

ENHANCEMENT OF BOBSLEIGH SIMULATION REACTIVE FORCE

Masatoshi OGINO, Tsuyoshi TAKI, Shinya MIYAZAKI and Junichi HASEGAWA

Graduate School of Computer and Cognitive Sciences, Chukyo University
101 Tokodachi, Kaizu-cho, Toyota-shi, 470-0393 Japan
E-mail: h10501d@st.chukyo-u.ac.jp, {taki,miyazaki,hasegawa}@sist.chukyo-u.ac.jp

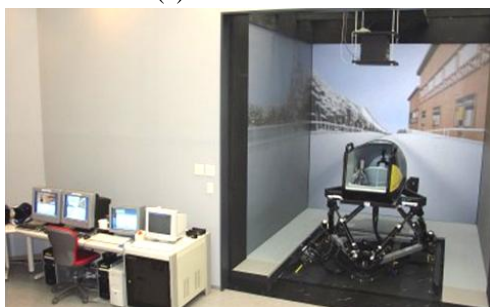
ABSTRACT

The bobsleigh is a winter sport which use a sled to slide down an ice-covered course. There is a big expectation for having a training environment and being able to train year round. At present, training is very limited due to the season or course facilities. A variety of VR (Virtual Reality) equipment has been developed in recent years, and it is beginning to spread. We have also made our contribution in bobsleigh simulation. The reactive force applied in our bobsleigh simulation is much smaller than that of a real bobsleigh. This paper proposes a method to enhance reactive force of bobsleigh simulation in real time. The reactive force is magnified instantly in the physically-based simulation. The Laplacian filter is applied to the sequence of reactive force, this technique is often used in the field of image processing. The simulation is comprised of four large scale surround screens and a 6-D.O.F. (Degree Of Freedom) motion system. We also conducted an experiment with several motion patterns to evaluate the effectiveness of enhancement. The experimental results proved useful in some cases.

Keywords: Bobsleigh, Simulator, Surround Screen, Motion Base, Virtual Reality, Reactive Force



(a) Cabin details



(b) Bobsleigh simulation exterior

Fig. 1: Exterior of bobsleigh simulation and cabin details

1. INTRODUCTION

VR is developed as a technology that gives the sense of existing in virtual space giving visual information. It gradually clarifies that we not only conduct various virtual experiments in virtual space but also work more safely and efficiently. Early research of VR studies was mainly in device development, such as binocular vision display, 3D position sensing and force-feedback generation. And now, we have entered the phase of more practical application, constructed with understanding the characteristic of individual devices and how to coordinate them. For the social role of the VR technology, it is important to apply visualization technology to the central component of it. The application of it can be used for all fields (e.g. Industry, Medical treatment, Sports, and Amusement). Now, it is more important to discover new applications to enhance VR contributions to society. The field of sports training is also expected to make great advancements.

Simulation is a great asset for large scale sports, especially winter sports, because training is limited due to weather or lack of proper facilities. Our target bobsleigh has limitations. Some bobsleigh training simulators have been developed and have been tested in foreign countries [1-4]. Hubbard and his colleagues' bobsleigh simulator was made in method to display the physical simulation results of a bobsleigh cabin onto monitor, and movement of the cabin is controlled according to the simulation result and reflects force feedback to the steering. In another research, motion base system is used frequently for virtual experience type attractions such as in amusement parks etc., and plays a major role in improving the reality. It is difficult to reproduce the real acceleration exactly and automatically, because the system does not have the ability to create the real magnification of acceleration. Therefore in reality, the result of motion generation has to be corrected manually.

And, it is necessary to enhance acceleration because the range possible to generate is very narrow. In addition, previously interactive simulation such as driving a car, is impossible to correct motion manually. To overcome this, it is necessary to give some rules to enhance acceleration based on the result of simulation. Therefore, this paper purposes a method to enhance reactive force of bobsleigh simulation based on the use of large scale surround screen and 6-D.O.F. motion system. The acceleration is enhanced by Laplacian filter applying to the sequence of acceleration vectors. The bobsleigh simulation course imitates an existing bobsleigh course in Nagano city of Japan, and the bobsleigh motion is processed by a dynamic physical

simulation. In bobsleighting, it is important to control the sleigh blades and weight shifting of the players. If these elements are achieved in simulation, it can lead to improving the result of gliding more effectively.

2. BOBSLEIGH SIMULATOR

The exterior of bobsleigh simulation is shown in Fig 1. The simulator is comprised of four large scale screens and a 6-D.O.F. motion system. These screens consist of front, side and floor size of 3m x 3m. A 6-D.O.F. motion system (MMS612EII made by Mitsubishi Precision Co.,Ltd.) exist in the center of the surround screens. A cabin modeled in the bobsleigh is fixed on the motion system, and a couple of speakers is fixed to the front of the cabin. The speakers emulate bobsleigh motion sound.

The CG (Computer Graphics) images show a 3DCG environment along the course (Fig.2). These images use real time 3D application development tool Vega (made by MultiGen-Paradigm Inc.). The floor below the front screen always reflects the shadow of the cabin. However, it is of little use to passengers because they seldom look at the floor.

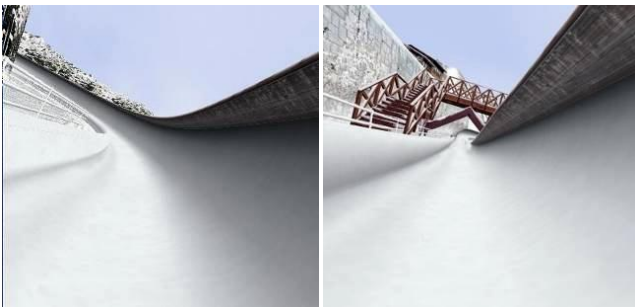


Fig. 2: CG images during gliding

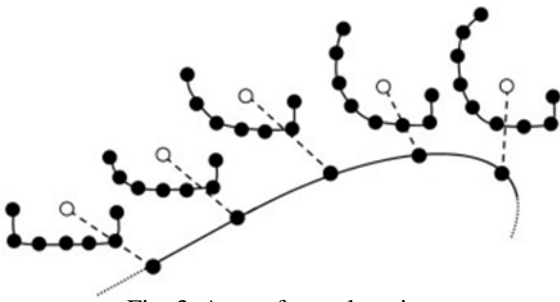


Fig. 3: A set of sample points

(White points trace the center axis of the course, and black points indicate the cross-sectional shape of the course surface.)

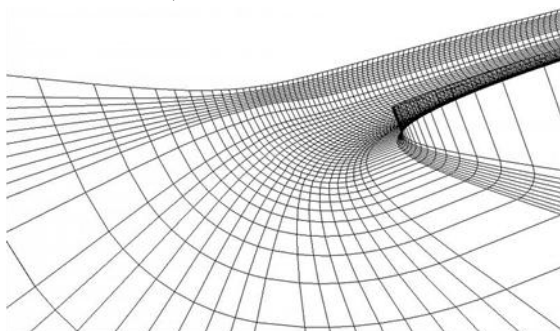


Fig. 4: Wireframe rendering of the bobsleigh course

3. THE KINEMATIC BOBSLEIGH MODEL

Bobsleigh gliding is considered to be the free-fall of the material point on a curved rigid body of sufficiently friction coefficients. In the case of dynamics simulation of rigid body motion based on physics, Euler's method is usually applied to calculate and find positions step by step with the time line. However, this method has a disadvantage to reduce process time which is necessary to reduce the interval of the movement rate in change of force. In our case, the friction between course surface and sleigh corresponds to this fault. Therefore, motion generation is unfavorable in high-speed processing. Then, this simulation is processed by method of restricting the course surface by dividing acceleration and velocity into a horizontal (gliding and side elements) and perpendicular direction. As a result, we are able to get the gliding simulation of the restricted surface with high-precision and high-speed.

3.1 Course Data

The course layout is variously designed, but is generally made up of a combination of the straight lines, circle lines, and oval lines. The data is made up of sequential points of the center line at every 50cm intervals and the points of section for them (Fig. 3 and 4).

3.2 The Normal Vector and Curvature

The affect on the cabin corresponds to gravity, frictional force, air resistance, and etc. This simulation use gravity and centripetal force. To use dynamic simulation requires normal vector and curvature for cabin position. These parameters are calculated as follows:

- A normal vector at each sampling point is estimated by averaging normal vectors of neighboring polygons which vertices include the sampling point. By this way, a normal vector at every sampling point is obtained.
- A normal vector of the cabin is obtained from four normal vectors on vertices of the polygon including the cabin according to the Hermite interpolation.
- The cabin curvature is calculated from positions and normal vectors of the cabin and course polygons.

4. CONTROL OF THE MOTION SYSTEM

The main force affecting the cabin can be obtained in method by section 3.2 and applied in each step of dynamic simulation. This calculated force is resolved in three directions (forward, sideway, and vertical directions of the cabin), and input into the motion system. Three direction acceleration is shown in Fig.5. The black point shows the position of the bobsleigh, and the acceleration vectors in the forward (broken line), sideway (dotted line), and vertical directions (solid line) based on it. The vertical acceleration vector is far larger than the other direction vectors, so this vector is displayed at a rate of one-tenth. "C no." in that upper figure shows each corner number.

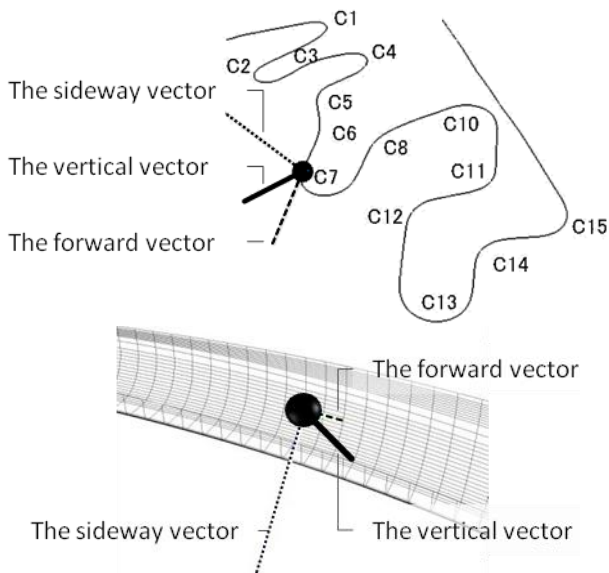


Fig. 5: Direction vector coordinates of the bobsleigh cabin

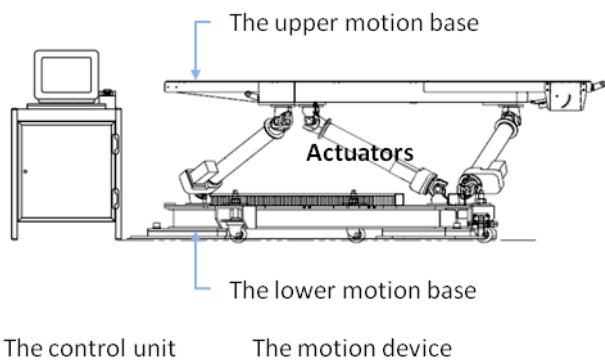
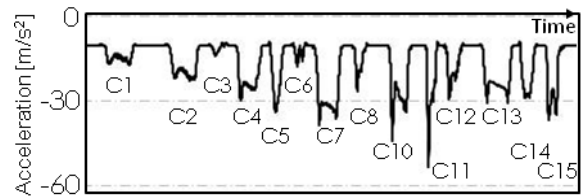


Fig. 6: The exterior of MMS612EII

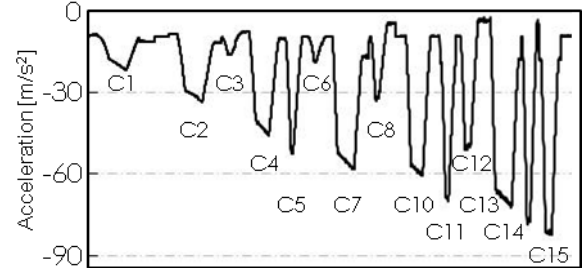
Table 1: The Specification of MMS612EII

	Axis	Waking Range	Maximum Speed	Maximum Acceleration
System Function	X	+170 -200 mm	300mm/sec	2400mm/sec ²
	Y	+180 -180 mm	300mm/sec	2400mm/sec ²
	Z	+220 -180 mm	300mm/sec	2400mm/sec ²
	Rolling	+17 -17 deg	25deg/sec	-
	Pitching	+18 -16 deg	25deg/sec	-
	Yawing	+15 -15 deg	25deg/sec	-
Mechanical Function				
	Payload	less than 500kg		

A physical simulation result is requested as a value in a local coordinate based on the bobsleigh. Obtained acceleration and attitude angle are given to input into the motion system. The attitude angle suggests the pitch and

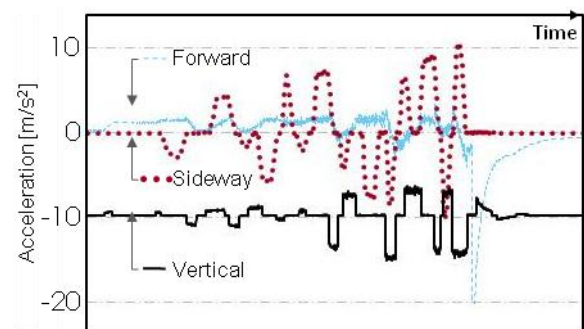


(a) Vertical acceleration by motion system maker

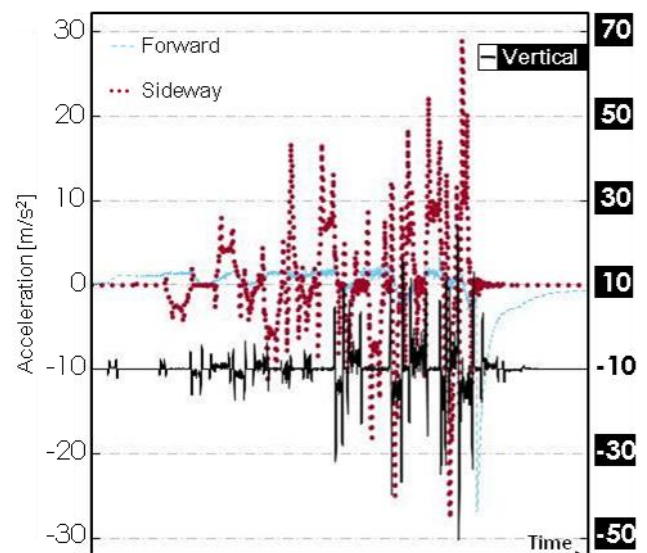


(b) Vertical acceleration by our simulation

Fig. 7: Comparison of downward acceleration in the cabin coordinates



(a) Physically-based simulation result



(b) Enhanced result

Fig. 8: Enhanced physically-based simulation results

roll angles from a horizontal plane.

The CG image is displayed in consideration of the position and the attitude angle. Fig. 6 and Table 1 show exterior and specification of the motion system.

4.1 Enhancement of Acceleration

The maximum acceleration value by physical simulation was about 8G or less in the final corner (C15). In the case of actual bobsleighting, it is about 5G because there is friction and air resistance. However, the motion system can be hardly represented over 1G. In the case of amusement usage, it enhances acceleration for improving reality.

The graph of Fig. 7 shows vertical acceleration in the local coordinate of the cabin. (a) is the acceleration made for the concept of amusement usage by the motion system maker and (b) is the calculation results of physical simulation. The sharp drops in this graph corresponds to each corner (the corner number is the same as Fig. 5). Both graphs show basically similar tendencies. But the acceleration of (a) in the entrance of the corner is sharper than (b). It is difficult structurally to continue acceleration in the same direction for a long period of time. Acceleration can be reduced by controlling it, by decreasing the integration value of acceleration while enhancing it.

Such acceleration can be easily enhanced if simulation results are already-known, and movement calculation result of real-time must be enhanced. The Laplacian filter is applied to the sequence of reactive force. This technique is often used in the field of image processing. Fig. 8 (b) is a result of subtracting Laplacian filter radius eight from former data and applying it to the result of real-time simulation, shown in Fig. 8 (a). Even when enhancement effects are more magnified, this data is better compared with Fig. 7. Acceleration is higher than the input value of the motion system, so it needs to be corrected within the limited range of the system.

4.2 Experimentation

To prove the effectiveness of enhancement, we evaluated it and the gap between moving image and cabin motion. Then, we experimented with the enhancement effect and the perception gap with the four following motion patterns:

1. No enhancement effect
2. A weak enhancement effect (filter radius =8, amplitude ratio =3.5)
3. A strong enhancement effect (filter radius =8, amplitude ratio =5.0)
4. Revision delay of motion pattern 3.

There is a delay in the Laplacian filter radius caused by real-time processing (as Fig. 9). In the example above, the delay time became 167ms at simulation time. Motion pattern 4 is made in state without delay. Then, we evaluated whether the delay was perceived by the tester.

The motion patterns from 1 to 4 were realized for sixteen men and women in their early twenties, and the perception result was answered by nine levels on the effect of enhancement and delay. The middle level (the fifth level) shows no enhancement effect or delay. In the enhancement effect, it was instituted that high levels were stronger than

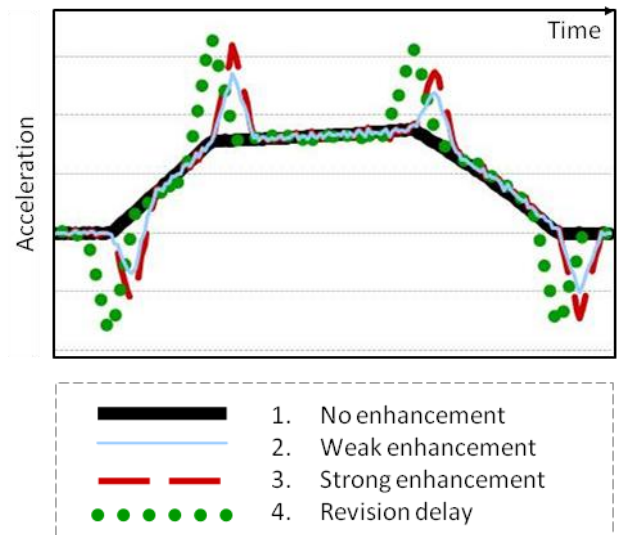
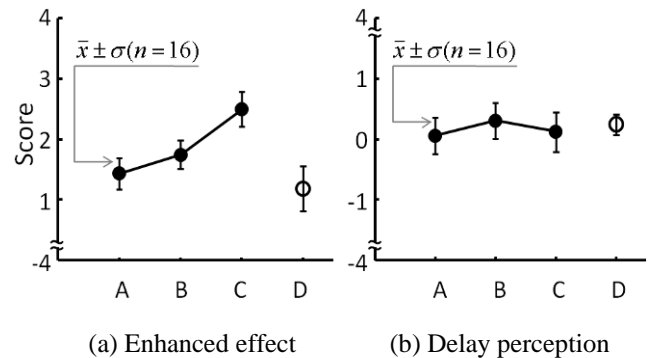


Fig. 9: An example of enhanced feedback



- A: Comparing motion pattern 2 with 1
 B: Comparing motion pattern 3 with 1
 C: Comparing motion pattern 4 with 1
 D: Comparing motion pattern 4 with 3

Fig. 10: Experimental results of enhancement efficiency perception

low levels. And, in delay, high levels were instituted that the image comes earlier than motion in the cabin, and in low levels images come later than motion.

Fig. 10 shows the result. In this graph, each point shows average of respective answer, and the score is defined what the middle level of the answer sheet means zero point. Approximately the tester could realize the effects of enhancement. And, the experiment proved that strong patterns were more effective than weak ones and the revision pattern proved more effective than strong patterns. As to delay, it was almost not applicable in all patterns (Fig. 10(b)). It is thought that the influence of this delay can be disregarded because delay time is so small, and force corresponds to the delay set off because several continuous corners exist. As a result, the experiment proved the enhancement process to be valid.

4.3 Expert Opinions

We asked bobsleigh specialist their opinions about the effectiveness of a training support system. One is a coach and manager of Japan's national bobsleigh team, and the four others are bobsleighters. The results are as follow:

- The result of physical simulation appeared to be similar to the real thing.
- The simulation of no blade operation looked like low level sliding.
- The motion effect was very low compared to actual acceleration, however, to add the effect was quite easy.
- It is necessary to improve the design of the cabin because of unlikely comparisons.
- This system is useful in training inexperienced or immature players under the present conditions.

5. CONCLUSION

The development of a bobsleigh simulator imitating a real bobsleigh course in Nagano City in Japan has been discussed in this paper. This simulation used four large scale surround screens and a 6-D.O.F. motion system. For high-speed physical simulation of a bobsleigh, we proposed easily calculations by a combination of the Euler method and space limitations. For the motion system, we proposed a method for improving reality by enhancement processing of the result of slide simulation. In conclusion, we proposed enhancement processing the Laplacian filter for more realistic feeling in real time motion simulation.

6. REFERENCES

- [1] K. Huffma and M. Hubbard, "A Motion Based Virtual Reality Training Simulator for Bobsled Drivers", in the Engineering of Sport, S. Hakke(Ed.), Balkema, Rotterdam, pp.195-203, 1996.
- [2] A. Kelly and M. Hubbard, "Design and Construction of a Bobsled Driver Training Simulator", Sports Engineering., 3, 13-24, 2000.
- [3] M. Hubbard, M. Kallay and P. Rowhani, "Three Dimensional Bobsled Turning Dynamics", Int. J. Sport Biomechanics, vol.5, pp.222-237, 1989.
- [4] Y. Zhang, M. Hubbard and K. Huffman, "Optimum Control of Bobsled Steering", J. Optimization Theory and Applications, 85(1), pp.1-19, 1995.