Contributions of Sensor Networks to Improve Gaming Experience

Orlando R. E. Pereira
Department of Informatics,
University of Beira Interior
Covilhã, Portugal
opereira@ubi.pt

Joel J. P. C. Rodrigues
Instituto de Telecomunicações,
Department of Informatics,
University of Beira Interior
Covilhã, Portugal
joeljr@ieee.org

Abel J. P. Gomes
Instituto de Telecomunicações,
Department of Informatics,
University of Beira Interior
Covilhã, Portugal
agomes@di.ubi.pt

Abstract—Wireless sensor networks (WSNs) have evolved from primary military applications into everyday life. Sensor networks rapidly began spreading to civil applications like environment monitoring, education, intrusion detection, motion sensing, gaming experience, among others. Wireless sensor networks are thought to lead to a world plenty of smart objects in the future. In addition, gaming is a widely recognized part of our cultural landscape and as old as our human ancestors. The earliest computers were very slow and the interaction with the user was rudimental. In the early 40’s, computers evolved, and programmers started to develop new virtual worlds and surprising ways of interaction between the user and the machine. Following the growing popularity of computer games and the common use of wireless sensor networks, we survey on how both technologies can be combined together to provide a better gaming experience.

Keywords—Body Sensor Networks; Gaming Experience; Wireless Sensor Networks.

I. INTRODUCTION

Sensor networks have been identified as one of the most important technologies for the 21st century [1]. This technology makes us thinking of how to realize the vision of a world full of smart sensors that will be used to collect data from a vast number of phenomena. In addition, the increasing growth of the entertainment field (i.e. an increasing number of gamers and game products) will take us to a new level of gaming experience, where cutting-edge technology coexists and provides the user with an innovative way of interaction with the hardware.

Gaming experience involves several activities. The principal one is how users interact with the game itself. The interaction tends to be some person fingers touching a joystick. In the physical world an entertainment activity is, for instance, to play with remote controlled toys. Nowadays, many types of toys are offered such as cars, airplanes, helicopters, and even robots with guns. Combining such hardware with the cutting-edge sensor technology results in a new group of input devices.

Using special input and output devices such as data gloves, joysticks or others, allows users to receive feedback from computer applications in the form of tactile sensations or other body sensations [2]. Nintendo Wii remote is promising not only as input gaming device but also as a device capable of integrating clinical and home based rehabilitation into exercise therapy systems [3]. Using the accelerometer of the Nintendo Wii remote will improve the efficacy of computer-simulated therapy. Taking into account the available proposals to gather contributions from sensor networks for gaming, this paper details how both technologies can contribute for providing a better gaming experience.

The remainder of the paper is organized as follows. Section II presents the wireless sensor networks, while Section III provides some insight on gaming experiences relying on sensor networks. In Section IV, the authors reflect on sensor networks contributions for gaming. Finally, Section V concludes the paper.

II. WIRELESS SENSOR NETWORKS

Wireless sensor networks (WSN) [4] came out of military applications, namely for target tracking, battlefield surveillance and enemy detection. In a given scenario, sensor nodes were placed in harsh war environments and left there forever. Wireless sensor networks rapidly began to be applied to civil applications like environment monitoring, home/office automation, intrusion detection, motion tracking, gaming industry, among many others.

A wireless sensor network may be compounded from up to thousands of smart sensing nodes. These nodes communicate between them and with an external network through a base station (BS), also known as a sink node. The sensors must have small size and low cost development process in order to make them economically viable. Sensors have the following five main components: memory, battery, transmission-receptor, processor unit, and the sensor itself. These components impose some technical limitations that may compromise the functionality of these networks.

WSNs may be classified between dynamic and static. A dynamic WSN is auto-configurable, auto-manageable and auto-sufficient, while the static WSN needs a specific configuration because it is based on pre-determined routes between sensors. Both kinds of networks have some limitations because sensors must have small sizes and, as a consequence, they have limitations in respect to network bandwidth, processing and battery life [5].
Using WSN technology to human monitoring and biofeedback, results in the well-known body sensor networks (BSN) [1]. Usually, BSNs are used for gathering physiological data from a patient, the so-called biofeedback [6]. Nowadays, BSNs and their motion sensors also are used in gaming to capture the movement of the human body.

Body sensor networks can be also applied in biomedicine. BSNs are equipped with technology that can sense various signs obtained through the human body. For example, it is possible to perform a full electrocardiogram or an electromyogram in a non-obstructive way. Using accelerometer sensors allow us to get data concerning the heartbeat or a full movement of a person to create a live person inside a computer.

III. RELATED WORK

This section describes several important game approaches that rely on sensor networks in order to improve game experience. Such sensor networks can be classified as wireless sensor networks, body sensor networks or a combination of both.

A. Remote Control Gaming

Remote gaming control is the ability to control several devices, such as cars, robots or even airplanes through the use of input devices such as game pads, joysticks, among others. They follow the same methodology but differ in terms of complexity. Starting from small to big, ready to use or assembled-yourself models, too many solutions are available. These kinds of games are used outdoors in a real track environment until no energy is left.

Pablo Guerrero et al. [7] took the digital multiplayer gaming interaction into the physical world of remote control toys in order to enrich the remote control gaming experience. Currently, there are many toys ready to interact with digital multiplayer games but no middleware is available that allow this kind of interaction. The goal was to offer a framework that enables a team-based and goal-oriented gameplay to participants relying on a wireless sensor network.

An infrastructure to support this idea must constrain the following three different domains: digital multiplayer games, remote control toys, and the middleware for wireless sensor networks. Authors refer to it by Multiplayer Real Life Games. Wireless sensor networks assume sensing and data computing functions. In this case, the wireless sensor network is used for three main goals: a computational model to specify the game rules, a way to disseminate the information between interested parties, and a placeholder that triggers and executes the actions or rules of the game itself. In this infrastructure wireless sensor nodes are placed on each game component in order to not change its mobility. Afterwards, the deployment of nodes and its configuration should be performed. Then, two steps must be taken, (i) the organization of the nodes (usually, they are auto-adjustable) and (ii) the routing tables relying on the network protocol.

In order to update the game state, sensor nodes exchange messages in a many-to-many relationship. This network works as a traditional one where only one sink node exists. To ensure data integrity the network protocol must provide an efficient routing scheme because all the components change their location very fast and constantly.

B. Mobile Pet Game

A mobile pet game is a pet that lives in your cell phone, and is ready to play with you whenever you wish. The user has to take care of his/her pet; otherwise he/she may find it dead.

An architecture that integrates both mobile pet games and wireless sensor networks is proposed by Liu and Ma in [8]. The name of this game is S-Pet. They create an environment that can adapt to the real environment and reconfigure the gaming platform, if needed. This mechanism relies on a wireless sensor network and each node supports reconfiguration. This game introduces real environmental elements such as noise, temperature, and light into the virtual world. These elements become the game more real and the pet is affected not only by the virtual world but also by real environmental data. For example, if the weather gets cold, the pet becomes sick easily. Both virtual pets and players live in the same natural environment.

The physical pets are deployed on different rooms and they will start communicate between them and with the Internet through a sink node. The architecture of this game is focused on four layers. The first layer is the sensor node itself. Each node corresponds to a virtual pet on the game server and is responsible for executing instructions disseminated by the sink node. The second layer is the sink node. This layer acts as a gateway and is responsible to merge both wireless sensor network and the pets giving direct orders to each pet. The third layer is the device that can be used to communicate with the network. This is usually a handheld mobile device (mobile phone or a personal digital assistant). With this device the players can see the status of the network, pets and furthermore, they can give instructions to the network. The last layer is the pet game server. The server must sync all information between the handheld mobile devices and the network. It assembles all the messages transferred and route them correctly. An illustration of this architecture is shown in Figure 1.

The authors have created a mechanism of environment aware self-reconfiguration according to a sensing and analyzing process. The sensor nodes are aware of the variation of the environmental data and, analyzing it, they can self-reconfigure and adapt to the new environment state. They created this mechanism based on three modules. The first module is the Decision Making module, which is responsible for detecting changes and determining whether they can cause reconfiguration. This module is pre-configured by the players and has all the instructions about threshold values for reconfiguration. The second module is the Script Providing module, which generates, manages and sends information to the nodes. The last module is the Script Executing module, which executes scripts on a given node.
The S-Pet gaming relies on a system consisting of four platforms. Each one is allocated on the above-mentioned layered approach. The first platform runs on the mobile device and it provides network connectivity to the players and a user-friendly interface to interact with the pets. The second platform refers to the pet game server. This platform has two sections, one focused on the game itself and the other related with the service logic and policies. The sink node hosts the third platform. This platform must connect the sink node with both wireless sensor network and the pet game server. It has three modules for communication, script generation and script compilation. The last platform refers to a virtual machine hosted on each node. This virtual machine will assure that each node will execute all the instructions received by the sink node.

With this scenario the authors have a real time monitoring pet game. Relying on the architecture created, an emergency system that can directly support a person in a diversity of situations could be implemented.

C. Nintendo Wiimote

In 2006, Nintendo released its newest video game console, the Nintendo Wii. The Wiimote, also called the Nintendo Wii gamepad, is considered as one of the most significant technological innovations in 3D spatial interaction for gaming (Figure 2). At the very beginning the Wii seemed significantly underpowered in comparison with its competitors [9]. However, it became the leader of the console market.

The Wiimote is more than a normal gamepad because it senses 3D motions. This 3D motion sensing is captured by a 3-axis accelerometer, allowing the users to interact with games in the 3D real world (e.g. swinging a bat or tennis racket). Besides, it allows for communication via Bluetooth making it a wireless device, and has an optical sensor for pointing, but this later feature requires the usage of a sensor bar. Other features include a high-resolution high-speed IR camera, a speaker, and a vibration motor. With these features, the Wiimote became one of the more popular input devices available today, not only for gaming but also for developing new ways of interaction.

As Lee noted in [9], the hacking community succeeded in unveiling part of the Wiimote’s technical specifications. An infrared camera sensor is placed on the tip of the Wiimote. The camera chip incorporates an integrated multiobject tracking engine capable of processing high resolution, high-speed tracking of up to four simultaneous IR light sources. The camera seems to provide location data with pixel resolution higher than the one provided by comparably priced webcams, a 100 Hz refresh rate, and 45° horizontal horizontal FOV (field of view). In addition to the 3-axis linear accelerometer for motion sensing, the Wiimote has a small vibration engine that provides tactile feedback. It also has a 5.5 Kbytes onboard memory, which is used for adjusting the device settings, storing data, and maintaining output state. Besides, two AA batteries ensure an operating time between 20 and 40 hours, depending on which components are active over time.

With a Bluetooth connection, users can connect the Wiimote to any computer and start using it as an input device of the computer. After the initial paring step, the user must install the software library in order to develop custom applications. Custom applications include those that grant simple access to some Internet websites [10], those that create complete virtual worlds for gaming, or even applications to rehabilitation purposes.

To interact with Wii console, the user holds the remote controller in one hand, pointing it at the television having a sensor bar. Typical interactions using the controller as a pointer are selection, navigation, drawing, rotating objects, and push-pull interactions. In gaming, using the accelerometer encourages players to swing the Wiimote in the virtual context of bowling, boxing, golf, tennis, baseball, golf, or car racing. Although the Wiimote has led to enhancing the gaming experience of many people, a countless more uses can be devised for it, including those in education and medicine.

D. Human Body Gestures as Inputs for Gaming

Natural ways of input, in particular body gesture-based input, may work as a means to enhance the gaming experience for the new generation of the gaming systems. In this respect, Wang et al. [11] presented a novel method capable of learning human body gestures using depth image recognition techniques. Depth images have significant advantages over
grayscale and color images, simply because they are more robust against illumination changes, textures complexity, and background interference.

Interestingly, there are several research studies focusing on recovering human body poses using depth image. The poses can be then used to recognize human body actions. For this purpose, we can use active sensing technologies (e.g. structured lighting or time-of-flight sensing) to capture the depth map accurately and with less computation, but with the disadvantage of being necessary to use active illumination.

![Fig. 3. Depth Image.](image)

Wang et al. proposed a method for human body gesture recognition that basically had three components: depth image acquisition, data processing, and Hidden Markov Model (HMM) based gesture recognition. For data acquisition, they use a stereo camera to capture calibrated image pairs, from which depth images can be generated in real-time. Data processing eliminates depth noises, separates the background from foreground parts of images, and extracts the gestures of interest. The last component relies on an HMM-based machine learning system to store and classify the different gestures.

To validate their system, Wang et al. used a boxing game scenario where they distinguish boxing gestures such as jab, hook, dodge, and uppercut, in a way that is similar to the one depicted in Figure 3. For that purpose, they used calibrated stereo cameras correctly posed for geometric and photometric distortion. The experimental results were quite acceptable; the method can efficiently distinguish subtle differences among the gestures referred above. Interactive gesture-based systems have a lot of potential because they can be used not only in gaming but also in the real world.

### E. Virtual Car and Driver in a Reality Parking Game

Bannach et al. [12] introduced a system that combines ambient intelligence and computer gaming applications. They focus on the automatic recognition of human hand gestures using wearable motion sensors. In order to test the feasibility of their approach they used a virtual parking game that employs motion sensors and hand gestures as its solo input game controls.

Despite all the technology introduced in games, the game control remained quite crude mostly relying on text input, joypads, or mouse clicks. Recently, some 3D input devices have been introduced a new world of 3D input devices. Those devices shift towards better and more immersive game control because they copy the real movement of a person and the person real movement directly affects the game itself.

The authors envision to employ inexpensive wearable sensors to achieve their goals, preferable tiny motion sensors worn by people on their bodies, integrated on their clothes or on any personal gadget. Such sensors provide a way to motion analysis while the players move freely. Players interact with the game using special gloves that have small motion sensors in real time.

Bannach et al. prototype was fully implemented with a three-layer approach. The first layer is the content recognition network toolbox, the second one is the gesture detection and sensor interface, and the last one is the car movement and the driver simulation. The content recognition network toolbox allows us to build distributed context recognition systems by plugging together reusable components. Thus, it provides a set of algorithms and a runtime environment that support complex synchronous and asynchronous data flows. Moreover, the toolbox facilitates portability between platforms to easily achieve adaptation and flexibility. All the tasks are executed in parallel and the toolbox continuously process data. The second layer comprises the gesture detection and the sensor interface. A standard glove with a motion sensor was used for the hand gesture interface. The motion provides 3D acceleration used for data sensing. In order to obtain the gaming system, sixteen unique gesture classes were defined. The last layer is all about the driver simulation and real car interaction. In order to create the virtual world, authors used Java 3D and Blender. All the interaction between the user and the virtual world is done using classes created for that purpose.

To achieve hand recognition and give further movement to the car, some pre-requisites were assumed. For each class, circular motions, non-periodic motions, amongst others, were recorded about 40 small hand movements. This data was recorded on a movement detection algorithm. In order to evaluate the game, the authors created two kinds of performance tests, the recall and precision tests. The results are the recognized gestures classified into relevant types or categories. The game is quite educational in nature because it really requires discipline for correct hand gestures. Within this scenario, authors end up having a game that can be used for several purposes. It can be used not only for entertainment
purposes but also for medical uses, such as therapy or impairments.

Nowadays, a variant of this technology is used by Mercedes’ parking guidance system. This approach uses radar technology to help the driver find a suitable space to park his/her car. During the parking maneuver, the guidance system continuously monitors the steering angle and vehicle position. If the driver stops before reaching the recommended position, for example, the system automatically recalculates the ideal steering angle for smooth parking.

F. Virtual Reality and Spatial 3D

LaViolla et al. [13] introduced a new way to play video games, integrating both real and virtual world using specific hardware for that. In the late nineties, arcade games have introduced several innovations in the design of user interfaces, and virtual reality (VR) technology appeared in video games. Those interfaces used a scale model of a real object and charm the players to use them as a simulated real object. Those technologies could not be used at a home scenario because of the high costs and low portability. After that, games became more complex in terms of story, graphics, sounds, but especially in gameplay.

For the last 20 years, video game industry has done real 3D computer animations and integrated them with the people’s living room through simple but yet effective technology such as computer head vision (Figure 4) and motion sensing. Such technology could be found on Nintendo U-Force or Sega 3D glasses. Although those devices have been a real innovation they failed and could not really connect the virtual and real world to players together. Recently, an upgraded version of those devices appeared as new commercial products, such as Sony EyeToy and Nintendo Wii. Unlike their predecessors, these new devices have a lot of success and they keep growing in the market.

This phenomenon is sustained in the following idea: “3D User Interfaces”. Basically, there are three interaction approaches for 3D video game interfaces. The first approach maps 2D input and interactive devices, say mouse, keyboard, and joystick, among others, to game elements living in 3D virtual world. The second approach simulates the real world using physical replicas of real devices such as, for example, steering wheels, guns, swords, or even musical instruments. These 3D input devices aim at providing more realism to gameplay, but they do not necessarily introduce 3D interaction in the game. The third approach has to do with the true spatial sensor-based 3D tracking of the user body whenever he/she moves around and makes to control objects in the 3D virtual or gaming world. This last approach will lead us to the next step of innovation presented in the next section.

IV. SENSOR NETWORK TECHNOLOGY

Nowadays, the sensor technology offers faster and cheaper sensors, faster processors, better battery life that can perform complex motion tracking, and motion recognition. Those sensors allied to the newest devices, finally, provide a true 3D spatial integration for games.

The area of sensor technology is huge and there are different kinds of sensors [14]. Currently, they are used in order to obtain a simple specific goal like location bearings using infrared sensors, proximity range acquired by radio frequency sensors, or physical location using global position system (GPS). These sensors are common, but there are others, not so common, that introduce a new level of technology in gaming and in daily life, such as a light sensor, a temperature sensor or even an accelerometer.

We believe that sensor technology offers a totally new experience for a person but there are some open issues that must be carefully taken into account. One example is the security and privacy associated to sensors. On this technology a lot of research is still in progress. For example, almost everyday, all emergent hardware and software receive new features and new security holes are uncovered. So the use of sensors must be as much reliable as possible.

Despite all the disadvantages of emergent technologies, there are too many advantages on their use. For the cooperative combination of sensors and gaming, one can offer new horizons for games, such as open-air games/area, tabletop games, implicit games or even introduction of fuzziness. Sensor networks can offer an unlimited virtual world combined with real world. A player may be at home sit on his/her sofa playing a racing game without any physical wheel, only with some small sensors attached to his/her clothes, but he/she can also play the same game sitting on his/her car or even on some entertainment center.

Introducing sensor networks into gaming field offers a totally new gaming experience. New worlds, new ways of interaction, a totally new vision, a vision without old and big hardware attached, only a small and unobtrusive sensors that can offer more fun, entertainment and happiness. Such technology that can have different configurations, various types of sensors, and a vast number of hardware combinations can do more than entertainment. It is possible to use it on rehabilitation field [15] or even on medical care.
V. CONCLUSIONS

Recent advances on hardware technologies result in more powerful sensors. Natal [16] is the most recent project from Microsoft. This is a complex, full-body, hands-free, motion sensitive control system. They entered the sensing area through an innovative motion sensitive control system that will attach to the Xbox 360 console via USB port. Such system will use two cameras for full body movement mapping and tracking. Each video camera has an infrared sensor to capture user movements, range finding, and 3D depth to determine the target distance from the console. Several algorithms translate the data from the cameras to appropriate 3D movements on game scenes.

The creators of this project believe that Natal will be able to recognize motions as small as finger movements and determine the actions of body parts not visible in a game scene, such as a character arm behind his back. It will also be able to use the speed of a player’s motion such as punching or baseball bat swinging to determine the level of force a player applies to a character or object in a game. In addition, Natal recognizes user genders through face, body and hair shape.

This paper addressed some techniques and technologies that may be used to enhance gaming experience relying on wireless and body sensor networks. Sensor networks can be used on a wide range of applications on both real and virtual world. On virtual environments they can be applied on games, such as playing car games, pet games, or even a tennis game. In the real world, sensors may be applied in medical applications and biofeedback, or other challenging areas, such as advanced e-learning systems.

In terms of future developments, we consider that a wide range of applications will make sensor networks an integral part of our lives. However, sensor networks need more improvements, mainly, to solve the constraints introduced by factors such as hardware, network topology, mobility, or environment. Nanotechnology [17] will be an active support for sensor networks given its unique characteristics. With this paper, we hope to contribute for a deep understanding and further utilization of wireless sensor networks in both virtual and real worlds.

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