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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 use in elderly exergaming. On the hardware front, the Wii Remote, Wii Nunchuck, Wii Balance Board and Kinect vie for the crown of optimal exergaming controller using existing commercial full body control games [18].

On the software front there are several studies with interesting results. In [21] a gardening game in which elderly users are utilizing gesture control, detected through the Kinect sensor is used as a case for exploring overall design principles for elderly exergaming. Results include the need for additional motivation to elderly users and the need for natural gesture use for common tasks in order to reduce training overhead to the elderly. In [1], by exploring the Wii family of controllers (Wii Remote and Wii Balance Board), an assessment is made of the responsiveness of the elderly to the games as motivators for engagement in physical activity. Results demonstrate that the engagement in fun activities make the elderly people overcome the boundaries that they perceived themselves to be limited by. Multiplayer mode for these games was also a factor of motivating the users to continue through the exercise gaming sessions.

In [22], a virtual walk in the country with mini games of hand to eye coordination and balance control utilized the Wii Remote and Wii Balance Board controller in order to assess the design needs of assistive games for elderly frail people in nursing homes. From this study, special game design requirements for this specific group of users were explored. Results include the need for catering to the elder's special needs, for example avoiding the use of small buttons in game controllers, or compensating for movement impairments when utilizing full body controllers.

2.3. Elderly healthcare monitoring: sensors and robotics

Beyond interventions, contemporary controllers such as the Kinect are utilized as sensors for healthcare monitoring. This device has been used as a healthcare monitoring device in order to assess probability of fall of elderly persons using gait and posture analysis [56,34]. The Nintendo Wii Balance Board was able to detect changes in posture and swaying as the user performed visual tasks, thereby proving that it can be used as a healthcare monitoring tool for assessment of standing balance in large scale screenings [32]. The Neurosky Mindwave probe has been documented to detect significant changes in the EEG pattern before a fall as early as 3 s, thus providing an invaluable predictive tool that can allow for timely interventions in order to prevent upcoming falls [75].

In the field of the, once futuristic, Robotics, camera sensors have been used for facial recognition to enhance human computer interaction [35]. Moreover, a robotic device has been proven to be able to successfully track the movement of a human even in complicated patterns such as zig zag movements using as a sensor the Kinect [40]. Thus, a robot, in conjunction with the Kinect sensor, was used as coach for elderly users in their home [15]. The robot has been trained by experts on the relevant moves of each exercise and instructions have been recorded. The robotic coach was then used to teach and supervise the elderly users in their home on the correct and prompt execution of their exercise routines with encouraging results [24]. Additionally, a robotic assistant for tracking elderly people in risk of getting lost has also been developed. The robot used the ZigBee sensor device in order to uniquely identify the user that it is tracking. The elderly user's position was tracked through the Microsoft Kinect sensor, with testing providing optimistic results for elderly user tracking and prevention of accidental loss of orientation [28].

2.4. Cross platform sensor integration and ubiquitous computing

Beyond mainstream gaming, which was their initial core market, unconventional controllers like Wiimote, Wii Balance Board and the Kinect also found use in the field of ubiquitous computing. The mantra on this field from the inception of the term [73] was the disappearance of the medium and the transparent aggregation of user input and contextual information through unobtrusive, invisible and ever pervasive hardware. With the advent of standard web technologies, research in ever present, ubiquitous devices has explored ways for these devices to tap into relevant services and transparently provide added value to users [2]. Even in the field of robotics, technologies providing transparent access between robot sensors and users have been explored [26]. In fact, the pervasiveness of ubiquitous computing is such that simulation based validation methods have been explored for applications where realistic testing is not feasible [64]. The advent of integrated sensors/controllers like the Kinect has enabled this contextual utilization of user input, for example through recording and analyzing the posture of a human body and inferring from it significant information about a person's emotional state [68]. However, much less hardware overhead is currently required than in the past. Multitudes of cameras and other sensors presented unprecedented challenges for tasks as simple as monitoring passengers in airplane seats [63]. In fact, in situations where there was need for complex monitoring such as in the eve of formulating AAL environments there was a need for architectural provisions in order to cater to the sensors infrastructure that would be needed [37]. Recent literature findings reveal that the fusion of these unconventional controllers, as well as, attempts of streaming their input to the web, present research interest due to their applications potential. For example, fusion of the Wii suite of controllers with the Kinect 3D sensor facilitates transparent, gestural user interfaces for increased productivity in the management of tiled display [39]. The fusion of these two families of unconventional controllers has been tested for enabling user interaction in 3D applications like Bing maps in order to provide a more tactile and intuitive way to immerse the user in a 3D experience [19].

Streaming of controller input through the web has been also an interesting topic, prompting research from Microsoft itself, the creators of Kinect. The result was the creation of a toolkit that allows web developers to stream gestural and voice input to web based applications [38]. However, besides this official support, interest was significant enough to trigger research into the creation of tools that would allow compression, transmission and sharing of Kinect data through the web [62]. Current research also provisioned for messaging exchange along with Kinect streamed data [53].

2.5. Cross device applications

Moving beyond a single platform and into the field of cross device application design, migrating UI components across brands, devices and platforms is the norm rather than the exception. The tenet of existence for these applications is the enabling of the user through the seamless integration of several diverse devices into her or his workflow according to need. This necessitates implicitly, the use of natural, unconventional and unobtrusive control schemes and control devices [54]. It is interesting to note that a significant part of research in the field of cross device applications is aimed towards optimizing models, frameworks and tools for cross platform user interfaces. In fact, from the topmost, conceptual level, research has laid down a logical framework for systematically identifying the conceptual dimensions of architectural design of multi device user interfaces [57]. Based on similar conceptual principles a modeling approach for designing and developing multi-platform distributed user interfaces was described [43]. Entering the purview of implementation, there is work on formulating an infrastructure for enabling the streamlined development of applications that provide a uniform user experience across different deployment platforms (tablet, mobile phone, PC) [59]. On the purely implementation level, significant work (in fact proceeding, as is natural, the conceptualization of the design principles of multi device User Interface) provides a concrete toolkit, utilized in the implementation of specific multi device software as proof of application cases [42].

It is interesting to note that, even in light of such a vertical (from concept to implementation) research work in this field, the advent of the Kinect sensor provided such an intuitive tool for its utilization in the context of cross-platform applications that its integration in their design philosophy is described as an architectural advantage even without solid usefulness testing in the scope of these applications [54].

2.6. Previous experience – motivation

It is the experience of the authors' team in the fields of exergaming and unobtrusive assisted living that became the incentive for this work. On one front, through the Long Lasting Memories (LLM) [5,23] project, our work is based in the utilization of the Wiimote and Wii Balance Board controllers in order to engage and motivate the elderly users to exercise through gaming. Through the LLM project this team has developed an exergaming platform consisting of a modular web service architecture that can cater to a number of different situations of elderly people engaging to cognitive and physical training [6]. This provided the main incentive for utilizing the Wii Balance Board and Wii Remote controller for these exergaming platforms [9] and exploring ways of integrating them in future developments.

On the second front, incentive for this work is based on the challenges that needed to be overcome in order to facilitate the goals of the USEFIL project of developing unobtrusive smart environments for elderly assisted living [51,79]. Specifically, in a part of this project, a group of devices and algorithms have to be fused in order to infer the senior's emotional cognitive status. Although the vast majority of the algorithms utilize the Kinect (transferring, dressing), the Wiimote is also used as a way of interaction with a smart TV set which is the UI hub for the training applications of the platform and which should be intuitively and transparently accessible by elderly peoples [11]. Furthermore, the dual utility of the Kinect sensor both as an exergaming controller and as a sensor in the AAL environment necessitated a solution for integrating and routing simultaneous access to these devices from different applications, in a device transparent and application naïve way.

3. Materials and methods

3.1. Controller Application Communication (CAC) framework description

The CAC framework functions as an intermediary, facilitating the connection of a series of controller devices to any applications requesting their input. Our framework functions as a number of loosely coupled services that (a) encapsulate the raw device information, in a custom structured way (b) formulate all application requests for controller data, in a uniform, framework aware, format and (c) utilize ubiquitous internet communication technologies to facilitate the routing and transmission of requests and data to applications running on a multitude of devices, through a distributed server structure (Fig. 1).

Developed as lightweight, extensible and transparent, this framework exposes structures and functionalities specific for every supported input device. Structured information is pushed from the devices to the service. A processing unit is responsible for acquiring information from the device and communicating it to the server. This processing unit is either an application that utilizes the devices libraries (e.g. Microsoft Kinect SDK) and drivers or, when technology makes it possible, the exposed functionalities of the device itself as it would be made available by emerging ubiquitous computing technologies. This information (for example, the Kinect skeleton data and/or the balance of senior person on a Wii Balance Board) is then polled by the applications or pushed by the service to the applications. It must be noted that applications that would consume the framework's communicated data can be either conventional computer applications or embedded software in custom hardware such as Smart TV sets, tablets, Smart phones or robotic devices and in general, any piece of software or hardware that can communicate over internet technologies.

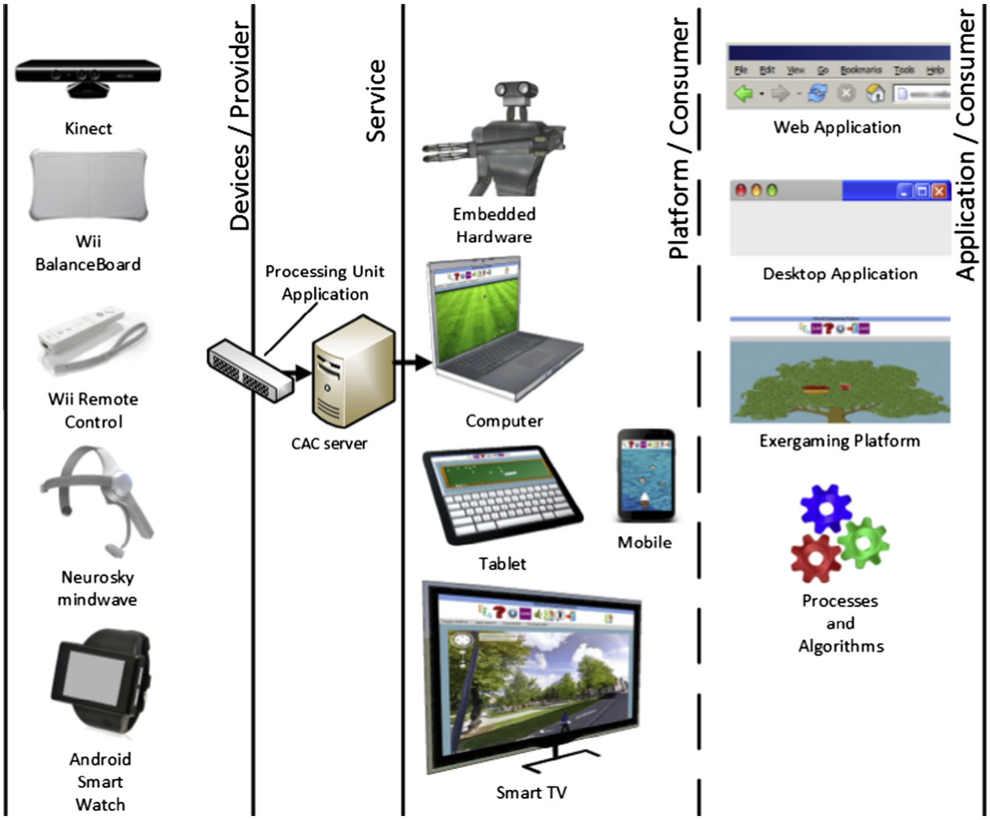

Fig. 1. Controller Application Communication framework (CAC framework) overview.

The framework follows distributed processing principles in its implementation. Its server structure (Fig. 2) consists of a dynamic network of cloud proxies for negotiating and streaming the devices' information, leveraging the optimal usage of network resources by bringing, transparently, to requesting applications an open and standardized network infrastructure customized for input controller devices including but not limited to Kinect, wii motion controllers, neuro-feedback devices, Android mobile devices, etc. The CAC framework server is the coordinator for all devices, applications and distributed servers. Every client (device or application) has to initiate its communication with the server in order to register itself. The server keeps a registry of all these clients and redirects devices and applications to any distributed registered CAC server. Distributed registered servers may be instantiated at the sensors' physical site in order to help reduce network load.

Through the provision for custom but standardized encapsulation of application requests and controller data, as well as the utilization of the standard real time communication technologies over the internet, this framework facilitates device and platform independent communication between controllers and applications.

3.2. Architecture and functionality

The outline of the framework's architecture along with the functionality of each layer, is presented in Fig. 3. Our framework functions by a number of loosely coupled services and schemas on the (a) client of the controller's gateway, (b) on an in-between distributed communication server, and (c) on the client of the application's platform.

On the controller gateway's layer, the client captures the data from the relevant input device. Subsequently, each temporal instantiation of the captured data (each data frame) is processed and the device information is exported. The framework's implementation assigns then relevant identification information to each data frame, consisting of public and internal (LAN) device IP, as well as the device and session ID. The implementation of the framework on the client of the device gateway then proceeds to formulate a structured packet for each data frame according to a predefined schema unique for each supported device. The relevant information is then transmitted to the server through either Websockets or RESTFUL web services.

On the server layer, after the structured data is received, the server formulates, if not existing, a device specific time series of data frames on which it keeps a finite number of temporal instances (removing the oldest when exceeding a predefined maximum) of each device's data frames to be available for temporal post processing. Following that, any such post processing that was applicable to the specific device's data frames as well as any other algorithmic computation can be applied to

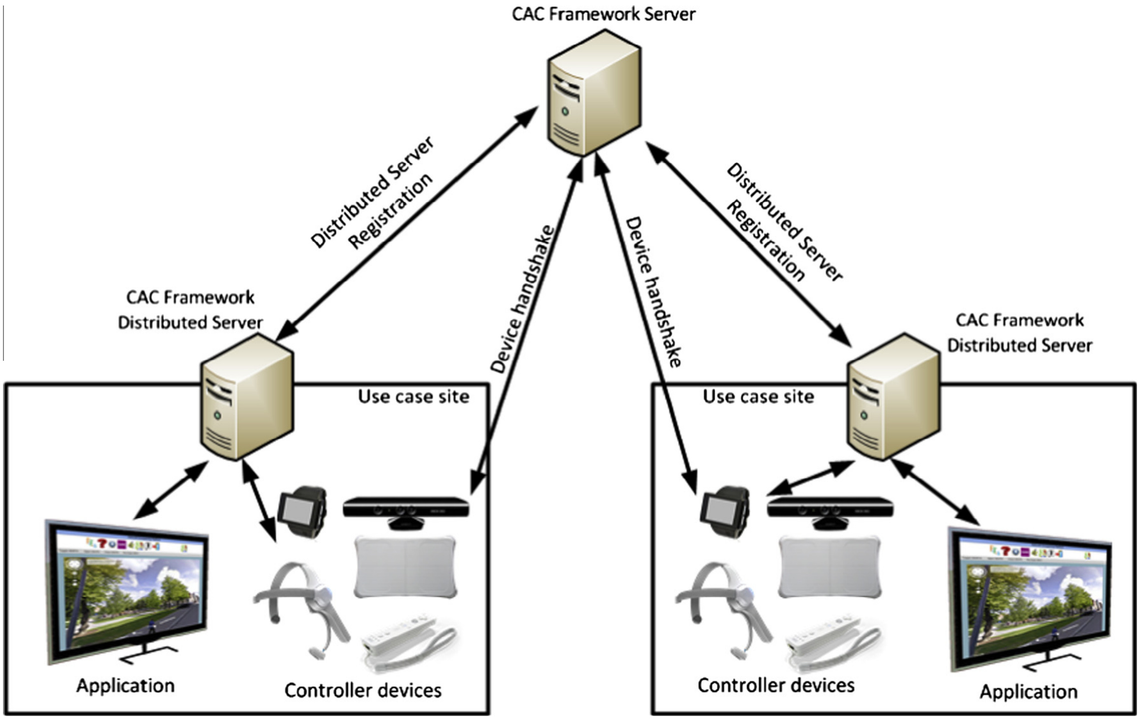

Fig. 2. The CAC rramework server follows distributed processing principles by registering new distributed server and redirecting controller devices to the appropriate instance (based on session criteria).

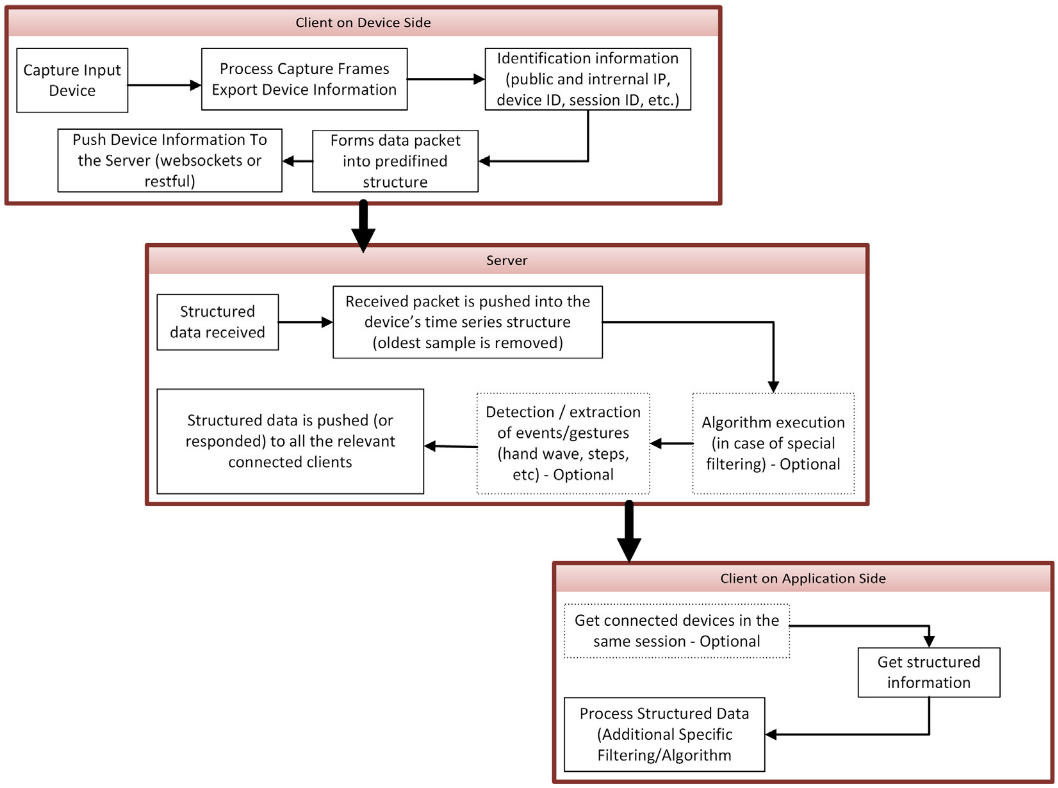

Fig. 3. The client on the device side capture the data and formulates it in a structured packet. The server is responsible for make the data available to any client in the same session. The client on the application side exploits the received structured data.

the data frames' time series. Then the processed structured data is likewise pushed or long polled (Websockets or RESTFUL WSs) to the connected application clients of the specific session.

The application layer's structure facilitates both outgoing and incoming communication tasks. On one hand, this layer controls the configuration of all communication session information, namely what information will be requested from which controller. On the other hand, this layer is the final receiving end for all structure data packets, as per its request, where final additional filtering and post processing may occur before the structured controller data are consumed and the relevant information is passed on to the application that requested the framework's facilitation.

At this point it would be useful to describe the session management of the framework in more detail in order to gain useful insights about the distributed server structure. The session management functionality is demonstrated in Fig. 4.

Each device or application that connects to the framework declares its presence by its specific identification information, specifically its own internal and public IP and the device ID. If the identification information is found registered then the device is assigned to the session ID that was initially allocated to. If the device ID details are not found, then a handshake process is initiated, whereas the ID details of the device, (internal, public IP and hardware device ID) or application (Session ID declared to server) are compared to those requested or provided, respectively, by existing applications and devices. If these existing session criteria are met, then the device is allocated the relevant session ID, or the application is prepared to accept, in its own session, data frames from the already registered devices. In effect, each session, identified by its unique session ID, is the core logical unit of the framework that defines each cluster of devices and applications that meaningfully exchange data frames and requests. The session ID can be temporarily or permanently correlated with a group of devices and applications. The members of the group may provide the defined session ID during handshake irrespective of the public IP that the devices are under. In addition to devices and applications, the main CAC framework server can accept connections from other instantiations of itself defining parts of a distributed service architecture. In this case the negotiation process is different. After the handshake between the main and the distributed servers' services, the new service is registered to a registry list of distributed services on the main server. Additionally, any devices that are defined in the sessions of the distributed service, but are also registered with the main server are redirected to the newly registered endpoint. In that fashion, devices, applications and gateways sharing the same Session ID are delegated by the framework's service to this local gateway as a server, thus distributing the framework's load throughout the connected infrastructure.

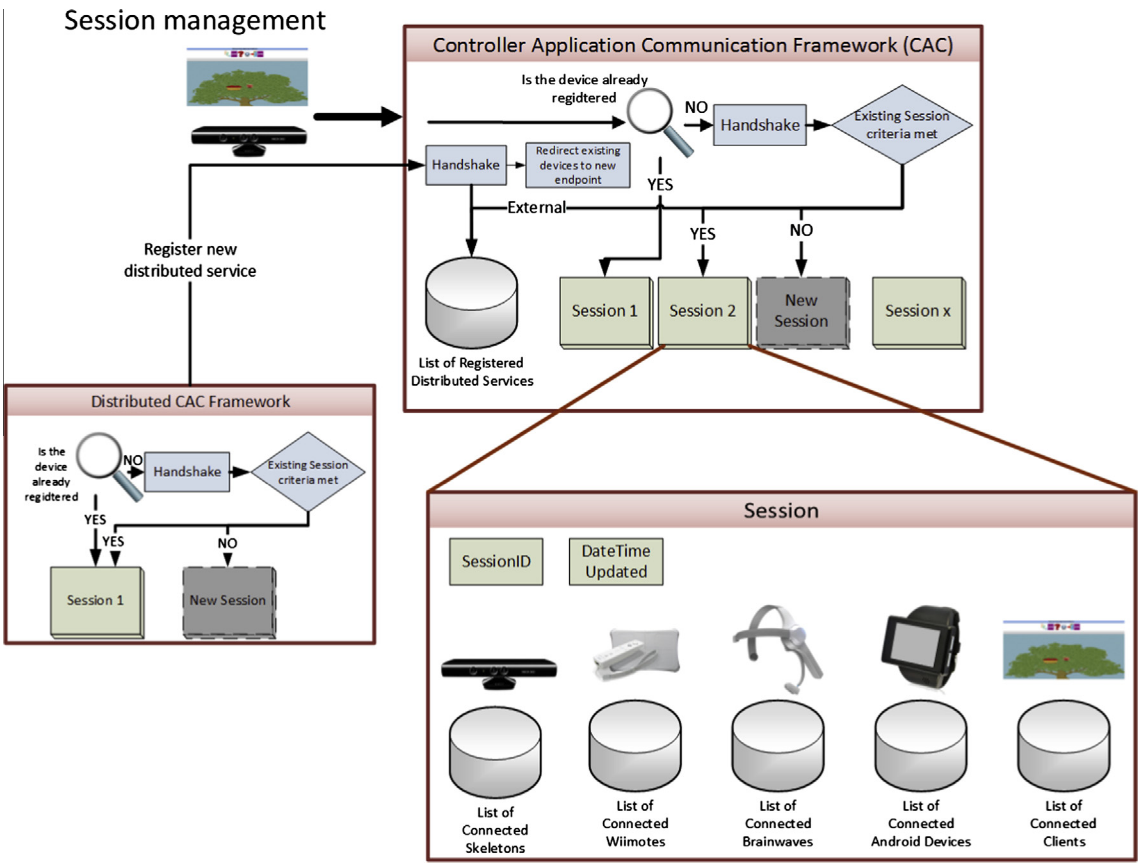

Fig. 4. Session management of the Controller Application Communication framework.

Table 1
The device object information which is inherited by any device or application.

Attribute	Description	Example
Session ID	Identifies uniquely the session of devices and applications	69109525-037b-44e9-b002-80f40d52d779
DeviceID	The unique devices ID (manufacturer device ID)	Manufacturer's device ID in string format
PublicIP	The public IP that is used for sending information to the server	155.168.0.1
LanIP	The internal IP that is used for sending information to the server	192.168.0.1
LastUpdateDateTime	The datetime of the current instance of the device information	Date(1381854563952)
DeviceType	The device type according to the specific enumeration provided by the service	0: Unknown 1: Kinect (skeleton) 2: Wiimote 3: WiiBalanceboard 4: Mindwave neurofeedback 5: RGBVideo 6: DepthSensor 7: Android Sensor
Mandatory transmission	Indicates that the packet cannot be dropped during streaming	

From the description of the framework's architecture it becomes clear that even though the framework schemas implemented on the controller gateway's side, are aware of controller specifics in order to correctly encapsulate their information, this information is consumed within the framework's boundaries and thus the communication between the controller and the requesting application is always device and platform transparent.

Throughout the previous description it became clear that communication through the framework's services is realized through ubiquitous internet technologies that can cope with real time data transmission. In that context, as already mentioned, we have utilized RESTFUL web services long polling and Web Socket communications. RESTFUL Web services are supported for reasons of robustness and legacy compatibility. Through their capabilities, the application requests, in real time, information (responses) from the server with the unavoidable drawback of overheads every time a request – response takes place. However, the technology that is typically utilized when no compatibility issues exist is Web Sockets. Through this technology, an end to end channel is opened between controller client and application, through the framework's server structure. This enables the real time pushing of data to any requesting application from any serving device.

3.3. Standardization schemas

In the current implementation of the framework four families of controllers are supported; namely, the Kinect, the Wii controllers (Wiimote and Wii Balance Board), Mindwave neurofeedback device and the Android mobile device's sensors. For each family of controller a different description schema (model) has been developed.

However, while each controller is derivative of a device class, some meta-information is common to all schemas as summarized in Table 1.

Since the streaming of video, skeleton and other possible connected devices creates a big data throughput, it is possible for a client to, occasionally, need more time to process a packet. In order to avoid this delay, the CAC service recognizes if a client has not received the previous packet, within a predetermined, optimal time frame and accordingly transmits the new one or drops it. This way, high streaming speed is maintained at the cost of dropping some packets. The "Mandatory" flag overrides this process, if true, and ensures that important packets, containing information such as exceptions, commands and gestures, will not be dropped due to transmission optimization.

Table 2 summarizes the properties of the Kinect, Wii family, Mindwave and Android sensors that are encapsulated through the relevant schema. The framework provides the structures of the input device information in order to define the models available. On the transferring layer the JSON format is utilized. Table 2 represents the information in JSON format of the Kinect, the Wii Balance Board Mindwave devices and Android sensors.

The Kinect schema utilizes data types from the well described Microsoft Kinect SDK such as JointType [45], TrackingState [46] and Position [47]. This similarity in nomenclature is intentional in order for developers utilizing this schema to be able to easily implement it in their own client applications since the Microsoct Kinect SDK is rather widespread and has a mature and large user/developer base. Moreover, the RGBVideo schema contains the base64 format of an RGB image.

For the Wii family of controllers, the utilized schema consists of two parts. On the first part, the data relevant to the Wii Balance Board are encapsulated. These include center of mass, distribution of weight across the Wii Balance Board's quadrants and total weight. On the second part of the schema, the data relevant to the Wii Remote controller are stored. These include the various buttons of the controller and the relevant variables for the controller's motion detection. The cross-schema metadata variable DeviceType that is encoded together with this schema too, is the defining attribute in selecting which part of the schema is applicable (Wii Balance Board or Wiimote). Furthermore, the schema is enriched with additional information concerning extensions of the Wii family (guitar, motion plus, etc.).

The Mindwave neurofeedback controller schema encodes the EEG frequencies Delta, Theta, Low/High Alpha, Low/High Beta, Low/High Gamma. Additionally it encodes the Blink Strength which provides a value representing the intensity of

Table 2
Input device information models in JSON format. The table presents both the objects and an example of an instance of the objects.

Controller device	Instance of data in JSON format
Kinect (skeleton)	{“Device”:{“DeviceID”:“A00362901906044A”,“DeviceType”:1,“LanIP”:null,“LastUpdateDateTime”: “\/Date(1382372183294+0300)\/”,“PublicIP”:null,“SessionID”: “0e87ac96”,“DeviceExceptionCmd”:0,“ObligatoryTransmission”:false}, “FrameNumber”:13526,“Skeletons”:[{“Joints”:[{“JointType”:0,“Position”: {“X”:0.0753650814294815,“Y”:−0.4235561192035675,“Z”:1.0822073221206665},“TrackingState”:2},{“JointType”:1, “Position”:{“X”:0.076691031455993652,“Y”:−0.37665122747421265,“Z”:1.084294319152832},“TrackingState”:2}, {“JointType”:2,“Position”:{“X”:0.15291579067707062,“Y”: −0.16353470087051392,“Z”:1.06369948387146},“TrackingState”:2} ...., {“JointType”:19,“Position”:{“X”:0.51896208524703979,“ Y”:−0.95888435840606689,“Z”:1.536409854888916}, “TrackingState”:1}],“Position”:{“X”:0.077118568122386932,“Y”:−0.16210742294788361,“Z”:0.87752747535705566}, “TrackingId”:“584”,“TrackingState”:2}],“Timestamp”:258758299,“TrackingMode”:0}
Wii family controller	{“AccelState”:null,“BalanceBoardState”:{“BottomLeftKg”:21.0562458,“BottomRightKg”: 109.705109,“CenterOfGravity”:{“X”:14.2199678,“Y”:−3.75173545},“TopLeftKg”:40.36385, “TopRightKg”:209.351486,“WeightKg”:95.11917},“Battery”:101.041664,“ButtonState” :{“A”:false,“B”:false,“Down”:false,“Home”:false,“Left”:false,“Minus”:false,“One”:false,“Plus”:false,“Right”:false, “StrumDown”:false,“StrumUp”:false,“TriggerL”:false,“TriggerR”:false,“Two”:false,“Up”:false,“X”:false,“Y”:false,“ZL”:false,“ZR”:false}, “ClassicControllerState”:null,“Device”:{“DeviceID”:“3f48617d-5142 ”,“DeviceType”:3,“LanIP”:null,“LastUpdateDateTime”:“\/Date(1382372148420+0300)\/”,“PublicIP”:null,“SessionID”:“0e87ac96”, “DeviceExceptionCmd”:0,“ObligatoryTransmission”:false},“DrumsState” :null,“Extension”:true,“ExtensionType”:5,“GuitarState”:null,“IRState”:null,“LEDState”: {“LED1”:false,“LED2”:false,“LED3”:false,“LED4”:false},“MotionPlusState”:null,“NunchukState”:null,“Rumble”:false, “TaikoDrumState”:null}
Mindwave	{“Alpha1”:16244,“Alpha2”:16885,“Attention”:63,“Battery”:0,“Beta1”:7797,“Beta2”:6266,“BlinkStrength”:0, “Delta”:29181,“Device”:{“DeviceID”:“1234”,“DeviceType”:4,“LanIP”:null,“LastUpdateDateTime”:“ \/Date(-62135596800000)\/”,“PublicIP”:null,“SessionID”:“0e87ac96”,“DeviceExceptionCmd”:0,“ ObligatoryTransmission”:false},“Error”:false,“Gamma1”:6372,“Gamma2”:41375,“Meditation”:64, “PacketsRead”:261,“PoorSignal”:0,“Raw”:9,“Theta”:54317}
RGBVideo	{“RGBVideo”:{“Width”:640,“Height”:480,“FPS”:30,“base64String”: “/9j/4AAQSkZJRgABAQEAYABgAAD..............aZjy2obkVSeJozW0VyKhkhVutTzNBZM/9k=”}}
AndroidSensor	{“Device”:{“ID”:0,“DeviceID”:“123456789”,“PublicIP”:null,“LanIP”:null,“GUID”:null,“DeviceType”: 7,“LastUpdateDateTime”:“\/Date(-62135596800000)\/”, “SocketID”:null,“SessionID”:“demo”,“DeviceExceptionCmd”:0,“ObligatoryTransmission”:false}, “TouchMousePosition”:{“MousePoints”:[{“X”:2.5,“Y”:8.7},{“X”:2.5,“Y”:8.7}],“Single Tap”:false,“DoubleTap”:false,“LongPress”:false,“Fling”:{“Point1”:{“X”:0,“Y”:0},“Point2”: {“X”:0,“Y”:0},“velocityX”:0,“velocityY”:0}},“AccelerometerSensor”:{“Values”:{“X”:1,“Y”:2,“Z”:3}}, “AmbientTemperatureSensor”:{“Value”:4},“GyroscopeSensor”:{“Values”:{“X”:1,“Y”:2,“Z”:3}}, “LightSensor”:{“Value”:5},“MagneticFieldSensor”:{“Values”:{“X”:11,“Y”:12,“Z”:13}},“PressureSensor” :{“Value”:14},“ProximitySensor”:{“Value”:15},“ButtonState”:{“A”:true,“B”:false, “Down”:false,“Home”:false,“Right”:false,“Up”:false},“Battery”:5}

Table 3
Communication protocol between websocket/restful clients and server.

Web socket	Restful method	Description
SessionID={sessionid}, PublicIP={publicip}, InternalIP={internalip}	/rest/HandShake/?sessionID={sessionid}&PublicIP={publicip}&InternalIP={internalip}	Parsing identification parameters during handshake for session allocation
StartReceiving={deviceid}	Not implemented	A client may require to start receiving data from a specific session device
StopReceiving={deviceid}	Not implemented	A client may require to stop receiving data from a specific session device
The server pushes the data to the client (unless the client configure the session not to do it)	/rest/GetWiimote/?sessionID={sessionid}&deviceID={deviceid}	The client gets the last temporary instance of the device store in the server
The client pushes the JSON packet to the server	/rest/SaveSkeletonFromJsonGet/?skeletonx={skeletonx}	The input device sends the information to the server as a JSON string
GetClientInfo={deviceid} GetClientInfo=ALL	/rest/GetClientInfo/?sessionID={sessionid}&deviceID={deviceid}	The client receives a list of information of all the registered devices or a specific one

the user’s most recent eye blink. Its value is reported whenever an eye blink is detected. The value indicates the relative intensity of the blink, and has no units. Besides these, the Mindwave device, reports two more values ready to be consumed by applications as they are correlated with the user’s mental status. The first is “attention” which indicates the intensity of a user's level of mental focus, or attention, such as that which occurs during intense concentration and directed (but stable) mental activity. Distractions, wandering thoughts, lack of focus, or anxiety may lower the Attention meter level. The second is "meditation", which indicates the level of a user's mental calmness, or relaxation. Meditation is related to reduced activity by the active mental processes in the brain.

The schema for the Android mobile devices' sensors encodes the touch mouse position, the accelerometer and gyroscope sensors, the ambient temperature and light sensors, the magnetic, pressure and proximity sensors as well as the buttons status. Especially, the touch mouse position incorporates gestures like single and double tap, long press and flings.

3.4. Communication protocol implementation details

The communication layer of the CAC framework is served by both WebSocket and Restful calls. WebSocket is a real time internet communication technology designed for web browsers and web servers. However, it can also be used by any client or server application. The WebSocket protocol facilitates real time web content such as live streams and real time games. This is made possible by providing a standardized way for a server to keep a connection open with a client, sending content to a browser without constantly being solicited by the client. The CAC framework utilizes the Websocket protocol by allowing the client and the server to exchange messages forming either commands or controller information models. On the other hand, a Restful web service is a web API implemented using HTTP methods explicitly which dictates the familiar POST and GET polling methodology. The CAC framework defines a lightweight communication protocol on top of the communication layers. Table 3 presents the set of commands supported by the protocol. The handshake procedure accepts combination of the SessionID, the Public and the Internal IP. The WebSocket's message would contain this combination while the Restful service would accept the parameters as depicted in Table 3. Moreover, the Websocket implement options for start or stop of receiving of specific device's data (as the server pushes them to the client). Contrary to this, it is meaningless for the Restful service to implement such a method since this approach follows a polling architecture and thus the server cannot push any data to the client. However, the client decides whether it would get or not device information by polling the server or not. The client on the device side pushes data to the server according to the schema formed as JSON string in both

Table 4

Accessing skeleton information from the server by utilizing WebSockets (javascript source code example). During onOpen the client application sends the SessionID in order to handshake and to receive relative to the proper devices infromation.

```
function InitializeWebSocketsInputDevice() {
  try {
    host = "ws://endpoint:8083";
    websocket = new WebSocket(host);
    websocket.onopen = function(evt) {
      onOpen(evt);
    };
    websocket.onclose = function(evt) {
      onClose(evt);
    };
    websocket.onmessage = function(evt) {
      onMessage(evt);
    };
    websocket.onerror = function(evt) {
      onError(evt);
    };
  } catch (exception) {
  }
}
function onOpen(evt) {
  websocket.send(' SessionID =' + inputDeviceSessionID);
}
function onMessage(evt) {
  var F = jQuery.parseJSON(evt.data);
  if(F. Device. DeviceType === 1)
  {
    window.KinectSource = F;
    for (var sk = 0; sk < window.KinectSource.Skeletons.length; sk++)
    {
      var skeleton = window.KinectSource.Skeletons[sk];
      if (skeleton.Joints[SkeletonJointEnum.WristRight].TrackingState === 0) {
        jQuery('#remote-cursor-' + skNum).hide();
        continue;
    }
  }
}
```

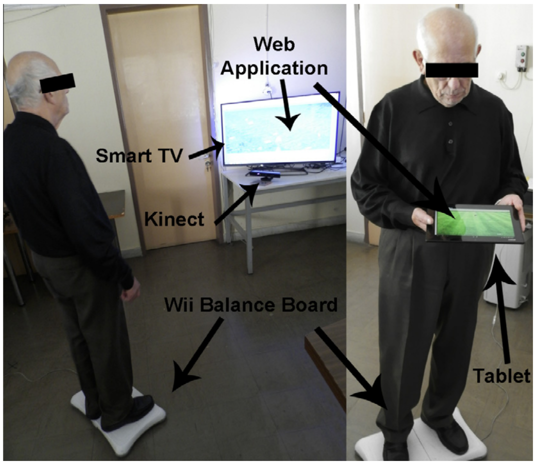

Fig. 5. A senior interacting with the Smart Tv and the Tablet by utilizing Kinect and Balance Board. Laboratory trials in the realm of the USEFIL project.

technologies, while only the Restful approach implements a get device data method. Finally, each client is able to require from the server information related to its own session and especially regarding the connected devices and clients (e.g. in order for an application to decide which controller to exploit).

Whenever a client has to be redirected to an already registered distributed remote server, the server responses to any request with "ServerEndpoint={IP Address}". The client has to configure itself in order to redirect its requests to the new endpoint. The client does not require to be registered again since the session information has been transferred to the new server during distributed server handshake.

Table 4 provides a javascript sample code for accessing the skeleton information from the server by utilizing WebSockets. The function "onMessage" receives a message from the server and parses it as an object. If the object recognized as a skeleton, the code reads the Tracking state of the right wrist. The authors have also developed and released libraries for .NET and javascript for effortless incorporation in third party developed software (available on www.cac-framework.com).

4. Scenario

This work was the solution to a very specific problem in the context of the USEFIL project [51,79]. The aim of this project is the creation of an integrated unobtrusive smart home environment supporting independent living of elderly people. The goal of this smart environment is twofold. First, is the unobtrusive monitoring of the elderly and the capacity for alerting relevant agents (healthcare experts, family members, etc.) in cases of emergency or serious deterioration of the user's condition. For example the platform should be able to trigger an alarm emergency support in case of a fall or alert a formal or informal carer (doctor, family member) on the onset of psychological deterioration (e.g. depression). This goal is achieved through a set of sensors, central of them being the Kinect. With its key capacity for full 3D spatial recognition it is the most efficient way for monitoring the necessary home areas without resorting to cumbersome multi camera systems [3].

The second goal is the support for maintaining a healthy lifestyle of the elderly through unobtrusive motivation for the necessary provisions and activities for the elder user; the latter would enable and assist them in maintaining (or improving obviously) their physical and mental capacities thereby preventing decline. This is achieved through Smart Home technologies providing features such as reminders for medication and motivation for mental and physical exercising, through an exergaming platform. The main hub of the USEFIL platform, regarding user interaction, is the Smart TV set that provides access, through internet technology, to all necessary resources (e.g. medication calendar, exergaming platform, interactive remote advice from experts, etc.). The Smart TV with the familiarity it presents to the user [55], facilitates both unobtrusiveness (no weird electronic devices to interact with, just a TV set) and ease of use (elders are familiar with TV remote controls). To support this hub, the exergaming platform is attached to it through sensors such as the Kinect, the Wii family of controllers and the Neurosky Mindwave device.

These sensors are used as customized exergaming controllers. Gaming through such transparent and easy to use control interfaces, helps reducing learning overhead [8]. This leads to positive behavioral attitudes and happy affective states [31] motivating towards exercising in order to achieve a healthy independent lifestyle.

In the described platform input from a group of devices (e.g. the Kinect sensor) and algorithms (a suite of software components integrating to a decision support system) are fused in order to infer the senior's emotional cognitive status. The CAC framework in this case facilitates the routing of Kinect skeleton data to each requesting component. In that fashion it is possible for the sensors to cater even to simultaneous requests for inputs from different application components In another part of the described platform a customizable exergaming suite requires the input from multiple game controllers such as the Wii

Balance Board, Wii mote and Kinect. To that extent, the deployment of the CAC framework catered to the seamless fusion of controller data to each requesting component of the exergaming suite. Thus, the CAC framework was the component of the USEFIL platform that managed the routing and communication between the USEFIL controller/sensor infrastructure and the software components that utilized them. The Clothes Change Detection component [65], responsible for identifying possible changes of the clothes of the user (Activities of Daily Living), utilized the CAC framework in order to utilize the Skeleton and the Video of the Kinect sensor in the realm of the USEFIL project. In that capacity, it provides transparent, device independent, simultaneous access to all relevant sensors by any requesting software component. Moreover, the CAC framework utilizes standard encodings for device data encapsulation, namely JSON formatted strings. This allows the inclusion of any new sensor types by simply encoding their data types in appropriate JSON strings. From the application side, the CAC service enables different algorithmic and functional entities to exploit multiple sensor input without the need for them to be implemented as a monolithic programming solution, specific to each sensor. Since the framework's architecture is application naïve, it allows the streamlined inclusion of components (algorithms, application, etc.) as USEFIL candidate members since no additional architecture modifications would need to take place. Through this service it was possible to fully integrate the existing exergaming platform of the LLM project and conduct preliminary functionality testing with real elderly users (Fig. 5, and see also relevant Youtube video at http://www.youtube.com/watch?v=lR-cEsuuOow.)

During the pre-trial evaluation period of the USEFIL project, an AAL ecologically valid environment was established in the Lab of Medical Physics of AUTH's Medical School. The environment set-up consisted of a living-room space, a bathroom-like space and a hall-kitchen space, all in the same room. A number of elderly volunteers were visiting this environment daily and performing a set of daily activities. There, a CAC client, acting as recorder of the streamed data, has been implemented. It was connected to the CAC service and was listening to any streamed information. The received data were saved by the client to a MongoDB database for subsequent use. A mean throughput of 10 GB per hour was recorded, which has produced thus far a 1 TB base of data. The author's intention is to design an online framework for streaming these data on demand. Therefore, interested researchers and developers will have the opportunity to experiment and to test their algorithms on data stemmed from an ecologically valid environment in lab settings. During the pre-trial phase, the CAC service supported the required infrastructure flawlessly by presenting valuable stability and reliability. Additionally, a preliminary evaluation of the service implementation and usability has been conducted on the programmers/developers front with encouraging results [30].

5. Discussion

With the increase of the elderly population in the developed countries and the subsequent stress that this increase poses on the healthcare systems, there is an urgent need and therefore a recent focus for utilizing smart technologies in order to facilitate independent aging [29]. AAL, and specifically elderly independent assisted living is one of the more important fields for utilizing ubiquitous computing with cross device applications. It facilitates affordable infrastructures for daily life management of elderly people and for their independent living even when suffering from mild cognitive impairment.

An approach proposed for implementation of AAL platforms [3] consists of mainly unobtrusive consumer electronics, such as Smart TV sets, enriched by Information and communication technologies (ICTs). Elderly users are more familiar with a TV set, contrary to a computer interface [55]. In fact, TV watching is one of the fields in which smart technologies apply. In order to provide elderly with content that is preferable and useful to them, Smart TV sets decode the metadata available from content and create media recommendation profiles [36]. To this end, applications targeting elders, for example MindGym, are provided through TV sets [25]. Likewise, physical assessment tasks like Choice Stepping Reaction Time (CSRT), which can be conducted by Kinect [20], could be part of the daily routine through Smart TVs enabled by the CAC framework. Finally, Kinect based serious games for rehabilitation could be played on smart TV and web browser without additional plugins [71].

To this extent, this paper has presented an architectural framework that utilizes Smart TV sets as hubs for monitoring the status of elderly in AAL environments. communicating alerts to relevant healthcare professionals, providing feedback to the user through the Smart TV, and allowing them to exercise through games in their own home convenience [67]. In fact, recent research has highlighted the importance of harnessing the ambient contextual information that can be provided in the scope of such an assisted living environment [16]. In this kind of environments, fused smart devices over wireless communication networks find many applications. Studies have shown that devices such as smart TVs, smart phones and tablets are far more useful to elderly users for access to internet based services [74]. The ease of access, that these devices provide, far outweighs the lack of versatility in comparison with traditional computer systems. Thus, in integrating an assisted living smart environment, the use of a diverse set of sensors and devices is an essential design characteristic of a successful such implementation.

The ubiquitous, transparent communication of controller device data from sensors and devices within a house, to any requesting application, in a standardized way is the problem that the herein described CAC framework has met and resolved by technologies of AAL for the elderly. The current implementation of this framework as deployed in the USEFIL project platform is the first step towards this goal.

In its current implementation, this framework is based on a series of custom schemas that uniquely describe each of the supported controllers. These schemas have been developed in order to solve the aforementioned and very specific problem and in that respect are both custom and non-streamlined. Specifically, while there is one schema for the Kinect sensor and another one for the Mindwave neurofeedback controller, the Wii Remote and the Wii Balance Board share a common schema. This design discrepancy stemmed from an implementation choice. In order to support a streamlined implementation of these schemas, we maintained the nomenclature of the data types from popular device management libraries such as the MS Kinect SDK [48] or the Wiimotelib open source library[80] in lightweight models. This legacy approach to design of the specific controller schemas meant that conciseness would be sacrificed for expeditiousness and ease of implementation. However, it is with these legacy design choices that this framework was realized in the context of unobtrusive assisted living as functional proof of application for cross device, cross platform, controller-application communication. It consumes, transparently multiple controller data and serves them in the same fashion to any requesting application without either end having to be aware of implementation specifics of the other. As such, it aims to be the first step towards incorporating these contemporary controllers into applications of the Future Internet (see for example the FI-STAR EU funded project: www.fi-star.eu) and the emerging paradigm of the Internet of Things (IoT).

Definitions and visions for this rapidly developing paradigm differ from: "a world-wide network of interconnected objects uniquely addressable, based on standard communication protocols" [81] to "a world where things can automatically communicate to computers and each other providing services to the benefit of the human kind" [14]. Conceptual visions aside, there are a couple of key features that define the Internet of Things paradigm.

Ubiquitous connectivity of everyday objects to the internet, provisions for unique internet device discoverability, pervasive device application through internet infrastructures, semantic enrichment of devices and data to allow for smart semantic middleware, all these are characteristics of this emerging networked computing paradigm [4,27]. These defining characteristics of the IoT hint to the specific place that our current work finds as the first step for integrating contemporary controllers and smart assisted living environments to this paradigm. The CAC is in fact a middleware that sits between the controllers (them being the "Things" of the Internet of Things paradigm) and the applications that aim to leverage their functionalities in order to provide additional functionalities and capacities.

Exploring the features of the CAC framework several similarities between it and the IoT features emerge. The CAC framework provides connectivity, albeit in the ecology of the framework in a ubiquitous and transparent way. The unique device ID following the data packet of every single controller utilizing the framework caters exactly to the specification for unique internet identifiable tagging of devices of the IoT paradigm. While the controllers are not wirelessly and ubiquitously connected their very nature as computer peripherals ensures that they are always available from a computer endpoint and the provisions of the CAC framework allow for communication of their data through standard internet technologies Furthermore, while semantic enrichment has not been applied in the encoding of the device data the implementation of custom but standard schemas for each controller type allows for the CAC server infrastructure to facilitate appropriate, optional, quality of service provisions (e.g. filtering or post processing) relevant to the controller's specific characteristics as applications would require. It must be noted that the CAC framework in its current implementation does not adhere to the strict vision of the IoT architecture [4]. It should, however, become clear from the previous discussion that the design principles behind this first implementation are in alignment with the IoT approach.

6. Conclusion

The CAC framework was built in order to cater for a very specific need, namely the concurrent use of sensor/controller devices by different applications in an AAL. Our future efforts are currently focused on three axes. The first is the integration of additional device types into the framework's schema infrastructure. The aim of this axis is to facilitate even more devices, such as healthcare measurement devices (glucose meters, oxymeters, etc.) to be transparently available to multiple software components in an assisted living environment. The second one is the transition of the framework to a Service Oriented Architecture [12] with reusable service components capable of being combined with complex functional processes according to various application requirements. This future work aims to build upon the currently implemented framework in order to align integrated smart assisted living environments with the IoT paradigm. An obvious third axis, is the creation of a repository of AAL data that will be able to be served on demand from this service in order to assist third party developers for the optimization of AAL algorithms and functionalities. To this extent, a multi-country, multi-centric trial pilot is currently under design within the realm of the USEFIL project. It remains to be seen, how effective these technologies will be in facilitating the users' experiences and improving their life quality. However, the CAC framework is an already achieved technical milestones that open new avenues in exploiting devices and services with a clear field of application within the scope of elderly AAL environments.

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