexts to the whole activity may not be relevant contexts at this moment, because only the contexts that contribute to the success of the action under focus are considered relevant temporarily. In other words, even the overall (physical) situation does not change, the shift of attention ofrom one action to another will trigger an adaptation process.

2.3.2 *Activity replanning when facing obstacles*

Change of contexts may sometimes cause the failure of executing a plan based on the currently selected recipe. For example, a device may normally expect receiving location data from a GPS sensor. In such cases, presenting a map of current location will be easy. However, if the GPS sensor network suddenly stops working, we still need to get the location data to ensure the success of the rest of the activity. The activity will adapt to this contextual change by triggering a 're-plan' process to choose another recipe. Assuming that a backup recipe is invoked which uses geo-referencing street address to identify the location. If the mobile device is aware of such context change, it will be able to adapt to the failure of GPS event, but such adaptation is mediated through a conscious knowledge about what part of the activity has been replanned and how such replan affect the mobile information service.

3. A SCENARIO

Based on our previous work on the use of conversational dialogues to construct models of geographical activities [3], we implemented a mobile map adaptation application, called Context-Aware Map Tailor (CAMT). We will use a scenario to explain how the context-aware adaptation is achieved in CAMT. Suppose that a user, **Tom**, is taking a tour in the city while he can use CAMT to access touring information. Tom plans to visit a museum to catch a special exhibit at 2pm after touring an aquarium. And he needs to have lunch before visiting the museum. This activity includes several tasks that are interrelated both temporally and logically. In order to plan for 'have lunch', one needs to know how much time Tom can spend on lunch, which is, in turn, dependent on how long it takes to travel to the museum. Tom asks CAMT how long it would take to get to the museum. CAMT responds that it will take 20 minutes from the nearest metro station to the museum. The exhibition at the museum will begin in 35 minutes. There is only less than 15 minutes left for Tom to have lunch. So Tom decides to grab some fastfood. He asks CAMT to recommend a restaurant. The construct for this activity is shown in figure 2. The recipe for "identify the restaurant" includes two parameters: food style of the restaurant; and location of the restaurant. Using these parameters, CAMT can filter the whole restaurant dataset to get the appropriate response to the user.

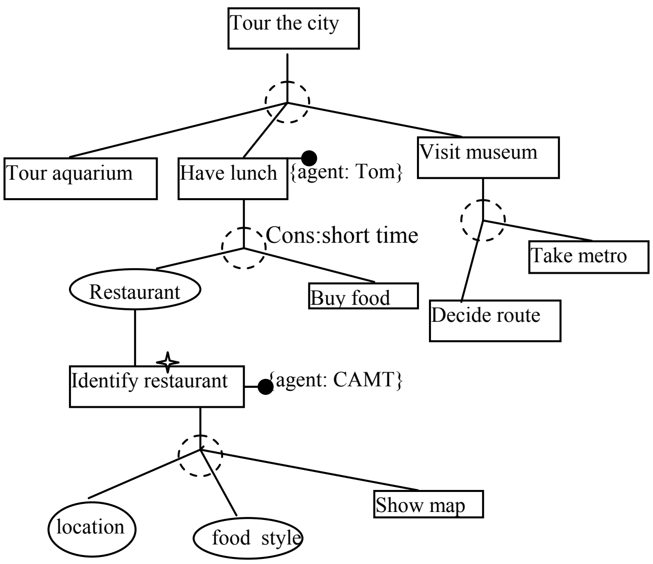

Figure 2. The collaborative plan of activity for a city tour (The focus of action is "identify restaurant")

To identify "food style", CAMT first searched Tom's food preference stored in his profile, and find that Tom likes seafood. However, CAMT does not believe that Tom has enough time for seafood. Then CAMT asks Tom directly the food style he prefers for lunch, which results in the choice of fastfood. Similarly, for "location" parameter, CAMT has two pieces of contextual knowledge that are potentially relevant: user's location (sensed from GPS) and metro station's location (which can be communicated using maps). By consulting the plan graph of the activity, CAMT is aware that the current focus of the activity is to decide the location of the restaurant for lunch. CAMT compiles proper map information to assist the action, and Tom finally chooses a restaurant located on the way from user's location to the metro station. From this scenario we can see that neither user's profile alone nor predefined fixed items of context can ensure an appropriate decision. Activity provides a comprehensive context for mibile adaptation.

4. RELATED WORK

There have been many attempts to design context-aware mobile applications, especially in the domain of tour guides. Although a large number of complicated context factors have been discussed [5], existing context models tend to be simple. Typically, different contexts are enumerated in a fixed template as a one-dimensional structure [1][4][8]. Template-based approaches suffer from a number of difficulties in designing context-aware behavior. First, it only works for routine activities, where contextual states and adaptation strategies can be determined a prior at the design time. Second, they tend to treat contextual factors as isolated variables that can be interpreted and adapted to individually and independently. Third, they do not scale up with the number of contextual factors involved. As a consequence, template-based context adaptation often focuses on one type of contexts or a very small number of context factors. Last, existing context-awareness mobile applications almost exclusively focus on physical contexts and pay less or no attention to human cognitive contexts. Our proposed activity-based model of contexts has the potential of overcoming the problems mentioned above. Since binding of contexts, activities and adaptation strategies are delayed till run-time, it is much easier and robust to determine what contexts are relevant and what appropriate actions to be taken.

5. CONCLUSIONS

In this paper, we have addressed the difficulties of modeling dynamic mobile contexts for fluid and situated activities in mobile applications. The proposed activity-oriented context model unifies the handling of physical, cognitive, and social contexts by associating contexts to the collaborative plans of an activity at the run-time. Future work will address the issue of reliably recognizing and constructing activity models even in case of missing contexts.

6. ACKNOWLEDGEMENT

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