Constructing assemblies in the health care domain: two case studies

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Abstract. This paper describes an early design study in which the concept of assembly has been adopted to interpret the composition on the fly of digital services and devices in mobile settings. Two case studies for the health care domain (i.e. physical and cognitive rehabilitation and work practice at the Neonatal Intensive Care Unit) will be presented in order to exemplify the proposed concepts.

Keywords: assembly, end user composition, user control

1 Introduction

The notion of ambient computing has been consolidating focusing on the design of distributed, pervasive and reactive systems able to communicate with the users and to continuously adapt to their needs and expectations. On the other hand the users must always remain in control of the system and preserve a solid understandability of the processes [1]. Balancing transparency and automation with awareness and control is one the main goal of PalCom (PalCom, http://www.ist-palcom.org), a European project that aim at developing an innovative design approach called Palpable Computing. Palpable computing aims at supporting user control by composing and de-composing assemblies of devices and services. Within the software architecture the assembly is a first-class object, a set of coordinated services and a construction that developers may directly use to construct their program, e.g., through a set of specific classes in an OO framework [10]. The assembly is designed as a 'service' itself that had the responsibility of coordinating other services. In this context a 'service' is a functionality (running in a process) that announces itself on the network and that can be accessed through messages to another process [1].

Components as services put in an assembly become interactive units able to communicate each other and to exchange data. This creates technical challenges since assemblies are re-created over time among devices [3], [4]. The assemblies are configurable by the user depending on the context of use.

In this paper we concentrate on two exemplar applications based upon the Palpable computing paradigm; 1)'Active Surfaces' for cognitive and physical rehabilitation [3], [4], [5] and 2)'biosensors assemblies' applied at the Neonatal Intensive Care Unit

(NICU) [6]. These are two examples of applications under development within the PalCom project for the health care domain. Both the application prototypes have been developing in collaboration with the Aarhus School of Architecture, the University of Aarhus and the Lund University.

2 Case Study 1: Active Surfaces

Active Surfaces is thought of as mobile and distributed system of devices that can serve for mobile gaming and rehabilitation activities in water. The swimming pool itself represents a privileged environment for rehabilitation, the water supports the body and takes the weight off the joints and movements within the water are easier and less painful and Active Surfaces constitute a powerful tool for the therapists to engage the patients and guide the exercises.

Active Surfaces is conceived as a number of tile-components acting as building blocks that can be combined with a library of content (e.g. images, sounds and pictures). Two kinds of tiles are now implemented in the system: the Assembler Tile (AT) and the normal play tiles. ‘One’ Active Surface consists of a tile, measuring 30*30 cm. Each Active Surface is thought of as a modular unit that can communicate with the others by its six sides [3].

The tiles are able to recognize their relative positions in respect to other tiles. A number of tile components can be assembled to constitute a network of physical (and software) objects that communicate and exchange data. Each configuration of tiles is thus intended as an assembly of components. Today a prototype is being used for evaluation purposes based upon a Basic Stamp 2 micro controller and IR communication [3].

The therapists can configure these assemblies of components to define rehabilitation tasks. To support the user configuration of the assembly the Migrating User interface (MUI), developed within the PalCom project [7] is used to create general input/output schemas for different games. They can save successful configurations, keep memories of previous configurations and generate new assemblies to support patients’ specific needs. The rehabilitation activities enabled by the active surfaces allow a smooth integration of cognitive and physical task.

In the scenario below the Tiles’ states are described through the use of a “happiness” state. These terms are used with specific meanings in the scenario and in the code development. We consider different states of happiness (conditions’ satisfaction) for the position and orientation of the tiles in the assembly [4], [5].

- *SideHappiness* means that a tile realizes that it is correctly connected on a particular side. On the side(s) that are Happy the tile provide the users with HappySide feedback.

- *LocalHappiness* means the tile is properly connected to the others and it has on each side the tiles it was looking for. It is in the right position and it is correctly orientated in the assembly

- *AllHappiness* means all the tiles satisfy the *LocalHappiness* and, knowing that all the others are sending that feedback, they realize a global happiness, satisfaction of the activity game.

The configuration of the activity is performed outside the pool, maybe even at the home of the therapist/trainer or in a remote office. This can also be done in the vicinity of the pool, but there is no specific need for that from a system perspective. The therapist brings the assembler tile, attach it to the MUI browser and configure the future activity by setting configurable game parameters (e.g. Type of Game: Position game, Output Mode: Blinking Light).

The therapist can now bring the AT to the poolside and align the play-kind of tiles she would like to include in the game in the 'winning' position or pattern. Now the AT is connected to the structure of tiles and this initiates a number of activities. The therapist triggers the motion sensor on the AT with a 'one touch'-input. This sends a broadcast message to the connected tiles to remember their own and their neighbour's positions. After executing this command all the tiles have memorized their own and their neighbor's position and orientation. They also notify the therapist that the configuration and assembly of the game is successful completed through the requested winning output (since the tiles now are in the *AllHappy* state).

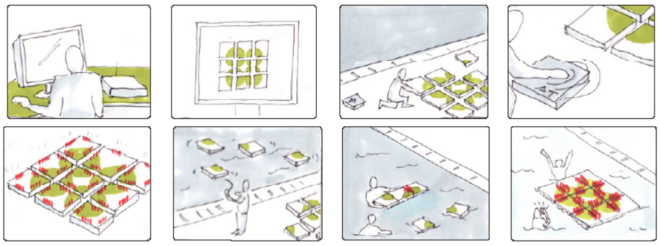

Fig.1 Scenario storyboard

The therapist is now ready to start the activity with the patient and throws the tiles into the pool. The child tries different wrong alternatives by moving the tiles around the pool. At first the child puts two tiles aligned correctly, but still not with the complete solution presented. This gives a local feedback that the two tiles are correctly placed while the final feedback is still not given. This *LocallyHappy*, or even only *HappySide* provides the user with a (for example) light output, isolated to the correctly aligned side(s). The child finally aligns all the tiles in the right position. This gives the final winning output. The game is solved.

3 Case Study 2: User composition of assemblies at Neonatal Intensive Care Unit

The fragility of the NICU application domain requires specific consideration when introducing mobile technologies. Indeed the health conditions of the babies and the delicate work of medical staff, often dealing with emergencies, necessitates a level of accuracy in order to preserve the safety standard of this environment. The NICU is characterized by: (1) a high level of re-configurability, i.e. each incubator should be conceived as an ad hoc entity, tailored on the baby's conditions and dynamically changing over time. (2) The work practice is based on the continuous combination and integration of data coming from different sources. (3) Different actors have different access to the incubator depending on their role: this implying a different access to the information to be displayed. (4) This setting should support co-existence of emergence situations as well as daily care [8].

The design of a mobile system to be implemented in the standard incubator is in its early phases of prototyping. The software development is currently ongoing to prototype an initial version of system. The prototype under development integrates the following components:

Biomonitors: the system monitors biomedical signals from premature newborns by use of wireless biomonitors [9]. The biomonitor collects biomedical signals from the baby's body when placed on the newborn.

Bio-sensors: different bio-sensors can be used in the prototype. The ECG is available, while CO2, SpO2, and temperature are under development. Each biosensor is connected to an Atmel 8L microcontroller that has been Bluetooth enabled. This allows each bio-sensor to communicate with a host without wires [9].

Access point: a BlueGiga Bluetooth base-station running the platform acts as an access point or bridge between a number of Bio-sensors and a larger network [9]. If a base-station is within range a biomonitor will automatically connect to it. On the other hand if no base-station exists or it fails then it is possible to communicate directly with a biomonitor from e.g. a mobile phone or a PDA [9].

Network: the Access point is connected to a LAN enabling not only monitoring of bio-values but also the possibility to further transmit data (e.g. to other wards within the hospital) when explicitly needed.

Mattress: A special mattress for a preterm child to rest upon inside the incubator has been developed. It measures (in a grid) pressure points and can move (raise/lower) parts of itself upon request. A number of pressure sensors are placed in a pattern inside the mattress which detect and communicate what is the pressure on each unique point on the mattress surface. Depending on the data detected by the sensors, the mattress reconfigures itself to prevent postural problems and pressure sores. The mattress's design also allows for remote manipulation and can provide the baby with a small, slight but continuous stimulation, similar to the one in the mother's uterus.

Web-cam: A normal web-cam is used to provide visual feedback and together with bio-sensor data as a medical aid system.

Assembly: The different components of the incubator can be assembled or de-assembled according to current needs [1]. Different assemblies can co-exists in parallel, e.g. having different assemblies of biosensors depending on the situation.

MUI browser: A Migrating User Interface (MUI) is used for allowing end-user composition of services and devices [7]. The MUI allows the medical staff to discover the services and devices available, to access and monitor data as well as to create, manipulate and visualize assemblies during the everyday care activity.

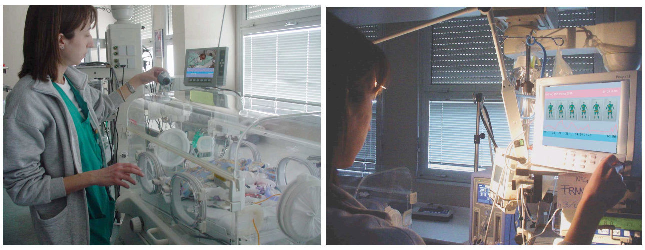

Fig.2 : Physical assembly of services and devices.

The concept of the described incubator is conceived as an assembly of services and devices [6]. The possibility to use diverse components to support the necessary tasks allows the configuration of both devices and functionalities depending on the babies' conditions: for example different biosensors can be combined by the neonatologist in order to monitor parameters but also to get a richer or more complete view of the situation that is at present difficult to reach (e.g. by combining EEG + Video recording to monitor the central nervous system development) [6]. As it has emerged along the assessment activities carried out till now in the NICU, configuring the assemblies at- hand is a major strength in PalCom [3]. The different elements of the incubator (e.g. the dome, the mattress, the biosensors and the modules containing the different machineries), can be easily added, removed and combined on-the-fly to support the diverse care objectives.

4 Discussion

The PalCom paradigm purposely addresses the way in which humans meaningfully interact with distributed computational systems available in the environment. The "Palpability" can be described as an emergent property-in-use in both the tiles' and the biosensors' assemblies. Both the presented case studies present characteristics of high level of (re-)configurability and adaptation, user control, composition and handling of devices and services.

PalCom assemblies have to guarantee understandability to the users while handling devices and services. Tiles and biosensors assemblies create flexible ad-hoc networks connecting the single devices where each unit preserves its own identity and dynamically seek for available ones in the vicinity. A key characteristic of this notion of assembly is the possibility to integrate different kind of devices by dynamics of physical construction on-the-fly. By mean of automatic recognition and communication the end-users can flexibly adapt the assembly to the context by introducing new devices. These components continuously inspect what communication processes are taking place at the moment looking for specific connection.

The possibility to manage dynamic assemblies in the described settings raises issues of flexibility and robustness in assemblies' networks. Ad-hoc networks are constituted in order to cope with both the changing conditions of the rehabilitation setting and the NICU safety critical setting and emergencies. They provide the professionals with the proper support for their work practice.

The presented applications are still under development but have triggered the need to explore the properties mentioned here above in order to investigate them better as valuable concepts in Palpable Computing paradigm. However, the impact of these properties ought to expand outside the PalCom framework into a more generic ubiquitous computing setting and for pervasive technologies design.

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