Location-based Variability for Mobile Information Systems

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Abstract. Advances in size, power, and ubiquity of computing, sensors, and communication technology make possible the development of mobile or nomadic information systems. Variability of location and system behavior is a central issue in mobile information systems, where software behavior has to change and re-adapt to the different location settings. In this paper, we motivate the need for integration of variable location and variable software behavior. We adapt the goal-oriented framework $i*$/Tropos to model and analyze the alternative goal satisfaction strategies and the location where each alternative can be adopted. We introduce analysis techniques for the proposed location-based models.

1 Introduction

Advances in computing and communication technology have recently led to the growth of interest in Mobile Information Systems (hereafter MobIS). MobISs emphasize mobility concerns (space, time, personality, society, environment, and so on) often not considered by traditional desktop systems [1]. Technology advances do not necessarily imply the easiness of exploiting it, rather more challenges are introduced. Nomadic user expects smarter information systems, able to adapt their behavior without human intervention. MobIS has to reason about the surrounding location, including user itself, and adapt *autonomously* their behavior to location settings. Consequently, we need to model and analyze the variable location and the variable behavior and define how location influences behavior.

Behavioral and location variability are complementary. Supporting two alternative behaviors, without specifying when to adopt each of them, arises the question *"why do we support two alternatives and not just one?"*. Conversely, considering location variability without supporting alternative behaviors arises the question *"what can we do if location changes?"*. We use $i*$/Tropos [2, 3] goal-oriented framework to model alternative strategies for MobIS to satisfy a goal, and specify location properties that apply to each alternative. This allows us to support the decision making process when deriving a location-tailored MobIS instance and make possible different kinds of reasoning. The intended automated reasoning allows to answer questions like: "*are all MobIS objectives achievable in a given location?*", "*what is the optimal alternative to achieve an objective in a given location?*", and "*what is the optimal modification that is needed in one location to satisfy some MobIS objectives?*".

2 Location-based Goal Models

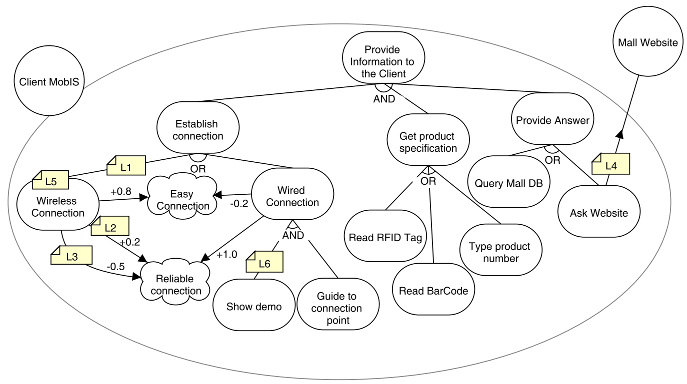

Fig. 1. A location-based goal model.

In *i**/Tropos, the system is modeled as a set of inter-dependent actors having goals, and that can commit to strategies to satisfy their goals. Autonomous selection among goal satisfaction strategies requires criteria an actor builds its decision upon. One alternative can be recommended in a certain location, while it can be even unapplicable in others. The criteria to select among alternatives is not explicitly modeled in the current *i**/Tropos goal model. Fig.1 shows a partial goal model of a PDA MobIS intended for a client in a shopping mall. As a step to support location-based variability, *i**/Tropos can attach location properties to its following variability points:

1. *Location-based Or-decomposition*: Or-decomposition is the basic variability construct; in current *i**/Tropos the choice of a specific Or-alternative is left to actor intention, without considering location properties that can inhibit some alternatives. E.g. (from Fig. 1): goal *Establish connection* can be achieved using *Wireless Connection* only if the mall has a wireless network and client is authorized to access it, and client's PDA supports WiFi (L1).
2. *Location-based contribution to soft-goals*: the value of contributions to soft-goals can vary from one location to another. E.g. the contribution from goal *Wireless Connection* to soft-goal *Reliable Connection* changes depending on the level of received signal: if user is in a location where the signal coming from the WiFi access point is high (L2), the contribution will be positive, while if the client is far from the WiFi access point and the signal level is poor (L3), the contribution will be negative.
3. *Location-based dependency*: in certain locations, an actor is unable to satisfy a goal using its own strategies. In such case, the actor might delegate this goal to another actor that is able to satisfy it. E.g. the MobIS can satisfy goal *Provide Answer* by fulfilling *Query Mall DB*; while if the database is offline and a mall website exists and has a mobile devices version (L4), the MobIS can delegate the goal to *Mall Website* browsing that website.

4. *Location-based goal activation*: an actor, when location settings change, might find necessary or possible triggering (or stopping) the desire of satisfying a goal. E.g. if the MobIS has adopted the alternative *Wired Connection* to establish a connection, and while the client is getting to one cable-based terminal, the PDA detects a wireless signal (L5), the goal *Wireless Connection* could be triggered to better satisfy the soft-goals.
5. *Location-based And-decomposition*: a sub-goal might (or might not) be needed in certain location, that is some sub-goals are not always mandatory to fulfill the top-level goal in And-decomposition. E.g. to satisfy the goal *Wired Connection*, the MobIS has first to show a demo to client only if the client is using the system for the first time (L6).

3 Defining, Eliciting and Modeling Location

We refer by "location" to an environment with high degree of commonality, like shopping malls, museums, or airports. The commonality concerns location constructs: resources (physical and informational); actors having responsibilities, objectives, and relations with resources and other actors; and rules that coordinate the interaction among actors and the use of resources. Using i^*/Tropos concepts, we define location from the perspective of an actor as: "*the set of available actors and resources that can be employed to achieve actor goals*". Goal analysis will capture location properties that are needed at each variability point, and this in turn will enable us to construct location model. In our broad vision, location will be the input that guides MobIS derivation process: MobIS will be instantiated according to the location model instance as shown in Fig. 2.

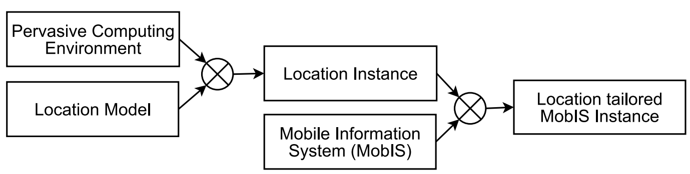

Fig. 2. The process of instantiating a location-tailored MobIS instance.

4 Analysing Location-based Models

The proposed location-based goal model has two components: (1) the goal model that describes how a goal can be satisfied and (2) the location properties that constrain each alternative. Location properties are predicates specified over a location model, whose truth values can be either true or false at a certain location. By formalizing location model and location-based goal model, we can do several analysis. We outline now three types of such automated analysis:

1. *Location-based goal satisfiability (LGS)*: it verifies whether a goal is achievable through one alternative in a specific location.

2. *Location properties satisfiability (LPS)*: this analysis checks if the current location structure is compliant with the MobIS goals. It is exploited to identify what is missing in a particular location where some top-level goals have been identified as unsatisfiable by LGS. When a goal cannot be satisfied, LPS will identify the denying conditions and find ways to solve the problem.
3. *Preferences analysis (PA)*: this type of analysis requires the specification of preferences over alternatives. Preferences can be specified using soft-goals as in [4]. We need this analysis in two cases: 1) when there are several alternatives to satisfy a goal: the selection will be based on the contributions to preferred soft-goals. 2) when there is no applicable alternative: in this case, LPS might provide several proposals about the needed location modifications. The adopted modifications are those leading to better satisfying preferences expressed over soft-goals.

5 Discussion and Future Work

We have briefly shown how to integrate goal satisfaction strategies with the concept of location, and what kind of analysis we can do over the location-based models. More details and a concrete example can be found in our technical report ([5]). For the future, we need to define a modeling language for location, and to study how to capture location model and integrate it with system behavior variability at different levels (goal satisfaction is one of them). Formalization is a basic need, since location is perceived and needed to perform reasoning. We will look for an appropriate formalism to automate the analysis techniques.

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