ABSTRACT
New mobile devices can be difficult to use because they give users access to powerful computing devices through small interfaces, which typically have limited input facilities. One way of overcoming these shortcomings is to think of new interaction methods that could be utilized by the user. We report in this paper on a new interaction method for mobile devices in which the user can point his or her mobile device at a building and view a virtual representation of it. In addition, the user can view the building at different times in its past and literally see it morphing into its current state. Another interesting aspect of our prototype is that as the user moves the device the view they see on their mobile interface moves with them, thus allowing the user to experience the real and the virtual world at the same time.

Keywords
User Interaction, 3D Models, Orientation, Location Based Services, Virtual Reality.

1. INTRODUCTION
The advent of 3G technology and more complex mobile devices poses challenges to researchers and application designers who are trying to build mobile applications, mainly in how to address the limitations of mobile interfaces e.g. the restrictions of tiny displays and keypads, context of use and information retrieval on the fly. These and other factors add to the difficulty of producing a useful and usable design. However, we would also counter that the advent of this new computing power also provides opportunities. Our research project focuses on the development of a possible alternative interaction method to try and ease these problems but also offers a completely new way for users to interact with their mobile devices. We track the user’s movement in the real world and link it to the virtual world displayed on their device. We link these two views together by using the user’s position and 3D orientation.

To evaluate the options of this orientation-based human interface we have developed a 3D model of the architectural environment optimized for mobile devices. The model has a temporal dimension, allowing the user to navigate in space as well as in time to experience cultural heritage of the past. The 3D orientation makes hardware navigation buttons for rotation and tilt obsolete. For example, the system is able to distinguish between north and south and to decide whether the user looks towards the ground or gazes at the sky. Movement by the user of just a few degrees enables him or her to request different information e.g. by aiming a device at a statue the interface automatically presents information about it.

We present in this paper a new method for interacting with a mobile device and a prototype application in which we demonstrate how this type of interaction could be of benefit to users. We also speculate upon what other applications or benefits there could be for users if such an interaction method were available on all mobile devices. The paper concludes with what we have discovered so far and describes the future work we are planning to carry out.

2. BACKGROUND
One of the ways that researchers are investigating new interaction methods is to look at the different modalities currently available e.g. sound [7, 1]. Others have been more experimental and investigated how to utilize existing functionality on mobile devices and put them to other uses e.g. the MIXIS project uses a digital camera (available now on the majority of mobile phones) to track a fixed point and thereby establish a 3D interaction space wherein the position and rotation of the phone can be tracked. Of particular interest to our research was the investigation of Chittaro et al [3] into how tourists can select information via location-aware visualization of a 3D world. However, they encountered problems as they found that when the user is moving, their current orientation can be automatically obtained from the GPS data but when the user stops, deriving the user’s orientation is impossible. They comment that an interesting solution to this could be to integrate an electronic compass in order to obtain more accurate orientation information. We agree that this would provide a better solution and have included one in our prototype for this reason.
The wider topic area of mobile guides and what they can offer a user is related to our work. Brown and Dunlop found that to be beneficial a digital guide should always offer something more than paper maps or guidebooks [2]. Some solutions have been suggested on what this added benefit could be for example, the ability to query the map by tapping on various parts to obtain extra information or providing dynamically updated content e.g. the guide will tell you the current opera that is showing at the opera house. However if you look at the current mobile guides being offered you quickly notice that what is being offered in practice provides a heavy load for the user e.g. the user must synchronize their mobile device through a PC, or via WiFi hot spots, or synchronization at a tourist office [4] in order to receive this dynamic information. It could be claimed that this is not really convenient and does not really provide up-to-date information more easily than currently available methods, so where is the added benefit? It has been suggested that GPS could enable updating of current information given the user’s location, but we, and others [3] would counter that GPS information is problematic if it is used on its own as it would be difficult to obtain accurate positioning if the user were inside a building or if the street were narrow and the buildings aligning it were high.

We believe that the potential additional benefits are fine suggestions, but this ‘added benefit’ of mobile guides could go further, offering us different views of the building we are looking at, at important times in its history, e.g. while it was being built, during a war (perhaps the building was bombed?) and so on. Another potential enhancement is that a guide book does not know what you are currently looking at and in addition is limited in the amount of data it can provide so certain information must be left out. What would happen if a tourist were able to obtain potentially unlimited information on any building or artifact they pointed at?

Another related area of research is that of tilt-based interaction. For example [5] have implemented tilt-based automatic zooming and scaling in a mobile device. They found that users found that using a single hand to control the interface was a comfortable way of interacting with their mobile device. In their small study they found that users felt that this mode of interaction was an intuitive solution to the problem of large documents and small displays. It could be supposed that this method of interaction would also be useful if the user is looking at a large interaction space as well e.g. a whole piazza/square.

On the technical side, handset manufacturers are beginning to integrate acceleration sensors to measure movement of the handset (“Motion Detector”). We could have additionally added a module to provide information about orientation and heading. This, depending on the sensitivity of these sensors, might also have led to a possible enhancement of the positioning.

3. Technical Description
The position of the user is measured by a GPS receiver. In our prototype the device is small enough to fit into the user’s pocket and communicates with the mobile via a Bluetooth interface. In future we expect most mobile devices to carry embedded GPS (and Galileo) receivers. This opinion is supported by the fast A-GPS standardization progress of the 3G world [10, 11] and the rather expensive and unsatisfying developments of terrestrial TOA-based localization technology. The accuracy of positioning by such portable GPS receivers is about 10m RMS, which means that 67% (1 sigma, dependent on error statistics, assuming a Gaussian distribution) of all estimates fall within a circle of 10 m around the user’s true position. Bad line-of-sight conditions in heavy urban areas will counteract the deployment (starting in 2005) of Galileo with higher transmission power and 30 additional satellites.

To complement the knowledge of the position for navigation and user interface aids we use an electronic compass. These devices sense the direction of the earth’s magnetic field and hence allow us to determine the position of the user. This is possible even if the user is not moving as required and if the position would be computed by the difference of the two most recent position fixes (GPS heading). Unlike optical image recognition, we do not need additional information about landmarks nor extensive computational power.

Modern digital compasses use thin (1nm) magnetic films such as Permalloy for detection. Deposited on a silicon wafer it changes its electric resistance by 2-3% with an applied magnetic field. Appropriately mechanically arranged the electric field can be measured as a function of the angle. No large mechanical parts like coils are necessary resulting in a small and fast device, this is critically important for mobile computing because of limited space and the fastness of the response time required.

The first mobile devices utilizing SVD technology are already available but lack pitch and roll compensation and thus are not able to output the position for any orientation. The two-axis compasses require the user to hold the compass platform reasonably flat with respect to gravity. This might not be a problem for vehicles, but would limit acceptance in mobile devices.

![Figure 1: 3D compass block diagram](image)

For the general 3D case, the compass system must have a minimum of a three-axis magnetic sensor and a two-axis tilt as shown in Figure 1. Then, the heading calculation relies on all three magnetic components (x, y, z) so the compass orientation can be transformed back to the horizontal plane allowing a simple computation of the position (Figure. 2).

The pitch and roll determination is most suitably done for small mobile devices using micromechanical accelerometer sensors which measure the Earth’s gravitational field. Compared to gyroscopes or electrolytic fluid based sensors, these types of sensors do not have any moving or pendulous parts and are thus
easier to miniaturize. This results in small structures, hence in higher resonant frequencies and in turn in higher operating frequencies, these easily achieving 100Hz, thereby allowing the detections of fast user movements.

Figure 2: Tilt sensor coordinate system
Our prototype uses a three-axis, tilt compensated compassing module from Honeywell. Its small size (1” by 1.75” print) allows us to fix the mechanical mounting on the back of a mobile device. Current technical boundaries in this device limit the measurement area to +/-60 degree for pitch (y-axis) and roll (x-axis). A simple mechanical mounting of the sensor rotated around a defined origin allows us to shift the measurement area towards the most likely used boundaries. For example, it is unlikely that users are interested in the ground as well as in the sky. For this case the sensor mounting is shown in Figure 3.

Figure 3. Sensor Mounting
The solid line denotes the original orientation of the mobile (screen). The dotted and dashed-dotted line denotes the minimal and maximal angle the 3D orientation sensor can resolve respectively. The compass error is the overall difference between compass heading and true heading and is the sum of variation and deviation.

3.1 Rolling, Rotating, Imagining, Interacting
In our prototype the user is concurrently interacting with the real world and interacting with a parallel virtual world, which is shifted in the temporal dimension. For example, moving a display up or down in physical space is used to change the virtual view on the handset. This interplay between the real and the virtual is central to the development of augmented reality spaces, according to Rodden et al [8], as where the movement of a device is within a space may manifest itself in effects that are both real and virtual. This merging of the virtual and the physical also allows the user more freedom to thoroughly investigate or view a building e.g. by moving the handset to one’s right the virtual view moves to the right, enabling a user to view an enhanced view of the building without having to scroll or user buttons.

3.2 Prototype Application
Our prototype application features the Josefsplatz in the city of Vienna, where the 3D modeling was done from photographs representing the space as it currently is and from paintings and pictures from its past, to enable historical accuracy [9].

Figure 4. The image on the left shows the Austrian National Library rendered in 3D as it would be seen on a mobile. The image on the right is an aerial view of the same scene and the dot in the middle signifies the users location.

The initial point of the prototype scenario is a user equipped with a mobile phone and located somewhere in front of points of interest. The user can start a traditional sightseeing tour by walking around and viewing the buildings. This, however, limits the user to a present view of the buildings which are actually famous for their past. In our prototype, the user can additionally use the mobile phone as a location and orientation aware visualization device. The screen acts as “window to the past”. A historically accurate 3D model of the site and its monuments is presented, viewed exactly from the user’s current real world position and orientation. Looking for instance towards the Austrian National Library at Vienna’s Josefsplatz and aiming the mobile device in the same direction allows the user to sweep back in time to experience how this building has changed during the last decades. After adding appropriate small icons to the rendered 3D model, linked to various kinds of documentary such as sound, speech, text, and video, the user will be able to experience a multimodal presentation of Vienna’s cultural heritage.

4. CONCLUSIONS & FUTURE WORK
The prototype we are currently building is an implementation of a very specific concept e.g. a user visits Josefsplatz in Vienna and can view an enhanced 3D rendering of the particular building they are looking at. They can then watch via their mobile device the changes that have taken place, over time, to that building. This is an interesting development, but what is potentially more interesting is that it takes a precise reading of where the user is and enables them to point to a particular part of a building and get a 3D vision of it. Because of this exact positioning the user can also make use of an enhanced interaction mechanism that allows
them to view an almost panoramic visualization of the building in the past on their mobile device. This is a completely new way of making use of location-based technology and opens the door to other interesting developments.

We are currently finishing the final prototype and will commence user testing in the autumn. We are also looking at other possible applications and services which could benefit from the enhanced user interaction we describe in this paper.

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6. REFERENCES


