Multimed Tools Appl (2014) 71:1635–1649
DOI 10.1007/s11042-012-1297-4

Slingshot 3D: A synchronous haptic-audio-video game

**Mohamad Eid · Ahmad El Issawi ·
Abdulmotaleb El Saddik**

Abstract Recent advances in multimedia and human computer interaction technologies have paved the way for rich contents across multiple media such as haptics, audio, and video. This paper introduces a multimodal game named the Slingshot 3D Game: an interactive and synchronous haptic-audio-video shooter game over the Internet network. The game incorporates two types of haptic feedback: tactile feedback using a haptic jacket and kinesthetic feedback using the Novint Falcon haptic interface. Furthermore, the game utilizes a depth camera to track the player's (upper) body movements and detect collisions between the player's body and the shot projectile. To promote availability and cost, the game uses the Internet network as the communication medium between the players, by utilizing the Admux communication framework [10]. The game design and implementation are detailed in this paper. Both the player performance analysis and the user satisfaction analysis have shown that the incorporation of synchronous haptic-video multimedia has enhanced the perception of player presence and the overall quality of performance.

Keywords Haptic video gaming · Multimedia haptics · Tele-haptic · Interpersonal communication · Human computer interaction · Natural computer interaction

---

M. Eid (✉)
Division of Engineering, NYUAD, Abu Dhabi, United Arab Emirates
e-mail: mohamad.eid@nyu.edu

A. El Issawi
Lebanese University, Nabatieh, Lebanon
e-mail: ahmadissawi@email.com

A. El Saddik
University of Ottawa, Ottawa, Canada
e-mail: elsaddik@uottawa.ca

1 Introduction

Gaming genre is one of the largest and fastest growing industries in the world these days – for instance the global video game market has grown to US$65 billion in 2011 and is expected to continue to grow [11]. In addition to the explicit goal of entertainment, computer games can also be used for 'serious' applications such as rehabilitation, education, training and socialization. According to Nilsen [24], the game experience is comprised of four aspects: physical, mental, social, and emotional. Computer games are traditionally controlled with keyboards, mice, joysticks, and/or game pads.

One criticism of traditional gaming is that the interaction tends to be stark, largely due to the lack of multiple media communication channels (such as audio, video, touch, gesture, etc.) or the absence of physical interaction [3]. Several studies have shown that the absence of physical interaction can cause various physiological problems, including obesity and straining disorders [18]. Furthermore, existing games function quite well when the interaction is limited to audio-video channels (video games are commonplace nowadays). Future gaming interfaces should provide natural communication means using multiple media channels to promote intuitive and natural interactions. Stimulating the mental, social, and emotional experiences of players has reached mature levels with auditory and/or visual media. The next wave in industry and research is to provide alternative interfaces such as body movement and haptic modality to promote the physical and mental aspects of game experience.

Meanwhile, the last decade has witnessed a significant growth in multimodal applications involving various media such as audio, video, smell, haptics, etc. [22]. Of a particular interest, haptic modality has the ability to change gaming from an activity you watch into actions you can perform and feel [16]. With haptic feedback, players can feel the physical properties of in-game objects and/or interact with other players. Force feedback technology enhances the physical aspects of the game experience by improving the physical skills of the players and imitating the use of physical artifacts. Furthermore, the introduction of affordable personal haptic interfaces, such as the force feedback Falcon Novint device (costs less than $200 US) [25] and several vibro-tactile prototypes such as the haptic jacket [9], has fueled haptic-enabled gaming.

In this paper, we introduce a novel game named Slingshot 3D that incorporates synchronous haptic, audio, and video feedback between two players over the Internet network. The game is composed of two players, wearing haptic jackets that embed vibro-tactile actuators to simulate the feel of hits, and lobbing projectiles at each other using the Novint Falcon device to mimic the feeling of a real handmade slingshot. Furthermore, the game utilizes a depth camera (Z-cam [32]) to track the player's upper body movements to detect collisions between the fired projectiles and the player body. Finally, Admux communication framework is utilized to deliver synchronous haptic audio video data over the Internet network [10]. A distinguished feature about the proposed game is the incorporation of both tactile and kinesthetic feedback into the game environment as well as the synchronized haptic-video interaction.

The remainder of the paper is organized as follows: section 2 presents an overview of the related work in multimodal gaming and entertainment. In section 3, the SlingShot 3D game rules and the architectural design and specifications are presented, along with an explanation of the implementation details. The performance evaluation, including both the player performance analysis as well as the player satisfaction analysis, is presented in section 4. Finally, a summary of the game and a perspective for future directions are presented in section 5.

2 Related work

Researchers have been exploring the use of multiple media as means of interaction for computer gaming. While these applications are not yet commonplace, there are examples where multiple media channels are integrated to enhance the user experience (ranging from expressed non-verbal behaviors to voice and haptic feedback) [17, 20]. For instance, the authors in [4] introduced a multipurpose device that provides players with multimodal feedback. A chess board game was prototyped and used to experiment with the multimodal interface. An interesting finding was that tactile feedback about navigational information does not prevent the user to focus on cognitive tasks. However, real video streaming was not included in the study.

In November 2010, Microsoft introduced a new game controller technology called Kinect [30] that introduced a new perspective for computer gaming due to its ability to track movements and interpret 3D scenes without the need for additional devices [14]. For instance, the authors in [13] developed a hand tracking algorithm using Kinect technology for wearable haptic gaming applications. However, one limitation is that Kinect works well when the distance between the camera and the user is around 1.4 m [21]. A recent publication has shown the feasibility for integrating the Kinect interface in Tele-robotic applications such as Tele-surgery [27]. The author urged for the development of novel haptic rendering algorithms based on the depth information captured by the Kinect device. A similar research demonstrated the use of Kinect for rendering real-time virtual fixtures is shown in [28]. A similar technology is the Wii; an interactive computer gaming system for tracking user movements (poses) that eliminates the need for traditional hand-held controllers [31]. To the best of our knowledge, Wii and Kinect interfaces are not yet well explored with both tactile and force feedback haptic applications.

Several researches have confirmed that haptic modality is significant to increase gamer's co-presence and immersion [23]. For instance, the authors in [3] examined the effectiveness of touch to provide higher degrees of co-presence and immersion. The research is conducted with digital representations of humans (human objects). Results show that participants touch human objects with less force than nonhuman objects, touch with less force in the face than in the torso, and touch female avatars with less force than male avatars. Existing work for haptic gaming is classified into either tactile or force feedback gaming. Tactile feedback games use haptic feedback as another medium of communication to acquire knowledge about the physical aspects of the game, whereas force feedback (also called kinesthetic feedback) provides a means to control and manipulate the game environment by applying forces. Examples of tactile-based games include the haptic brick game [26], and the Tactile Gaming Vest (TGV) [19], and the ones found here [7, 29]. Furthermore, several force feedback games are proposed such as the Haptic Airkanoid ball-and-paddle game [12], the HapticCast game [1], the virtual reality billiard game [8], among others.

In contrary to all the aforementioned literature, the Slingshot 3D Game provides synchronous haptic-audio-video interaction over the Internet. The game provides multi-modal interactions with the player (including haptic interactions, video conferencing, and audio and textual chatting). A distinguished feature in this game is the haptic-video synchronization where the video scene (player movements and graphics cues) is synchronized with the haptic feedback. Furthermore, we strive to examine the manners in which people use and interact with multi-modal interfaces and evaluate the contribution of different media (as well as combined) to enhance the quality of user experience.

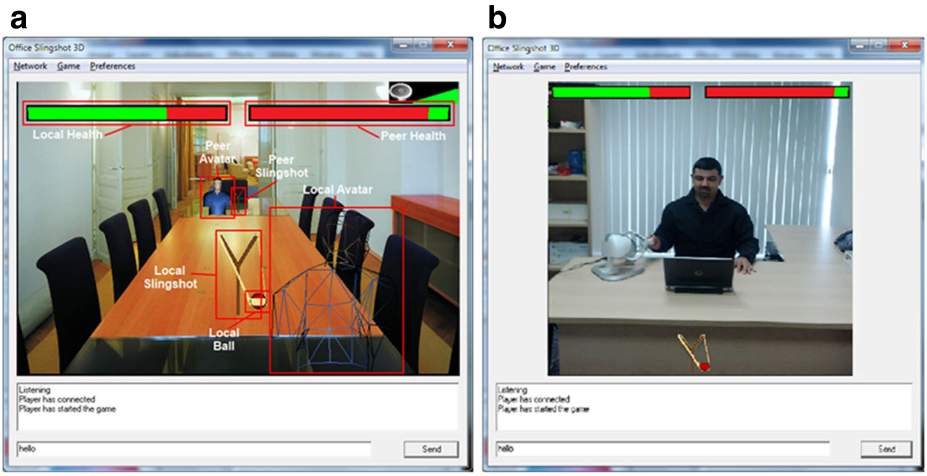
3 SlingShot 3D game

The Slingshot 3D is an interactive one-on-one slingshot game that offers real-time multi-modal interaction. The players can effectively launch projectiles at each other using the Novint Falcon haptic device while attempting to dodge incoming projectiles that can be felt using the haptic jacket. The Z-camera is used to track the player's movement to detect collisions between the launched projectiles and the player body.

3.1 Game overview

Figure 1 shows two configurations of the Slingshot 3D game: an avatar-based configuration (Fig. 1(a)) and a video-based configuration (Fig. 1(b)). In the avatar-based configuration, the players are shown virtual representations of each other (avatars) and a skeleton of their own upper body (the player does not see the video of the remote player, instead he/she sees an avatar representing the remote player). On the other hand, the video-based configuration takes the form of a video-conferencing game where the players see the actual video streams into the GUI (as shown in Fig. 1(b)).

The various game elements are shown in Fig. 1(a). The local and peer health bars are located at the top of the page. Whenever a user is hit, his/her health decreases depending on where the hit has been detected, whether he was hit on the shoulders, chest, or head (-1 point for a hit to the shoulders, -2 points for a chest hit, and -3 points for a head shot). Furthermore the local and peer slingshots are shown as graphical objects that are immobile and representing the users' weapon used to fire balls towards his/her opponent. The ball shown is controlled by the users' Falcon device (where the elasticity of the slingshot is felt using the Falcon device) and gets launched when he/she lets go of the button. The velocity and projectile of the ball are determined according to the laws of physics (using the rubber band elongation, the ball mass, and the rubber band elastic constant). The players' avatars are shown as bounded boxes that move as the user moves (in the avatar-based configuration). A hit is detected between the peer's ball and the local avatar if the ball is ever detected within the bounding boxes defined for the local player (one for the chest, one for each arms and one



Listening
Player has connected
Player has started the game

hello

Avatar-based configuration Video-based configuration

Fig. 1 Slingshot 3D game

for the head). The game provides a chatting facility (at the bottom of the screen), in addition to the verbal communication (audio channel). Finally, when a player's health runs out, the game is over and either the winning or losing screen will appear. In the current implementation, there is no limit for the number of balls a player can launch against the other player.

Technically, the video-based configuration is an augmented reality application where the video captured by the remote camera is superimposed by virtual objects (the score bars at the top and the slingshot model at the bottom of the screen as shown in Fig. 1(b)). The video-based configuration is implemented using the Augmented Reality Tool Kit (ARToolKit) [2].

3.2 Game system architecture

The SlingShot 3D game system architecture comprises two subsystems: the Multimodal Acquisition Subsystem (MAS) and the Multimodal Rendering Subsystem (MRS). Notice that the two subsystems (MAS and MRS) are implemented at both ends of the game to enable mutual synchronous multi-modal interaction between the two players.

3.2.1 Multimodal Acquisition Subsystem (MAS)

Figure 2 shows the components of the MAS subsystem. The MAS subsystem captures, processes, and delivers the various media data over the Internet network to the other player. In particular, the MAS captures (1) color (RGB) and depth video streams using the depth camera, (2) the player voice via a microphone, (3) the markers positions to keep track of the player movement, and (4) the launched shots with the Falcon haptic device. All the captured information is encoded using the corresponding media codec and delivered to the Admux manager that multiplexes the media streams into one data streams and dumps the data into the Internet network. The followings provide detailed explanation of key components in this subsystem.

Depth video camera The depth video camera is capable of generating RGB and D (Depth) signals. The depth signal is a grey-scale bitmap image where each pixel value represents the distance between the camera and the corresponding pixel in the RGB image. The concept of operation is simple: A light beam is generated using a square laser pulse and transmitted along the Field Of View (FOV) of the camera [15]. The reflected beam carries an imprint of the objects depth information. The depth information is extracted using a fast image shutter. The game uses the Z-Cam$^{\mathrm{TM}}$, developed and marketed by 3DV Systems [32] but we can use Kinect interface to track body movements in a similar way.

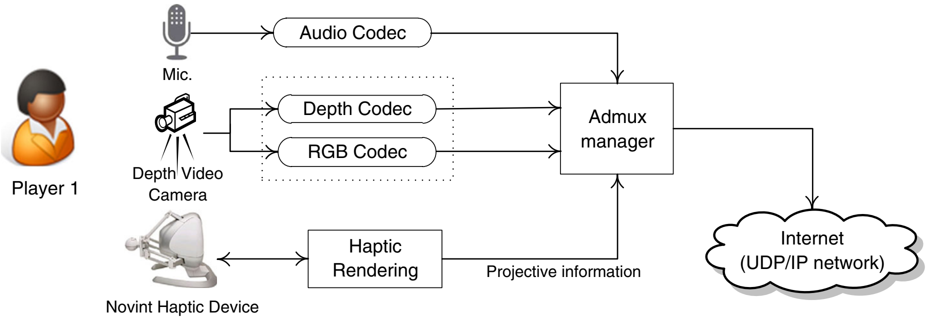


Fig. 2 MAS subsystem

Haptic rendering The haptic rendering module calculates 3D interaction force between the transformed depth image and the Falcon device position according to the haptic rendering algorithm described in [6]. Furthermore, the elasticity of the rubber band is rendered using the laws of physics via the Falcon device.

The haptic rendering is described as follows: the depth image is composed of a 2D array of gray-scale pixels, each represent the depth of the pixel in the corresponding RGB image (an example is shown in Fig. 3(a)). The depth image is triangulated into a 3D surface by connecting the tips of the depth vectors vertically, horizontally, and diagonally to form a continuous surface (as shown in Fig. 3(b)). The derived surface is used for collision detection as follows: the line segment between the current Haptic Interaction Point (HIP) proxy and the previous proxy is projected onto the 2D representation of the depth image in order to find the list of candidate triangles which should be checked for collisions (for example, the shaded area in Fig. 3(c)). Then, cells within this candidate list possessing elevation values below that of the line segment can be discarded and thus the algorithm can execute faster. In addition, the optimized collision detection does not need bounding boxes that require additional computation and memory space.

The haptic rendering component simulates the tension of pulling the slingshot to enhance the realism of the game. Note that the haptic rendering is based on the communication of the depth image, which is at the rate of 30 Hz; much less than what is usually needed for haptic communication (1 kHz).

Admux manager Admux is an adaptive multiplexing protocol for multimedia data communication that enables the application to define the communication QoS for multiple media channels based on the application requirements and network conditions. Admux communication framework is demonstrated in Fig. 4. The distinguished features of Admux are the followings: (1) Admux is highly customizable and adaptable to the application requirements and needs, (2) Admux utilizes independent channels for different media data that are multiplexed into one transport stream, (3) a protocol is designed to support media prioritization so that proportional resources are assigned to each input channel, (4) and finally channel prioritization can be dynamically changing based on the network conditions and application interactions/events using multiple buffering schemes.

Four media channels were created for the proposed game: haptic (depth stream), audio, video (RGB stream), and graphics. The graphics channel transmits chatting data, the body tracking information, and the hit projectile. Furthermore, it is important to mention that the haptic device position/force information are never transmitted over the network. This decision was made to avoid overwhelming the network with high rate haptic packets since haptic rendering requires an update rate of 1 KHz.

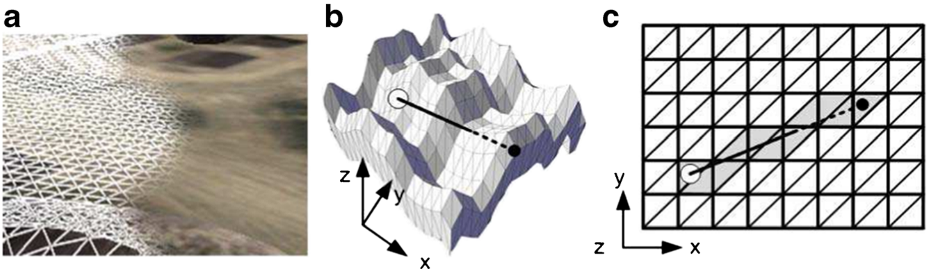


Fig. 3 Triangulation of depth image and optimized collision detection

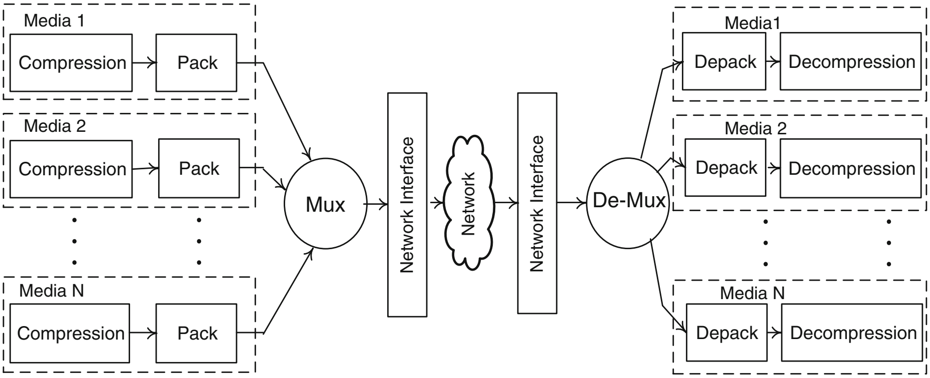


Fig. 4 Admux communication framework

3.2.2 Multimodal Rendering Subsystem (MRS)

The MRS subsystem diagram is shown in Fig. 5. The MRS subsystem receives the media streams from the network interface via Admux manager and renders the various media to the other player (audio, video and tactile feedback rendered using the haptic jacket). Furthermore, the MRS keeps track of the remote player upper body movements and calculates the hit point on the human model (whenever the shot projectile hits the human model). The followings provide detailed explanation of key components in this subsystem.

- *Human model manager* The human model manager keeps track of the user body movements and calculates the hit point on the human model. This is accomplished by continuously sending the updated positions of the markers (at a rate of 30–60 Hz). The human model manager maintains a graphical representation of the remote player using a set of bounded boxes. The positions and/or orientations of these boxes are updated every time the remote player moves. The human model manager is consulted by the haptic jacket driver component (Fig. 5) to check for possible collision between the peer projectile and the local player model. In order to track the upper part of the player body, the Augmented Reality Tool Kit (ARToolKit) [2] is utilized to track markers, attached to the haptic jacket.

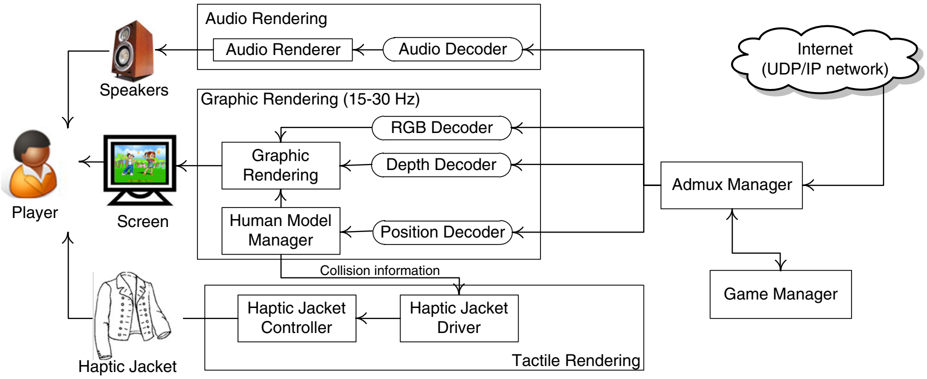
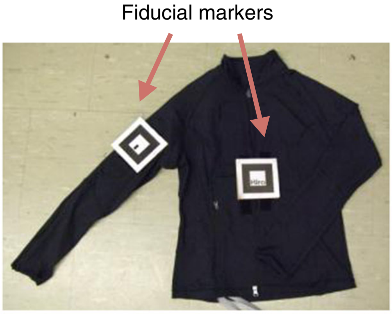
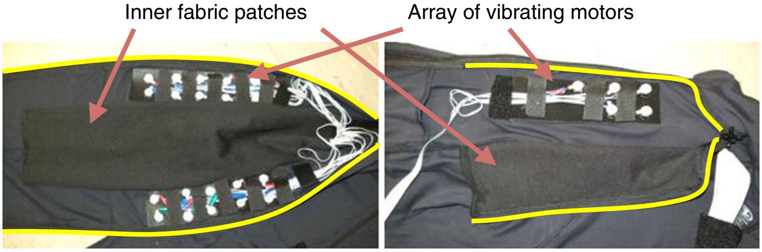


Fig. 5 MRS subsystem

- *Tactile renderer* The tactile renderer is composed of two components: the Haptic Jacket Driver and the Haptic Jacket Controller (see Fig. 5). The haptic jacket driver is essentially an API (Application Programming Interface) to simulate different touch feelings such as a poke or a hit. For instance, to simulate a poke, a concentric layout of motors is used where the center actuator simulates the poke whereas other circularly distributed motors form the surrounding concentric circles feeling. The API accepts the coordinates for the collision point, as well as the type of interaction (such as poke, hit, etc.), and instructs the jacket controller accordingly. Eventually, the jacket controller sends electric signals (in the form of Pulse Width Modulation (PWM) signal) to activate the grid of actuators accordingly.
- *Graphic and audio rendering* The graphic rendering module renders the 3D scene using OpenGL. All the pixels of the depth image are transformed into 3D space by using camera parameters and triangulated (with low resolution for fast rendering and the RGB image is mapped on it as a texture. In the avatar-based configuration, the avatar model is superimposed on top of the scene and all together rendering onto a 2D image, which is played using any video players. The avatar movements are updated in real-time as new positions are received from the human model manager. The audio rendering is composed of audio decoder and an audio player that interfaces to the speakers and play the sound of a hit.
- *Haptic jacket* Figure 6 shows the haptic jacket that is embedded with arrays of vibrotactile actuators. In order to measure the positions of the chest part and the upper arm, two different fiducial markers were attached on the middle of the chest and the upper arm as shown in Fig. 6(a). For easier maintenance, the arm part of the jacket was cut along and the zipper is attached along the cut line, and then the array of vibrating motors was attached on the inner part of the jacket and one layer of inner fabric arm was attached to



a Haptic jacket with fiducial markers



b Inner part of the upper arm **c** Inner part of the upper chest

Fig. 6 Haptic jacket

prevent the vibrating actuators and the electric lines directly touch the skin. Same approach is applied to the chest part: the array of vibrating actuators was attached on the inner part and a layer of inner fabric patch was attached to zip them together. Fig. 6(b) and Fig. 6(c) show the embedded vibrating actuators zipped open (yellow lines represent the zipper lines). More details about the haptic jacket design and implementation can be found in [5].

- *Game manager* The game manager administers the game and enforces its rules. For example, it keeps track of the health bars for the two players, keeps track when a player wins the game, and maintaining the game status (such as to start the game, pause, resume, or exit). Furthermore, the game settings are also defined in the Game Manager. For example, the players might change the elasticity constant of the rubber band (to make it rougher or softer), setting the input/output interfaces (the player might want to use the keyboard in case the Novint Falcon device is not available), or switching from one configuration mode to another (avatar-based versus video-based). Same applies if the haptic jacket is not available; in such case, the user will see the balls sticking on her/his own avatar.

4 SlingShot 3D performance evaluation

The objective of the performance evaluation is to investigate whether incorporating synchronous haptic-video multimedia into the game experience would enhance the quality of player experience, in particular immersion and co-presence. To achieve this objective, we ran experiments with the two game configurations (the avatar-based and video-based configurations) and the player experience was evaluated and compared. Two evaluation techniques are used: player performance analysis and player satisfaction analysis.

Twenty adult subjects (12 male, 8 female) participated in the experiment with an age range 20-35 years – all are familiar with computer games. Eight subjects have had previous experience using haptic interfaces (6 male and 2 female). The results presented in this section are based on averages of 5 trials per player (to make the results statistically more significant). Furthermore, the players were alternating using the haptic jacket (as only one prototype was available at the experiment time).

The experimental test bed is composed of two Pentium 4 PCs with 2 Gb RAM and 100Mbs Ethernet cards, two Novint Falcon haptic devices, two depth camera, and a haptic jacket. Internet network conditions were simulated using a software tool we developed for this experiment. The average delay between the two hosts was set to 40 ms and the jitter 6 ms during the time of performing the experiment. A snapshot of the experimental game setup is shown in Fig. 7.

4.1 Player performance analysis

The player performance analysis compares the gamer performance with the two configurations (Avatar-based and Video-based configurations). Four features are incorporated to evaluate the quality of player performance: the Hit Error Rate (HER), the Game Completion Time (GCT), the Range of Shoulder Movements (RSM), and the Average Mechanical Work (AMW) performed by the player while using the Falcon haptic device.

The HER parameter is used to measure the precision with which the player performs and is computed as the number of missed hits divided by the total number of launched balls. As shown in Table 1, the players have performed with significantly less error (11.4 % with the video-based configuration as compared to 24.4 % for the avatar-based configuration). Minor

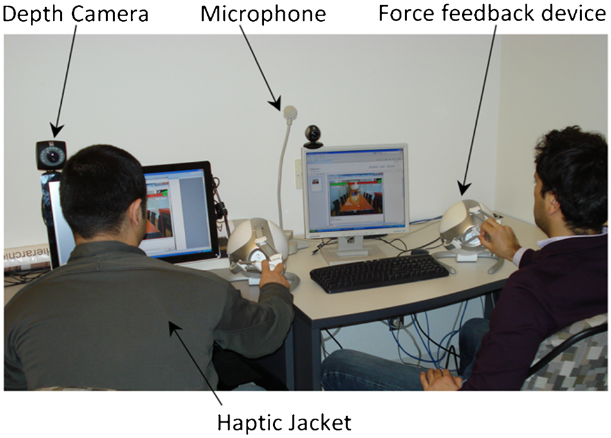


Fig. 7 Setup of the experimental evaluation with the avatar-based configuration

differences were observed as per the users' gender (almost same performance was observed in the video-based configuration). Therefore, synchronous haptic-video multimedia has enhanced the player accuracy and thus tends to enhance co-presence.

The Game Completion Time (GCT) is the measure of the time spent playing the game. Every player started with 20 points health score, and whenever hit, the score is decremented (by 1 point for a hit to the shoulders, 2 points for a chest hit, and 3 points for a head shot) until the score is zero; a winner is declared. The GCT can be correlated with the HER feature to provide a better measure of the quality of performance. The Range of Shoulder Movements (RSM) measures the range of player bending while avoiding the balls shot by the other player (in angular displacement) – which can also be used to measure the quality of player immersion. Finally, the Average Mechanical Work (AMW) measures the amount of work exerted by the player to launch balls, and is computed as the average forces applied by the player multiplied by the total travelled distance (in Joules). Table 1 shows the average measures for the four features for each gender as well as the total measures.

4.2 Player satisfaction analysis

The player satisfaction analysis uses the questionnaires assessment tool to measure presence – simply by asking players about the quality of the interaction and the degree of connection with the other player while playing the game. The following questions were asked to every subject in a paper questionnaire: Q1: Would you like to play this game once more? Q2: Do you prefer to use the Falcon device over the keyboard? Q3: Do you prefer using the video-

Table 1 Player performance features for both avatar-based and video-based configurations

Feature	Male (12 players)		Female (8 players)		Total (20 players)	
	Avatar	Video	Avatar	Video	Avatar	Video
Hit error rate	26 %	11 %	22 %	12 %	24.4 %	11.4 %
Game completion time (min)	13	11	15	13	13.8	11.8
Range of shoulder movements (Degrees)	± 33	± 41	± 32	± 36	32.6	39
Average mechanical work (Joules)	12.36	14.91	12.23	12.44	12.31	13.92

Table 2 Subjects responses to four key questions in the questionnaire

Subjects	Q1: Play more than once?			Q2: Do you prefer to use the Falcon device over the keyboard?			Q3: Do you prefer using the video-based configuration over the avatar-based configuration?			Q4: Did the jacket make hits feel more realistic?		
	Yes	No	Not sure	Yes	No	Not sure	Yes	No	Not sure	Yes	No	Not sure
8 (female)	6	1	1	7	0	1	5	1	1	7	1	0
12 (male)	12	0	0	11	0	1	11	1	1	12	0	0
Total	18	1	1	18	0	2	16	2	2	19	1	0
% of total	90 %	5 %	5 %	90 %	0 %	10 %	80 %	10 %	10 %	95 %	5 %	0 %

based configuration over the avatar-based configuration? And Q4: Did the jacket make hits feel more realistic? A short debriefing was conducted right after the experiment to get insight into the user experience with the game.

Overall, the evaluation revealed that 95 % of the players have commented positively about the Slingshot 3D game. Table 2 shows the players responses for the four key questions with total percentages for each. Question 1 revealed that only 5 % disagreed to play the game another time, 5 % were neutral, and 90 % agreed. Out of the 20 players, 95 % agreed that the haptic jacket made hits feel more realistic, only 5 % (1 player) disagreed. Furthermore, 90 % of the players preferred using the Falcon device over the keyboard and/or mouse while 10 % of the players were not certain. Finally when asked about the video-based versus avatar-based configurations, 80 % of the subjects agreed that they prefer using the former, 10 % disagreed, and 10 % were neutral.

4.3 Discussion

Our results show that, when users are given a choice between the two game configurations (avatar-based versus video-based configuration), they expressed a strong preference for the latter (video-based configuration). This may be because the video-based configuration has provided a more natural and intuitive interaction that most users expect. However, one player mentioned that she indeed preferred the avatar-based configuration as she did not want to reveal her identity with video gaming. Another player commented that the depth dimension is not intuitive to perceive and suggested adding a graphics clue to enhance the perception of depth.

Overall, additional gains were realized by combining the three modalities; haptic (both tactile and kinesthetic), video, and audio, however, some players caution that engaging too many modalities in a non-complementary manner actually reduces task performance due to sensory noise. Finally, few players report that the chatting facility in the game was of no significant use since the players were using the haptic device to launch balls and it was not intuitive to use the haptic device and the keyboard simultaneously.

5 Conclusion and future work

Developing synchronous multimodal games is a new and challenging task. In this paper, we introduced the Slingshot 3D game that provided synchronous haptic-audio-video interaction over the Internet network. The game supports two setups: avatar-based and video-based configurations. Both player performance analysis and user satisfaction analysis have demonstrated that haptic-video configuration has enhanced the player immersion and the overall quality of experience. Among the 20 participants in the usability testing, 95 % of the subjects gave positive comments about the game and the multimodal interaction.

As per future work, first of all, we plan to investigate extending the software architecture of the game to make it possible to plug-and-play different haptic interfaces to play the game. The current state of the game implementation works only with the Falcon device. Secondly, the body tracking technology we are using (using body markers) does not provide sufficient flexibility for the players to move around while playing the game. Any alignment that results in hiding or distorting the marker results in loosing track of the player body. Therefore, we will consider using other technologies (such as the Kinect technology by Microsoft) that provide more flexible and convenient means to track the player's body movements. Finally, we plan to investigate the potential of extending the game for multiple players where more than two players engage in the game and launch projectiles against each other.

Acknowledgment We acknowledge the members of the Sunstrike team for helping in the implementation of the game: Alexandre Bradley, Kevin Mottashed, Philippe Doré, Daniel Grisé, and Benoit Renaud. Also, we thank all the subjects who took part in the evaluation and gave valuable feedback about the current state of the game as well as for future perspectives.

References

1. Andrews S, Mora J, Lang J, Lee WS (2006) “HaptiCast: a Physically-based 3D Game with Haptic Feedback”, Proc. of Future Play, London, ON, Canada
2. AR Toolkit website, http://www.hitl.washington.edu/artoolkit, [Online; accessed 09-April-2012]
3. Bailenson JN, Yee N (2008) Virtual interpersonal touch: haptic interaction and copresence in collaborative virtual environments. Multimedia Tools Appl 37(1)
4. Caporusso N, Mkrtchyan L, Badia L (2010) A multimodal interface device for online board games designed for sight-impaired people. IEEE Trans Inf Technol Biomed 14(2):248–254
5. Cha J, Eid M, Barghout A, Rahman AM, El Saddik A (2009) “HugMe: Synchronous Haptic Teleconferencing,” ACM International Conference on Multimedia, the Multimedia Grand Challenge, Beijing, China
6. Cha J, Eid M, El Saddik A (2008) “DIBHR: Depth Image-Based Haptic Rendering” In proceedings of the EuroHaptics conference, pp. 640–650, Madrid, Spain
7. CuteCircuit website: http://www.cutecircuit.com, [Online; accessed 09-April-2012]
8. De Paolis LT, Pulimeno M, Aloisio G (2007) “The Simulation of a Billiard Game Using a Haptic Interface,” 11th IEEE International Symposium on Distributed Simulation and Real-Time Applications, pp.64–67
9. Eid M, Cha J, El Saddik A (2008) “HugMe: A Haptic Videoconferencing System for Interpersonal Communication,” IEEE International Conference on Virtual Environments, Human-Computer Interfaces, and Measurement Systems (VECIMS), pp. 5–9, Istanbul, Turkey
10. Eid M, Cha J, El-Saddik A (2011) Admux: an adaptive multiplexer for haptic-audio-visual data communication. IEEE Trans Instrum Meas 60(1):21–31
11. “Factbox: A look at the $65 billion video games industry”. Reuters. 6 June 2011. Retrieved 17 July 2011
12. Faust M, Yoo YH (2006) ‘Haptic Feedback in Pervasive Games’, Third International Workshop on Pervasive Gaming Applications, Dublin, Ireland
13. Frati V, Prattichizzo D (2011) “Using Kinect for hand tracking and rendering in wearable haptics”, 2011 IEEE World Haptics Conference (WHC), pp.317–321
14. Giles J (2010) Inside the race to hack the Kinect. New Sci 208(2789):22–23
15. Gvili R, Kaplan A, Ofek E, Yahav G (2003) Depth keying. SPIE, California
16. Hamam A, Eid M, El Saddik A, Georganas ND (2008) “A Quality of Experience Model for Haptic User Interfaces” In Proc. of Haptic in Ambient Systems (HAS 2008) Workshop, Quebec City, Canada
17. Heo H, Lee EC, Park KR, Kim CJ, Whang M (2010) “A realistic game system using multi-modal user interfaces,”. Consum Electron IEEE Trans 56(3):1364–1372
18. Höysniemi J (2006) Design and Evaluation of Physically Interactive Games, University of Tampere, Dissertation
19. iRoboticist: http://iroboticist.com/2010/03/26/tgv/, Tactile Gaming Vest (TGV), demoed at Haptics Symposium 2010
20. Jovanovic M, Starcevic D, Minovic M, Stavljanin V (2011) “Motivation and multimodal interaction in model-driven educational game design,”. IEEE Trans Syst Man Cybern A Syst Hum 41 (4):817–824
21. Khoshelham K, Elberink SO (2012) “Accuracy and resolution of kinect depth data for indoor mapping applications”. Sensors Basel 12(2):1437–1454
22. MacLaverty R, Defee I (1994) “Multimodal interaction in multimedia applications”, In proceedings of the IEEE First Workshop on Multimedia Signal Processing, pp. 25–30, Princeton, USA
23. Neviarouskaya A, Tsetserukou D, Prendinger H, Kawakami N, Tachi S, Ishizuka M (2009) “Emerging system for affectively charged interpersonal communication,” ICCAS-SICE, 2009, vol., no., pp.3376–3381
24. Nilsen T, Linton S, Looser J (2004) “Motivations for augmented reality gaming”, In Proc. of the New Zealand Game Developers Conference, pp. 86–93
25. Novint Technologies, Inc., http://home.novint.com/, [Online; accessed 09-April-2012]
26. Park W, Kim L; Cho H, Park S (2009) “Design of haptic interface for brickout game,” IEEE International Workshop on Haptic Audio visual Environments and Games, pp.64–68

27. Ryden F (2012) "Tech to the Future: Making a "Kinection" with Haptic Interaction,". IEEE Potentials 31 (3):34–36
28. Rydén F, Chizeck HJ, Kosari SN, King H, and Hannaford B (2011) "Using Kinect and a Haptic Interface for Implementation of Real-time Virtual Fixtures", Robotics, Science and Systems (RSS) Workshop on RGB-D Cameras, Los Angeles, CA
29. Teh KS, Lee SP, Cheok AD (2006) "Poultry Internet: A Remote Human-Pet Interaction System", Proc. ACM CHI, pp. 251–254
30. Wikipedia. Kinect — Wikipedia, the free encyclopedia. http://en.wikipedia.org/wiki/Kinect, 2012. [Online; accessed 09-April-2012]
31. Yuanqiang D, Conrad D, DeSouza GN (2011) ""Wii Using Only 'We'": Using background subtraction and human pose recognition to eliminate game controllers", 2011 IEEE International Conference on Robotics and Automation (ICRA), pp.3887–3892
32. 3DV Systems, http://www.3dvsystems.com, [Online; accessed 09-April-2010]

Mohamad Eid received the PhD degree in Computer Engineering from the school of Electrical Engineering and Computer Science, University of Ottawa, in June 2010. He was a research and teaching associate at the same school from 2008 to 2011. In 2012, he moved to New York University Abu Dhabi, division of Engineering, as a visiting research associate. His current research interests include multi-modal human computer interaction, haptics, and serious gaming.

Ahmad El Issawi is currently an assistant professor at the Lebanese University, Lebanon. Dr. El Issawi has a PhD in Mathematics from France in the domain of "Math Discret-Théorie des Graphes-Relations Binaires" at Universite Claude Bernard - LYON I. His current research interests include multi-modal human computer 443 interaction, graph theory, and ambient intelligence.

Abdulmotaleb El Saddik a University Research Chair and Professor in the School of Electrical Engineering and Computer Science at the University of Ottawa, is an internationally-recognized scholar who has made strong contributions to the knowledge and understanding of multimedia computing, communications and applications, particularly in the digitization, communication and security of the sense of touch, or haptics, which is a new medium that is significantly changing the way in which human-to-human and human-computer interactions are performed. He has authored and co-authored four books and more than 350 publications. He has received research grants and contracts totalling more than $16 Mio. and has supervised more than 90 researchers. He received several international awards and is ACM Distinguished Scientist, Fellow of the Engineering Institute of Canada, and Fellow of the Canadian Academy of Engineers and Fellow of IEEE.