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Natural Interaction Framework for Navigation Systems on Mobile Devices

Ceren Kayalar and Selim Balcisoy
Sabanci University
Turkey

1. Introduction

Mobile Augmented Reality (AR) applications based on navigation frameworks try to promote interaction beyond the desktop by employing wearable sensors, which collect user's position, orientation or diverse types of activities. Most navigation frameworks track location and heading of the user in the global coordinate frame using Global Positioning System (GPS) data. On the other hand, in the wearable computing area researchers studied angular data of human body segments in the local coordinate frame using inertial orientation trackers.

In this work, we introduce a combination of global and local coordinate frame approaches and provide a context-aware interaction framework for mobile devices by seamlessly changing Graphical User Interfaces (GUIs) for pedestrians navigating and working in urban environments. The system is designed and tested both on a Personal Digital Assistant (PDA) based navigation system prototype and ultra mobile PC based archaeological fieldwork assistant prototype. In both cases, the computing device is mounted with a GPS receiver and inertial orientation tracker. We introduce a method to estimate orientation of a mobile user's hand. The recognition algorithm is based on state transitions triggered by time-line analysis of pitch angle and angular velocity of the orientation tracker. The prototype system can differentiate between three postures successfully. We associated each posture with different contexts which are of interest for pedestrian navigation systems: investigation, navigation and idle.

We introduce the idea that once orientation trackers became part of mobile computers, they can be used to create natural interaction techniques with mobile computers. Currently, we are integrating our interaction ideas to a Mobile AR system, which is designed to assist fieldwork in archaeological excavation sites.

2. Related Work

As the technology evolves rapidly; faster, smaller and multifunctional mobile computing devices integrate into our daily lives. Most common mobile devices, i.e. mobile phones and PDAs, are not only serving to make phone calls, send/receive text messages, check e-mails, write documents or watch video; beyond, they are capable of rendering complex 3D graphical environments and connecting with diverse positioning or orientation devices through faster communication interfaces. Naturally, computer graphics researchers begin to

exploit mobile computing devices as core device for Virtual Reality (VR) and Augmented Reality (AR) applications.
However, these applications should take advantage of the system's mobility by offering novel interaction techniques and user interfaces, which reduce the users' effort while providing relevant data. The decision about which information is relevant under which conditions and how to react to it is taken by the application designer, so the mobile AR application is informative about the real environment without distracting the user. Extracting such results requires observing the environmental conditions, collecting data, analyzing it and obtaining statistical results about possible user activities and context.

2.1 Context-Aware Mobile AR Systems

AR is an active research area in Computer Graphics. It is the discipline of augmenting real-time video images with computer generated 3D graphics in real-time. As defined by Azuma, an AR application should satisfy the following properties: combines real and virtual, interactive in real-time, registered in 3D (Azuma, 1997).
The users of mobile systems are pedestrians or traveling in vehicle, hence interacting with the environment while using a mobile phone or PDA. Most of such systems are deaf and blind to anything occurring in the environment other than change in position. But mobile AR applications, which combine the real world with computer generated graphics, are

- increasing the richness of human-computer interaction,
- preventing perception distraction,
- offering more useful computational services than regular mobile applications by increasing the perceived information level,
- minimizing explicit interaction effort of users.

These applications take full advantage of context-awareness and provide us the sense of being acquainted by the application interactively and intelligently, where context is defined as any environmental information that is relevant to the interaction between the user and the application, and that can be sensed by the application (Salber, 2000). Some example research systems are *ArcheoGuide*, real-time virtual reconstruction of a cultural heritage site's remains (Vlahakis et al., 2002); *Backseat Gaming*, a mobile AR game about finding virtual clues of a kidnapping case by interacting with the roadside objects (Brunnberg & Juhlin, 2003); and *MARS*, a mobile AR tour-guide system (Höllerer et al., 1999).

2.2 Mobile Navigation Applications

Two crucial services that are usually provided by most mobile guides are navigation support and information delivery. Navigation support allows users to obtain directions to navigate in an environment and to locate themselves and points of interest in the surrounding area. Information delivery provides users information about the point of interests located in the visiting area (Burigat & Chittaro, 2005).
Cyberguide project defines several prototypes of a mobile context-aware tour guide, which are aware of the user's current location and as well as a history of past locations (Abowd et al., 1997). This project is partitioned into components with different functionalities: map, information, communication and positioning. Prototypes are built on Apple MessagePad and pen based PC platforms acquiring position data from GPS (outdoor) and IR (indoor). Cyberguide was one of the first complete prototypes clarifying the thoughts on how context-

aware computing provides value to the emerging technology promising to release the user from the desktop paradigm of interaction.
Another example, *LAMP3D* is a system for location-aware presentation of VRML (Virtual Reality Modeling Language) content on mobile devices. This system is used to provide tourists with a 3D visualization of the environment they are exploring, synchronized with the physical world through the use of GPS data; tourists can easily obtain information on the objects they see in the real world by directly selecting them in the VRML world (using a pointing device such as the PDA stylus or their fingers) (Burigat & Chittaro, 2005).

2.3 Activity Recognition

As emphasized by Salber, another important context attribute is activity (Salber, 2000). Beyond determining a person's current location, by recognizing what she/he is doing using diverse types of sensors or wearable computers, novel interaction mechanisms can be created.
Detection and recognition of upper body postures and gestures are also studied by several research groups. The proposed methods aim generically to aid daily life, reduce human effort to use computing systems and integrate computers into the environment seamlessly.
Amft et al. introduced a recognition system for detecting arm gestures related to human meal intake (Amft et al., 2005). The idea of this project is based on dietary monitoring used by health professionals. They mounted two orientation sensors on the wrist and upper arm to detect gestures, i.e. moving the arm towards the mouth and back.
Recognizing arm postures is used to introduce a new technique for entering text into a mobile phone. Orientation of the tilt sensor mounted mobile phone is used to resolve the ambiguity faced by standard text entry technique. Tilting the phone in one of four directions chooses which character on a particular key to enter (Wigdor & Balakrishnan, 2003). They also reported that 20 to 50 Hz sampling rates are required for robust tilt implementations.

2.4 Interaction Paradigms

Before the advent of wireless, mobile and handheld technologies, prevailing paradigm in interaction design was to develop applications for the desktop, where the user is interacting with keyboard, mouse and looking to a monitor. The term, which unifies concepts of GUIs representing the user's desk accessories and the whole desktop environment, is the *desktop metaphor*. Mostly such an interface is based on WIMP (windows, icons, mouse and pointers) using a regular monitor. However, recent trends in interaction paradigms try to promote beyond the desktop.

2.4.1 Ubiquitous computing

The interaction paradigm for ubiquitous computing is based on technology disappearing in the background, which means we would be no longer aware of the computers in the environment while they are integrated seamlessly into the physical world, interacting with each other and extending human capabilities. Mark Weiser, the founder of ubiquitous computing, built a prototype system called "tabs, pads and boards", which consist of hundreds of computers equivalent in size of post-it notes, sheets of paper and blackboards (Weiser, 1995). These computing devices are to be used in office environments without noticing that they are computers and offering more functions than desktop metaphor.

2.4.2 Wearable computing

Researchers try to embed technologies in everyday environment. Wearable computing focuses on systems which people can wear or mount on the clothes. Such a system allows the user interact with and take advantage of digital information while moving in the physical world.

A complete wearable framework, which consists of a backpack containing a laptop with a wireless interface, a positioning system, an orientation tracker, a see-through Head Mounted Display (HMD) and a camera doesn't introduce a natural interaction mechanism, because it prevents the user move freely. Rather than this heavy setup, a mixed reality platform consisting of a PDA with localization and orienting capabilities and a lightweight see-through HMD operates with same capabilities and allows a free movement, natural interaction to the user (Peternier et al., 2006).

Due to the small screen space of PDAs, screen based interaction mechanisms controlled with UI widgets are confusing and ineffective. Thus, small screen space forces the interaction mechanisms to be more natural. If the interaction is provided with widgets on the PDA screen, these widgets must be large enough to be distinguished from the content on display and to be practical for relevant interaction. This fact limits the displayed content size, and it is better to build natural interaction mechanisms and avoid virtual interface widgets.

Höllerer et al. introduced a gaze-directed selection mechanism for outdoor UI interaction in their mobile augmented reality system. The display unit of this system is a see-through head-mounted display, which augments the real world with virtual labels and flags. Gaze-directed selection is accomplished by the user orienting her/his head so the desired object's projection is closer than any other to the center of the head-mounted display (Höllerer et al., 1999).

2.5 Visualizing Data on Small Screen

Most of the previous work on location-aware mobile guides uses 2D maps of the area where the user is located; pinpointing her position and usually providing visual information on the nearest points of interest and on the paths she has to follow to reach specific destinations. Maps are powerful tools for navigation because of the richness of information they can supply and the rate at which people can absorb this information.

Rakkolainen and Vainio have proposed a system that combines a 2D map of an area with a 3D representation of what users currently see in the physical world; study the effects of 3D graphics on navigation and way finding in an urban environment (Rakkolainen & Vainio, 2001). They concluded that 3D models help users to recognize landmarks and find routes in cities more easily than traditional 2D maps. The prototype was implemented on a laptop computer, not on a PDA. Moreover this project was focused only on navigation support and no information delivery service was provided about point of interests.

Realistic visualization of large and complex 3D models, such as those used in mobile guides, is a very important task for other application areas as well: scientific simulation, training, CAD, and so on. However, mobile devices do not include the specialized hardware typical of high-quality graphics boards, thus it is not always possible to obtain a good quality level for the visualization. A possible approach to this problem is to carry out rendering on a powerful remote server (or a cluster of workstations) connected through a wireless network and display the results on the mobile device as a video sequence (Lamberti et al., 2003). This solution has two advantages: the data to be visualized is processed by specialized hardware, thus bypassing the problem of the low computational power of mobile devices, and the source data is not transmitted to the client device, thus allowing for data independence. On the other side, due to the limited bandwidth of current wireless networks, this remote computation solution needs complex algorithms for the preparation of the data to be transmitted.

2.6 View Management for AR Applications

Designing a 2D or 3D graphical user interface (UI) for augmented reality applications is a challenge in different manners;

- according to the changing viewing direction, the UI components must be relocated to maintain visibility,
- virtual objects can disappear in front of the real world scene because of lighting and rendering parameters,
- any annotations or virtual objects can overlap each other in a crowded scene.

Such problems have been discussed by researchers under the term view management. Bell et al. defined view management for interactive 3D user interfaces as of maintaining visual constraints on the projections of objects on the view plane, such as locating related objects near each other, or preventing objects from occluding each other (Bell et al., 2001). Azuma and Furmanski handled this discussion from 2D point of view and according to their research; view management is about the spatial layout of 2D virtual annotations in the view plane of augmented and mixed reality applications (Azuma & Furmanski, 2003).

Other than the layout of annotations, text readability is affected from the interference of the background texture in the dynamically changing AR environment. Leykin and Tuceryan introduced a pattern recognition approach to automatically determine if a text placed on a particular background would be readable or not (Leykin & Tuceryan, 2004).

3. Mobile Augmented Reality System

3.1 Hardware components

The proposed mobile AR system provides a context-aware interaction framework for pedestrian, wandering in urban environments. As reported in relevant research based on navigation, it is important to acquire what the user's geographic position is and where she is looking at. In addition to these context-attributes, this research provides a natural interaction mechanism to the navigation system by inferring application dependent arm posture. These services are implemented and tested with two hardware configurations:

PDA prototype (Figure 1):

- HP iPAQ Pocket PC h2200 series operating on Pocket PC 2003 with Intel XScale 400MHz processor, 64MB RAM, and 320x240 pixels 64K color TFT display.
- Fortuna GPS receiver is connected to PDA via Bluetooth and sends global positioning data in National Marine Electronics Association (NMEA) 0183 format with a frequency of 1 Hz.
- InertiaCube2 is an inertial orientation tracking system and provides angular data in 3 degrees-of-freedom with a frequency of 180 Hz. It is connected to PDA via Sync port and uses an RS-232 interface.

Ultra-mobile PC prototype (Figure 2):

- Sony VAIO UX 280p operating on Windows XP with an internal camera capable of capture videos in 640x480 resolution.
- GPS receiver used in this prototype is the same as the one in PDA prototype.
- XSens' MTx is an inertial measurement unit and provides 3 degrees-of-freedom angular data with a frequency of 100 Hz. It is connected via USB.

Figure 1. PDA based hardware prototype

Figure 2. Ultra-mobile PC based hardware prototype

3.2 Software components

Software in the mobile and ubiquitous computing area is expected to be modular, simply modifiable to accommodate for new user needs, expectations, and a constantly changing environment. To implement the navigation application a diverse set of APIs are integrated to the development environment. Table 1 lists the libraries, which we used in our system.

System hardware	User Interface, Windowing / Rendering	Video and Image Processing	Sensor Communication	Data Handling
PDA prototype	• Vincent Mobile 3D Rendering Library (OpenGL | ES) • GLUT | ES Windowing Library	-	• InertiaCube2 Software Development Kit for Pocket PC 2003 • Bluetooth Communication Interface	-
Ultra Mobile PC prototype	• OpenGL Library • Freetype Font Library	OpenCV Library	• MTx Software Development Kit • Bluetooth Communication Interface	• PostgreSQL 8.3.1 (PostGIS included) • Libpqxx 2.6.9

Table 1. Software components of two hardware prototypes

4. Posture Recognition

As mentioned in the related work section, all of the orientation tracker work is based on either to assist precise tracking and positioning of the user in space or gesture recognition using several sensors. In this work, the goal is to create a stable differentiation mechanism between several arm postures and map them to several application dependent contexts.
The developed recognition algorithm is based on state transitions triggered by time-line analysis of orientation and angular velocity of the sensor. The angle between user's forearm and upper arm is obtained from the orientation sensor as pitch angle, α, and analyzed to recognize different postures. We have gathered sample data from mobile users with various walking speeds, while moving their hands between three postures:

- *vertical*, where pitch angle is around 0°,
- *horizontal*, where pitch angle is around 90°,
- *idle*, where the hand may move freely (Figure 3).

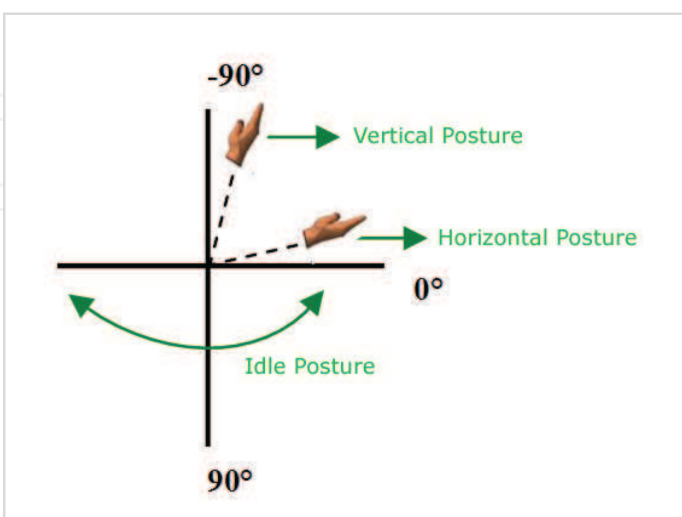

Figure 3. Drawing of target three hand postures from side view

Figure 4 shows pitch angle measurements of the user's arm movement in three different conditions: standing, walking, and running. Transitions between diverse arm postures can be inferred from the top left plot of Figure 4: For 0s ≤ t < 5s, the posture is on idle state. After this interval the user moves her hand up and stabilizes on horizontal posture until t ≈ 10s. For 10s < t < 20s, the user moves her hand down, stabilizes on idle state and moves her hand up. For 20s ≤ t < 27s, vertical posture is observed, and so on.

The measurements indicate that with the increase of velocity the noise on the measured signal increases significantly. The noise can be observed on the top right plot of Figure 4, where the transition from idle posture to horizontal posture is not clearly recognizable at t ≈ 40. Our current algorithm performs acceptably with users walking with low speed but the accuracy decreases significantly with increased speed due to the high frequency noise introduced into data by walking and running motion.

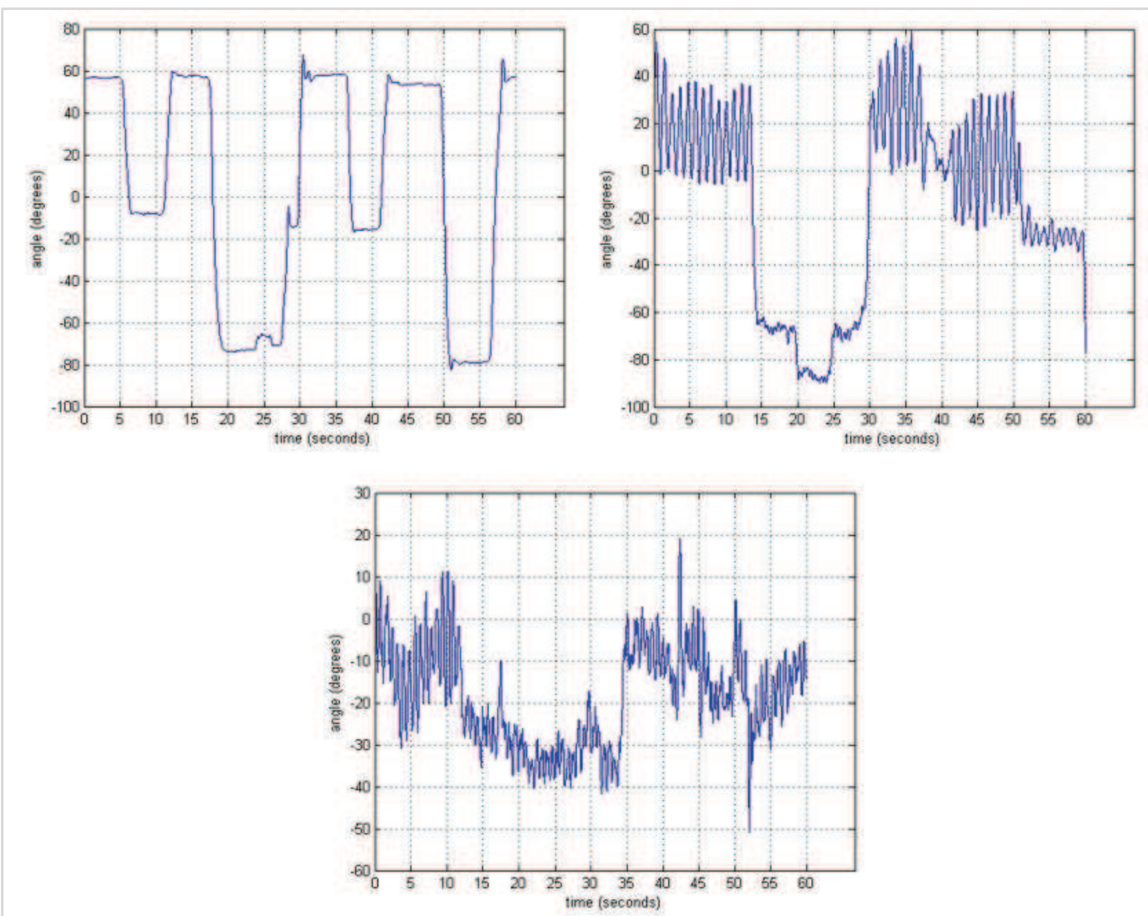

Figure 4. Pitch angle measurements while user is stationary (top left), walking (top right), and running (bottom). Data is collected with MTx

We implemented a sliding window to detect changes of the hand on pitch angle, α. A window, which contains five angle values obtained in time interval [t-1, t-5], is created at each time step and upcoming angle is estimated by multiplying them with increasing weights.

$$0.1 * \alpha_i + 0.1 * \alpha_{i+1} + 0.1 * \alpha_{i+2} + 0.2 * \alpha_{i+3} + 0.5 * \alpha_{i+4} = \alpha_{estimated} \quad (1)$$

The $\alpha_{estimated}$ angle is compared with the measured angle α_{i+5} to identify if the hand is moving up or down.

$$\alpha_{i+5} > \alpha_{estimated} \Rightarrow downside\ change \tag{2}$$

$$\alpha_{i+5} < \alpha_{estimated} \Rightarrow upside\ change \tag{3}$$

$$\alpha_{i+5} \cong \alpha_{estimated} \Rightarrow no\ change \begin{cases} \alpha_{i+5} \longrightarrow -90°, & vertical \\ \alpha_{i+5} \longrightarrow 0°, & horizontal \end{cases} \tag{4}$$

However using the pitch angle in one single direction is not sufficient enough to have robust posture recognition. We have also evaluated the case, where the user performs short tilts (rotations around the longitudinal axis) causing an inference on the state transition. For such cases, a filter is implemented on the system which increased the state transition accuracy.

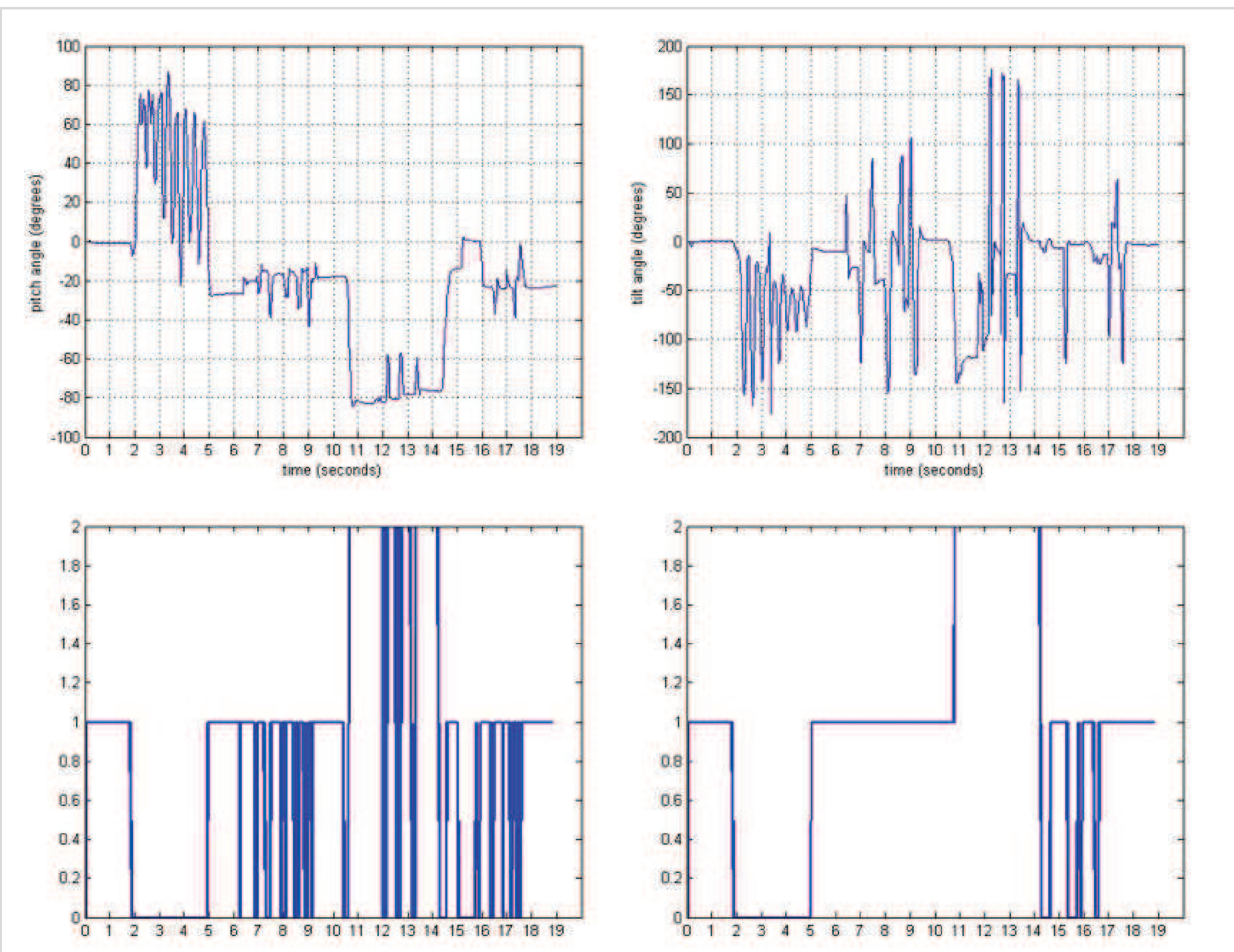

Figure 5. Sample pitch angle measurement (top left). Tilt measurement of the same posture (top right) causing erroneous estimation – 0: idle state, 1: navigation state, 2: investigation state (bottom left) and increased estimation accuracy with tilt filter (bottom, right). Data is collected with InertiaCube2

Figure 5 shows plots of sample pitch and tilt angle measurements of the same motion and corresponding state estimations. For 7s< t <9s, tilt angle is increasing and decreasing instantly (top right plot, Figure 5) which affects the pitch angle. In spite of the fact that the user holds her hand stable around -20° during angular data measurement, the top left plot of Figure 5 shows that the pitch angle is changing up to 20°. Same erroneous measurement can be observed for 11s < t < 15s. These unexpected changes cause inaccurate state estimation (bottom left plot, Figure 5). Therefore, estimation accuracy is increased (bottom right plot, Figure 5) by introducing the system with a tilt angle filter, which locks the state to the previous one if major changes occur on tilt angles.

The system becomes unstable and produces erroneous results when users perform other occasional movement patterns. Therefore we have introduced an additional data, angular velocity, to the recognition system. The change of angular velocity together with the angle allows us more stable recognition results.

Finally we developed a finite state machine to map all possible postures into one of the three states: investigation, navigation and idle (Figure 6). The investigation state is when a user holds a mobile terminal in vertical position to use it in an augmented reality context. In this condition the user needs to investigate point of interests and receives environmental information according to her gaze direction in the local coordinate frame. The navigation state is when a user holds a mobile terminal in horizontal position to use it to render maps or Geographic Information System (GIS) information. Thus, the user receives environmental information in the global coordinate frame. There is a third idle state, where the user is not in either posture and moves her hand freely. In this state, rendering is minimized to allow power save property.

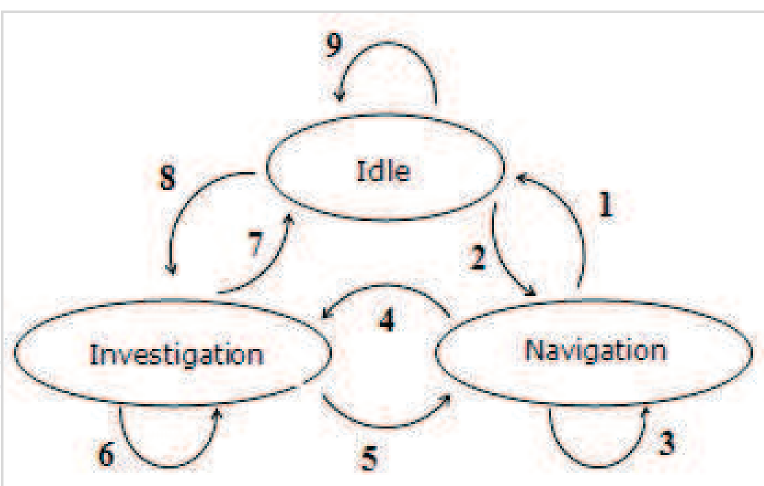

Figure 6. State transitions

The conditions satisfying the state transitions in Figure 6 are defined in Figure 7. In this algorithm, firstly, the estimated pitch angle value is compared with the angular value perceived from the orientation sensor at that time step. If they are approximately equal, user's arm posture is estimated to be stable and either in investigation or navigation state (3rd and 6th columns of the table in Figure 7). Other enumerated transitions include conditions which define possible changes between states, i.e. while arm posture is on idle state and the user moves her hand upwards, then it is possible to switch state to navigation or upside change on arm posture continues and state is switched to investigation. The state

estimation algorithm is empowered by introducing angular velocity and tilt angle filter to the system.
Unexpected arm movements of the user can affect the accuracy of the system. While the user holds the PDA in horizontal or vertical position (navigation or investigation state) and suddenly performs fast upward or downward movements with her hand, i.e. waving to somebody, the system is stabilized in the former state with a tolerably accuracy rate.
We performed a user study to examine the accuracy of our system. In this test, all possible state transitions emphasized in Figure 6 are performed. The overall accuracy rate is calculated as approximately %87. Performing sudden up-down movements in navigation state and investigation state produced some erroneous results.

1	2	3	4	5	6	7	8	9
$\alpha > 0°$ $\omega < -0.75$ $\Delta\alpha < 0$	$\alpha > 0°$ $\omega > 0.75$ $\Delta\alpha > 0$	$\alpha \approx 0°$ $\omega \approx 0$ $\Delta\alpha \approx 0$	$\alpha < 0°$ $\omega < -0.75$ $\Delta\alpha < 0$	$\alpha < 0°$ $\omega > 0.75$ $\Delta\alpha > 0$	$\alpha \approx 90°$ $\omega \approx 0$ $\Delta\alpha \approx 0$	$\alpha > 0°$ $\omega > 0.75$ $\Delta\alpha > 0$	$\alpha < 0°$ $\omega < -0.75$ $\Delta\alpha < 0$	$\alpha > 0°$ $\lvert\omega\rvert > 0.75$ $\Delta\alpha \neq 0$

ω = angular velocity (rad/s)
$\Delta\alpha = \alpha_{true} - \alpha_{estimated}$

Figure 7. Conditions defined to change system states

5. Case Studies

5.1 Navigation system for campus environment

After connecting necessary hardware and building software components, the prototype system is studied with a context-aware pedestrian navigation application. Location, orientation, and activity of the user are the affecting context attributes. As a standard navigation system working outdoors, this application locates the user using GPS data and gives information about the point of interests around. Moreover, it offers different interfaces by changing them seamlessly according to the user's arm posture. This feature is achieved by mounting the orientation tracker to the Pocket PC's rear and integrating the posture recognition algorithm discussed in the previous section. Currently, power is supplied to the orientation tracker only with a power adapter. A battery pack connection must be built carefully. Therefore, the interface transition mechanism could only be tested indoors with previously collected GPS data.
The navigation application is tested in our university campus, but it is possible to add different environment data and run the navigation system without doing massive changes in code. This modularity increases the scalability of the prototype.
The screen captures of three application dependent interfaces can be observed in Figure 8. The *idle state* is where the user is moving her hand freely, possibly not looking at the screen. Thus rendering is minimized to save battery power. The *navigation state* is where the user holds her hand in approximately horizontal posture (Figure 3) and the campus buildings are represented in 3D coordinate system. During this state, the user can get information about her position in the area, heading and speed. Campus buildings are labeled with their names and represented with rectangular shapes changing size according to the distance to the user, i.e. if the distance decreases the height of the building increases by a predefined scale. The

user can change the view by rotating the camera using hardware buttons. The size of the buildings' names change according to the position of the camera to maintain visibility. The *investigation state* is where the user lifts the PDA in her gaze direction. In this state, the campus buildings are placed in user's local coordinate system and change their position as the user changes her heading and position. We intended to switch to an augmented reality view but the rendering capabilities of the PDA didn't guarantee the video processing requirements. Thus we improved our ideas in the following case study using an ultra mobile PC.

Figure 8. Screenshots from PDA screen displaying three application dependent contexts

5.2 Mobile AR system for archaeological excavations

Currently, we are working on this case study and integrating our interaction ideas to an archaeological fieldwork assistant tool.

Archaeological site excavation is a destructive and irreversible process. Archaeologists try to follow the phases of the excavation using traditional methods, i.e. querying access databases, examining excel sheets, analyzing Computer-aided design (CAD) files etc. According to archaeologists, there is a certain need to visualize and analyze the previously collected data and completed work. Over the past years, researchers have developed virtual reality and augmented reality applications for cultural heritage sites. The current applications are mainly focused on AR context, where 3D virtual objects are integrated into the real environment in real-time. They can be classified into two main categories: mobile tour guides (Vlahakis et al., 2002; Vlahakis et al., 2004) and reconstructive tools of remains (Benko et al., 2004; Green et al., 2001). Although there are examples of excavation analyzers in indoor augmented reality and 3D virtual reality contexts, there is no such application which offers real-time on site digital assistance using outdoor augmented reality. We are testing our tool in Yenikapi Marmaray rescue excavation site in Istanbul. This site is an exciting discovery for the history of Istanbul because archaeologists revealed the ancient port of Constantinople, which was the capital of the Roman Empire for centuries.

Figure 9. Navigation interface (aerial view) displays the information sheet of a POI

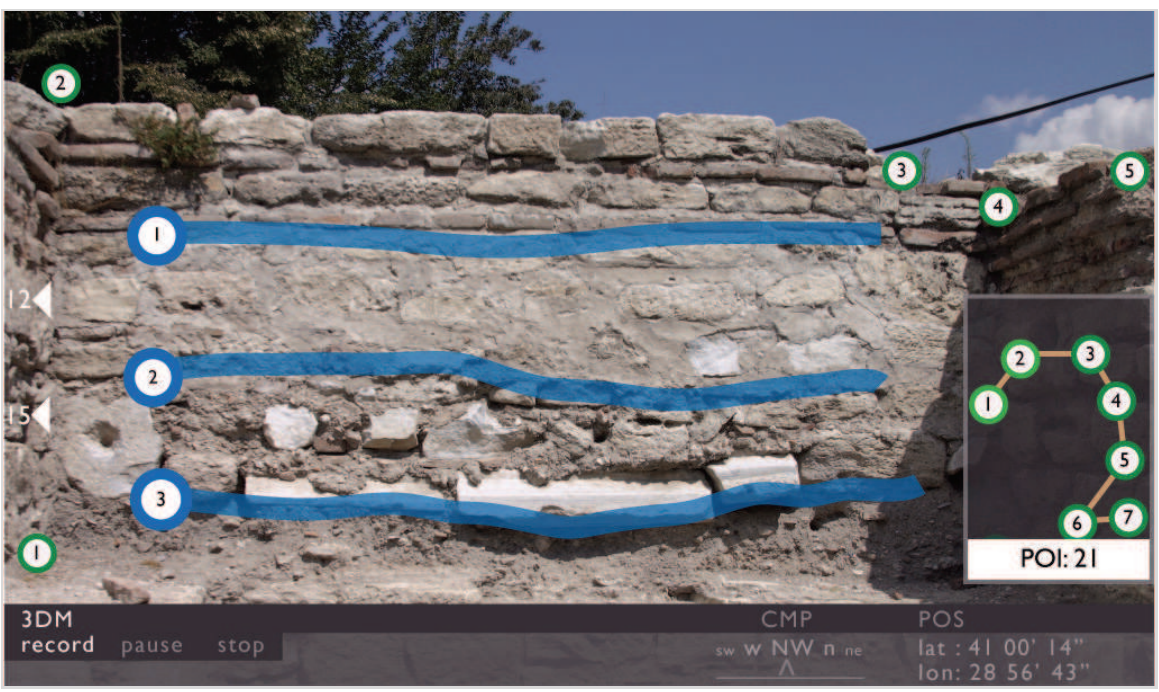

Figure 10. 3D modeling interface

We mapped the states in Figure 6, except the idle state, into two different viewing options of the site: navigation interface (aerial view) and rough 3D modeling interface. The navigation interface is where the archaeologist holds ultra mobile PC in approximately horizontal posture as shown in Figure 3. The point-of-interests (POI) are archaeological artefacts, i.e. in our case, remains of port walls, which are pinned to their actual locations on the aerial view (Figure 9). The color coding of each POI represents how much work is completed for that POI, i.e. as the color gets darker the completeness of the work decreases. The archaeologist can observe her location and orientation on the excavation area. Each POI has its own data sheet, which is editable in this interface. If the archaeologist wants to investigate a POI in detail, she walks to that POI using the navigation interface and as she stands in front of the POI, she lifts the ultra mobile PC to her gaze direction. Using the state transition mechanism introduced in the posture recognition section, the 3D modeling interface is enabled. The real-time video capture of the POI is mapped to the interface and a 2D plan of that POI is given as a reference for modeling on the screen. The archaeologist can start the modeling process by selecting the real corners of the wall according to the corresponding reference points in an augmented reality interface (Figure 10).

6. Conclusion and Future Work

In this research, we introduced a posture recognition system to integrate a natural interaction mechanism to mobile devices. The system consists of an inertial measurement unit attached to a mobile device (PDA or ultra mobile PC) to distinguish between two different postures of the hand and an idle state. This data can be used to differentiate between three states, which enable to switch between different interfaces seamlessly. We tested our approach on two different hardware prototypes.

In the global coordinate frame, we used GPS sensor data to locate the user, acquire her gaze direction, embed GIS data and provide information about point of interests. In the local coordinate frame, we used orientation sensor data to allow the user interact with the mobile device while performing natural arm postures and perceive information on different user interfaces. By combining these interaction techniques of global and local coordinate frame, we provide a context-aware interaction framework for pedestrian navigation systems on mobile devices by seamlessly changing graphical user interfaces.

We want to improve our approach by introducing different interaction techniques in mobile augmented reality context by employing wearable sensors. Since augmented reality is the discipline of augmenting the real world with computer generated graphics, and the user is interacting with the real environment, the interaction methods used in these applications must feel more realistic and natural.

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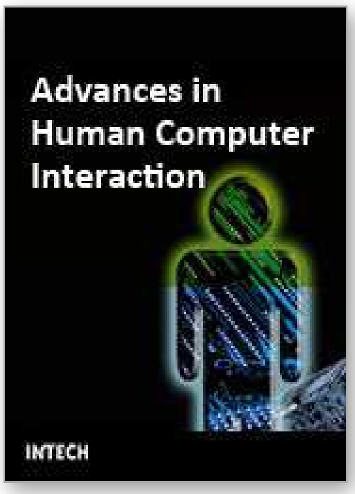

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In these 34 chapters, we survey the broad disciplines that loosely inhabit the study and practice of human-computer interaction. Our authors are passionate advocates of innovative applications, novel approaches, and modern advances in this exciting and developing field. It is our wish that the reader consider not only what our authors have written and the experimentation they have described, but also the examples they have set.

InTech Europe
University Campus STeP Ri
Slavka Krautzeka 83/A
51000 Rijeka, Croatia
Phone: +385 (51) 770 447
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中国上海市延安西路65号上海国际贵都大饭店办公楼405单元
Phone: +86-21-62489820
Fax: +86-21-62489821