

```
DUCTOR ENERGY  
Q 1 0 90  
L 1 2 200MH IC=0  
S 2 0 5 0 SMOD  
D 2 3 DMOD  
R 3 1 20  
VCONTROL 5 0 PULSE(-10 10 0 10N 10M 10MS 10MS)  
TRAN 1M 100MS 0 .1M UIC  
PROBE  
MODEL SMOD VSWITCH(RON = .001)  
MODEL DMOD D  
END
```

control for switch
setting time of 0.. ms
gives smooth traces
switch model on
resistance set to 0.01
default hide model

Augmented by reality: Experiments with natural user interfaces

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Abstract

Human-computer interaction is not limited to the traditional input combination of keyboard and mouse. Natural user interfaces take advantage of input devices that react to real world actions such as gestures or motion. We present our experiments with prototypes including multi-touch table top display, Kinect sensor and a treadmill. Most of the prototypes are used in context of virtual reality where the usage of a natural interface increases user immersion. The immersion is even better if the interface and the action controlled by the interface share the same semantics. Our experience proves the intuitiveness of these interfaces but also documents their limits.

Keywords:

natural user interfaces, tangible interfaces, augmented reality, interaction

► Introduction

For a long time, the input devices used for human-computer interaction were synthetic and artificial: keyboard and mouse are two devices that have no counterpart in real life and it takes some time for the user to learn to operate them. Computer keyboard might be a digital counterpart of a real-life typewriter but the typewriter itself is rather artificial when compared to actually speaking or handwriting. Also the mouse might be a metaphor for pointing with a finger (hence the popular hand cursor) but it's quite distant from what we actually do when we point our fingers in real world.

We decided to experiment with natural user interfaces (NUI [1]): devices and approaches that use real world objects or user's body as the means of communicating with a computer. In contrast with augmented reality [7], where the real world is augmented by artificial computer-generated objects, we call this approach "augmented by reality" because the computer world becomes extended towards the real world by using real physical objects as input devices.

We developed several prototypes to test and explore the effects of NUI on navigating and exploring virtual environments [8, 9]. We experimented to see if the NUI improve the immersion into the virtual world or if the users find the new ways of interaction intuitive and entertaining. Our experience with virtual reality and related environments shows that the users often get distracted by the cumbersome user interface or input devices. For example, navigating in a 3D environment by the keyboard only or by the keyboard and mouse requires a significant amount of training before it feels natural. Eliminating this obstruction will improve the acceptance and penetration of virtual reality applications among the public.

The following sections present five of our experiments, the construction of the prototypes, usage scenarios and our observations of the users interacting with them.

► Flying Over Bratislava

Virtual Bratislava [6, 11] is an initiative of the Comenius University that incrementally digitizes the town of Bratislava and develops methods of rendering the model and accessing related data. We adopted the data for use with our visViewer real-time renderer of urban scenes and built a gesture-based user interface on top of it.

The set-up consists of a computer, a 3D display (or projection screen) and a Kinect [5] sensor to record user movement.

The traditional navigation in a virtual 3D scene using mouse and keyboard was replaced by user body movement. We tested several gestures and postures to find the most suitable set of interaction options. Our finding was that the users prefer reduced interaction options for the sake of simplicity in contrast to totally free 3D space navigation which requires multiple input options.

The usual 3D navigation tools contain several modes of movement (walk, fly, observe [2,3, 10]) and employ many movement options: walk forward, walk backward, strafe (or turn) left, strafe (or turn) right, look up/down/left/right, rotate view...). We have found this large set of options confusing and cumbersome for many users. Our application of flying over Bratislava contains the following modes and movement options:

- Fly, with options to turn left/right, move forward/backward, move up/down
- Walk, with options to turn left/right, move forward/backward, move up

The transition between the modes requires no special user input. Moving up from a walk mode switches to fly mode. Moving down up to the street level in fly mode switches to walk mode. Moreover, our fly mode is just a modified walk mode because we restricted the traditional yaw/pitch/roll orientation to yaw only. This makes the user move the same way in walk mode (where there is no pitching) as in fly mode, further simplifying the navigation.

This set of navigation options is represented by body postures read by the Kinect sensor:

Gesture / posture	Action
Hands along the body	Movement off
Hands straight out at a degree	Movement on
Right hand raised	Move up
Left hand raised	Move down
Step closer to sensor	Increase speed
Step further from sensor	Decrease speed
Tilt body leftwards	Turn left
Tilt body rightwards	Turn right

This reduced set of navigation options, accompanied by a visual manual (see Figure 2) proved to be intuitive enough so that the users were able to operate it without any training or extensive guidance.

Figure 1: Flying over Bratislava at the Virtual world exhibition at the Avion shopping mall.



Figure 2: Manual sheet with the gestures and postures for navigating in the 3D world.



The system has been extensively tested in a public environment during the Virtuálny svet 2012 (“Virtual world 2012”) exhibition [13] in a shopping mall where it was used by many users of various age and technical skill.

► 3D VIRTUAL showcase

Computer graphics for presentation of cultural heritage is one of our major lines of research. We designed a prototype virtual 3D showcase for interactive observation of 3D objects. Again, in order to replace the synthetic input options, we use the user’s body and posture as input device. The goal is to display a rendered 3D model of an object which reacts to user movement and rotates around horizontal and vertical axes. This object rotation relative to user movement might create an illusion of walking around a physical object showcase, such as in a museum or a gallery.

Figure 3: A young visitor observing a virtual duck in our Virtual 3D Showcase



The rotation is fixed on the head position of the user. If the head descends, the object rotates upwards, so that the user gets to see objects bottom part. Analogically, ascending head rotates the objects downwards. Moving the body right or left rotates the object left or right respective to reveal the sides of the object.

This set of input options proved to be intuitive enough for the users. However, the effect of the immersion is largely affected by the surrounding environment. When tested in quiet and dark environment (our laboratory), the illusion of moving around a spatial object was reported by the users as being perceived stronger. A noisy and colourful environment (such as that of a shopping mall) was too distractive for the users and significantly less of them reported the illusion to work. We believe this is not a significant drawback though. The assumed usage of this set-up is a museum or a gallery, where the environment options can be tuned to support the illusion.

► Virtual Sandbox

The multi-touch input has already become a well-established platform for natural user interaction. The sense of touch and grasping things is biologically natural to humans. Replacing mouse interaction by touch is intuitive and proves effective, especially for multi-point interaction [4].

We went even further and created a prototype that does not use fingers for touch input but uses actual physical tools to move sand in a virtual sandbox. (Do not confuse this sandbox with a software system performing code execution in a closed environment – also called a *sandbox*). Our sandbox includes various objects hidden under the sand, much like in an archaeological dig site. Brushes of different size can then be used to remove sand from the selected areas thus revealing the hidden objects.

Figure 4: Using a hand sweeping brush to discover a small dinosaurskeleton hidden in the virtual sandbox.



This activity is perceived as entertaining by the users and can e.g. be used for edutainment purposes in museums.

We used our multi-touch table which registers 32 different touch inputs. Additionally, it uses infrared technology which, in contrast to more popular capacitive or resistive sensing, records also the area size of the touch [12]. Therefore, we are able to distinguish among different brush sizes and vary the sand removal accordingly. Larger brushes remove the sand rapidly and in

large areas, smaller brushes are delicate and slower. We added a particle effect of dust raising and settling upon the brush interaction to increase the realism.

Traditional interfaces would have used GUI button options to select brush size and finger interaction. We removed the synthetic buttons and use actual objects as input options to intensify the immersion.

► Treadmill

The Kinect sensor is already well embraced by the HCI society as an attractive user input device. It is being used by game developers and researches to record human activities such as walking, running or jumping. However, due to the construction of the device, the user has to stay within a relatively small space and walking or running is only mimicked by raising knees while standing in the same spot.

But there is a cheap and familiar device that does that: an exercising treadmill. We attached a rotation sensor to the treadmill internal wheel and record the current walking speed in real time. The walking speed is then mapped to the speed of a camera being moved along a predefined path on a virtual island that is being projected in front of the exercising individual.

A similar extension – a video of a moving country – is sometimes used for indoor cycling but a pre-recorded video has little options to react to speed changes and is bound to real-world environments. Our prototype is entertaining for the users, it visualizes their current speed in real-time and creates an environment that can include fantasy or science-fiction worlds or can even interactively react to user's movement. The recorded pace along the given path can be re-used to create a virtual competitor on screen, thus the user can compete with his/her previous runs or even with other users runs.

Figure 5: Walking through a virtual 3D fantasy island on a real exercising treadmill.



► MARS

During our research on combining multi-touch input with augmented reality display, we designed a presentation/exploration platform: Multi-touch augmented reality system (MARS). It combines a multi-touch table top display, a camera recording the user interacting with the table and a projection of the recorded video feed augmented by virtual objects in real-time.

We focused on a seamless transition of attention between the table top display and the augmented reality display. Our experiments show that the users are able to perform multi-touch interaction tasks on the table top display even when looking at the augmented reality display if the virtual space presented on the augmented reality system is spatially aligned to the real world coordinate system of the table top display.

The details of this system are described in another paper. Proposed usage scenarios include urban planning, product design or exploratory visualization of multidimensional data.

Figure 6: MARS set-up with an interactive map of Bratislava augmented by 3D models of historical sights.



► Conclusion and Acknowledgments

Our experiments with natural user interfaces, or as we call it – interfaces augmented by reality – show that many serious obstructions of using virtual environments can be removed by simply replacing the standard keyboard and mouse combination by real world objects as input devices. Users react very enthusiastically when confronted with NUI and quickly adapt to the new way of interaction. We discovered that many users find the sole interaction entertaining, e.g. when learning to fly in our application or when learning to observe the virtual showcase. This creates a sort of a mini-game within the application and we believe this could be used to increase attractiveness of educationally- or culturally- oriented applications. We are further testing and improving our prototypes and preparing several of them for commercial release.

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