Vicarious Adrenaline

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Abstract - *This project investigates the transference of adrenaline-based motor sport experiences to an observer through a complex inter-modal interaction. Two riders competed in the Irish National SuperBike Championships in 2003 with both rider and motorcycled data recorded onboard. An interface was subsequently designed and built at Media Lab Europe where people can experience this high adrenaline sport vicariously through a tightly coupled visual, audio and haptic presentation. The result is an experience which uses a multi-axis force stimulus through an active chair with an audio overlay of a heartbeat on the video and audio footage from the race. The visual stimulus provides the primary activation of the experience and hence the context. The use of an active haptic device augments this experience with the aim of achieving a strong sense of observer immersion in high adrenaline sports.*

Keywords: Haptic devices, data acquisition, multi-modal niterfaces

1 Introduction

There are a considerable range of sporting activities that require significant learning, time and commitment in order that one can participate. Consequently, not everyone has the opportunity nor the inclination to participate in high-adrenaline extreme sports. On the other hand, the huge popularity of MotoGP or Formula 1 for example, demonstrates the potential for expanding on the 2-dimensional television-based experience that currently exists. Multi-modal haptic interfaces can facilitate a 3-dimensional physical experience-based interface for an observer whereby they become more involved in the extreme sporting event.

Haptics is viewed as the science of implementing some form of touch (tactile) sensation and control to our interaction with a generally computer-based application. The word haptic is derived from the Greek word haptesthai which means to grasp or touch with Braille readers being the first computer-based haptic interface. Recent work in haptics has demonstrated the power of being able to physically feel objects in virtual reality haptic devices, for example, the Virtalis SensAble Phantom Desktop or the CyberGrasp CyberGlove.

Figure 1. Team Media Lab Europe competing at Nutts Corner race circuit in Northern Ireland with data logging

This paper deals specifically with the design and construction of an active haptic chair and the corresponding control mechanism based on the data retrieved from two riders and their motorcycles who have competed in the Irish National Motorcycle Championship in 2003. The use of the haptic chair augments the traditional visual experience with the aim of achieving a strong sense of immersion in high adrenaline sports.

2 Background

While current research on motorcycle simulators aim to provide as realistic force and displacement experience as possible such as found in the MORIS project [1], this work aims to use the physical actuation of the user via the active chair as a reinforcement of the visual stimulus to create an adrenaline-based experience. The Honda Riding Simulator [4] uses the reference of a motorbike mock-up to develop a sense of realism in order to “train the riders to anticipate and react to potential road hazards in a 'safe environment'”. The Motorrad-fahrsimulator SAFE II [3] has similar aims.

Experiential devices, on the other hand, aim to develop and maintain an experience which, in this case, draws on real data from a season’s competitive racing. In understanding the motivations behind not using a physical replica of a motorbike for the vicarious adrenaline experience, an analogy can be drawn with Mori's Uncanny Valley [2] regarding anthropomorphism. The closer the artificially created experience is to the real, the greater the risk for a complete perceptual failure in experiential devices. It's an issue of managing expectations. The true sport of motorcycle racing is a lot more than forces acting on the rider and a visual stimulus. This work consequently aims to fuel our expectations and allow the user employ their imagination to experience the race and specifically *not* to explicitly recreate a race as accurately as possible for an observer. If the experience is not real, then the artificial should aim to be a judicious balance between expectation and experience.

3 System Design

Two riders (Brian Duffy & John Bourke) competed in the Irish National SuperBike Championships in 2003. The competition motorcycles were equipped with an onboard camera, 3-axis accelerometers, a Polar PCBA receiver and each rider wore a wireless Polar heart-rate monitor. The data is recorded onboard and subsequently downloaded after each race.

An active chair and a corresponding MatLab-based control interface were designed and built to process this data and provide a seamless control system for an immersive environment for the participant. The active chair (figure 3) is driven by three pneumatic cylinders with variable air speed and pressure controllers. The physical construction and inclination of the chair are designed for increased relaxation with the aim of facilitating the immersive experience. A USB hardware interface allows a PC control the position of each of the pneumatic cylinders and provides a simple and flexible control solution. This is achieved through a PIC controller (PIC16F87x) with a Serial Communications Interface in full duplex mode (asynchronous) with a USB interface board.

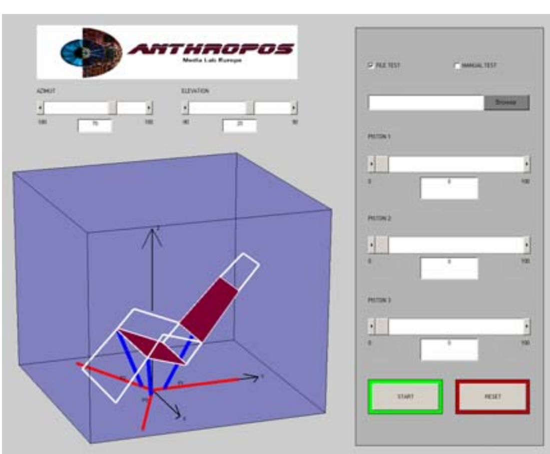

Figure 2. MatLab control interface for the active chair

In figure 2, the interface shows a schema of the chair with the three cylinders (blue lines), which can move simultaneously with the movement of the chair. The interface allows a manual control to fix or move to any piston location. A "load file" option allows the user select a data file to control the chair.

Figure 3. Vicarious Adrenaline Haptic Chair

In designing the vicarious adrenaline experience, three key data sets were retrieved whilst participating in the 2003 racing season: 3-axis accelerometer data, video footage from an onboard camera mounted at the front of the motorcycle, and the heart rate of the rider (which is not discussed in this paper). The force displacement of the motorcycle during a race is consequently translated into the movement of the active chair (figure 3). The number 1 piston at the rear of the chair provides the sensation of acceleration (down) and braking (up). The pistons number 2 and 3 angle the chair right and left according with the motorcycle tilt in cornering.

In order to obtain a data signal to describe the acceleration, braking (accelerarion-braking signal) and tilt (tilt signal) of the motorbike and hence drive the actuation of the chair, two methods have been considered: Accelerometer Method, Visual Method.

3.1 Accelerometer Method

The accelerometer method used the 3-axis accelerometers mounted on the motorcycle during each race. The X-acceleration signal gives information about acceleration and braking, Y-axis corresponds to tilt and Z-axis is ignored due to the stiffness of competition specification suspension and the resulting noise.

The acceleration data is numerically integrated to obtain velocity data using a cumulative trapezoidal numerical integration. The result of the integration is multiplied by the sampling time to properly scale the velocity data. It appears as a linear trend, a by-product of the DC offset in the acceleration data and is removed using a high pass filter. Using the same method, the velocity data is numerically integrated to obtain displacement data. The acceleration-braking signal corresponds to the X acceleration signal.

During the data analysis following the races, the accelerometer data retrieved proved very difficult to work with due to a very high signal to noise ratio. Due to the constraints of the project, further investigation into managing the noise problem could not be undertaken. Consequently, the following Visual Method strategy was investigated and developed as a cleaner strategy for feature extraction.

3.2 Visual Method

The visual method utilises the fixed camera mounted on the front of the motorcycle which shows the engine RPM counter and the route simultaneously. The tilt values of the motorbike are obtained by rotating each image until a horizontal horizon is achieved. The RPM Counter provides information about the acceleration and braking. The data obtained from the Kirkistown circuit give the acceleration-braking and the tilt signal presented in figure 4. They are the signals of two laps with a start and end point between the Fisherman's corner and the Chicane (red dot in figure 5).

Figure 4. Motorcycle lean calculated from video

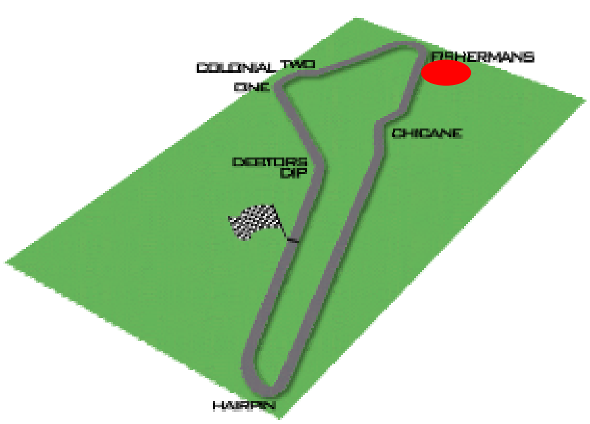

Figure 5. Kirkistown race track, Northern Ireland

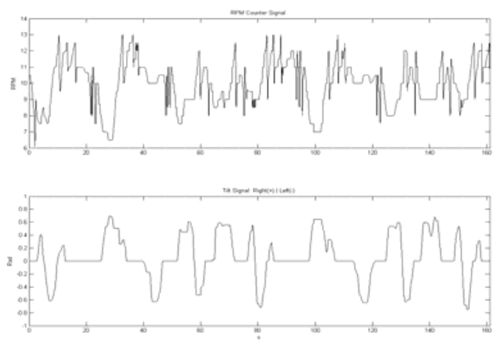

Figure 6. Motorcycle acceleration/braking and tilt data respectively calculated from video

With a suitable selection of images and using a cubic or spline interpolation we obtain both signals.

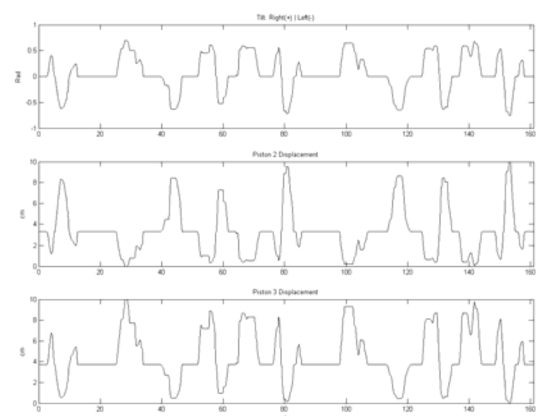

Figure 7. The tilt data and resulting displacement data of piston 2 & 3 respectively

The visual method was found to be most successful as it removed the issue of considerable noise present in the accelerometer data but was computationally intensive. On the other hand the accelerometer method would be the fastest technique if the severe noise issue could be resolved or at least significantly reduced.

4 Control Algorithm

Using the resulting acceleration-braking and tilt signals from the Visual Method, the pistons displacement signals were calculated. This therefore requires that the data is translated into the linear actuation of three angled cylinders (see figure 2 and 3). The control system then has to subsequently perform two functions: to translate the positions values as a set of data messages, and to send these messages with respect to time to the PIC board, which acts as the hardware interface with the pneumatic solenoids of the chair.

The first step involved the calibration of the speed of actuation of each pneumatic cylinder of the chair for a given weight of participant (comfort speed). A speed of v_c equal to 10 cm/s was decided upon through preliminary tests as it provided a sufficient degree of physical reaction to the visual stimulus available to the participant sitting in the chair through watching the video feed from the onboard camera of the race bike. This comfort speed is not fixed but is easily adjusted for differing weighted participants.

4.1 Piston 1 Displacement

We use the RMS signal as a displacement signal to move piston 1. When the RMS signal reduces, piston 1 moves up. The opposite occurs when the RMS signal is raised.

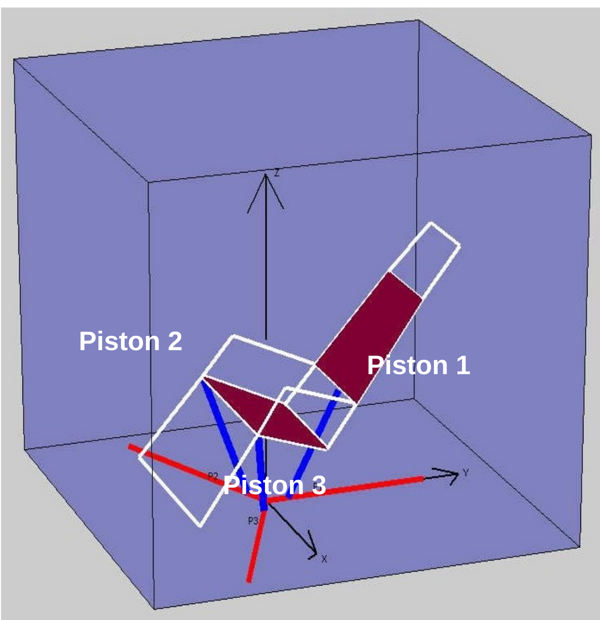

Figure 8. Motorcycle acceleration/braking and tilt data respectively calculated from video

The requested speed of actuation of piston 1 has to respect the comfort speed selected. The derivate of the displacement sometimes gives a higher speed value than this limit. A high pass filter is therefore used with a fc=1.45 Hz to obtain a displacement signal which has a derivate with a speed lower or equal than the comfort signal. The displacement signal obtained was configured according with the real movement of the pistons of between 0 and 10 cm, located as indicated in figure 8.

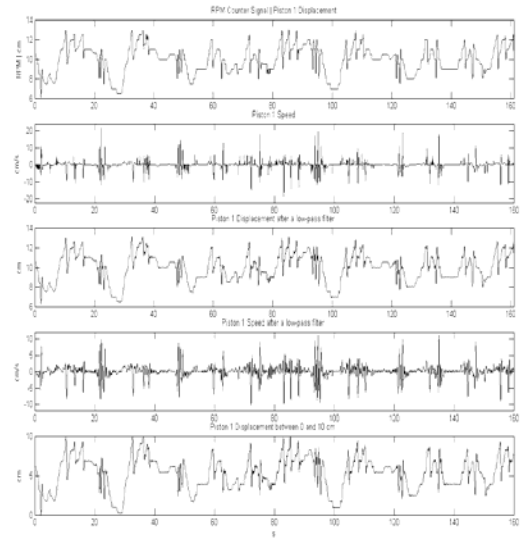

Figure 9. Graphs showing piston 1 displacement and corresponding speed with filtering

4.2 Piston 2 and 3 Displacement

The tilt signal was used to move pistons 2 and 3. When the motorbike tilts on the left during cornering with a angle α, piston 3 comes down and the piston 2 comes up a angle β.

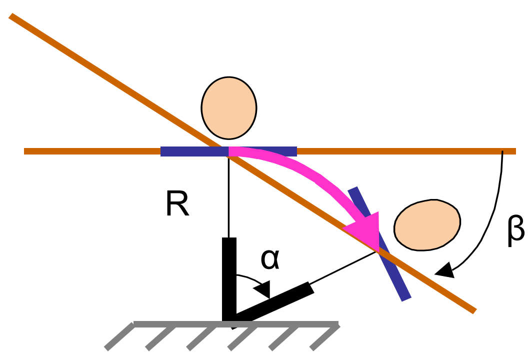

Figure 10. Correlation between the angle α and the angle β

The relation between a tilt of angle α and the tilt of angle β of the arm chair is:

$$tan(\beta) = \frac{1 - \cos(\alpha)}{sin(\alpha)} \qquad (1)$$

The equations between the pistons 2 and 3 displacement (d_2 and d_3) with the tilt of angle β is :

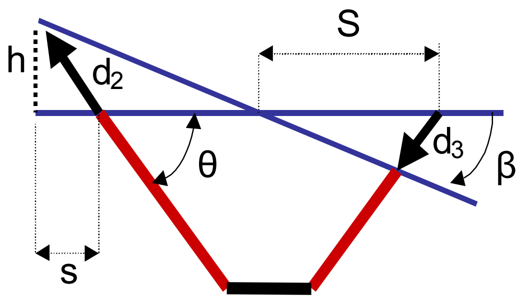

Figure 11. Correlation between the pistons 2 and 3 displacement (d2 and d3) and the tilt of angle β is

$$d_2 = \frac{-S \times \tan(\beta)}{\cos(\theta) \times \tan(\beta) - \sin(\theta)} \quad (2)$$

$$d_3 = \frac{S \times \tan(\beta)}{\cos(\theta) \times \tan(\beta) + \sin(\theta)} \quad (3)$$

Using these equations with the tilt signal we have the piston 2 displacement signal and the piston 3 displacement signal as shown in the following figure.

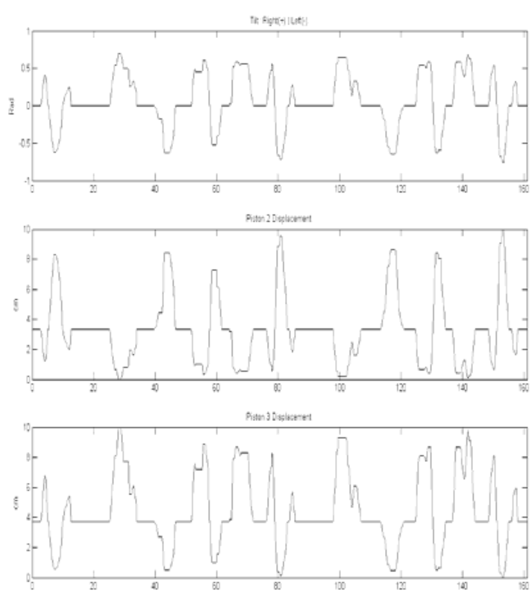

Figure 12. Piston 2 and 3 displacement signals

4.3 Displacement Piston Control

Each piston i (i=1,2,3) has a displacement signal S^i and comfort speed v_c. A piston i at the instant t_k will have a position d^i_k. At a time $\Delta t = t_{k+1} - t_k$ later, a piston i will have a displacement $d^i_k + D$ if the movement is up, $d^i_k - D$ if the movement is down, and d^i_k if the position doesn't change ($D \cong v_c \Delta t$) (see figure 13).

The control algorithm compares the value of displacement signal S^i_{k+1} at the time t_{k+1} with three positions of the piston: the position of piston d^i_k at the time t_k, d^i_k+D and d^i_k-D. Subsequently, it chooses the min {abs {Equal=S^i_{k+1} – t_k, Up=S^i_{k+1} - (d^i_k+D), Down=S^i_{k+1} - (d^i_k-D) }}.

The PIC controller performs the order Equal, Up or Down for a time Δt through the use of either a "0", "1", or "2".

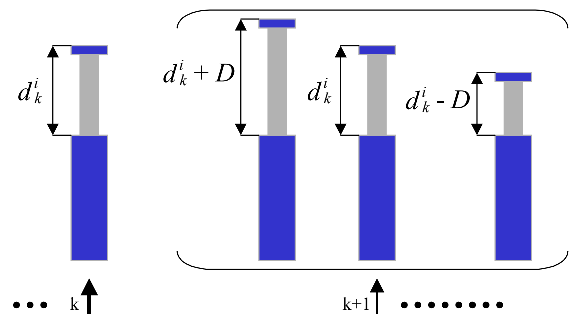

Figure 13. Piston displacement

4.4 Displacement Piston Performance

The value of v_c is fixed by the degree of comfort (severity of actuation of the chair and therefore the participant seated in the chair), the error between the displacement of piston i and its displacement signal S^i depends of period Δt. With a small value for Δt the error reduces and the sensation of continuity (smoothness of the experience) raises but this value must allow the control algorithm to work in real time. A value of Δt = 40 ms was selected. With this value the system works with a sensation of continuous movement in real time.

5 Conclusion

This work has shown how two very different methods have been researched to create an adrenaline-based observer experience. The visual method was found to be the most successful as it removed the issue of a problematic signal to noise ration present in the accelerometer data.

The Vicarious Adrenaline currently runs as an on-going demonstration at Media Lab Europe with a considerable number of people having tried it to date during Open_House events. It has been found through user participation that one of the features important to the perceptual success of the system is the tight coupling of visual stimulus and chair actuation. When the rider turns suddenly into a corner or alternates direction as found in a chicane, the chair must move at the exact same time. By directly linking the chair actuation system to the video feed through the Visual Method proposed, this has been possible.

Work is currently underway to refine the technologies implemented and provide a robust vicarious adrenaline experience.

Acknowledgements

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References

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