Persuasion Mobility in Ambient Intelligence

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***Abstract*—Persuasion can be archived with much greater impact using ambient intelligence. Ambient systems may be used to positively influence users' behavior, especially with regard to healthcare. Unfortunately, current state-of-the-art persuasive ambient systems use either mobile devices or are statically bound to dedicated infrastructure. In this paper, we introduce the concept of persuasion mobility. This supports continuous persuasion even when users move between different environments. Besides a discussion of the potential benefits of this approach, we analyze current and developing technological building blocks towards a persuasion mobility architecture.**

***Keywords*—ambient intelligence; persuasion; mobility.**

I. INTRODUCTION

Persuasive technology, a term coined in 2003 by B.J. Fogg [1], has been described as "software or information systems designed to reinforce, change or shape attitudes or behaviors or both without using coercion or deception" [2]. Since its inception, a great deal of progress has been made in understanding and developing persuasive technology aided by new technological developments.

With programmable mobile phones, persuasive applications have been created that promise to interact with users whenever and wherever they are. This technology offered to increase the persuasive effect by the promise of persuading in the right moment at the right place, often called *kairos* (named for *Kairos*, the Greek god of "the favorable moment") [1]. Now, with an ever increasing number of sensors on the phone as well as the almost uninterrupted connectivity to the Internet, smart phones provide us with even more ways to achieve persuasion, not just based on place and time, but even on sensed context.

Proposed by Mark Weiser [3], the vision of Ubiquitous Computing is fast becoming a reality. The vision of Ambient Intelligence extends on the idea of ubiquitous computing, proposing a more user centered approach to generate applications in these intelligent spaces to suit the user's needs [4].

With the advent of Ambient Intelligence, technology may again become more persuasive as it adapts to the new paradigm to include not just the resources of mobile personal computing devices but dynamically include the environment as an active component too. Aarts et al. [4] have defined *ambient persuasion* as the use of context-aware, networked devices that enable context-sensitive system behavior to deliver persuasive content.

In this paper, we analyze the key advantages of persuasion strategies combining the power of (personal) mobile devices and (public) ambient devices. Proposing to combine the power of these paradigms, we expand the concept of ambient persuasion by adding the idea of persuasion mobility. Persuasion mobility is defined by the mobility of the act rather than the mobility of the hardware.

Combining and adapting previously developed technology and standards, we show how such mobility may be achieved in ambient persuasion.

The remainder of this paper is structured as follows: Sections II and III describe the two main types of persuasive systems: The mobile device and the ambient infrastructure solutions, focusing on how the advantages of each computing environment are harvested. Section IV extends the properties of ambient persuasion by defining persuasion mobility. Section V provides an overview of technologies and standards that may be used to enable prototyping of mobility in ambient persuasion. In Section VI we conclude with a discussion of future work and draw conclusions.

II. PERSUASION WITH MOBILE DEVICES

Persuasive solutions using mobile devices have been generated targeting a wide range of different problems. In the area of health, the dangers of sedentary work, smoking, bad sleep habits, environmental hazards or psychological problems are among the problems targeted.

BeWell [5] is an application using sensors and mobile phones to enable users to measure their activity level and compare it with the level of friends.

txt2stop [6] is a smoking cessation support system that provides motivational SMS-messages and information to users intending to stop smoking. Messages are send to users for a month providing information as well as distraction.

UbiFit [7, p. 78] is an application geared to promote an active lifestyle. The system uses the internal sensors to infer data on the user's lifestyle and present them on the screen in a garden metaphor.

SoundOfTheCity [8], an environmental monitoring platform using the phones' microphone to measure the noise exposure for users, employs a notification strategy, prompting users to leave a loud area, when a dose threshold is reached.

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These systems show the persuasive power of mobile technology, consisting of a) the *constant connection* to service providers, either using SMS, the Internet or other wireless technologies; b) access to *sensors* that can gather data to infer high level *contextual data* to assess a users behavior; c) the possibility to use the phone to allow for *private access* to sensible information; and d) the *ability to reach* and thereby prompt or nudge the user at the right time.

However, mobile systems do not yet fulfill the promises of *kairos* entirely. The device itself does not truly offer permanent peripheral awareness as it resides mostly in the users' pocket. Handling the phone is not appropriate in all situations and the device itself is limited in the types of actuation it can provide.

III. PERSUASION IN AMBIENT ENVIRONMENTS

Spaces can be persuasive by their properties themselves based on the architecture and design of a space or building [9]. However, the persuasiveness of a space can be increased using ubiquitous computing technology.

In such environments, computer aided persuasion is achieved by amending the physical objects with capabilities that allow them to act in the service of persuasive systems.

Medical mirror [10] is a mirror that augments the reflection of the user with current health data gathered with sensors in the home environment, allowing the user to self monitor his or her health.

APStairs [11] is a project in which the authors have rigged a flight of stairs with sensors to detect the Bluetooth signature of those climbing up as well as an ambient display encouraging users to rather take the stairs then the elevator.

Breakaway [12] uses ambient actuators on a desk in offices to alert occupants when they work too long in a seated position. The project uses the actuator as a reflection of the user allowing for an assessment of one's actions at a glance.

Using physical objects at the location of the user provides advantages over the use of mobile devices. Actuators can enrich everyday objects like mirrors, which the user is accustomed to and knows how to utilize, or artifacts placed naturally into the environments to transmit information peripherally, utilizing a broader range of modalities and stimuli then available to the mobile device.

The medical mirrors and *APStairs* system show how contextual data from sensors placed in the environments can increase the persuasive effect. However, these projects work with a specifically designed hardware-platform and software-architecture, having complete control over the sensors and actuators that only exist in one place and only serve this purpose. In ambient intelligence scenarios, such static constructs will no longer be viable.

IV. PERSUASION MOBILITY

Ambient Intelligence contains, at its core, the idea of a smart environment that changes to accommodate users' needs and wishes when a person enters it. Technology enables environments to gather those needs, either by sensing or by retrieving them from the user's personal profiles and resources. Among a persons' needs may be the execution of systems that take persuasive actions in the environment.

Aarts et al. [4] argue that each ambient persuasive system is context-aware through the use of sensors, and is able to deliver persuasive content to the user. Concerning such delivery, Oinas-Kukkonen and Harjumaa [13] remark that successful persuasion is predicated on the information, that the system has deemed relevant, being presented to the attention of the persuadee (the one being persuaded) and being comprehended. Kaptein [14] extends these requirements by proposing *adaptive* persuasive systems as systems selecting appropriate strategies for the individual user based on estimated success, instead of using a pre-set persuasive strategy that is effective on average. These systems have three core requirements a) *Identification* of the persuadee; b) the technological ability to change *representations* of appeals and c) the ability to *measure* the success of the persuasive attempt.

However, when the person is leaving an adaptive, persuasive smart environment, the persuasive actions should leave with the user and their execution should continue in the next environment the user enters. This includes slow migration situations, where some of the current smart objects get out of reach and new ones appear. In such cases, while these sensors and actuators are properties of the space, the persuasion would be mobile.

Such dynamically instantiated mobile persuasion combines the advantages of persuasion using mobile devices (being where the person is) with the advantages of ubiquitous persuasive entities by allowing to combine the power of both personal and environmental sensors and actuators depending on properties like availability, security, privacy or modality. Only through such combination can *kairos* be truly claimed.

In such a scenario, the environment as traditionally defined by the physical space is replaced by the user environment. The *user environment* may be defined as the physical and virtual environment of the user, consisting, at any given time, of sensors that can sense the users actions and the users surroundings, and actuators that are able to evoke change perceivable to the user.

In the following, we will understand *persuasion mobility* as the act of persuasive software that is dynamically executing its appropriate strategies in the user environment utilizing available sensors and actors.

Persuasion mobility increases the potential persuasiveness of Ambient Intelligence by providing consistency of persuasion even if changes in the user environment occur. It allows for persuasive action to be taken independent of the availability of specific technology rather only based on the determination that a persuasive act is required. Combining this feature with the aforementioned properties of adaptability provides a powerful basis for ambient persuasion.

V. TOWARDS MOBILITY IN AMBIENT PERSUASION

We present a set of technologies and protocols from different fields that, in combination, may provide support to develop persuasive systems that leverage the power of persuasion mobility. In our proposed architecture, the control

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of the persuasive actions would lie solely on the personal mobile device, but the actuation is orchestrated in space.

A. Context Abstraction

We have developed *Ambient Dynamix* [15], an ambient intelligence framework for Android-phones that allows to connect dynamically to the ever evolving set of actuators and sensors in the user environment. Ambient Dynamix supports context generation, abstracting from the hardware to high-level contextual data that is provided to applications subscribing to it, independently of the source of data.

Ambient Dynamix approaches the challenge of the wide area of possible actors and sensors by providing a framework for plug-ins that enable communication with these physical or virtual entities. These plug-ins can be written by domain experts and provided during runtime to the users phone.

Using Ambient Dynamix, applications obtain independence of specific sensors by only subscribing to the high level context that may be generated from different sources as the user environment evolves. Similarly, actions in space can be induced via abstract commands executed dynamically on available actuators. With these capabilities, Ambient Dynamix provides the necessary hardware abstraction to allow a persuasive system to execute its persuasive actions independent of specific devices. Instantiating the actions manually for every possible environment would be inconceivable considering the heterogeneity of smart environment technology.

B. Identification

Moving persuasive actions with the user is only possible, if the controlling entity of the smart environment can identify the user. Kaptein [14] identified this as a condition for adaptive persuasive systems, allowing the system to adapt its means and strategies according to the person. In mobile persuasion, identification is a prerequisite to gain an understanding of the user environment. Proposals for such identification have been made, ranging from RFID or Bluetooth-keys to face recognition or fingerprinting [14, p. 103].

We propose that such identification can be inherently achieved by moving the controlling intelligence into the personal mobile device of the user. Since such a mobile device is inherently personal and usually co-located with the user the persuasive systems run on it can personalize their actions for the specific user in the environment.

C. Device Discovery

Using the mobile device as the central control system for ambient persuasive systems with Ambient Dynamix as the context-abstraction layer it becomes necessary for the mobile device to discover available hardware ad-hoc. The mobile device connects to the ambient devices using different (mostly wireless) standards, such as RFC3927 [16], SLP [17], UPnP [18] and others which allow for discovery and the establishment of services.

Smart phones implement a host of wireless services that can be used to communicate to sensors and actors.

D. Device Capabilities

Current standards for device discovery, like the aforementioned UPnP, offer mechanisms for self descriptions, however, the currently used device profiles lack in information concerning stimulus modality and other actuation features relevant to persuasion. UPnP-profiles have been adapted for the use in different smart environments, indicating that the standard can be used in such a way [19]. When proposing to perform an action with an ambient actuator, Ambient Dynamix has to be made aware of the capabilities of the devices it connects to. Only with such knowledge can it choose the right actuator given an abstract action description. Conceptual structure for ambient actuators as well as the logic of binding actuators to an action have been proposed in the literature [20].

E. Unobtrusive Transfer of Device

When the user environment is evolving, it may become necessary to transfer an ongoing action from one actuator to another since the user has moved out of the scope and can no longer perceive the action. Mobile persuasion requires such transfer of device to happen unobtrusively, without the user intervening. Similarly, the sensors used to produce a relevant context may change.

By orchestrating the persuasive environment from the personal mobile device, this central controlling instance can discover new available local sensors and actuators on the go. Potentially, given a description of the action to be taken, the controlling instance could choose an appropriate actuator as soon as it is found, transparent to the application. This may include the transfer between stimulus modalities, switching, for example, from auditive to visual action if more appropriate.

El-Khatib at al. [21] describe such an architecture for service mobility, using background services on a mobile device to discover available Bluetooth-devices and execute actions on them, handing off services to new devices if needed. In multimedia presentation, the Session Initiation Protocol (SIP) [22] can be used to provide support for session mobility, switching between devices mid-session [23].

F. Coordination of Actuation

According to [24] combining several modalities can enhance the understanding of the message. Since comprehension is one of the key factors in persuasion according to [13], such combination would increase the persuasive effect. Multimodal execution has been discussed in [25]. It requires the coordination of distributed actors in space, which is currently neither supported by Ambient Dynamix nor by the actors.

The heterogeneity of environments means that synchronization between actuators cannot be ensured on the device level. Such coordination must then be, as far as this is possible in distributed systems, be supported by the controller on the mobile device.

G. Measurement of Success

Kraft et al. [26] argue that the “structure of digital health interventions should reflect the psychological chronology of the change process”. Such can be said for all persuasive

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technology as the interactions of the system with the persuadee must track the progress made towards the set goal.

Potentially, an additional middle-layer on the controlling device could offer support to ambient persuasive systems by allowing them to define trigger-context specification (in which the persuasive system would be alerted to act) and goal-context specifications (which could be used to estimate the success of the action taken after the trigger-event).

VI. CONCLUSION AND FUTURE WORK

The future discussion on mobility in ambient persuasion must also include the social sciences, tasked with the question how, with the regard to the way a medium shapes a message, different circumstances and environments impact the persuasiveness of any action. Additionally, only psychological research can validate the approach of mobile persuasion.

By providing architectural and systematic support for mobility in ambient persuasion at the device and the middle-ware level, we hope to enable prototyping of systems that can dynamically call upon mobile ambient persuasive means. In this work, by analyzing the advantages of persuasive systems using mobile devices and persuasive systems using the environment, we have defined the parameters of such means and propose a set of technologies which may enable them.

In the long term we hope to tackle the more general question of cross-application persuasion support for persuasive systems on mobile devices. With advances in the development in ambient persuasive systems, system-properties and system requirements due to the persuasive intent of the designer will arise. Providing an additional layer of mobile middle-ware purely aimed at the support of those demands, may enhance rapid prototyping and enable designers to focus more on the persuasive strategy and less on specific implementations.

Ideally, persuasive strategies can be handed as mobile services to the persuasion middle-ware that executes them according to the user's needs and available actuators .

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