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The Role of Haptics in Games

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1. Introduction

Today, playing a video game is a different story than what it was twenty years ago in many senses. Game consoles have steadily gained popularity not only among kids but also among other age groups. For example, today, the Xbox 360 from Microsoft comes with Kinect technology which is based on webcam built in system for users to control and interact with the console without the need for conventional game controller to bring entertainment and playing games to people of all ages. On the other hand electronic gadgets including smart phones have changed the way game controllers, pads, buttons, joy sticks can be used with the incorporation of haptic and sensing technologies. Additionally, impressive graphics and 3D rendering displays are creating virtual environments more realistic which have the potential to capture the gamer's attention all throughout the gaming process. As stated by Jurgelionis and others: "The increasing number of broadband users, and a demand for quality and diversity in entertainment services drives the development of new pervasive entertainment systems" (Jurgelionis et al., 2007). Indeed, they also stated that such entertainment systems should be accessible without any limits on time and location.

In the real world, people receive and disseminate information in three-dimensional space. Computers, through graphical user interfaces, allow users to perceive an imitated three-dimensional world that exists in the real world. Such a virtual world can be enhanced in a more complete imitation of the real space by the introduction of an artificial support technology called haptics. A haptic interface is a device that allows a user to interact with a computer by receiving tactile and force feedback. The interaction can embrace the entire body or only the tip of a finger, giving the user information about the nature of objects inside the world. The introduction of haptics permits one to enhance a vast spectrum of human tasks in a virtual environment.

Currently, haptic research and technology has been focused on designing and evaluating prototypes of different features and capabilities for the use in virtual environments. The evidence is that, some of these prototypes have become commercially available to the market. In that sense, applications of this technology have been invaded rapidly from devices that can interact with sophisticated graphical user interfaces (GUI's), games, multimedia publishing, scientific discovery and visualization, arts and creation, editing sound and images, the vehicle industry, engineering, manufacturing, Tele-robotics and Tele-operations, education and training, as well as medical simulation and rehabilitation.

For the time being we could argue that haptic research related to home entertainment and computer games has blossomed and impacted the development of technology during the past few years.

It is well-known that the game experience comprises four aspects: physical, mental, social, and emotional (El Saddik, 2007). It is on the physical aspects that, force feedback technology (haptics) enhances the game experience by creating a more realistic physical feeling of playing a game. This physical experience can be translated for example in improving the physical skills of the players, and imitating the use of physical artefacts. By using existing, well-developed game engine components—specifically, a scene graph library and physics engine – and augmenting them with the design and implementation of haptic rendering algorithms, it is possible to create a highly useful haptic game development environment.

This can be reflected in a rich environment which provides to players or users a higher sense of immersion as well as new and interesting ways to interact with the game environment. In addition this simulated world can be used to do research on applications such as physical rehabilitation, driving training simulation and more.

Currently, a diverse spectrum of games available in the market take advantage of the force feedback stimuli effects offered by mainstream haptic interfaces. Here we intend to give a broad view of past and present developments aimed at enabling game environment with haptic augmented interfaces, while discussing the strengths and weaknesses of such developments.

2. Machine haptics

In order to fully understand the potential and capabilities of haptics in the gaming environment, let us first look how the sense of touch has brought a more complex and appealing dimension to the human computer interaction. Haptics was introduced, at the beginning of the 20th century by research work in the field of experimental psychology aimed at understanding human touch perception and manipulation. Psychophysical experiments provided the contextual clues involved in the haptic perception between the human and the machine. The areas of psychology and physiology provided a refreshed impulse into the study of haptics and it remained popular until the late eighties. Researchers have found that the mechanism by which we feel and perceive the tactual qualities of our environments are considerably more complex in structure than, for example, our visual modality. However, they opened up a wealth of opportunities in academic research and development to answer the many questions that the haptic cognition discipline has. Therefore the discipline that put in practice many of the theories developed in haptic perception domain were addressed by *machine haptics*.

Machine Haptics involve designing, constructing, and developing mechanical devices that replace or augment human touch. These devices, also called haptic interfaces, are put into physical contact with the human body for the purpose of exchanging (measuring and displaying) information with the human nervous system. In general, haptic interfaces have two basic functions; firstly, they measure the poses (positions and/or orientations) and/or contact forces of any part of the human body, and secondly, they display the computed reaction touch to a haptic scene that populates touchable virtual objects with haptic properties such as stiffness, roughness, friction, etc. Haptic interfaces can be broadly divided

into two categories: force feedback devices and tactile devices. Force feedback devices display force and/or torque and enable users to feel resistive force, friction, roughness, etc. Tactile devices present vibration, temperature, pressure, etc. on the human skin and display textures of a virtual object or provide information such as showing direction, reading text, displaying distance, etc.

Turning to the robotics arena in the seventies and eighties, most researchers were considering the systems aspect of controlling remote robotic vehicles to manipulate and perceive their environments by touch. The main objective was to create devices with dexterity inspired by human abilities. Robotic mechanical systems with a human being in their control loop are referred to as Tele-manipulators, where an intelligent machine is expected to perceive the environment, reason about the perceived information, make decisions based on this perception, and act according to a plan specified at a very high level. In time, the robotics community found interest in topics including but not limited to: sensory design and processing, grasp control and manipulation, object modeling and haptic information encoding.

Meanwhile, terms such as tele-operation, tele-presence, tele-robotics and supervisory were used interchangeably by the robotics community until the mid-nineties. From those terms two were especially important to develop haptics systems; Tele-operation and Tele-presence. Tele-operation refers to the extension of a person's sensing and manipulation capabilities to a remote location. Tele-presence can be described as a realistic way that an operator feels while physically being at a remote site. Motivated by these concepts, the Tele-presence and Tele-operation research communities developed several projects in the several related fields such as the nuclear industry, sub-sea, space and the military markets.

In the early nineties, the use of the word haptics, in the context of computer haptics was introduced. Much like computer graphics, computer haptics is concerned with the techniques and processes of generating and displaying haptic stimuli to the user. In fact, computer haptics uses digital display technology as a medium for physically tangible interaction where objects can be simulated in an interactive manner. This new modality presents information to the user's hand and/or other parts of the body by exerting controlled forces through the haptic interface. These forces are delivered to the user depending on the physical properties of the objects that can be perceived. The hardware components of this interface play an important role in displaying these forces through the response sensors to the user. Unlike computer graphics, the behaviour of haptic interaction is bidirectional, due to energy and information flow in both directions from the user to the haptic interface and vice versa.

Only recently, have haptic technologies become integrated with high-end workstations for computer-aided design (CAD) and, at the lower end, on home PCs and consoles, to augment the human-computer interaction (HCI). Effectively this implies the opening of a new mechanical channel between human and computer so that data can be accessed and literally manipulated through haptic interfaces.

Nowadays, computer haptic systems can display objects of sophisticated complexity and behaviour; thanks to the availability of high-performance force-controllable haptic interfaces, affordable computational geometric modeling, collision detection and response techniques, a good understanding of the human perceptual needs, and a dramatic increase

in processing speed and memory size. With the commercial availability of haptic interfaces, software toolkits, and haptics-enabled applications, the field of human-haptics interaction is experiencing an exciting exponential growth.

3. A roadmap to haptic interfaces in games

Haptic research in the realm of home entertainment and computer games has blossomed during the past few years. The game experience comprises four aspects: physical, mental, social, and emotional. In particular, force feedback technology enhances the physical aspects of the game experience by creating a deeper physical feeling of playing a game, improving the physical skills of the players, and imitating the use of physical artefacts. Plenty of games available in the market take advantage of the haptic effects offered by mainstream haptic interfaces. Car racing games can be enhanced when players drive over a rough section of road by receiving vibrations in their joysticks or steering wheels. However, how did we come to realize such novel interfaces that enhance our gaming experience? In this section we present a roadmap to past and present work, which can give a picture of how haptic interfaces came to be what they are today.

3.1 Evolution of the videogame industry

It is known that Egyptians were playing games since around 3000 BC when an expedition in 1920s by Sir Leonard Wooley found two board games in tombs. Thus the Royal Game of Ur gets its name from the two game boards which are associated with first dynasty of Ur (before 2600 BC). Each of the game boards contains a set of twelve squares and a set of six cases which were linked by a bridge of two cases (for review consult "Histoire des jeux de société by Jean Marie Lhôte, 1994). The rules of the game are very similar to backgammon, the goal is to introduce seven pawns and move them along to designated path and be the first to have them also out of the game. At this point it is possible to state that games have existed along the existence of humanity. Thus many games have remained as they were designed but the way to play them has changed radically. The sole relationship between human societies with games can fill entire books.

The video game industry itself could be dated from the late 19th century, more precisely in 1889 when Fusajiro Yamauchi established a company called Marufuku to distribute and manufacture a Japanese playing card game-Hanafuda. In the 1950s Marufuku company became Nintendo which means 'leave luck to heaven'. Meanwhile in the USA, Martin Bromley buys slot machines and creates a game rooms concept named Service Games(SEGA) (Kent, 2001).

Later on, David Rosen opens a business in Japan and he starts shipping photo booths. Then Rosen imports coin-operated electron mechanical games machines to launch this industry in Japan. At the beginning of 60s, a student from Massachusetts Institute of Technology(MIT), Steve Russell developed an interactive game computer called Spacewar.

At the time Rosen Enterprises merges with Services Games to become Sega Enterprises. Then, in mid sixty's Ralph Baer starts interactive television games at Sander Associates meanwhile Sega in Japan was charging \$0.25 cents per play arcade games to overcome with the high shipping costs, which then eventually become the standard price for playing arcade

games. In 1970 Magnavox licenses Rapt Baer's television game from Sander Associates and a year later released as Odyssey based on Ping-Pong Baer's game. In the mid 1970's Atari designed a prototypical Home Pong unit and Namco starts creating video games.

In the late 70's Atari released the video game computer system known as 2600 and Mattel introduced a line of LED-based handled video games, also Nintendo released its first home video game in Japan. In 1979 Atari releases Asteroids, which became an all time bestselling game and Mattel Electronics introduces the Intellivision game console. In addition Milton Bradley released Microvision, the first handled programmable game system. In the 80's the practice of selling home versions of arcade machines hits the business. The same year Pac-Mac was released which is the most popular game by Namco (Kent, 2001).

In 1983 Cinematronics released Dragon's Lair, the first arcade game to feature laser-disc technology. One year later Nintendo released the Family Computer (Famicom) in Japan and then become in the USA the Nintendo Entertainment System(NES). In the mid 80s Tetris was created by Alex Pajinov and also Atari released the 7800 game console. Later on NEC released the 16-bit/8-bit hybrid PC-Engine game console in Japan and Sega unveils 16-bit Meha Drive game console. Early 90s Sega ships SEGA CD peripheral for Genesis game console. In 1993 Atari launches the 64-bit Jaguar and Id software publish Doom for PCs. One year later Sega releases 32X, a peripheral device that increases the power of the Genesis. In mid 90s Sony releases PlayStation in the United States and Nintendo Virtual Boy and also unveils the 64-bit Nintendo game console in Japan. At the late 90s Sega releases Dreamcast game console in the USA. In 2000 Sony released PlayStation 2 and Microsoft unveils plans for XBOX. In 2001 Nintendo release GameCube and Microsoft Xbox worldwide (Kent, 2001).

Development of video games industry has also been based on a close relationship with the well established amusement industry (Kent, 2001). To extend such criteria, Kent has stated that pinball games had made a huge impact in the development of videogame and computer industry in general. In his book he assumes the position that the creator of *Baffle Ball* game David Gottlieb was a great influence in the development that we know today as video game. In the first stage of development the *Baffle Ball* game was used with no electricity and it was built in a countertop (worktop) cabinet and had only one moving part the plunger. Players could enjoy the game by spending a penny¹ and get seven balls to try into scoring holes. *Baffle ball* was successful at the time that Gottlien created a company to deal with a shipping load of 400 cabinets per day.

Later on, competition was in place, thus this industry in the 70s had five game manufactured companies to place and distribute equipment in restaurants, bar, bowling and stores. On the other hand the development of computers was growing fast from the 60s when the computers occupied the whole room to the introduction of transistor which replaced the vacuum valves and later on the silicon chips which replace the transistors making computers more robust and fast. Thus more academic society and students were involved in the development of computer languages and interaction. The first game was created by engineers at Sander Associate a contractor company. The game was created from idea of which a hard-wired logic circuit projected a spot flying across the screen. The original idea was for players to catch the spot with manually controlled dots. Over time, the

¹ A penny is a coin or a type of currency used in several English-speaking countries. It is often the smallest denomination within a currency system source: Wikipedia 2011

player's dots evolved into paddles and the game became "ping-pong". One the main developers of this concept was Baer who sold the idea to Magnavox but they first of outrageously priced and poorly advertised at the time that this game had gone almost unnoticed until Magnavox released later on as Odyssey which change dramatically the way to play games (Kent, 2001).

3.2 Enhancing the experience with the sense of touch

In a first generation we started out with the modest beginnings of Pong, a two dimensional simulated table tennis where players were only allowed to move the game-paddle vertically to control a moving dot, or Pac-man which through a maze eats Pac-dots, Tetris and video pinball, video games. Then we moved to a second generation with the Super Mario Brothers where the player controlled Mario in a one-player control based strategy and a second player acted as Mario's brother Luigi in a second controller approach. The game was intended to race through the Mushroom Kingdom, survive the main antagonist Bowser's forces and save the princess Toadstool, Wolfenstein 3D, Command and Conquer, Microsoft Flight, then to Quake the first shooter video game which was released on June 1996. The game engine of Quake popularized many advances in the 3D game domain such as polygonal modeling instead of pre-rendered sprites, in addition pre-rendered lightmaps and also allowing end user to partially program the game (QuakeC). Then half-life, World of Warcraft.

In this new era of gaming, we have moved far from the Pong game trend, to more realistic virtual scenarios. Particularly, such perception of reality can be enhanced by the development of computerized games influenced by technology such as haptics to make the entertainment more sophisticated.

The first work on development of haptic devices such as joysticks was carried out at Massachusetts Institute of Technology (MIT) and University of North Carolina at Chapel Hill (UNC), which resulted in a 3-DOF device that simulates an object's inertia and surface texture (Minsky et al. 1990).

Currently, vibration feedback joysticks and steering wheels from companies like Logitech are widely used as input devices in video games. In this sense, haptic research has introduced new forms of complexity in the development of games by emulating the user experience based on this particular bidirectional feedback. Pioneering attempts at introducing modern haptics to gaming include Haptic Battle Pong (Morris et al. 2004), a pong clone with force-feedback that, thru haptics, displays contact between a ball and a paddle using the PHANTOM Omni device (Sensable 2010). The PHANTOM is used to position and orient the paddle and to render the contact between the ball and the paddle as physical forces.

Nilsson and Aamisepp (Nilsson and Aamisepp, 2003) worked on the integration of haptics into a 3D game engine. They have investigated the possibility of adding haptic hardware support to Crystal Space, an open source 3D game engine.

By using existing, well-developed game engine components such as Unity 3D, a scene graph library and physics engine, and augmenting them with the design and implementation of haptic rendering algorithms, it is possible to create a highly useful haptic game development

environment. This can result in a rich environment, which provides players or users with a higher sense of immersion, as well as new and interesting ways to interact with the game environment (Andrews et al. 2006). In addition, this simulated world can be used to do research on applications such as physical rehabilitation, driver training simulations, and more.

There is also a haptic device called HandJive designed for interpersonal entertainment (Fogg et al. 1998). The concept is described as a handheld object that fits in one hand and allows remote play through haptic input and output. It communicates wirelessly with similar devices, and provides haptic stimuli. In fact, haptic devices are becoming more accessible to the average computer and console user and will play an important role in providing innovative forms of entertainment. As further evidence, in 2008, Novint Technologies introduced the Novint Falcon device, which is affordable, even for mainstream consumers (Novint 2010). This device is now integrated with several popular video games.

4. Haptic controllers

4.1 Force feedback wheels

Although drivers obtain a substantial amount of information from driving from vision, information from other sensory modalities may also provide relevant information about the state of the car or even the surrounding environment (Liu & Chang, 1995). Force feedback steering racing wheels provides mainly realistic resistance to the wheel rotation and providing precise throttle response. This is achieved by emulating the real steering system through a mechanism that also provides vibration feedback. From a tele-operating system perspective, the energy which flows between the driver and the vehicle front wheel through the mechanical linkage can be considered to be mainly effort and flux exchange which corresponds to force and velocity (Mohellebi et al, 2001).

In addition driving-simulators fidelity is usually defined by the quality of its visual and motion cueing system (Katzourakis et al. 2011). Katzourakis experimented that the quality of driving-simulator's haptic cues are very important and rely on the hardware and control properties of the system design. Despite the hardware characteristics there is also important to consider the model of vehicle dynamics. An experimental work was carried out by Toffin et al in order to answer questions such as how do drivers use the force appearing on the steering wheel when driving in curves?. Well, they have found that a wide range of adaptation results that occurs mainly at the haptic level rather than in the internal model of the vehicle dynamics. Many features provided by commercial force feedback steering wheels is based on exclusive design and technology proprietary of IMMERSION Technologies.

In 1992 Thrustmaster Enzo Ferrari Force Feedback Racing wheels was released which did not provide a satisfactory sense of precise force feedback for some users. In 1998 Logitech the leading company of gaming controllers for PCs and consoles released the Logitech Formula™ Force GP racing wheel with more than one million sales worldwide and actually it was the first force feedback wheel found in any game console. The force feedback in racing wheels attracted a more sophisticated method for racing aficionados immersed in more realistic playing environments.

In 2002 Logitech introduces a Speed Force Feedback wheel for GameCube. In 2005 the R440 Force Feedback Wheel from Saitek has busted open the doors to affordable racing fun. In

2006 more realistic racing simulators and more affordable appeared in the scene. For instance the Logitech G25 wheel offers advanced features which, until now, could be found only in specialized or custom-made racing simulators that sometimes cost thousands of dollars to assemble, thus introduced the industry's first two-motor force-feedback mechanism with the G25 wheel console, providing stronger and more precise feedback as well as 2 1/5 rotation feature(900 degrees). With a second motor, the directional forces are more realistic and evenly distributed throughout the wheel – drivers will feel everything from the banks in the road to impact with walls, structures and other cars.

In 2007 things were tuned up with Forza Motorsport 2 on the Xbox 360 using the Microsoft Wireless Force Feedback Wheel. Force feedback is an extremely useful haptic interface. It provides real-time info on several key aspects of Forza Motorsport 2's physics model. Obviously, force feedback simulates the steering wheel torque created by having the front tires on different terrain types, such as asphalt, rumble strips, or grass. It also simulates load balance between tires as well as slippage. At the end of 2007, Saitek has launched its new R660GT Force Feedback Wheel, a USB racing wheel with force feedback and switchable gearstick. The R660GT wheel comes with a solid G-clamp to securely fix the wheel to a desk, and the soft handle finish ensures a strong grip. Its setup includes pedals that can be customized to suit the driver, so that they can operate independently of each other or can be combined to suit different games or a player's driving style. Unlike most other driving wheels, the R660GT pedals accurately reflect the positioning of pedals in a real car, pivoted from the top rather than the bottom, whilst the brake offers more resistance than the accelerator. 2009 is the era of wireless, therefore Logitech Speed Force Wireless Racing Wheel Works With EA's Highly Anticipated Racing Game Need for Speed™ Undercover.

4.2 Joysticks

The joystick has been the principal flight control in the cockpit of many aircraft, particularly military fast jets. It has also been used for controlling machines such as cranes, trucks, underwater unmanned vehicles, and wheelchairs but also very popular to control video games. It is an input device consisting of a stick that pivots on a base and reports its angle or direction to the device it is controlling. Its origins date since early 20th century and are related to the aviation pioneers where its mechanical origins are uncertain but the term “joystick” was coined to Robert Loraine.

An arcade ticks is a large-format controller for use with home game consoles or computers. Most joysticks are two-dimensional, having two axes of movement (similar to a mouse), but one and three-dimensional joysticks do exist. An analog joystick is a joystick which has continuous states, i.e. returns an angle measure of the movement in any direction in the plane or the space (usually using potentiometers) and a digital joystick gives only on/off signals for four different directions, and mechanically possible combinations (such as up-right, down-left, etc.). Digital joysticks were very common as game controllers for the video game consoles, arcade machines, and home computers of the 1980s.

The force feedback joystick is similar to ordinary ones however it has in addition a couple of electrical motors and gear train or belt system and microprocessor. The X-axis and Y-axis shafts are connected to the stick both engage a belt pulley. The other end of the belt for each axis engages a motor's axle. In this setup, rotating the motor axle will move the belt to pivot the shaft, and pivoting the shaft will move the belt to rotate the motor axle. The belt's function

is to transmit and amplify the force from the motor to the shaft. One thing that differentiates force feedback joysticks from traditional joysticks is the lack of a centering spring. This spring keeps the joystick's neutral position in the middle (at 0,0 in terms of the x- and y-axis). Force feedback joysticks do not have the traditional centering spring; instead they rely on small servos or motors to push the joystick into the center of the range of movement

In 1977, the Atari 2600 game console was launched with a joystick that had one button to use. In 1978 a patent was released which disclosed a joystick controller that includes a plurality of pressure actuated switches disposed about the axis of the joystick handle. The ZX Interface 2 was a peripheral from Sinclair Research for its ZX Spectrum home computer released in September 1983. It had two joystick ports that were mapped to actual key presses and the hardware came with ROM cartridge which was very limited. Released in 1987, the Atari XE Game System (XEGS) came with a detachable keyboard, joystick, and light gun. Essentially, the XE was a repackaged Atari 65XE, hence the compatibility with almost all Atari 8bit software and hardware.

In 1989 a joystick handle which is telescopic like a car antenna was released. This joystick can save space when not in use and it can save space when packed for shipment. The joystick length is customizable to the individual user's input needs as described. Another type is a miniature joystick incorporated into the functional area of the keyboard. This miniature joystick has been successfully incorporated into a number of laptop computers. In 1995, Dear Ace Pilot The Phoenix Flight and Weapons Control System by Advanced Gravis is getting lots of raves among gamers. It's fast, ergonomic and completely programmable with 24 buttons that can map to keyboard or joystick functions.

Microsoft's latest Force Feedback 2 Joystick comes complete with feature rich enhancements and new force feedback effects. The most practical aspect of the force feedback in this game is that if the plane stalls in flight, the stick will shake just like in a real aircraft. You can also feel the thud when the landing gear retracts. The force feedback for these events is rather small - while you can feel the stick shake when the gear retracts, it isn't something that is going to disturb your control over the joystick. It's the small details like these, the added sensations, that will add to the gaming experience.

In 2004, Logitech is introducing its latest controller for the PlayStation 2 - the Logitech Flight Force joystick during the 2004 International Consumer Electronics Show in Las Vegas. For an immersive experience, the three-component Logitech Flight System G940 features a force feedback joystick, dual throttle and rudder pedals and has more than 250 programmable button options integrated into a fully featured HOTAS (or Hands On Throttle-and-Stick)

4.3 Game pads

It is the most common kind of game device that provides input in a computer game or entertainment system used to control a playable character or object. Its design was conceived to be held in both hands with thumbs and fingers used to press buttons to provide input. Thus the main goal of game controller is to govern the movement/action of payable body/objects in a video computer game. Gamepads usually feature a set of action buttons handled with the right thumb and a direction controller handled with the left. Later on some common additions to the standard pad include shoulder buttons placed along the edges of the pad.

Third generation of video game controllers included the Nintendo Entertainment System (NES) featured a brick-like design, Master System which has a similar design as NES and the Atari 7800. The fourth generation included Genesisi Mega Drive by Sega, TurboGrafx-16/PC-Engine and the Super Nintendo Entertainment System which had a more rounded dog-bone like design and added two more face buttons, "X" and "Y", arranging the four in a diamond formation.

In the Fifth Generation the Apple Bandai Pippin had a short live console designed by Apple Computer Inc. The Atari Jaguar was the first and last Atari console to employ the modern gamepad. Another example is the Neo Geo CD which was similar in shape and size to Sega Genesisi/Mega Drive game pads. Other examples include, The Sega Saturn, whose control pad introduced an analogue stick and analog triggers, Virtual Boy controller designed to use dual joypads, which was envisioned to control objects in a 3D environment. Sony developed a four direction D-pad, four actions were referred not by color or letter/number like most pads instead were colored shapes; triangle, circle, cross and square. The basic design and layout was based on that of Nintendo's SNES controller, as the PlayStation was originally developed as a CD add-on for the SNES, before becoming a console in its own right. It was the default pad for the first year of the PlayStation, until the release of the Dual Analog. It was often cloned for PC gamepads. The Nintendo 64 started to have both an analog stick and a D-pad. It has the traditional A,B,L and R buttons, along with a Z trigger button on its underside.

4.4 Haptic vests and jackets

Originally designed for medical investigation, Physician Mark Ombrellaro developed a haptic vest that enabled the wearer to feel the impact of bullets, explosions and/or even hand taps in the trunk of the player's body. The 3RD Space Vest is commercialized by TN Games and is advertised as the only gaming peripheral device that allows you to feel what your game character feels. It works with pressured air to provide the player pressure and impact forces that can emulate a wide scope of direction and magnitude (TN Games, 2011).

Others have worked on similar systems, and although they have not focused on the application in games specifically, it is clear how such technologies could also be applied in a game scenario. In the University of Ottawa in Canada, Jongeun Cha and others have worked in a device to enhance teleconferencing. They developed a jacket that enhances communication with the physical and emotional connection by allowing participants give encouraging pats to one another (Cha et al, 2009). Similarly, researchers at the National University of Singapore developed the Huggy Pajama wearable system, where the remote communication between parent and child is enabled through virtual hugs. This is possible by using a doll with embedded pressure sensors as input device and a haptic jacket as the actuator for the hug at the other end. The hug is reproduced by air pockets and the experience is further enhanced by adding a heating element to the device to mimic the warmth of a hug (Teh et al, 2008).

5. Haptics in mobile gaming

With the advent of smart phones, and other personal and portable devices such as MP3 players and tablets, which everyday include a richer set of sensory, processing, and memory capacities, videogames have finally make the jump from good old PCs and Consoles to the

mobile world. Smartphones and related devices are capable of rendering videogame graphics and sound in high definition, which aims at immersing the player in the game experience even with the limited size of the screen.

Because mobile video games are inherently restricted to small screens, game developers must rely on advanced user interface design to fulfill the input/output streams of media information necessary to play the game. Furthermore, most of the portable devices that serve as a platform for modern mobile games feature a touch screen as the main way of interaction with the device and its software interface. Most of the time such devices, either completely lack or, have very few physical buttons that the player can use to play the game. Even when physical buttons are present on the device, they are often located in places where using them as part of the game input controller makes it awkward for the player. In terms of haptic feedback, this is a limitation of such devices, since touch screens lack that physicality that players have grown used to with pc and other gaming consoles and their controllers.

To help with the lack of physical buttons and the sense of touch that they provide, mobile phones and devices are often capable of reproducing a vibration feeling. By controlling the moment, and duration of the vibration, to be synchronized with the touch of the screen, such mobile devices compensate the lack of hard buttons by giving a haptic feedback to the user whenever he/she presses a soft button on the touch screen. Although this is often good enough for common in-device tasks such as entering text on a virtual keyboard, from a gaming perspective the approach is very limited, as is the hardware available in most devices. Games require a higher degree of variation on the vibration to produce more rich and realistic experiences. Different levels of intensity, duration or even a specific vibration pattern must be applied for different events in the game play. The challenge in providing such degree of high definition on the haptic feedback is twofold. On one hand, hardware on the devices must be sufficiently advanced to permit the variation of intensity at which the internal motors will cause the vibration. And on the other the software must be sufficiently sophisticated to control the motors in such a way that a wide array of vibration effects can be rendered.

Research has been mostly focused in developing vibrotactile rendering techniques that can allow for a sophisticated touch feedback experience. Different algorithms have been tried to control the vibration motors and render the desired effects. Sang-Youn and others proposed a Traveling Vibrotactile Wave rendering technique which makes the effect of a traveling sensation across the device display. It is based on controlling the vibrations of two motors, which permits to specify the location where the overlapping of two waves occurs. This control further allows the generation of a sensation of continuous flowing vibration by constantly changing the overlapping point, adjusting the timing of motor actuation. They tested their rendering technique with a ball rolling game (Sang-Youn, 2009). In another related work, they tested a miniaturized vibrotactile rendering system based on an eccentric vibration motor and a solenoid actuator, which generates vibrotactile information having a large bandwidth and amplitude. Their intention was to generate event-specific vibrotactile effects for a car racing game in a mobile device. The system could render human discernible effects for the events of collision, driving on a bump, and driving on a hard shoulder (Sang-Youn, 2006).

A good example on the latest advances in this direction is the MOTIV platform from Immersion. Their solution provides a TouchSense embedded controller technology to

enables a high degree of control over the vibration motors of the device. On the software side, they provide MOTIV Integrator for OEMs to include in their devices a vibration profile manager that leverages on TouchSense, and MOTIV Software Development Kit to enable developers to build third party applications and video games that also take advantage of the high definition vibration effects provided by their platform (Immersion, 2011).

Another approach has been taken by Senseg, a company based in Finland whose latest haptic rendering solution is a promise to revolutionize the way we perceive computer generated haptic feedback on touch screens and other real world surfaces. Their E-Sense Technology is based on biophysics; where instead of having the device's surface vibrate, they create a sensation of vibration directly in the finger's skin by using an ultra-low electrical current from an electrode to produce a small attractive force. The modulation of that force allows the production of any number of touch sensations that can range from vibrations, clicks, textured surfaces and more. A direct implementation of this technology is in the mobile device industry, and the provided software APIs would allow the development of video games with a sophisticated array of touch sensations (Senseg, 2011).

In terms of evaluation of the effectiveness of the haptic feedback on mobile gaming, Chui Yin Wong and peers tested the playability of a mobile game, using a vibrotactile feedback soft keypad, against playing the same game with a hard physical keypad. According to their findings, although players had higher scores using the soft keypad, they reported a preference on using the hard keypad in term of a better experience in the game play (Chui Yin Wong, 2010).

6. Haptics and games for the visually impaired

Although haptics has proven to be a valuable technology to help gamers to have more immersive and realistic experiences, there is yet another type of game for which haptics is of essential value. Haptics is a very well suited type of interaction to address the problem of accessibility to games for the visually impaired.

There are currently different technologies that have improved the accessibility of electronic media to the blind people, such as automated reading software, voice synthesis, tactile displays with Braille and speech recognition. Yet, those are mostly focused in input/output of text and there is still some types of media that are still difficult to represent in a non-visual modality, particularly graphics (2D or 3D), which form the basis for any computer game. Computer haptics seems to be a suitable solution for this problem of game accessibility, but still there are plenty of problems and research to be done on the field. It is hard enough to have an accurate haptic representation of an object in a virtual world that can be properly recognized by someone who is not able to look at it, and even harder to do it for the multiple objects and events that need to be perceived during game play. In fact, in most instances the haptic interface must be accompanied by some audio feedback as a complement, as to not overload the user with haptic signals (Yuan, 2008).

There have been two main approaches to enable visually impaired individuals into computer games. The first one is to design games that are inherently designed and implemented with the purpose of not relying on visual feedback. That is games whose playability is completely subject to interaction based on audio or haptic clues.

A survey of strategies for making games accessible to the blind shows that audio is the most common used channel to either complement or substitute the visual channel (Yuan et al. 2010). AudioGames.net is an online community portal that has a repository of games whose interface is solely based on audio and the natural haptic interface of keyboard and mouse buttons (Audiogames, 2011). In terms of pure haptic games there are examples such as Haptic Sudoku for the blind, developed by Gutschmidt and others. In this technological solution they emulate visual perception completely by haptic perception. Players can feel the Sudoku board and scan the numbers by sense of touch using a haptic display, while audio cues alert the user of the outcome of their actions (Gutschmidt et al. 2010). Another example is Finger Dance, a sound based game for blind people. In FingerDance, user try to match musical rhythm patters to keystrokes in the keyboard. The game has no visual feedback at all (Miller et al. 2007).

The second approach is sensory substitution. In this case the cues that would normally come from the visual channel are replaced by haptic stimuli. This allows for the modification of currently existing games that were originally designed for non disabled individuals and adapted to be played by the blind.

Blind Hero is a typical example of a game where sensory substitution has been applied to a very well known video game (Guitar Hero from Red Octane). Guitar Hero is a rhythm action game that is played by using a guitar shaped input device with colored buttons on it that must be pressed following the corresponding visual cues that appear on the screen at the peace of some rock tune. In the modified version, Yuan and Fomer replaced the visual cues with haptic stimuli coming from a haptic glove that has small pager motors that stimulate the tip of each finger (Yuan and Fomer, 2008).

VI-Tennis and VI-Bowling are another example of sensory substitution from their analogous version of the Wii Console (Wii Sports, 2011). In this case the haptic interface is based on a motion sensing controller enhanced with vibrotactile and audio cues that allows the players detect the key events in game play. In the case of VI-Tennis the controller would provide vibrotactile feedback to reflect the event of the ball bouncing and the timeframe at which the ball should be hit in return, while audio cues were left the same they ware on the original Wii Tennis game (Morelli et al., 2010a). For the VI-Bowling they implemented a technique called Tactile Dowsing where the Wii Remote is used to sense the direction to where the bowling ball should be thrown. With the Tactile Dowsing the player moves the remote left and right in a horizontal pattern. The receiver will detect the motion of the remote and the software prompts a vibrotactile feedback on the remote in a pulsing pattern. The delay between vibrotactile pulses is regulated so that the closer the player points to the optimal direction of the throw, the lower the delay and vice versa. This way the player can sense the direction the same way by trying to position the remote in a direction that has a near continuous vibrotactile feedback (Morelli et al., 2010b).

7. Haptics and serious games

In general, the term "Serious Games" refers to computer video games that are used with a purpose beyond or other than entertainment. However some discussion has been going on for some time about the formal definition and some other details about what may or may not constitute a serious game.

According to a definition stated by the people on the Serious Games initiative, started in 2002 by Ben Sawyer and others (Serious Game Initiative, 2011), a serious game can be defined as follows:

“applications of interactive technology that extend far beyond the traditional videogame market, including: training, policy exploration, analytics, visualization, simulation, education, health, and therapy.”

Serious games have been developed for many areas, including education, government, military, corporate, healthcare, politics, religion and arts. Haptics technology has been present to different extent in the majority of these areas. However, we argue that two of the most prominent serious games application areas where the advantages of haptic technology can really be appreciated are healthcare and education.

7.1 Healthcare

In this particular area there has been great interest in research how computer haptics technology can assist in rehabilitation process of people who has had some damage to their motor skills, while playing a game. The combination of the properties inherent to computer haptics (force and tactile feedback) with the appealing and motivating factor offered by Virtual Environments have provided a framework for the development of various rehabilitation systems that often involve the patient, and the therapists.

Haptic Hand writing sessions and Ten Pin Bowling are two examples of haptic assisted game applications developed by Xu and others at the University of Shanghai for Science and Technology in China. Their Ten Pin Bowling is intended for training of the motor function of post-stroke patients, based on Virtual Reality. They also demonstrate that haptic based hand writing is an efficient way to improve motor skills, postural stability, control and hand to eye coordination (Xu et al, 2010).

Jack and others worked on serious games rehabilitation using a haptic glove. In their work, the interaction with a virtual environment is enabled by using a CyberGlove and a Rutgers Master II-ND (RMII) force feedback glove. The Virtual Environment was designed to promote the training rehabilitation of a specific parameter of hand movement: range, speed, fractionation or strength. Their system would adapt to the level of rehabilitation achieved by the patient (Jack et al. 2001).

Similarly Huber and collaborators developed a home based tele-rehabilitation system for children with Hemiplegia. They made modifications to a play station game console to support the use of a haptic glove and their custom made virtual environment game. The game consisted in making specific hand movements to scare away butterflies that would appear on the virtual environment (Huber et al. 2008).

Broeren et al. Studied the effects of virtual reality and haptics in stroke rehabilitation by using a VR station loaded with a library of games and a hand held haptic stylus device. User interacted with the virtual objects of the games, while the workstation collected data about the 3D hand movements of the patients. They found that the enhanced rehabilitation experience was highly motivational to the patients (Broeren et al. 2008).

7.2 Education

In the education field, most of the work has been towards providing a more immersive and hands-on approach to learning class content. In particular chemistry is one of the subjects often targeted thru haptic assisted learning tools (Fjeld and Voegtli, 2002).

As a good example, Sato and others designed a haptic grip and an interactive system with haptic interaction as a teaching aid. They focused on the interaction between two water molecules by constructing an environment to feel Van der Waals force as well as electrostatic force with haptic interaction (Sato et al. 2008). In a similar way, Comai and collaborators propose a framework for the implementation of haptic bases systems for chemistry education (Comai et al 2010).

A second point of interest for haptics in education is that of learning hand writing skills. Eid and others seveloped a multimedia system for learning hand writing in different languages. The system is based on a haptic stylus controlled by software in such a way that it can guide the movement of the learner in an analogous way that a teacher would hold his/her hand. The system supports various languages including Arabic and Japanese. The amount of strict guidance of the system can be adjusted so that overtime the user makes the writing by him/her self (Eid et al. 2007).

In a similar work, kindergarten children were subject to hand writing training using a Visuo-Haptic device to increase the fluency of handwriting production of cursive letters. Forty two children participated in the experiment that showed that the fluency of handwriting production for all letters was higher after the training with the tool than those children which were not subject to it (Palluel-Germain et al., 2007).

8. Summary

Computer video games have come a long way and have evolved from a pure graphics and visual rendering into a fully fledged multimedia experience. Videogames try to appeal to all senses of the human player. Video graphics are very sophisticated and the definition, speed and overall quality of the visual stimuli is at its best. Audio has become an integral part of any computer video game as well, from small audio clues about events on the game to full soundtracks that give character to the titles. We argue that video and audio were the dominant media channels in the videogame industry in what could be called the first generation of games.

In this new era where computers are miniaturized and with even higher capacities of processing and memory, developers and researchers have focused on extending the sensory experience to include the sense of touch. Initial implementations include vibrotactile feedback with a rumble effect on game input controllers. However, in an attempt to achieve a more immersive experience other haptics modalities have been explored, particularly force feedback. There are already haptic devices available in a consumer level market that have complex hardware implementation that allow for more realistic reactions from the controller to game dynamics and user actions.

Another trend on games has been mobility. The wide availability of low cost, high performance mobile phones and tablet PCs has created a whole new market for game titles

that can be played on the go. Along with this trend haptic technology has been introduced even on those constrained environment by means of sophisticated algorithms that can create a whole array of vibrotactile effects for each type of game condition.

Finally, games have ceased to be a purely entertainment element. The so called serious games are making people to engage in more practical and meaningful activities (in the fields of education, government, military, corporate, healthcare, politics, religion and arts), while still having the fun that game play always brings. Even in these particular type of games, haptic technology promises to enhance the activity and may be even provide a type of interaction or achieve a specific goal that would not be possible by using any other media channel.

In the future, it can be expected that machine haptics will evolve and improve into a more robust technology reaching a wide spectrum of human endeavour. And we are sure that gaming in all of its forms will always be one of the fields where the haptics potential can be exploited.

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There has been significant progress in haptic technologies but the incorporation of haptics into virtual environments is still in its infancy. A wide range of the new society's human activities including communication, education, art, entertainment, commerce and science would forever change if we learned how to capture, manipulate and reproduce haptic sensory stimuli that are nearly indistinguishable from reality. For the field to move forward, many commercial and technological barriers need to be overcome. By rendering how objects feel through haptic technology, we communicate information that might reflect a desire to speak a physically-based language that has never been explored before. Due to constant improvement in haptics technology and increasing levels of research into and development of haptics-related algorithms, protocols and devices, there is a belief that haptics technology has a promising future.

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