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A lightweight framework for transparent cross platform communication of controller data in ambient assisted living environments

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ABSTRACT

Elderly support ambient assisted living environments are focal in healthcare computing. Critical to their implementation is transparent integration of diverse hardware and its ubiquitous communication with multiple software components. Modern controllers (Wii family, Microsoft Kinect, Neurosky Mindwave) are especially useful in elderly smart homes, being used, for healthcare monitoring and exercise gaming interventions. Presented herein is a novel Controller Application Communication (CAC) framework for cross device, application independent transmission of controller data to multiple software components. For the first time, a framework supports multiple modern controllers concurrently communicating with multiple, device naïve, requesting applications, utilizing standard, real time, internet communication technologies, as opposed to current practices which focus merely on one device. The framework consists of uniform schemas for encapsulating controllers' data and of services necessary for communicating these data to the requesting software components. The framework's architecture is based on distributed computing principles, delegating server duties to use-site gateways for reducing main server load. This framework was utilized in the USEFIL project for simultaneous use of multiple controllers and sensors by different software components of the platform. The framework's design principles align with the Internet of Things (IoT) paradigm. Future work, enriching this framework, aims to facilitate a more diverse controller set, adhering to an IoT architecture implementation, as well as, allowing on-demand online data streaming, thereby enabling interested parties to test algorithms with data from ecologically valid environments.

1. Introduction

It is increasingly common for contemporary input devices to align with new paradigms of human everyday use of technology and the need for effortless execution of tasks in the realm of Human Computer Interaction. Devices like the Wii family of controllers (Wii Remote, Wii Balance Board), able to detect the users' movements [77] and the body's center of mass

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respectively [78], have been introduced in the last few years to support gaming activities. These device types support wireless connectivity providing the added benefit of use even when there are movement restrictions due to limited space [9,39]. Moreover, depth imaging devices such as Microsoft's Kinect [44] are considered suitable candidates for substituting or complementing traditional input methods for future applications and systems. With the release of powerful SDKs exploiting and enhancing Kinect-related information (by providing both image and body skeleton information), users are capable of controlling and interacting with applications and systems through natural postures/gestures, without touching a game controller. Novel ways of controlling presentations by natural gestures and voice [33,50,52] have increased Kinect's exploitability as an interfacing mean. Additionally, augmented reality commercial applications (e.g. a clothes fitting room with automatic size measurements [10]) and user interfaces, such as tiled display controls with natural hand gestures [70], have lead the Kinect sensor to receive widespread acceptance and become a trend for modern human computer interaction. To this extent, Kinect was proposed and utilized as a device facilitating interventions that improve the quality of life of people with health problems. From innovative one hand control for steering in cars, with immediate applicability to persons with disabilities [66], to facilitating Alzheimer patient care through gaming with intuitive and natural control schemes, the Kinect sensor has been also utilized in healthcare [41]. More exotic devices such as the Neurosky Mindwave, record and can translate into controller input, Electroencephalographic (EEG) data from a singular point that the device is recording [61,76]. These recordings can be quantitatively related to attention, or mental relaxation levels.

As was presented above, these devices have all been utilized as controllers and sensors on many cases for unconventional modalities of human computer interaction. However, their use in the field of elderly Smart Home or Ambient Assisted Living (AAL) environments presents unique technical challenges. A very definitive and specific challenge stems from the necessity of multiple sensors and devices to be seamlessly accessible from a multitude of diverse requesting application modules [27,69]. The aim of this work is to describe the architecture and implementation of a Controller Application Communication (CAC) framework that facilitates cross device integration of such controllers in a cross platform application environment. More specifically, the framework communicates through standard web technologies by fusing Kinect/Wii data in a standardized way to any requesting applications in order to support elderly people within their own AAL or smart home environment. It is the first time, to the author's knowledge, that a framework supports a number of modern controllers concurrently communicating with multiple, device naïve, requesting applications, utilizing standard, real time, internet communication technologies. Current similar works focus merely on one device, especially Kinect [38,53,62]. Additionally, we present herein the implementation scenarios for this software infrastructure in the context of improving elderly quality of life by means of an AAL environment that requires its functionality. Additionally, the proposed framework is developed adhering to an extensible architecture; it can easily support the addition of other controllers in its infrastructure. This work, also, gains more weight by the fact that this framework has already been validated in an elderly AAL environment and proved stable and robust in heavy realistic use. With these results at hand, possible directions of future work are explored such as the enriching of the service's capacities for streaming on demand the large amount of already collected data for optimizing and validating new approaches and algorithms. With that prospect, crucial for recording and inferring activities of daily living in elderly oriented smart homes, the evolution of this framework in the context of Ubiquitous computing are also discussed and explored.

2. Background literature

2.1. Contemporary controllers in elderly care interventions

As mentioned already, contemporary controllers have been accepted with quite a bit of enthusiasm in the field of elderly care. A large number of preventive and rehabilitation interventions have been implemented for exercise through computer gaming for elderly people (exergaming). A recent review [13] has identified several studies of interventions for improving balance in elderly. Control devices include inertial sensors, such as the Wii Remote controller, pressure sensors such as the Wii Balance Board, and camera systems, such as the Kinect sensor [60]. These controllers provide input for games that consist of hand to eye, or body coordination exercises. Gaming premises range from a simple arrow following by stepping to the right direction, shifting the body weight to guide objects towards on-screen targets, to full fledged dance simulators [13]. Even virtual reality has used the Kinect sensor as an input device in order to improve balance and reduce probability of falls in elderly [72].

Contemporary controllers such as the Kinect and the Wii Balance Board have been utilized in serious games for rehabilitation of stroke patients and elderly suffering from other disabilities [7,49]. A recent systematic review has identified at least 48 such relevant studies. Topics are diverse and include rehabilitation after cerebrovascular accidents, motor rehabilitation after age-related motor and balance impairment and elderly cognitive rehabilitation to augment functional cognition levels and overall operational capacity [58].

2.2. Elderly exercise gaming design considerations

Exergaming has become very popular in the last few years. As expected, research in this field is growing and several studies are currently exploring ways for optimal gaming design practice principles [17], as well as, optimal hardware design for