VIRTUAL REALITY SIMULATION: BOBSLED AND LUGE

IACSS International Symposium Computer Science in Sport, 2007

Richard M. Levy[1], Larry Katz[2]

[1]Faculty of Environmental Design, University of Calgary, Calgary, Alberta, Canada T2N 1N4;
[2]Faculty of Kinesiology, University of Calgary, Calgary, Alberta, Canada T2N 1N4

Abstract

This research paper examines the effectiveness and potential benefits of different simulation environments in the sliding sports of bobsled and luge. Visualization techniques have been critical components in training athletes for the psychological stress associated with a competition. Studies reveal that an athlete's performance can benefit from programs that use some aspect of visualization. Our focus is on the visualization experiences of driving a bobsled and steering a luge sled within a virtual world. The lessons learned from this research are being used to design future versions of simulators for training Olympic athletes engaged in sliding sports.

Keywords: Virtual Reality, Visualization, Athletic Performance, Luge, Bobsled

Introduction: Why a simulator for sliding sports?

Bobsled pilots are faced with many of the same training issues faced by fighter pilots (Bell & Waag, 1988; Brannick, 2005; Magnusson, 2002; Rhodenizer, 1998; Stone, 2002). High speeds and excessive G forces make learning the skills needed to control a fighter plane a challenging exercise. For a bobsled pilot, speeds exceeding 130 km/hour and G forces greater than five times the athlete's body weight are experienced (Kelly & Hubbard, 2000). This experience may be as close as you can get to flying a jet aircraft without leaving the ground. However, unlike fighter pilots, bobsled pilots steer down a fixed course that must be memorized and anticipated at every turn. Each turn presents a unique situation. In the Torino track the pilot must anticipate each of the 19 turns. Discussions with coaches suggest that successful pilots must essentially anticipate and start the turn before they actually can see the turn. Each course presents interesting challenges and demands. In most sliding sports, knowledge is built up over years of training on a particular course and during competitions on each of the almost 20 tracks worldwide. Traditionally, the initial introduction to a course will begin with study of a plan view and walk down the track. It is not surprising that accidents are associated with an unfamiliar track during competitions. With only a few practice runs before an event combined with the stress of competition on an unfamiliar track, disastrous results can occur (Figure 1). In the Torino 2006 Olympics numerous accidents occurred during the luge and bobsledding competition. Interviews appearing in the news media with athletes and coaches raised concerns that the Torino track may be technically too challenging for many competing Olympic athletes:

"It's not anymore about medals, everyone fights for life," said Italy's Anastasia Oberstolz-Antonova. "It's not sport anymore." Canadian luger Chris Moffat called it "the hardest track in the world right now." "It's definitely challenging every athlete," Moffat said. "I would have to say you'd have to be a loony if you weren't scared." Georg Hackl, a three-time gold medalist considered the sport's all-time best slider. "It's a race sport and that's always dangerous," Hackl said, moments after Grimmette and Martin wiped out. "But we have strict regulations and only the better drivers are allowed to compete. But even they crash, and that's sad." USA Today 2/16/2006 (AP story that appeared in USAToday.com).

An interview with Tony Benshoof, 1st place luge speed holder in the Guinness Book of World Records (86.6 mph) and 4th place in Torino, indicates that there were numerous technical challenges in Torino and, if the course was not properly executed, serious mishaps could result. In his description of Turns 6-8 of the Toro track in Torino (Hatch, 2006):

> Its called the TORO because from an aerial shot, it looks like some bull's horns. But what's unique about it is that there's three consecutive right-hand corners. That's challenging because if

> you mess up the first corner, that mistake compounds on the following curve and then of course, compounds again, almost exponentially, and the final curve often ends in a crash.

Later, recounting Turns 15 to 17, Behshoof explains:

> From curve 15 to curve 17 the sled probably accelerated 25 miles an hour. It's a huge drop in the course, you pick up a ton of speed, and it all kind of comes together on curve 17, they happen in 18 and 19, but they're caused by 17. So what happens oftentimes, is if some inexperienced sliders come into 17 the wrong way, they get a little scared case they're going 90 miles an hour, and the problems result in a crash, usually down in 19.

Based on these testimonial statements, a major factor contributing to the number of accidents is the lack of training time before the actual Olympic competition (Figure 1). Given the highly technical nature of the Torino track and all future tracks, safe environments for training and preparation in slider sports are indicated, pointing toward the use of simulators.

Though there is no systematic research on this topic, the history of flight training and simulation suggests that sliders could benefit from the use of training simulators. For pilots, generally, cockpit error occurs early in a pilot's career. Similarly, accidents with more experienced pilots occur when circumstances and situations are unfamiliar. Research evaluating flight simulator training suggests that pilots' reactions to simulated environments are transferable to conditions experience in real flight (Magnusson, 2002; Stone, 2002). Training in a simulator, an essential part of commercial and military flight preparation may also need to become a fundamental exercise of sliding sports. This paper will address the problems and technical issues concerned with development of a virtual reality environment for training bobsled pilots.

The Physics of Sliding

Bobsled simulators built in the early 1990's demonstrated the potential of real time simulation of movement through complex 3D space on a single screen display (Huffman, Hubbard & Reus, 1993; Huffman & Hubbard,1996; Kelly and Hubbard, 2000). Previous work in this area had produced simulators that can reproduce the visual component and some aspects of the physical experience of the piloting a bobsled. Under the direction of Profs. Hubbard and Huffman, Department of Mechanical, Aeronautical and Materials Engineering, University of California, Davis, several simulators for the USA Olympic Bobsled Team were built from 1991-1995 that aimed at reproducing the physical experience of sliding (Huffman & Hubbard, 1996, Hubbard, Kallay, Joy, Reus and Rowhani, 1989, Hubbard, Kallay, Reus and Rowhani, 1989) (Figure 2). Simulating the movement of a bobsled is a problem in applied physics Six forces act on a bobsled or luge: weight, aerodynamic lift, aerodynamic drag, normal force, friction, steering force (Huffman, Hubbard, & Reus, 1993).

At the start of a bobsled, luge or skeleton run, an initial impulse is applied to the sled (Huffman & Hubbard, 1996). This is done by as many as three runners in bobsled. Controlling the sled down a smooth curvilinear track is done, in the case of a bobsled, with two D-rings attached to a cable controlling the forward rails (Huffman and Hubbard, 1996; Kelly and Hubbard 2000). Steering of a luge is accomplished by applying leg pressure against the outside of the front of the runners and by small changes in the slider's position on the sled, which impacts the center of gravity of the sled. Accelerating under the force of gravity down a track is impeded by drag from the air and surface on which it glides.

To accurately simulate the motion of a bobsled, the changes in material properties of the sled and track at different temperatures that influence the speed of the sled or slider must be taken into account. Ice, as it gets colder become harder, and the coefficient of friction will change between the rails of the sled and the ice. G-forces will similarly influence the coefficient of friction of ice. Finally, altitude can also affect the speed of a bobsled. At higher elevations, ice becomes harder resulting in lower coefficient of friction and faster acceleration. Modeling these small changes in the coefficient of friction will impact the accuracy of any simulation. In real time simulation, the ability to calculate the action of physical forces on sled with the added weight of the athletes must be viewed at a minimum of 30 fps for any interactive environment (Zhang, Hubbard, & Huffman, 1995). Making this calculation (at 100 times a second) determines the location of the sled at any point in time as it proceeds down a track of about a mile in less then a minute (Huffman, Hubbard, & Reus, 1993).

Issues in building a simulator

Clearly in building a simulator, calculating the position of the sled is the first step in simulating the visual experience of a bobsled pilot. Recreating the view from the pilot's seat requires a real time rendering engine capable of producing some likeness of the visual experience of the slider or pilot of a bobsled. Gaming platforms can accomplish this task as the "Game Torino 2006" clearly demonstrates (2k Sports, 2006). In this game world you can take the viewpoint of the driver or slider going down the course in Torino, Italy. Complete with topography, buildings and spectators, the game player has a virtual ride down the course (Figure 3).

In creating a simulator, consideration must be given to the display of the synthetic viewscape. Most gamers experience their environments on a laptop, flat panel display or large screen TVs. For creating a more immersive experience, CAVE's and High-end HMD (Head Mounted Displays) are available and may offer a more true-life experience. With both immersive technologies there is the option of creating a stereoscopic experience, which simulates a sense of depth perception. Within a CAVE or high end HMD (http://www.sensics.com/news/pr/10-17-2006.php), the ability to offer a completely immersive experience offers an important advantage over a single flat screen. As Tony Besnhoof remarked in a 2006 interview (Hatch, 2006):

> It takes a long time to really trust your peripheral vision and your spatial awareness – where you are in the curve. When you're doing it the best, it's almost like you're using the Force, because you're going on instincts more than any rational thought.

In creating the visual experience of being on an object (sled) that is moving through space, two approaches can be considered: one, where your platform is fixed and the world moves around you or two, where the world is fixed and your position relative to the horizon changes using a motion platform. Without a doubt, incorporation of a motion platform that responds with a very small lag time can be challenging exercise. The UC Davis team in designing simulators for the US Olympic Bobsled team used this approach. In their simulators, the user can rotate along a single axis to produce the rolling experience of a bobsled. Flight simulators used for space and jet plane simulation also include yaw and pitch, which dramatically increases the expense of the hardware. Control of the bobsled in this case is accomplished through a set of D-rings found in the simulator, which actuate an electric motor that rotates the bobsled housing (Kelly & Hubbard, 2000).

The most common peripheral devices used to control action in a CAVE include: gloves, gyro-mice, wireless keypads, sensors and joysticks or any standard input device. To heighten the experience of motion in a CAVE environment, surround-sound becomes a critical component. Producing sound which is believable has been shown to be an important aspect of making game environments "believable" (Kim H, et al, 2004). Similarly, the addition of vibration and feedback can heighten the sense of motion in a simulator.

Current Research

In the research project at the University of Calgary, four screens powered by a PC cluster are the basis of our CAVE. For a CAVE simulation of sliding, the necessary camera view is that of a slider or pilot with a fixed camera attached to the sled. Not surprising, this is the viewpoint used by athletes when videotaping their trials. Many athletes will attach a small hand held video camera to their sled with duct tape to create personal records useful for study later. From this viewpoint, rather than from a rigid horizon, the sled appears fixed with the world rotating around the subject. This approach eliminates the need for a motion platform in a CAVE. Furthermore, this approach makes it possible to distribute simulation environments to users who have only a PC.

The prototype developed at the University of Calgary was based on the track at Salt Lake. Established from data in the public domain, the 3D geometry of the track was constructed in a CAD environment. Bobsled and luge sliders were also created and added to the environment to serve as avatars. Once these objects were built, they were imported into Virtools (Paris, France). Virtools was selected as simulation platform because it provided the research team with several important advantages:

- Real time rendering capability with high fidelity. Virtools has the capacity to render textures, shadows, bumps and reflections in real time.
- Physics simulation with the Havoc Physics Engine
- Support for multiple platforms including both single screen display and CAVES
- Support for a wide range of peripherals, including Ascension sensors, joy sticks and HMD's
- Distribution from Web with a free player
- Support for PC, MAC, and Game platforms including X-Box
- Scripting language for ease in prototyping
- Support for common 3D formats

With Virtools, it is possible to assign physical properties to objects, including mass and a coefficient of friction. It is also possible to simulate the force of gravity and to approximate the effects of drag on the sled. Although at this early stage in the development of the simulator, it was not possible to account for small differences in the coefficient of friction of ice from changes in the temperature and hardness of the ice, it was possible to compare the Virtools simulation against actual data from a controlled experiment. In calibrating the physics of real world, we have an opportunity to compare data collected from a year-round training facility against data collected from a virtual model. The CODA operates an "Ice House" which allows sliders and bobsled teams to practice their start. Placing a sled of know mass on this practice track and allowing it to accelerate from a dead stop could compare both position and elapsed time compared with a sled in the virtual world. To complete this test, a virtual model of the "Ice House" was also built and used to record position and time of a sled of known mass (Figure 4,5). Though not a perfect match, the approach of using a gaming engine for prototyping appears to give results promising results (Figure 6)

A keyboard was used to control the sled in the virtual world. An athlete would position himself or herself sitting, standing, or lying down on the floor of the CAVE (Figure 7). Feedback on elapsed time and current speed appeared as numbers displayed on the upper left hand corner of the screen (Figure 8). Sound levels in the simulation were controlled by the speed of the sled, which appeared to offer useful audio feedback.

Lessons Learned and Conclusion

In discussions with athletes and coaches from the Olympic bobsled, luge and skeleton teams, team factors and simulation features, which contribute to a successful training environment, were noted:

- Fixed Viewpoint – Having the sled fixed viewpoint for the camera was seen as beneficial to the athlete. Coaches felt that having a motion platform, where the centre of gravity doesn't change, could provide the athlete with inappropriate feedback. In an actual bobsled run, the center of gravity is always perpendicular to the track runners, which cannot be simulated in a rig that rotates in a fixed position.
- Training Environment – Coaches and athletes saw great value in having a training environment that gave them the opportunity to visualize a course from the vantage point of the pilot or slider. This aspect would be crucial in training an athlete to anticipate each turn. The simulator appeared to offer a safe environment for learning the intricacies of a track. The primary role of simulators was seen as being for unfamiliar or new courses.   At high speeds, a simulator would help athletes acclimate to the visual blur of moving down a track. Features that would help them prepare for an actual practice run would include:
    - A line along the track that shows the path for optimum performance.
    - A playback mode that would show the user's path in the simulated run against the optimum path.
- Avatars - An avatar presence in the visual field was seen as a distraction and not a reference point during the simulation. Most athletes using the simulation preferred the version with an unobstructed view of the track.
- Portability – Having the simulation available to athletes on a PC was seen as an important feature. Being on the road and having the opportunity to do virtual test runs was seen as important tool for both visualization and training.
- Physics - Given that coaches may not always be aware of subtle changes in ice quality, having a simulator that could account for small changes in speed from changes in ice temperature was not viewed as critical.

Like a flight simulator, a simulator for bobsled and other sliding sports would offer the athlete the opportunity to train in a controlled and safe environment. Clearly, building an environment that provides the user with a visual representation of the speed of an actual track is of primary importance. The ability to slide down an unfamiliar track will provide the user with a tool for memorizing the series of turns that make-up a track. Also noted by the athletes was the need for an environment that would expose sliders and pilots to the visual sensation of speed. At speeds of 130km/hr, athletes need to anticipate a turn before they can even have it in view. Having a safe environment where an athlete can practice and experience a track at higher speeds than ever encountered before could help eliminate injuries that are associated with lack of familiarity with a course during an actual competition. As part of a comprehensive program, simulation could add a new dimension to an athlete's training. In these environments athletes could also become familiar with new venues and practice under different weather conditions. Coaches could record, compare the different trials of athletes, and make suggestions that could improve their performance. Most important, with the construction of tracks that are becoming more and more technically challenging, training in a simulator has the real potential of reducing the number of serious injuries during practice and competitions.

References

2K Sports, *Torino 2006*

AP. Twisting track an Olympic nightmare for lugers, (2006) USA *Today, February 16, 2006*, http://www.usatoday.com/sports/olympics/torino/sliding/2006-02-16-treacherous-track_x.htm

Bell, H. H. &. Waag, W. L. (1988). Evaluating the Effectiveness of Flight Simulators for Training Combat Skills: A Review. *International Journal of Aviation Psychology*, *8*(3), 223-242.

Brannick, M.T. (2005). Can PC-Based Systems Enhance Teamwork in the Cockpit? *International Journal of Aviation Psychology*, *15*(2), 173-187.

Hatch, J. (producer) (2006). Interview with Tony Benshoof, American Luger http://www.usatoday.com/sports/graphics/torino2006_multimedia/cesana_pariol_orig.htm

Huffman R. K., Hubbard, M., & Reus, J. (1993). Use of an Interactive Bobsled Simulator in Driver Training. *ASME Winter Annual Meeting*, New Orleans. Nov. 1993.

Huffman R. K., & Hubbard, M. (1996). A Motion Based Virtual Reality Training Simulator for Bobsled Drivers, *The Engineering of Sport*, 195-203.

Hubbard, M., Kallay, M., Joy, K., Reus, J., & Rowhani, P (1989). Simulation of Vehicle and Track Performance in the Bobsled, *ASME/ASCE Biomechanics Symposium*, *Proc.*

Hubbard, M., Michael, K., & Rowhani, P. (1989). Three-Dimensional Bobsled Turning Dynamics, *International Journal of Sport Biomechanics*, 5, 222-237.

Hubbard, M. (1994). Simulating Sensitive Dynamic Control of a Bobsled, *2nd Conference on Mathematics and Computers in Sport, Bond University, Queensland, Australia, July 11-13*.

Kelly, A., & Hubbard, M. (2000). Design and Construction of a Bobsled Driver Simulator. *Sports Engineering, 3,* 13-4.

Kim, H, DiGiacomo, T, Egges, A, Lyard, E, Garchery, S, & Magnenat-Thalmann, N., Believable Virtual Environment: Sensory and Perceptual Believability. *Believability in Virtual Environment*. December 2004.

Magnusson, S. (2002). Similarities and Differences in Psychological Reactions Between Simulated and Real Air-to-Ground Missions. *International Journal of Aviation Psychology*, *12*(1), 49-61.

Rhodenizer, L. (1998). It Is Not How Much You Have but How You Use It: Toward a Rational Use of Simulation to Support Aviation Training *International Journal of Aviation Psychology*, *3*, 197-208.

Sensics, (2006). (http://www.sensics.com/news/pr/10-17-2006.php).

Stone, Robert J. (2002). "Serious Gaming." *Defense Management Journal 31*: 142–144.

Virtools, www.virtools.com

Zhang, Y., Hubbard, M., & Huffman, R. (1995) Optimum Control of Bobsled Steering, *Journal of Optimization Theory and Applications 85*(1), 1-19.

Illustrations

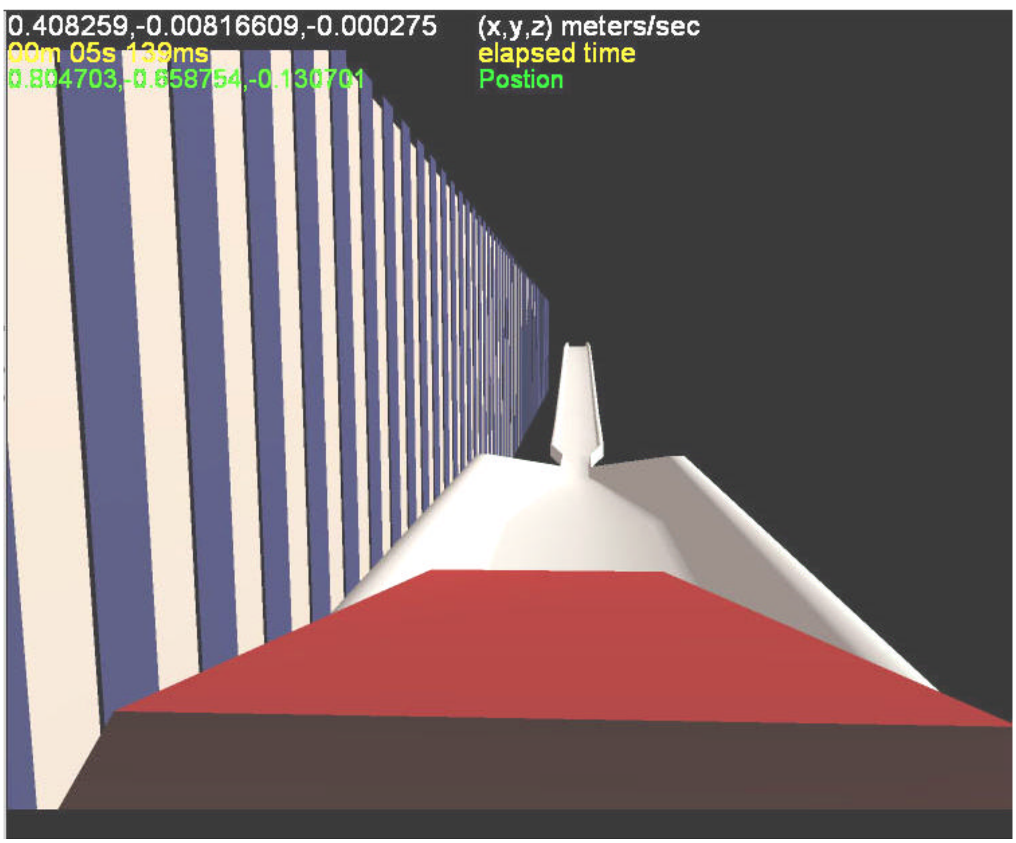
Figure 1. Canada's Ian Cockerline during the final run of the Men's singles, Torino 2006, John D. McHugh, AFP/Getty Images

Figure 2. Sports Biomechanics Laboratory, University of California Davis, Design and Construction of a Bobsled Driver Training Simulator, A. Kelly and M. Hubbard, Sports Engineering., 3, 13-24, 2000.

Figure 3. Image from “Torino 2006” 2K Sports.

Figure 4. Ice House, Canadian Olympic Park, Calgary, Alberta.

Figure 5. Test Sled Ice House, Canadian Olympic Park, Calgary, Alberta



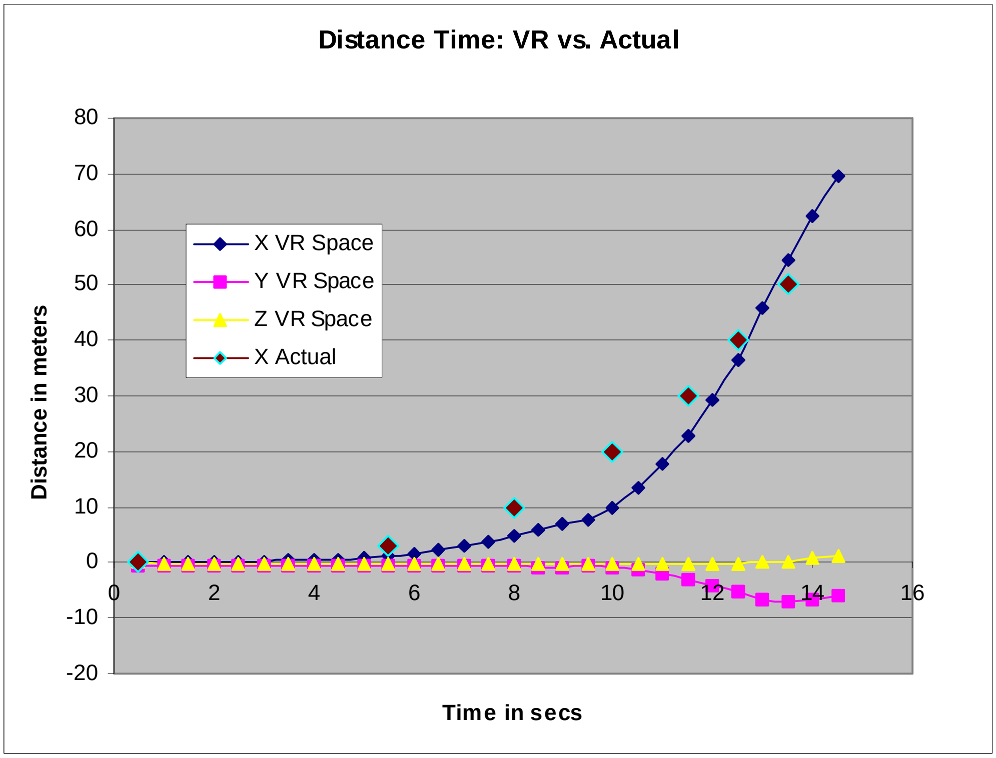


Figure 5. Virtual “Ice House”.

Figure 6. Comparison, Virtual and actual test sled.

Figure 7. View of simulation in the CAVE, I-Centre, University of Calgary.

Figure 8. View of Display, Luge simulation, PC.