Leveraging Web Technologies to Expose Multiple Contemporary Controller Input in Smart TV Rich Internet Applications Utilized in Elderly Assisted Living Environments

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Abstract. This work describes a lightweight framework allowing internet applications to access controllers such as the Wii remote, Wii balance board and MS Kinect irrespective of proximity or configuration. This is achieved by utilizing predetermined schemas for encapsulating the controller information and transferring this data through standard internet communication technologies (RESTFUL services and Web Sockets) in platform independent, device naïve ways. These features of the framework provide Rich Internet Applications (RIAs) with ubiquitous access to sophisticated human computer interaction schemes for diverse uses. The proliferation of Smart TVs as central information hubs in elderly assisted living environments, along with the need for simple gesture control schemes for these demographics, provides one application of this framework. Thus, we demonstrate how this service can be incorporated for developing internet applications and how it can be utilized for providing intuitive interaction methods for RIAs deployed through Smart TVs in elderly assisted living environments.

Keywords: cross-device communication, smart home, elderly, ambient assisted living, ubiquitous communication technologies, exergaming serious gaming.

1 Introduction and Background

1.1 Introduction

It has become increasingly common for contemporary and novel input devices to find fertile ground with new tasks in the realm of Human Computer Interaction. Towards this end, depth imaging devices are considered as suitable candidates to substitute or complement traditional input methods for future applications and systems. With the introduction of Microsoft's Kinect depth imaging device and the release of powerful SDKs exploiting and enhancing its information (by providing both image and body skeleton information), users are enabled to control and interact with applications and

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systems through natural postures/gestures, without touching a game controller. Recent literature promotes the usage of such devices as a trend for modern designs [1–5].However, one of the promising approaches on utilizing gaming input devices for new interactive designs, before the Kinect sensor was introduced in the market, had been based on Nintendo Wii remote control and Wii BalanceBoard. The former corresponds to the users' movements (accelerations) while the latter utilizes the body's center of mass. Both of the devices support wireless connectivity. Consequently, they can be utilized when there are movement restrictions due to limited space [6, 7].

Even more exotic sensors-as-controllers have been developed in order to facilitate specialized needs in human machine interface. Interface devices like Neurosky's Mindwave device utilize direct electroencephalography signals (EEG) to assess brain function [8, 9] and, with custom software, infer cognitive and emotional states and utilize them in a multitude of ways.

1.2 Background

Beyond mainstream gaming, unconventional controllers like Wiimote, Wii balance board and the Kinect found use in the field of ubiquitous computing [10]. The advent of integrated sensors/controllers like the Kinect has enabled this contextual utilization of user input [11]. Fusing unconventional controllers and streaming their input to the web provides interesting applications potential such as gestural user interfaces for increased productivity in the management of tiled display [6].Furthermore, in the field of cross device applications, the enabling of the user through the seamless integration of several diverse control devices, dictates implicitly the use of natural, unconventional and unobtrusive control schemes and control devices [12–14].

Focusing on enabling applications of cross-platform cross-device, ubiquitous computing the Smart Home is one of the most promising. Smart homes aim to augment people's lives through technologies that provide increased functionality, communication and awareness [15]. In that context Smart TVs are aiming to become the epicenters of interaction in smart homes. For one, due to the TV sets long lived existence there has been developed a strong familiarity with people of any demographic. For example, it has been suggested that there is a link between technology and area ownership of the home [16]. On the other hand, Smart TV sets have been successfully used for controlling aspects of the Smart Home [17].

While Smart Homes are an impressive quality of life enhancer for people of any age, they take a significance boost when seen within the scope of assisted living, and specifically in the area of elderly assisted living and quality of life improvement. In this field, contemporary controllers/sensors find significant use. For example, Kinect has been proven effective in monitoring the stance of a senior in order to anticipate and prevent balance loss [18], or the Wii suite of controllers (Wiimote, Wii board) has been used for enabling elderly people to increase their physical activity levels by engaging in games that utilize these controllers and drive the users to increased physical and psychological wellbeing [19]. In fact, research explored the utility of cognitive and physical training through computer games and provided significant conclusions, with results providing specific guidelines for topics as diverse as depression or interaction between generations [20, 21]. This kind of research has even coined a portmanteau term exergaming (exercise gaming) to describe computer software that facilitates mental and physical training in a computer gaming environment [20, 21].

1.3 Rationale

Incentivized by the presented context we developed a lightweight framework (Controller Application Communication framework – CAC framework) that allows internet applications ubiquitous access to controllers such as the Wii remote, Wii balance board MS Kinect and Neurosky Mindwave. This is achieved by using predetermined schemas for encapsulating controller information and transferring the data through standard internet communication technologies in a cross platform, and device independent way. In this work we briefly describe this framework and present the first technical assessment results from a developer base that implemented it in a small demo application. Additionally, we present a demo use case scenario of implementing this framework in an exergaming application of an elderly assisted living environment.

2 Materials and Methods

2.1 Description of the CAC Framework

The CAC framework [22] has the role of an intermediary, in order to allow the connection of a series of controllers to all applications that use the framework and require sensor input. The CAC framework functions as a number of loosely coupled services that

1. Encapsulate the raw information from the device, in a predetermined, structured albeit custom way
2. Format all requests for sensor/controller data from the applications, in a uniform, framework aware, data schema and
3. Utilize ubiquitous internet communication technologies (Websockets and RESTful web services) to make possible the transmission of requests and data from and to applications running on a multitude of platforms and devices, through a distributed server structure (Fig. 1).

The CAC framework exposes structures and functionalities specific for every supported input device. The appropriately formatted information is pushed from the devices to the service. A processing component of the framework acquires information from the device and passes it to the server. This component is either an application that uses the devices' libraries (e.g. Microsoft Kinect SDK) and drivers or, when technology allows, the exposed functionalities of the sensor/controller itself as it would become available by emerging ubiquitous computing technologies. This information (for example, the RGB stream of the Kinect or the weight of a person on the Wii Balance Board) is then either polled by the applications or pushed by the service to the applications. It must be noted that applications which consume the framework's communicated data can be either conventional computer applications or embedded software in custom hardware such as Smart phones, Smart TV sets, tablets, or robotic devices; in general, any piece of software, or hardware that can facilitate internet communication.

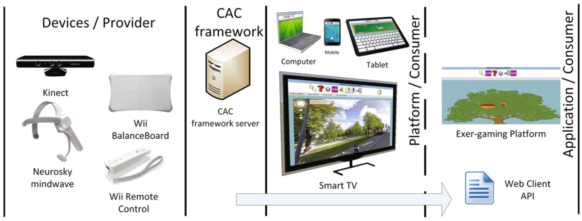

Fig. 1. Controller Application Communication (CAC) framework concept

Through the described provisions for custom but uniform across the framework encapsulation of controller data and application requests, as well as, with the use of the standard real time internet communication technologies, this framework facilitates device and platform independent communication between controller/sensor devices and relevant applications.

The next subsection presents the web client API that facilitates developers to incorporate the framework to web applications exploiting the usage of contemporary controllers.

2.2 CAC Framework's Web Client API

The CAC framework web client API (available information online at http://kedip16.med.auth.gr/cac-framework) brings contemporary input devices (e.g. Kinect, Wii, Mindwave) to modern web applications by utilizing the CAC framework in an easy to use way. The API isolates technological details (web sockets, restful calls) and gives the developers the capability to be more productive by allowing them to focus more on the exploitation of the controllers' information.

Table 1. Device object

Attributes	Description
DeviceID	The device hardware unique id
DeviceType	1:Skeleton
	2:Wiimote
	3:BalanceBoard
	4:Mindwave
	5:RgbColorImage
LastUpdateDateTime	The date and time of the last device capture
SessionID	The session ID the device belongs to.

The main data object delivered through the API is the Device Object which contains information regarding the device that streamed the data. Its attributes are depicted in Table 1. Depending on the device, the objects SkeletonSourceData, WiiSourceData, MindwaveSourceData and RGBVideoSourceData contain the transmitted information. The developer has access directly to those four structures. Each one of these structures apart from general attributes has its own information, coming from the nature of the sensory data that it captures.

The SkeletonSourceData contains an array of Skeletons. Each object of the array includes an array of Joints, corresponding positions and the TrackingState. The TrackingState represents the tracking status of an object according to Kinect (0: NotTracked, 1: PositionOnly, 2: Tracked). A skeleton with a tracking state of "position only" has information about the position of the user, but no details about the joints. The array of Joints contains 20 Joints each of them representing a Joint of the body. Each Joint implements a Position and a TrackingState.

The WiiSourceData contains AccelState (in case of wii remote controller) BalanceBoardState and ButtonState. The BalanceBoardState contains Weight in Kg, the CenterOfGravity (x and y axis) and the components of the weight at the 4 pressure sensors of the Balance Board (BottonLeft, BottomRight, TopLeft, TopRight). The ButtonState includes information of the buttons status being BalanceBoard or Wiimote.

The MindwaveSourceData contains the values of the processed EEG power spectrums (Alpha1, Alpha2, Beta1, Beta2, Delta, Gamma1, Gamma2, Theta), output of NeuroSky proprietary eSense meter for Attention, Meditation, and other future meters and signal quality analysis (can be used to detect poor contact and whether the device is off the head).

The RGBVideoSourceData contains the RGBVideo object which incorporates the width and height of the image and the base64String of the image data.

The consumption of the CAC framework through the API requires the developer to include the required javascript libraries, to define the unique session identifier [22] and to add the appropriate event listener to process the incoming packets. Table 2 implements the addEventListener for skeletonEvent, wiiEvent, while the MindwaveEvent and RGBVideoEvent can be used in the same way.

Table 2. CAC framework web client api example

```
document.addEventListener("skeletonEvent", function(e) {
    document.getElementById("y-position").value =
e.detail.SkeletonSourceData.Skeletons[0].Joints[0].Position.Y;
});

document.addEventListener("wiiEvent", function(e) {
    document.getElementById("weight").value =
e.detail.WiiSourceData.BalanceBoardState.WeightKg;
});
```

2.3 Evaluation of the Framework's Implementation API

In order to assess the technical feasibility and overall programming convenience of implementing this framework in realistic implementation scenarios, a user study was conducted. A demo web page was setup and a group of 17 programmers were asked to incorporate the framework client API into it. The participants had to include the required script files in order to read information from the devices and depict it through certain fields of the html page. The participants were provided with an API package of the framework in Javascript and its reference which contains descriptions of the API, its structures and short examples. The group of programmers needed to catch the data from a suite of controllers (MS Kinect, Wii Balance Board, Neurosky Mindwave) and populate the demo page with these data. The tasks that were to be implemented are summarized in Table 3. Fig. 2 demonstrates a developer's implementation with the demo page populated by the relevant data.

Table 3. Tasks to be implemented on the demo page by developers using the framework's javascript API

Task to be implemented	Relevant controller
Detect if User's hand is on the left or right of the User's center irrespective of height	MS Kinect
Display streaming RGB video	MS Kinect
Display the weight of the user	Wii Balance Board
Display the "Attention" [8] of the user (a measure of the User's attention level)	Neurosky Mindwave
Display the "Meditation" [8] of the user (a measure of the User's relaxation level)	Neurosky Mindwave

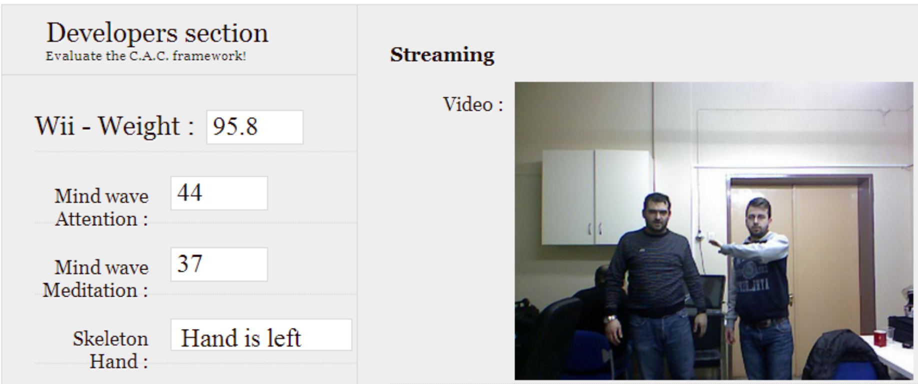

Fig. 2. The outcome web page after the completion of the task

After the implementation all developers were given a survey form to fill out in order to evaluate their experience with the API. Apart from a brief series of questions regarding programming experience and skills of this developer in different aspects of development, the survey explored the technical use specifications of the API (Ease of implementation, functionality, etc) and probed the developers for expressing their opinion regarding fields of application and some even more focused questions regarding the APIs potential as a facilitator of elderly assisted living control schemes. Apart from a couple of open ended probing questions all our questions contained responses rated on a five item Likert scale.

2.4 A Demo Use Case Scenario

Beyond the technical feasibility testing by the group of developers we have initiated, in the context of the USEFIL project [23], a demo use case in controlled lab environment in order to take away the look and feel of a real world application that would be empowered by the described framework. The aim of the USEFIL project is the creation of an unobtrusive elderly assisted living environment for both monitoring the elderly user's status and providing quality of life enhancers in the form of mental and physical exercise games. In that context the CAC framework was utilized for fusing the Wii and Kinect sensors in order to allow the elderly user to control and participate in several exergaming scenarios and for utilizing the Kinect as a monitoring sensor.

The demo use case that was tested thus far was a controlled experiment of an elderly user interacting with the exergaming suite repurposed into the USEFIL project through the Wii balance board and the MS Kinect sensor (Fig. 3). After the elderly user interacted with the demo platform a brief discussion took place where probing questions were asked regarding the user experience.

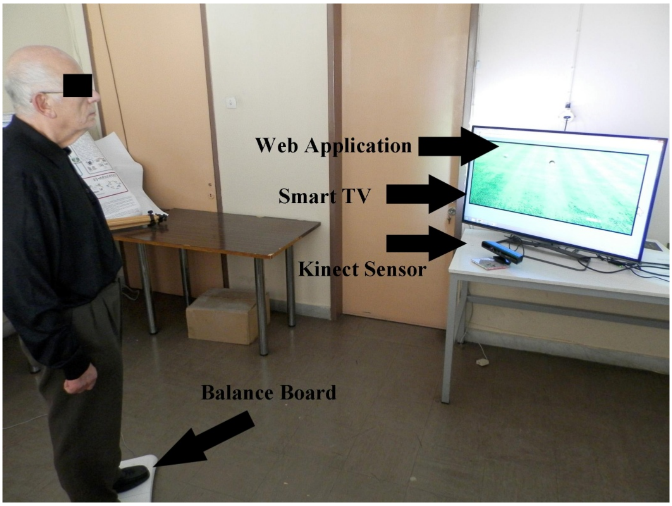

Fig. 3. Demo Use case of elderly exergaming scenario utilizing the CAC framework for fusing multiple controller data

3 Results

3.1 Developers' Survey

Most programmers who participated on this evaluation have reported good expertise regarding web technologies. On the other hand, they have on average little programming experience with sensing devices and programming apps for smart devices, such as SmartTVs and mobile devices. As it is presented in Fig. 4, none of the developers reported any difficulty in using the framework. The majority of the participants believe that the framework is functional and reliable, while most of them reported that they would adopt it within their applications. Furthermore, they believe that the CAC framework would provide added value to development on assisted living environments, while most of them think that the framework would enhance elderly accessibility to the web. The average time the developers spent to integrate the CAC framework was 13 minutes.

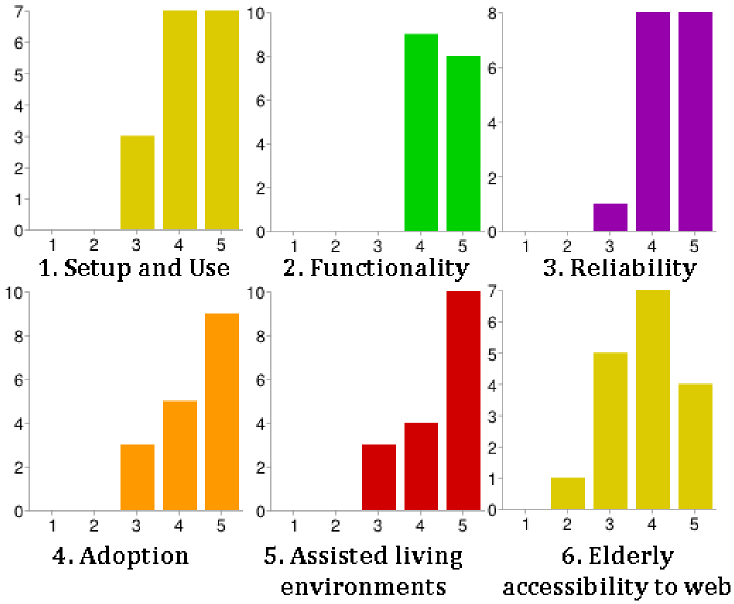

Fig. 4. Developers answers at the questions: 1. How would you rate the CAC framework regarding its setup and use?, 2. How would you rate the CAC framework regarding its functionality?, 3. How would you rate the CAC framework regarding its reliability?, 4. Would you adopt the framework within your applications?, 5. Do you believe that the CAC framework would provide added value to development on assisted living environments?, 6. Do you believe that the CAC framework would enhance elderly accessibility to the web? The x-axis represents Likert scale components (1-5), while the y-axis represents the count of programmers that specified the corresponding component.

When asked to spontaneously provide application fields for the CAC framework the participants of the survey mentioned exergames and physical training for elderly, but also went to more diverse fields such as map navigation, impaired people mouse substitute and monitoring applications.

3.2 Elder Users' Demo Use Case

When the elderly user was asked if the overall experience was a positive or a negative one he was enthusiastic that it was a positive one. When asked about the intuitiveness of the control interface the user mentioned that apart from a couple of glitches that led to the reset of the Wii balance board one time in order for it to work appropriately, the control scheme seemed to him very intuitive and non-intrusive. The user, however mentioned that the experience was a bit tiring, a fact that should be attributed at the battery of exergaming demo tests that he took. It should be noted that even though in the end he mentioned being tired, at the time of the experience, when asked if he would like to stop, he refused to do so. When finally the user was asked if he would consider such a control scheme to be useful for everyday use in an environment that would help him maintain a good level of quality of life, he was also enthusiastically positive.

4 Discussion and Conclusions

Our work was motivated from challenges that emerged in two fronts, namely in our exergaming development efforts and in our efforts for facilitating elderly assisted living in the context of the USEFIL project.

On the first front, it was necessary to utilize the Wiimote and Wii balance board controllers in order to engage and motivate the elderly users to exercise through gaming (exergaming) which proved to be an effective incentive for them to engage in physical and mental exercise thus extending their self-sufficiency and improving their mental and physical quality of life [7, 16, 17, 24]. Expert know-how has been invested into the conceptualization and design of a series of game applications within a specific methodological framework in order to apply effectively the results of research on physical and cognitive exercise through an electronic platform [20, 21].

On the second front, in order to infer an elder's cognitive state, a group of devices and algorithms should be fuzzed with the vast majority of the algorithms utilizing the Kinect (transferring, dressing), but also using the Wii suite of controllers, as a way of interaction with a smart TV set, which is the User Interface hub for the training applications, as well as a natural centerpoint for an assisted living environment [25].

From the results of the survey group it becomes clear that the described framework is an easy to use effective tool for fusing and streaming multiple controller/sensor input through the web. This can enhance further Rich Internet Applications (RIAs) with intuitive control schemes. While this provision is a nice interface enhancement in a general context, it takes a whole new importance in the area of elderly assisted living. It is noteworthy that even from this very controlled demo use case that was implemented with even a single elderly user the feedback was strongly positive.

While this work has largely fulfilled its purpose there is significant room for further work. With the advent of the emerging Internet of Things architectural paradigm [26], the switch from standard but ad hoc data formats to established namespaces becomes something far more than a novel improvement. Facilitating the transparent and ubiquitous interplay of devices and applications through frameworks and services like the one described here, becomes an important and viable avenue of research.

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