Body-Controlled Trampoline Training Games Based on Computer Vision

Leo Holsti
Aalto University
Department of Media Technology
P.O. Box 15500
FI00076 Aalto
Finland
leo.holsti@aalto.fi

Tuukka Takala
Aalto University
Department of Media Technology
P.O. Box 15500
FI00076 Aalto
Finland
tuukka.takala@aalto.fi

Aki Martikainen
Aalto University
Department of Media Technology
P.O. Box 15500
FI00076 Aalto
Finland
aki.martikainen@aalto.fi

Raine Kajastila
Aalto University
Department of Media Technology
P.O. Box 15500
FI00076 Aalto
Finland
raine.kajastila@aalto.fi

Perttu Hämäläinen
Aalto University
Department of Media Technology
P.O. Box 15500
FI00076 Aalto
Finland
perttu.hamalainen@aalto.fi

CHI'13 Extended Abstracts, April 27 – May 2, 2013, Paris, France.
ACM 978-1-4503-1952-2/13/04.

Abstract
This work in progress -paper describes our efforts in developing trampoline training games using computer vision technology. The study is part of a project about developing digitally augmented exercise environments for faster, safer and more engaging sports training. We describe four initial prototypes and the feedback obtained from testing them both with circus students and with people with no background in trampolining.

Author Keywords
Computer vision; games; trampoline; circus; exergames; exertion interfaces; augmented feedback;

ACM Classification Keywords
H.5.2 [Information Interfaces and Presentation]: User Interfaces; I.4.8 [Image Processing and Computer Vision]: Scene Analysis

Introduction
This paper investigates the enhancing of exercising and movement training with computer vision technology. The technology allows us to, e.g., measure the height of jumps in exercises where it is difficult to measure with traditional equipment, which helps in providing the user with both clear goals and immediate feedback. These are essential from the point of view of gamification and training motivation [8]. The topic is

broad, and in this paper we focus on trampolining, which hasn't yet been studied extensively despite the popularity of trampolines both at homes and at exercise facilities. We show how trampolines combined with screens and real-time computer vision can be used as a novel platform for games and interactivity.

Developed Prototypes

We built and tested four prototypes: platform jumping game (PG), virtual training space game (TG), simple delayed video feedback (DF), and delayed feedback combined with virtual training space (DFTS). Figure 1 shows the user study setup from a circus school.

The top half of Figure 2 shows the virtual training space with delayed feedback (DFTS) where one can, e.g., try to do a flip over a virtual marker while staying between two virtual walls. It is easier and less risky to place markers and obstacles in the virtual world instead of the real training space, especially considering that the trampoline bed is not static. The player is represented by a textured 3d mesh captured using the Microsoft Kinect depth camera. The mesh capture is delayed so that one can first perform a skill and then immediately watch a replay on screen. We also tested a game version of the virtual training space (TG), where the player mesh was updated in real-time with minimal latency. The goal was to keep jumping vertically over the marker while staying within the walls, and the marker was gradually moved higher and the walls closer to each other.

The bottom half of Figure 2 shows the platform jumping game (PG) inspired by Doodle Jump [13] where the goal is to constantly jump higher and higher. The player jumps back and forth on the trampoline, resulting in

Figure 1. User study setup. 1: trampoline, 2: Kinect depth camera, 3: user, 4: computer, 5: screen

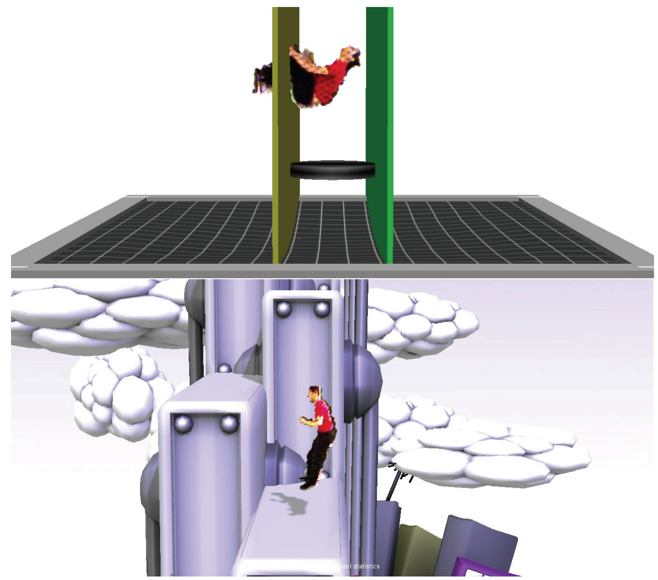

Figure 2. Top: screenshot of a virtual training space game (TG). Bottom: screenshot of a platform jumping game (PG). Video of the prototypes can be found at *http://www.youtube.com/watch?v=bpT8jpyrrqU*

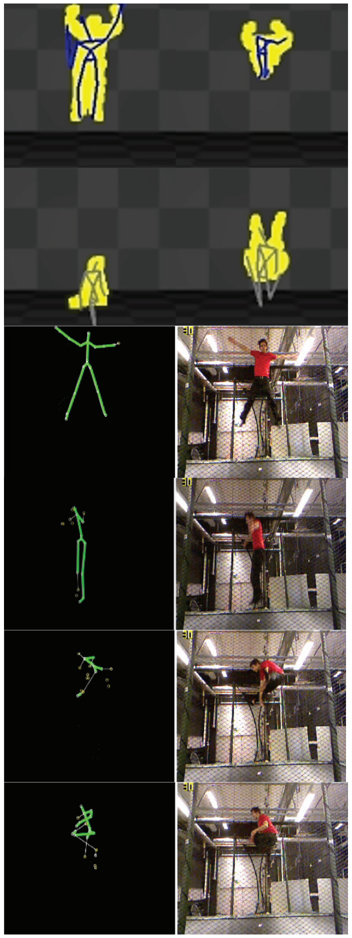
Figure 3. Examples of OpenNI (blue skeleton) and Kinect for Windows (green skeleton) tracking quality.

vertical and horizontal movement on the screen, and the depth location of the player mesh is automatically adjusted according to the underlying platform.

Both game prototypes (TG, PG) were designed for practicing high and precise jumps, which is the basic trampolining skill to learn before moving on to different landings and rotations [3].

Related work

The project continues the authors' earlier efforts in developing sports training and entertainment technology [4, 5, 11]. Our work is inspired by Myron Krueger's Videoplace, where the video image of the user was embedded inside interactive computer graphics [10]. Many motion games like Kinect Sports map the skeletal tracking data to a 3d character model, for which there are various approaches [2, 6, 18], but we chose to use the depth camera mesh visualization in Figure 2 to hide any skeletal tracking glitches and avoid missing any details of the player's movements.

Various authors have researched physically intensive full-body HCI and feedback design for motor skill learning and performance [12, 14, 16]. Feedback is essential when viewing learning as a cyclic process of trying something out and adjusting one's performance based on feedback, be it intrinsic proprioceptive feedback, visual feedback, or verbal feedback from a coach. The essential type of feedback for this paper is augmented feedback (AFB), i.e., information that would not be available otherwise, in this case provided by a computer system.

Considering the previous experiments with trampolines, computer vision has been used to analyze sport videos including trampolining [20], and Mori *et al.* have mapped the motion of the trampoline bed to movement in a virtual world [15]. However, to our knowledge, there haven't been studies about trampoline games with full body tracking or the player's image embedded in the computer graphics.

We are fascinated by trampolines as part of full-body user interfaces because they can give the player game-like super powers in the real-world. The player's skills and abilities are usually only enhanced on-screen, e.g., using exaggerated jumping and running [5] or acrobatics performed by only executing the safe beginning of a move, such as jumping and throwing one's arms up to do a back flip [11]. A trampoline increases the duration of one's jumps and reduces the impact of landings, making it safer to practice aerial acrobatics. Trampolines have also inspired new sports such as Bossa Ball and Slamball, i.e., volleyball and basketball played on a field with embedded trampolines. There are also interesting recent business ventures such as the JumpStreet indoor trampoline parks [7], which feature large halls covered with trampolines that run up the walls.

It should be noted that trampolines can be dangerous especially in recreational, unsupervised use [1, 19]. Attempting somersaults is not recommended and only one person should be jumping at a time [1, 19]. We believe that technology can be used to increase training safety, e.g., by using computer vision to monitor that there is only one player in the camera view. In addition to simple monitoring of safety guidelines, we are also trying to design goals and feedback to keep players interested longer in preliminary training before attempting high risk skills.

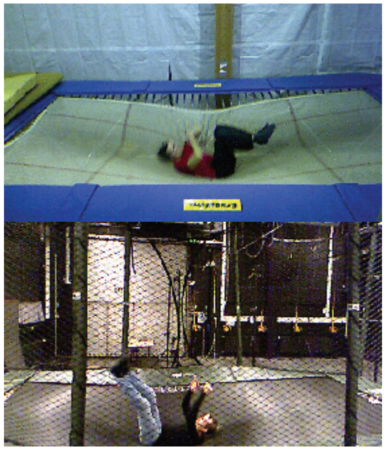

Figure 4. Kinect color images captured from two different trampolines.

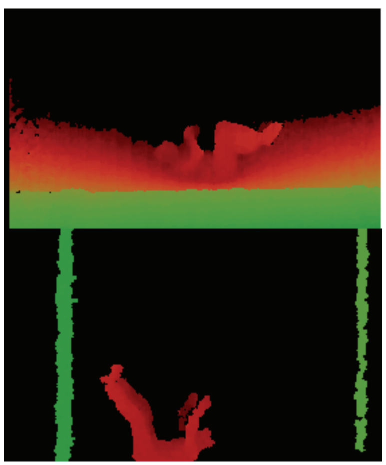

Figure 5. The depth images corresponding to Figure 4.

Implementation

The prototypes were developed using Unity 3D game engine and a custom plugin that gives Unity access to Kinect RGB and depth images (containing each pixel's distance from the sensor) as well as skeletal tracking data from OpenNI/NITE [17] and Microsoft Kinect for Windows SDK [9].

When starting the project, the first basic research question was whether it is possible to use current low-cost depth cameras for trampoline games. The answer is positive at least for the Microsoft Kinect camera. The field of view (43 degrees vertical) of the Kinect is just enough for our purposes, providing a vertical view of 3.15m at the maximum distance of 4m, which translates to maximum jump height of 1.35m for a 1.8m tall person when jumping with a straight body. According to our tests, this is enough for beginners and hobbyists with a few years of experience.

As shown in figures 4 and 5, a trampoline safety net does not interfere with tracking, because it is not visible in the depth image, probably because of the limited resolution of the structured light pattern that Kinect uses. However, Time of Flight (ToF) cameras might behave differently.

When jumping, the whole trampoline shakes, including the safety net support poles shown in figures 4 and 5. With the NITE and Microsoft trackers, the poles don't cause problems unless the user is directly behind one. The effect of the trampoline bed depends on the bed material. At the bottom of Figure 5, the dark bed is invisible in the depth image, probably because it does not reflect enough IR. The upper trampoline in Figure 4 caused a tracking loss every time the user was jumping and making contact with the bed. In the test setup in Figure 1, we aimed the camera so that the trampoline bed was outside the image. Note that this clips the user's feet when landing, and is not ideal for practicing landing on one's back and belly, which are the skills that beginners often practice after basic jumping [3].

As shown in Figure 3, the OpenNI and Kinect for Windows trackers work best when facing the sensor, and the quality decreases with occlusions and atypical poses that the trackers haven't probably been optimized for. We were able to implement the present prototypes without the skeletal tracking, using only the 3d bounding box of the user calculated based on the segmentation of the depth images to user and background pixels provided by the trackers. However, even the segmentation of the trackers fails if the trampoline bed is visible in the depth image. In the future, we will evaluate alternative trackers and possibly develop a custom special purpose tracker and/or segmentation.

In our previous games, we have found it quite easy to exaggerate the player's jumps by simply boosting the tracked upwards velocity and adjusting gravity. We did not initially realize that the exaggeration is more problematic in the case of trampolining where the user is jumping constantly, so that independent of jump height and platform height difference, the player must not land on the ground later in the virtual world than in the real world. Otherwise one starts to move back up before landing in the game. In the platformer (PG), the gravity is exaggerated so that the player lands early enough even with high jumps, but this seems to add a sticky feeling to small jumps, because the player stays on the ground longer than in real world.

"The delayed video is very useful. How about having both front and side views?"

"Video should be used more in training. You think your body behaves differently than what you see on the video"

"It would be nice to know if you jump higher than previously"

"I'd like to be able to slow down the replay"

"I feel motivated when I see what to improve. It's great that one gets immediate feedback. The video is more important than numbers"

"Does the video get recorded? If I was really practicing, I'd like to review the video later."

"This one provokes me to jump higher. It's exciting to look at the screen, it feels that the action is there and not here where I'm jumping."

Preliminary results and discussion

So far, we have been exploring the possibilities by creating a series of prototypes and testing them with users. In addition to the circus school setup in Figure 1, we tested the prototypes in our development space using a different trampoline shown at the bottom half of in Figure 4 and with a smaller 19" display. We organized four test sessions with a total of 12 users: sessions with 3 and 5 users at the circus school, and two times two users at the development space. The study participants were voluntary adults aged 30-49, 6 male, 6 female, with trampolining experience varying from none to several years of training and teaching experience. At the circus school, the users were recruited from an adults' circus class. The users took turns in testing each prototype for a few minutes. While one user was on the trampoline, the previous one was interviewed about the good and bad sides of the experience and about additional comments or suggestions. At the end of the test, the users also ranked the prototypes in relation to each other.

One of the most important results from the testing was that only one user commented that he had trouble following the graphics on the 19" screen. Screen placement and size was one of our initial concerns. It turned out to be surprisingly easy to watch a screen while jumping, although two circus students commented that watching the screen requires attention and makes it more difficult to focus on one's own body.

During the testing, we iterated the delayed feedback approach forward. In the first two tests, we used a basic delayed video view with no additional graphics (DF). In tests 2-4, we also used combination of delayed user mesh and virtual training space (DFTS), hoping to provide more possibilities for forming goals using the virtual obstacles. However, the simple video delay (DF) was ranked best by 7 out of the 8 circus practitioners who tested it, and only one ranked the virtual environment version better (DFTS). As a simple video delay has also been found effective in previous studies [4], we interpret these results so that it provides a baseline against which to evaluate future prototypes in a follow-up study.

Two circus practitioners and all other users ranked the platform jumping game (PG) the overall winner. For 10 out of all 12 users, the platform jumping game (PG) outranked the virtual training space game (TG). Users commented that it is good to see one's form in real time. Also, the delay is not of much use if one cannot perform skills where it is not possible to keep one's eyes on a screen. This is why we are currently developing a prototype that automatically recognizes moves where a delayed replay is needed and displays a real-time view otherwise.

We are also developing the platformer further (PG), since it needs more variety. Two users also commented that they felt intimidated jumping backwards on the trampoline bed. This is why we will probably change the display to the side of the trampoline so that the player jumps sideways and not backwards. It could also be interesting to project game graphics directly on the trampoline bed.

Acknowledgements

We thank all the volunteers who tested our prototypes and provided invaluable feedback, especially Mikko Rinnevuori from Circus Helsinki.

"Really interesting. It's scary that one doesn't see where the backside edge of the trampoline is. Could you visualize the edge of the trampoline on the screen as a wall or something? I didn't realize that I had a plenty of room."

"It's exciting. When looking at the screen one jumps higher without noticing it. It tricks me into having more courage."

"I didn't realize that I was exhausted, I was just jumping at full power."

"How come you notice how tired you are only after stopping jumping?"

"The delay is the best, because you focus on how your technique looks like. In the games, the game becomes more important than how I look and my technique. The games are more fun, but the delay is more useful."

References

[1] AAP Committee on Injury and Poison Prevention and Committee on Sports Medicine and Fitness Trampolines at Home, School, and Recreational Centers. *Pediatrics*. 103, 5 (1999), 1053–1056.

[2] Bleiweiss, A., Eshar, D., Kutliroff, G., Lerner, A., Oshrat, Y. and Yanai, Y. Enhanced interactive gaming by blending full-body tracking and gesture animation. In *Proc. SIGGRAPH ASIA 2010*, ACM (2010), 34:1–34:2.

[3] British Gymnastics *Trampolining*. A & C Black Publishers Ltd. 2009.

[4] Hämäläinen, P. Interactive video mirrors for sports training. In *Proc. NordiCHI 2004*, ACM (2004), 199–202.

[5] Hämäläinen, P., Ilmonen, T., Höysniemi, J., Lindholm, M. and Nykänen, A. Martial arts in artificial reality. In *Proc. CHI 2005*, ACM (2005), 781–790.

[6] Ishigaki, S., White, T., Zordan, V.B. and Liu, C.K. Performance-based control interface for character animation. In *Proc. SIGGRAPH 2009*, ACM (2009), 61:1–61:8.

[7] Jump Street indoor trampoline parks homepage. *http://gotjump.com/*.

[8] Kapp, K.M. *The Gamification of Learning and Instruction: Game-based Methods and Strategies for Training and Education*. Pfeiffer. 2012.

[9] Kinect for Windows SDK documentation. *http://msdn.microsoft.com/en-us/library/hh855347.aspx*.

[10] Krueger, M.W., Gionfriddo, T. and Hinrichsen, K. VIDEOPLACE - an artificial reality. In *Proc. CHI 1985*, ACM (1985), 35–40.

[11] Kung-Fu High Impact Trailer. *http://www.youtube.com/watch?v=jrgFCl2Jo0E&feature=youtube_gdata_player*.

[12] Liebermann, D.G., Katz, L., Hughes, M.D., Bartlett, R.M., McClements, J. and Franks, I.M. Advances in the application of information technology to sport performance. *Journal of sports sciences*. 20, 10 (Oct. 2002), 755–769.

[13] Lima Sky, the developer of Doodle Jump. *http://www.limasky.com/*.

[14] Magill, R.A. and Anderson, D.I. The roles and uses of augmented feedback in motor skill acquisition. *Skill Acquisition in Sport: Research, Theory and Practice*. N. Hodges and A.M. Williams, eds. Routledge. 2012.

[15] Mori, H., Fujieda, T., Shiratori, K. and Hoshino, J. Kangaroo: the trampoline entertainment system for aiding exercise. In *Proc. ACE 2008*, ACM (2008), 414–414.

[16] Mueller, F., Agamanolis, S. and Picard, R. Exertion interfaces: sports over a distance for social bonding and fun. In *Proc. CHI 2003*, ACM (2003), 561–568.

[17] OpenNI home page. *http://www.openni.org/*.

[18] Oshita, M. Motion-capture-based avatar control framework in third-person view virtual environments. In *Proc. ACE 2006*, ACM (2006), 2.

[19] Trampolines and Trampoline Safety Position Statement of the American Academy of Orthopaedic Surgeons. *http://www.aaos.org/about/papers/position/1135.asp*.

[20] Xian-jie, Q., Zhao-qi, W. and Shi-hong, X. A Novel Computer Vision Technique Used on Sport Video. *Journal of WSCG*. Vol 12, 1-3 (2004).