Virtual Navigator: Developing A Simulator for Independent Route Learning

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ABSTRACT
We present the initial design and development of Virtual Navigator - a virtual haptic and audio training simulator for route navigation. Virtual Navigator allows blind and visually impaired cane users to practice navigation skills and route learning in the built environment. Currently route training is supplied on a one-to-one basis causing it to be limited and expensive. We hope that development of Virtual Navigator will allow such training to be augmented with self taught sessions and be made more widely available.

INTRODUCTION
Navigation in the environment is a vital skill in allowing an individual to lead an independent life. For blind and visually impaired people however, such trips are challenging and require specialised training to learn routes as short as walking from home to the local shops. In the U.K., this training is usually provided by the local government authority and involves a mobility training officer developing a route between the two locations a user would wish to walk. The routes developed involve the user piloting between multiple landmarks that exist in the built environment (such as postboxes, drain-covers or lamp-posts). These routes are chosen to be safe and may therefore not be the most efficient or shortest routes available. Over several one-on-one sessions, the mobility officer trains the visually impaired user on the route. As the routes are complex, multiple sessions may be required and there is often a waiting list for training. Additionally, each individual will learn only a few routes. Therefore in cases where a primary route may be blocked (e.g. due to road works), the visually impaired person will not have an alternate route to navigate.

RELATED WORK
The problem of navigation by visually impaired people is not a new one and several research attempts have been made to allow independent navigation in the environment. Primarily these have consisted of satellite navigation (GPS) based systems to guide the user dynamically in the environment. GPS based systems offer the possibility of navigation without a visually impaired person needing to pre-learn a route (in a similar way that car GPS systems negate the need to read the map) [1]. However, as noted by Strothotte *et al.* [2], such navigation requires piloting between close together, small landmarks. Such landmarks are often much smaller than even high quality GPS accuracy, so might be missed. Walker and Lindsay's SWAN system [3], which uses audio beacons to navigate a route, recommends a position accuracy of less than 1m. Something that is not currently available.

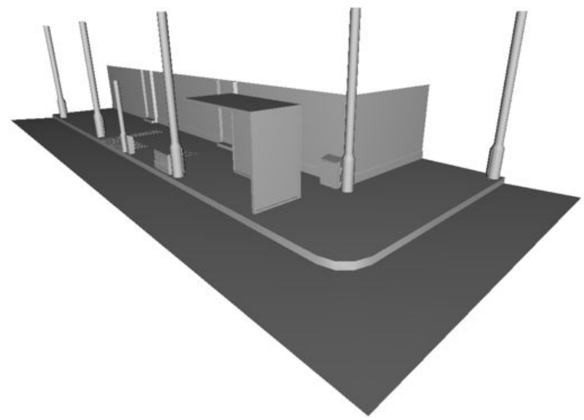

Figure 1. A model of the test environment used in the current version of Virtual Navigator.

DESIGN OF VIRTUAL NAVIGATOR
To overcome many of the problems identified, we have begun to develop an application called Virtual Navigator. Virtual Navigator is designed to augment the training supplied by mobility trainers and allow blind and visually impaired cane users to develop basic navigation skills and learn routes in safety. We do not argue that the use of Virtual Navigator will replace mobility trainers, but rather allow more opportunities for a learner to experience a route and thus make better use of limited training sessions that are available. We are developing Virtual Navigator in a participatory design manner, with feedback from users being incorporated into future versions. The version discussed here is based on initial interviews with, and observations of, mobility trainers and discussions with visually impaired users.

Virtual Navigator allows a user to interact with a virtual 3D model of a test route (see Figure 1) via the use of a haptic force-feedback device and spatialised auditory feedback. This allows many of the physical aspects of the environment that are used as landmarks to be simulated. The user explores the environment in a first person perspective (similar to a 3D "shooter" computer game). Figure 2 presents a screenshot of the visual interface of Virtual Navigator. The model is generated at a prototypical size as this most closely matches the world. I.e. a meter in the built environment is a meter in the real world. Our current models represent a fairly small environment so doesn't take very long to move through. In longer environments, such as prototypical routes, it remains an open question if the model scale could be reduced so that the route could be covered in less time with-

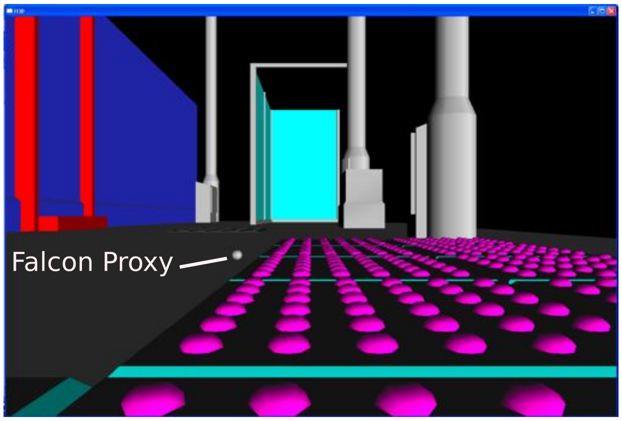

Figure 2. A screenshot of Virtual Navigator showing a simple street model with buildings on the left and a road on the right. Tactile paving, a bus shelter, lamp-posts as well as the point representing the Falcon proxy in the environment are also shown.

Figure 3. A picture of the NOVINT Falcon force feedback device used to allow haptic interaction with the environment.

out comprising learning. The model used in the simulator is currently produced via the Milkshape 3D (http://www.milkshape3d.com) modelling package. Future work will investigate automatically creating the model from both online map data and a toolkit of pre-built objects (such as post-boxes or lamp-posts) that can be dragged and dropped into the environment by the trainer.

Movement in the environment is achieved by using the directional cursor keys on the keyboard. Pressing the forward or backward keys cause the user to take a step in the corresponding direction. The sound of footsteps (one step sound per step taken) is used to provide an indication of distance travelled. The left and right arrows cause the user to turn 45° in the appropriate direction. As users are conventionally trained to turn on the spot to change direction and to pilot in straight lines, such a mechanism is more appropriate than stepping left or right.

Virtual White Cane Interaction

A NOVINT Falcon (www.novint.com) (see Figure 3) is used to act as a virtual white cane. The Falcon, as with many other force-feedback devices, works like a 3D mouse. As the user moves the end-effector around, a proxy object in the virtual scene moves (see Figure 2). When this proxy is determined to have come into contact with an object, a resistive force is applied providing the impression of a physical object. The Falcon provides a fairly limited workspace and only allows exploration of the scene with a single point of contact. In many applications this has been argued as a disadvantage of virtual haptic devices. However, in this case, it is very similar to the way in which a white cane acts when exploring the world.

Because of the impoverished nature of the feedback provided by a white cane, identification of landmarks is usually undertaken by sound caused by the interaction of the white cane on a landmark. Virtual Navigator deals with this by providing both contact sounds and movement sounds when the Falcon proxy comes into contact with the landmark. Both are important, as landmarks can take many different forms. Some, such as a post-box, will be identified through both physical forces stopping the cane moving, as well as the contact sound of appropriate pitch and timbre to indicate a hollow metal tube. Other landmarks, such as a manhole cover or tactile paving, will be identified via vibration and the repetitive striking sound as the user moves the cane over the surface. We used FMOD (www.fmod.org) to allow for low latency playback of recorded sounds when the user taps a feature in the virtual environment, or moves the proxy object over the surface.

The sounds used were generated by a visually impaired cane user tapping and scrapping surfaces made of different materials in the built environment. The sounds were recorded using an iPod Touch with microphone attachment and were processed in the WavePad software package. The sounds are triggered if the user touches or moves the Falcon along a surface in the virtual environment. We have found that combining these simple categories of sound with realistic physical models of the tactile paving and manhole covers in Virtual Navigator, naturally generate composite sounds in our environment that closely mirror the sounds of interacting with real world objects.

Auditory Clues

Whilst piloting between landmarks is the primary means of route navigation, other transitory features of the environment called clues are also useful. These are features of the environment that may or may not be available when navigating. If they are available, they provide useful indication that the correct direction is being taken. Whilst clues may be physical (such as a table outside a cafe), they are more likely to be auditory based. The way that sound changes on a street between rush hour and night time, or when walking under a tree lined avenue rather than an open street, can all be used to provide additional clues to the cane user that the correct direction is being followed. Virtual Navigator supports such clues by incorporating an environmental soundtrack that can be modified through FMOD to reflect the environment the user is passing through. So far we have included a simple reverberation to the environmental and footstep sounds as the user moves through more enclosed features of the environment - such as under a bus shelter.

DISCUSSION

So far, we have carried out qualitative evaluations with two late blind cane users on a simple street model and employed a mobility training officer to provide comments and guidance for improvement. In all of these evaluations Virtual Navigator was seen as a positive addition to route training and was felt to provide a useful ability to learn a route. However several key areas of improvement were identified before it could be practically useful. Firstly, was the use of the virtual white cane. In the initial system we modelled the cane as a single point. However as the user is sweeping left and right in the environment and walking at the same time, it is possible to miss small landmarks such as lampposts and simply sweep behind them. As the cane is modelled as a point, no indication that this occurs is currently provided. Our future work will change this model so that the virtual white cane is modelled as a stick, and contact at any point of the stick will cause haptic and auditory feedback. A further comment raised by the mobility trainer was that clues can be formed of multiple different modalities, of which haptic feedback and sound are only two. She noted that smells, such as a florist or chip shop could also be used as clues to allow a participant to orient his or herself in the environment. We intend to incorporate such feedback here using devices such as the Dale Air Vortex (www.daleair.com). In such a way Virtual Navigator will be able to provide a much closer set of landmarks and clues to those of the prototypical environment. We believe that with further development, Virtual Navigator can provide a useful augmentation for visually impaired and blind users in the important skill of environmental navigation.

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