# HeadRacer: A Head Mounted Wearable Computer with Ultrasonic Position Sensing*

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## ABSTRACT

This demonstration is in three parts. Firstly we are showing a wearable computer built into a cycle helmet. This comprises a gumstix single board computer, an ultrasonic receiver module and a lithium polymer battery. The helmet interacts with an ultrasonic positioning system. This system requires no RF or infra-red synchronisation enabling fast and accurate performance. Lastly we are providing an interactive game based on Tux Racer with which conference attendees can appreciate the performance of the overall system.

### Introduction

Our research is focussed on mobile and wearable computers and how these devices can interact with the environment. We are seeking to construct wearable computers which have minimal impact on the user by integrating them as far as possible with everyday clothing. We also are investigating technology which can be incorporated into the environment with the least effort.

**Figure 1: Cycle helmet wearable computer with ultrasonic receiver inset.**

For our demonstration we are showing a wearable computer based on a single board computer - the 'gumstix' [1]. This is mounted in a cycle helmet (see Figure 1) along with an ultrasonic receiver which listens for sequences of ultrasonic signals from transducers placed in the environment. We use a Bluetooth interface from our wearable to send position data to a laptop server running our selected application, the Tux Racer game. The data is translated into control signals enabling the game to be controlled using head movements. The game is displayed to enable both the user, and an audience, to enjoy the experience.

*Funding for this work is received from the U.K. Engineering and Physical Sciences Research Council, Grant No. 15986, as part of the Equator IRC.

### Wearable Computer

Wearable computers can take many forms, however their essential elements are that they should be worn, not carried; be user controllable; and operate in real time [2].

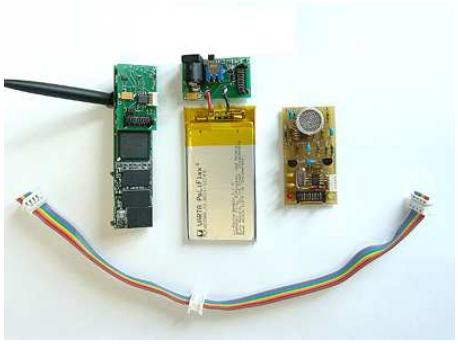

**Figure 2: Wearable components - gumstix sbc, LiPol battery and ultrasonic receiver, with interface bus cable.**

Our wearable computer here comprises of three modules (see Figure 2) mounted in a modified cycle helmet. These consist of the gumstix single board computer (sbc), an ultrasonic receiver and a flexible Lithium Polmer (LiPol) battery. The gumstix is a complete Linux system with a 400MHz XScale processor, 64MB SDRAM, 4 MB flash, MMC slot, USB, Bluetooth and serial interfaces measuring only 83mm x 36mm x 15mm - the equivalent size of a stick of chewing gum. This is interfaced using a power and serial bus to the high gain ultrasonic receiver with a wide angle of detection, and the 750mAh Lithium Polymer battery. The battery provides sufficient power for six hours continuous use.

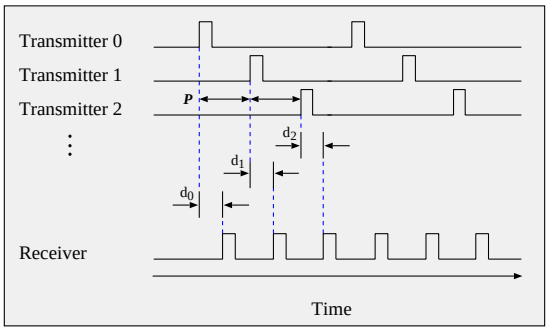


**Figure 3: Chirp train.**


**Figure 4: Tux Racer in action**

### Ultrasonic Positioning

A control unit with six remote ultrasonic transducers is installed in the demonstration room. Short ultrasonic signals (chirps) are emitted by transmitters on the walls and ceiling of the room in a cyclic and periodic fashion (Figure 3). The cycle helmet wearable calculates its position using the reception times of these chirps at the on-board ultrasonic receiver.

Software running on the wearable uses an extended Kalman filter to fuse a model of the periodic chirp transmission times with position estimates and chirp reception time measurements [3]. The RF-free, wearable-centric architecture means that our system is scalable in terms of wearable device density while at the same time providing update-rates of $\sim$ 35Hz and accuracies better than 5cm. Experiments in the lab show that the system is able to handle helmet accelerations of up to around 1g.

### Tux Racer Demonstration

Tux Racer is an open source project in which the user takes the form of Tux (the Linux mascot penguin) and races downhill through alpine trails. We have adapted this application to replace the QWERTY keyboard interface with head movements derived from our ultrasonic positioning system. Tux Racer is particularly suited for our demonstration as this game requires a fast response to control the penguin, as well as accuracy to provide the sensitive control needed for a smooth user interface.

The demonstration involves the user wearing our modified cycle helmet receiver/computer and playing the Tux Racer game while riding on a (stationary) toboggan. By moving the head forwards to accelerate, back to slow down and left/right to navigate, the user controls the penguin as he slides along an alpine course shown on a large display. Points are awarded by collecting blue herrings on the course with successful runs resulting in access to higher levels of difficulty.

### Discussion

Wearable computers have commonly been associated with box like devices worn on belts or carried in bags. The inevitable progress resulting from Moore's Law has resulted in a new generation of processors which can be mounted in radically smaller form factors. Our demonstration shows one such implementation and we believe is a precursor of minimal wearable computer designs with powerful processing capability.

Our original ultrasonic positioning system was previously presented and demonstrated at UbiComp 2001 [4]. Significant advances have been made since presenting the original system with a tenfold increase in both accuracy and refresh rate. With this increase in performance has come the ability to develop applications for ubiquitous computing which would normally be restricted to researchers working in laboratory environments.

This demonstration is thus intended to show the progress we have made both with wearable computing design and ultrasonic position sensing, and to provide a stimulus for further development of these technologies.

### Requirements

We require a floor area of at least 3m x 3m plus audience space (see Fig. 5); and access (by ladder) to the ceiling. Our demo will require 4 power sockets for one laptop, one projector and two battery chargers. We do not require network access, and will be using Bluetooth in the vicinity of the demo. Single person games each lasting 30-45 seconds are provided during the demo session. There is no associated audio.

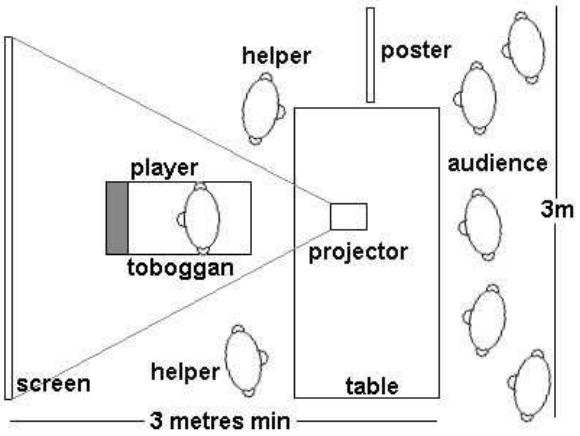


**Figure 5: Demo Layout**

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