Context-Adaptive Mobile Systems

Christian Kaspar
University of Goettingen, Germany

Thomas Diekmann
University of Goettingen, Germany

Svenja Hagenhoff
University of Goettingen, Germany

INTRODUCTION

Even though a major part of the industrialized world works with computers on a daily basis and operating computers became much easier since the introduction of graphic interfaces, many users do not experience their computers as work relief, but rather as an increased burden in their everyday lives. One of the most important reasons for this attitude is the unnatural mode of communication between user and computer: the natural interpersonal communication takes information from the communication situation (e.g., the location of the interacting communicators, their personal preferences, or their relationship with each other) implicitly into account. On the other side, despite the development of new interfaces—such as voice and character recognition, which are much closer to interpersonal communication than keyboard terminals—communication between user and computer is still complex and characterized by little intuition. This is where the objectives of the context-adaptive systems come into play: it is the aim of context-adaptive systems to implicitly collect information about the situation of a system request (context) in order to enable more efficient communication between user and computer.

Currently, the concept of context-awareness and context-adaptation has attracted particular attention in the area of mobile communication. This is largely due to the fact that the obligatory requirement of the devices' portability leads to certain constraints of mobile devices. Small-sized screens, low data processing capacity, and inconvenient ways of navigation and data entry are some examples for these constraints. To overcome these limitations is particularly relevant in the area of multimedia Internet content and therefore requires the communication to be as efficient as possible. One possible option to reduce the resulting problem of presentation and selection of content on mobile devices is to automatically offer the user only those contents relevant for the concrete situation of the service request. Such services require that the computer can sense the particular situation of the service request and autonomously respond with appropriate actions.

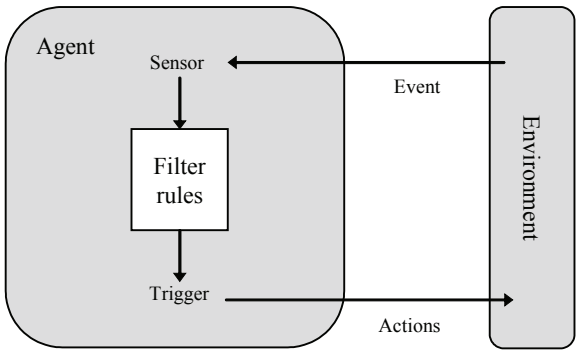
AUTOMATED CONTEXT-AWARENESS

In order for real situations to be sensed automatically by computing devices, the situations of these system requests have to be computed as abstract, automatically understood events, so-called contexts. A context is any information that is used to characterize relevant situations of people, locations, or objects that are important for the interaction between application and user (Dey, 2001). A common classification of context information traces back to Schilit, Adams, and Want (1994). They distinguish between the technical context of participating and available computing resources, the social context of users that are involved in the system interaction, and the physical context of the location of the system interaction.

Computing context describes available network connections and network bandwidth. Additionally, computing context includes accessible peripherals such as printers, screens, or additional terminals. For example, if a multimedia application knows the user's available network bandwidth, it is able to adapt a video stream to its capacity and ensures streaming without jerks and with the highest possible resolution. Furthermore, if the multimedia application is aware of a high-resolution display close to the user, it can suggest this device as an alternative screen for displaying the video stream. To be able to identify each other, mobile computing devices must have radio or infrared sensors. A computing device equipped with radio or infrared sensors spans a distinct logical space (a so-called "smart space") within its sensor coverage. If a device enters another device's sensor space, the device will identify itself and send its network address or appropriate commands for application requests.

The social context contains information about the users involved in the interaction. The user's information, such as identity, age, gender, and preferences, can be gathered either explicitly from surveys or implicitly by observing the user's behavior. Surveying each user's personal characteristics and preferences is the most common form of gathering user information. Most often, surveying user information is directly linked with service registration. Because the provider

Figure 1. Components of an agent system



has little means to control (usually voluntary) submitted information, information from user surveys is often of poor quality. Additionally, profiles that were gathered from a one-time survey remain static over time. Therefore, apart from voluntary authentication information on a specific Web site, the user can be additionally identified on the basis of his or her behavior. Every Web server has a protocol component that logs every server activity and stores these logs chronologically into different application-oriented protocol files. Analyzing these server protocols, it can be determined what requests for which resources have been completed during a specific unique Web site visit. To link recorded requests with an individual user, the IP address of the user's device or identification data stored as cookie on the user's device can be used.

Information about the physical context can be collected from a multitude of data sources such as contact-, thermo-, humidity-, acceleration-, torsion-, or photo-sensors, cameras, and microphones. Sensors that are equipped with processors not only collect data but also pre-process this data. Additionally, they can identify specific patterns such as fingerprints. The user's interaction location is of particular importance for the perception of the physical interaction context. "Location-based-services" are services that take the location of the user into consideration. These services promise to have great chances on the market (Lehner, 2003). The geographical location of a user that is required for services of this kind can either be determined by terminal-locating or by external network-locating.

Terminal-locating is carried out by an especially designed device that autonomously executes location measurements. The global positioning system (GPS) operated by the U.S. military is the best-known technology for self-locating. Receiving positioning signals that are beamed down by GPS satellites, a GPS device can accurately triangulate its position for up to 10 meters. Techniques that can position a location or object from a photo are more sophisticated than the GPS system. Yet they strongly resemble human orientation. Using photo cameras, these methods can calculate the angle and distance to a specific object (such as a building) with the help of a stored three-dimensional model.

Network-locating fixes a device's position using network information. The best-known method for network-locating is the cell identity technique (or cell of origin technique). This technique locates a mobile device within a cellular radio network using the network's cell-ID. Other network-locating techniques fix a particular position based on time differences of signals arriving at different base stations, the angle of arrival, or attenuation of signals from different base stations.

While Schilit et al. (1994) differentiated between three forms of context, Dey (2001) adds the primary and secondary context to these categories (Conlan, Power, & Barrett, 2003). The location, the type of device, the behavior of the user, and the time of inquiry represent primary request contexts. On the other hand, secondary request contexts are composed of a combination of primary context data. By taking the location and other people in the vicinity into consideration to form the secondary social context, the social situation of the user can be determined; for example, the user might be in his office with his colleagues, or out with friends. Furthermore, Chen and Kotz (2000) differentiate between the active and the passive context. The active context determines a change in behavior for the present application (e.g., by defining sections of interest for an adaptive online newspaper). A passive context shows the change in context conditions for the system inquiry only as extra information for the user. For example, a recommendation system can suggest a specific purchase in an online shop, or the user can see his location when using a navigation system.

CONTEXT-RELATED SYSTEM ADAPTION

A system is considered context-adaptive if it uses context information to offer its users relevant information or, rather, services (Dey & Abowd, 2000). Generally speaking, a context-adaptive system is characterized by a certain degree of autonomy when fulfilling its tasks. Therefore, adaptive systems are also referred to as agent systems (Russel & Norvig, 2003). Agents are software systems that, with the help of sensors, identify their environment as application-related events and by using pre-defined rules that activate respective events (see Figure 1). The actions that have been triggered by the agent can refer to information or they can contain control commands for other systems. The agent can either perform the action directly and autonomously (active context-awareness), or these actions are only a suggestion to the user (passive context-awareness).

A context-adaptive application consists of software objects that are automatically requested when the system senses