Prerequisites of Autonomous Software Operations in Home UbiHealth Described Formally with Denotational Mathematics

John Sarivougioukas, Gen. Hospital “G. Gennimatas”, Athens, Greece
Aristides Vagelatos, Ministry of Education, CTI&P, Athens, Greece
Isaac Lagaris, Department of CS & Engineering, University of Ioannina, Ioannina, Greece

ABSTRACT

In the home ubiquitous computing (UbiComp) environment the wirelessly and ad-hoc networked computing devices are connected with sensors and actuators monitoring, recording, and intervening in the performed activities. The unattended applications operating at this environment must be fault tolerant and redundant. However, the lack of standardization and the uncontrolled evolvement of the developed situations at home result in a hostile environment for computer applications. Also, the need to support the individual’s mobility at home increases further the level of difficulty of the associated computing efforts. The individual’s mobility is supported providing computing services which can migrate from the currently running device to the neighboring one in order to follow every inhabitant’s disposition. Migration presupposes the selection of adequate policies supported by the suitable software infrastructure to exploit the conceptual implementation of polymorphism that allows the preservation of functionality while autonomously transferred to another computing device. This paper provides a formal description with Denotational Mathematics of the operational prerequisites of such an autonomous system that achieves the migration of applications for the continuous support of the individual’s mobility. The infrastructure must be capable of enforcing strategies and policies related to migration either by transporting the supporting applications or by referencing them. The achievement of the provision of healthcare at the UbiComp home presupposes the continuous support of the individual’s mobility.

KEYWORDS

Denotational Mathematics, Homecare, UbiComp, Ubiquitous Computing

INTRODUCTION

Ubiquitous computing (UbiComp) refers to Mark Weiser’s vision (1991) about the computers’ dissemination into every fabric and thus indistinguishable from the physical environment and at the same time interacting in a natural manner, the way someone is using the eyeglasses. In such computing environments, each computing device is assigned a data structure, a conceptual construct called Active Space (AS) (Ranganathan, Chetan & Cambell, 2014), that contains the set of all variables and parameters with which each computer performs its operation and follows its interaction with other devices. The application of the UbiComp conceptual framework over healthcare generates the descriptive technical term UbiHealth. The application of the UbiHealth framework at the residential environment is referred by the term Home UbiHealth and it is employed to promote the inhabitants’ health status. The individuals’ health promotion within the Home UbiHealth framework takes
advantage of the ubiquitous computing characteristics: the accomplishments in nanotechnology, the engineering achievements in sensors and actuators technology, and the advances in medicine by being adapted in the residential unstructured environment.

Within the Home UbiHealth framework, the individuals’ health status is supported by software applications allowing them to be medically treated while enjoying the domestic comfort. The raised issues and challenges for the design, implementation, and maintenance of the supporting software applications are related, among others, with the individuals’ mobility. In other words, the individual should be able to move within the house without any concern about the type of the supporting device or the kind of the software application. The supporting software applications migrate from device to device (both code and data too), as the individual is moving within the residential space. Hence, a software framework is required to support migration which allows the properly designed software applications to be transferred and continue transparently supporting the individual. The adequately designed software applications must satisfy specific prerequisites allowing the adaptation (Scheuermann, 2009) of the software applications by achieving semantic equivalency between the departing and the arriving devices as the individual is moving freely in the area of the house. The software applications must fit into the destination device’s context (Rizwan Jameel Qureshi & Sabir, 2013) and they must be proactively aware about the possibility to migrate at a neighboring device. Decomposition and adaptation of the content and the structure of the migrating software application precedes re-composition with any additional components (Ranganathan, Chetan & Cambell, 2014), preserving the initial behavior and functionality.

The existing limited standardization in the Home UbiHealth framework reveals the need to define the design prerequisites and requirements. The design characteristics demand for a sound and complete formal description which can be accomplished with Denotational Mathematics. The Home UbiHealth framework must support the freely movement of the individuals within the house promoting the concept of mobility. The present work discloses the demand for the conceptual adoption of autonomy and polymorphism in order to achieve the transparent support of user’s mobility in the Home UbiHealth environment.

The necessity for the formal description of the Home UbiHealth model stems from the complexity of the functionality of ubiquitous computing environment at the physical level. Each type of operation must be uniquely described in order to achieve the corresponding uniqueness in both meaning and interpretation too. The description must be intuitive providing simplicity in its presentation to communicate the involved ideas and principles without excluding of the influencing specifications. Formality is used to achieve effectively verifiable avoidance of contradictions without missing in expressiveness of the involved specifications from which can draw consequently the implementation framework, the owned attributes, and the behavioral properties of the described applications.

The presented model involves the execution of interrelated processes that can be formally described employing the functional composition and computational attributes of \(\lambda\)-calculus. Moreover, the required concurrency features of the presented Home UbiHealth model can be formally described by \(\pi\)-calculus based on the execution of concurrently executing processes communicating over dedicated channels. Thus, \(\lambda\)-calculus and \(\pi\)-calculus, among others, support the development of the formed class of formal systems of process calculi or process algebra that include the embodiment of particular peculiarities of the computing and programming paradigms.

The formalism provided by Denotational Mathematics can be employed to rigorously describe software infrastructures that can be used to facilitate the designer’s, the developer’s, and the end-user’s interactions with the home UbiHealth system. The aims of the designer focus on the validation of the designed model while the developer is concerned with the verification of the implemented model.
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