# CONTROLLING VIRTUAL HUMANS USING PDAS

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The new breed of Personal Digital Assistants (PDA) and mobile phones have enough computing power to display 3D graphics. These new mobile devices (handhelds) have some other interesting communication and interaction possibilities as well.

In this paper we explore the potential applications of 3D virtual humans inside mobile devices and the use of such handhelds as control interfaces to drive the virtual humans and navigate through their virtual environments.

## 1 Introduction

Since its introduction in 1984 by PSION, the concept of Personal Digital Assistant has remained as an idea with great potential in the computing devices industry. Although the beginning was uncertain, as it is with the majority of innovative technologies, now-a-days the mobile devices are a reality.

The path to the success of this idea has passed by several technical and conceptual obstacles. The most important difficulties to overcome have been the hardware performance, the creation of dedicated content and the user interface.

The first problem has been solved thanks to the exponential improvements on the microprocessors and integrated circuits technologies. The last generation of PDA devices has a microprocessor with a RISC-like architecture and the computing power equivalent to that of a 10 years old workstation. This powerful CPU allows handling a 16-bit color display as well as different "peripheric" equipments such as a video camera, an integrated stereo sound system with recording capabilities, wireless network cards, etc. Having a fully functional high performance computer system which fits in the palm of your hand is a reality.

However, the second problem could be solved by special extra work on existing content, in order to consider the resolution problem and the size of the screen, or by providing special content.

Moreover, the reality hasn't yet fulfilled the dream; the third problem that remains unsolved is that of the user interface. Since the beginning, the main way to communicate with these palm-sized devices was handwriting. The PDA metaphor conceived it as an electronic note pad. This was comprehensible since the computing power of the early devices didn't leave much freedom to imagination. However, the last PDA generation stills privileges the text-based user-computer interaction. Efforts have been dedicated to add richer means of interaction with these mobile systems: speech recognition is reaching a mature level and will be improved as the processors power continues to increase. Nevertheless, the communication coming from the device is mainly text.

Mobile devices must go beyond the concept of "personal" systems up to the level of "individual" assistants and for this; a richer communication interface should be implemented. Since we are looking for an assistant, then, what better metaphor for a digital assistant than a virtual human? Now that the handheld devices have the computing power to animate 3D graphics, we can take the virtual humans out of their virtual world and put them in the palm of our hands, where they can help us in many ways.

In this paper we analyze the benefits of a "virtual human" based interface for applications on mobile devices and present a developed prototype. Following this trend of finding new applications for the handheld devices, we explore a second area as well. We go the other way: instead of having the virtual humans “controlling” the PDA, we could try to control them, and their world, from the mobile device. In the second part, a prototype of a remote control interface for 3D virtual environments is presented.

## 2 A Virtual Human as user interface

In this section we will justify the use of a virtual human as the main component of a rich user interface for PDA and other mobile devices.

The currently accepted user interface paradigm makes extensive use of windowed text messages and static images such as icons to communicate and interact with the user. While this windows-based, desktop metaphor has been useful on traditional PCs, the model is rather limited when the computer system doesn't have a keyboard and a "standard" pointing device. Windows-based interfaces are suitable for administrative applications such as agendas and planning software. However, to take full advantage of the computing power and features of the last generation devices, new applications must be developed. More memory, faster processors, wireless communication, etc. lead to think on new types of interface for different kinds of applications.

It has been stated by several authors ([14],[21],[10]) that the ultimate human-computer interface would include audio/video analysis and synthesis in combination with artificial intelligence (AI) techniques, dialog management and face/body gestures to allow an intelligent" and expressive dialog with the user. We are looking for an autonomous or semiautonomous software agent that will look, move, listen and talk as a real person. The "human inside the computer" (Virtual Human based interface) could serve as the ultimate personal assistant.

The natural targets for this interface paradigm are mobile applications where the digital Virtual Humans could be used to present contents, help in the search of information and interact with on-line services, etc. The non verbal communication and the speech synthesis from a Virtual Human can convey a higher amount of information in a more efficient and human-comprehensible way. And what better platform to have a human-like assistant that a personal device such as the last generation of PDAs. The objective is then to synthesize a Virtual Human (or 3D agent) on a PDA.

In the next subsection we present an overview of the state of the art on 3D agents rendering and evaluate the available technologies to implement them on mobile devices.

## 3 State of the art on 3D agents and mobile devices

Exception made of the unique VRML viewer available for pocketPC based PDAs developed by ParallelGraphics [17], there is no powerful 3D application on PDAs.

As in a previous work [11], we have developed a java-based MPEG-4 player oriented to PC platform; we decided to implement an MPEG-4 animation engine for mobile devices. The decision to be compliant with the MPEG-4 standard is related to the low bitrates needed to render a 3D animation and rich multimedia contents [4],[5],[6].

Besides, being MPEG-4 compliant allows us to use the same contents for our PC-based applications on the mobile devices with minimum or no modifications at all.

The next decision to take was the selection of the PDA platform. Although the choice of PDA devices is increasing all the time, the struggle for dominance in the operating system space (which is related to the hardware capabilities of the device) continues to be a battle between three main protagonists: Windows CE, EPOC, and PalmOS. These main players let us with basically two main platforms, putting aside the smart phones and similar devices powered by the EPOC operating system: PalmOS compatibles, such as Sony's CLIE; and the Windows CE, now called PocketPC devices [18]. The most powerful processors (Intel StrongARM, running at 206 Mhz) are found on the PocketPC PDAs manufactured by HP (Jornada) [8], Compaq (iPAQ) [8] and CASIO (Cassiopea) [7], among others. The new generation devices are powered by the XScale Intel processors running at speeds up to 400 Mhz, the new models are being launched by Toshiba (Pocket PC e740) [22], Fujitsu-Siemens (Pocket LOOX) [9] and Compaq (iPAQ series 3900).

We chose to implement the animation engine for the Personal Virtual Human Assistant on the PocketPC platform because these are the most powerful devices in terms of computing power and equipment. This kind of PDAs are situated on the high-end systems category, featuring advanced characteristics such as 16-bit color displays, audio reproducing/recording and wireless communication (wireless LAN, infrared, bluetooth). Additionally, this platform has a growing offer of software development tools and high performance graphics libraries.

To develop the animation engine we looked for the best 3D graphics rendering performance. Up to now, the choice of graphics libraries available for the Windows CE (PocketPC 2002) include the GAPI library; the pocketGL, based on the GAPI; and the DieselEngine. The GAPI library, provided by Microsoft, is based on DirectDraw and is oriented to the 2D games development [15]. It doesn't provide any function for 3D graphics; its main functionality is reduced to giving access to the video memory to display pixels on the screen. Although this library could give the fastest access to the video memory, it would have been a costly solution to create a 3D graphics library on top of it. The pocketGL library is implemented on top of the GAPI and features OpenGL like functions for 3D rendering [19]. Its performance and functionality are good, but it's still under development and has recently changed its status to become a commercial product. The DieselEngine API produced by INMAR Software was the most complete alternative, with good performance, high functionality and a coherent structure based on DirectX "look and feel" [12]. Even more, this is still free of use for non commercial applications and has been ported to the Desktop PC and EPOC platforms including a wide range of processors such as StrongARM, MIPS and SH3.

With our selection of operating system (PocketPC) and graphics library (DieselEngine), we developed a first prototype of a Virtual Human animation engine compliant with MPEG-4. In the next section we describe the technical specifications of the Personal Virtual Human Assistant.

## 4 The Personal Virtual Human Assistant

Here we describe the characteristics and technical details of the implementation of the Personal Virtual Human Assistant interface.

The working area of the current PDAs with the PocketPC OS is 240x320 pixels. This surface doesn't leave space to spare. We conceived our software to be as flexible as possible, allowing displaying text, images and the virtual human, the main component of the user interface.

We plan to make use of audio streams as well because there is not enough space on the screen to display a high amount of text. Besides, the kind of interface we propose tries to go beyond the idea of the PDA as an electronic note pad and privileges the use of more expressive multimodal communication means: images, sound, video. For 2D images and some 3D models, the computing power of the devices found on the market is enough. Concerning the sound, these personal equipments are also capable to reproduce audio in uncompressed (wave files) or compressed formats (mp3). Video streams with mpeg-2 compression for instance, could be played (there are players running on the current PocketPC PDAs), though for this we should wait for the faster processors which are currently being introduced.

As stated in the previous section, we have chosen the PocketPC OS as the target platform and the development tools we are using are freely available. The development platform is the embedded Visual C++ 3.0 with the PocketPC 2002 Software Development Kit provided by Microsoft [16]. The graphics rendering is achieved through the DieselEngine library [12] which can be used on both desktop PC (Windows family OS) and PocketPC devices. The figure 1: illustrates the main components of the PVHA:

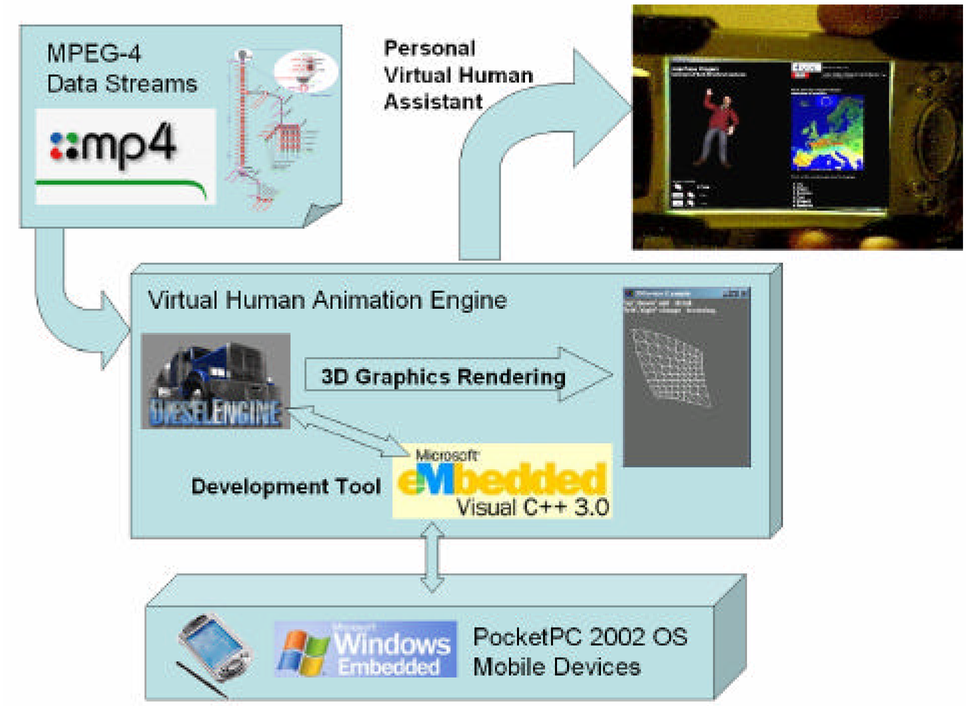


**Figure 1:** Components of the Personal Virtual Human Assistant.

The first prototype of the Personal Virtual Human Assistant (PVHA) consists of a Virtual Human animation engine that works with two main types of data streams:

- MPEG-4 Body Definition Parameters (BDP) which contain the 3D geometric description of the virtual human model. The BDP define a human body using a hierarchical structure that divides the body on joints (degrees of freedom) and segments (3D parts of the human such as the limbs, head, etc.). This stream is complemented with the MPEG-4 Body Deformation Tables which provide information needed to produce anatomical deformations on the virtual human joints, improving the realism on the animation.

- MPEG-4 Body Animation Parameters, this stream contains the animation frames for the virtual human in the form of rotation angles for each of its joints. Any kind of movement can be coded into a BAP stream with a relatively low bit rate.

For a more detailed description of the representation and animation of virtual humans using MPEG-4 streams, see: [4], [5], [6], [11].

The MPEG-4 streams are read from the local file system on the mobile device. The system architecture is described in figure 2.

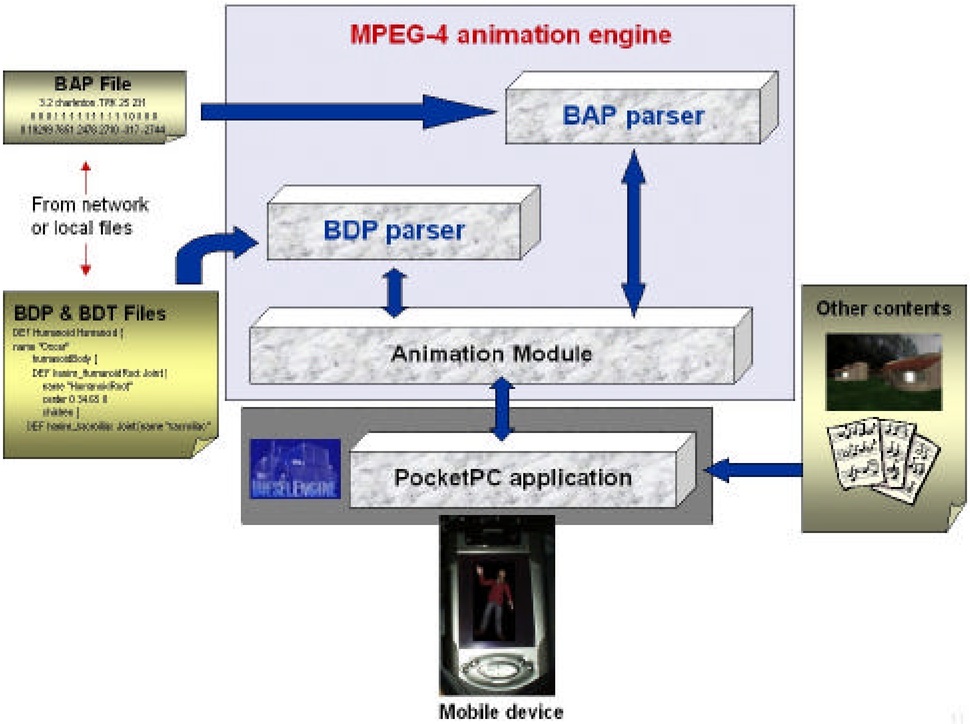


**Figure 2:** System Architecture of the MPEG-4 animation engine and the PVHA.

The main components are the parser modules which read the data streams and deliver the processed information to the animation module. The animation module is responsible of computing the rotations of the virtual human joints according to the BAP stream and calculating the anatomical deformations on the required zones.

Each animation frame is rendered by means of the DieselEngine library. Since the animation engine is independent of the graphics rendering graphics libraries could be used as well. The PocketPC application can integrate other types of information such as 2D images, text and sound files.

So far, our animation engine has 3D navigation controls that allow the user to view the Virtual Human from any point of view and zoom over it.

The application executable measures 250Kb. No special installation procedure is required; the user should only copy the application on the PDA file system.

We have tested the software with a 10,000 polygons model of a virtual human with more than 20 joints (each one with at least 2 degrees of freedom). This is a multi-textured model with a rather high level of detail on the face and hands (fully articulated/animated).

The stream containing the geometric description (MPEG-4 BDP) measures 1.6Mb, including the images files for the textures. The device used was a Compaq iPAQ model 3850 with 64Mb of RAM powered by a StrongArm processor running at 206Mhz. The OS was PocketPC 2002 (WinCE 3.0). This model takes a bit more than 1 minute to load on the hardware described and uses 1.24Mb of RAM. We got an animation frame rate of 15 frames per second with this high detail model. Better results can be achieved with less complex (lower number of polygons) virtual humans. The figure 3 shows the application running on the PDA.


**Figure 3:** The Personal Virtual Human Assistant on an iPAQ PDA.

In the next section we outline the potential applications for this interface.

## 5 Potential applications of the PVHA

In this part we share our "dreams" about a personal multimodal interface shaped on the form of a Virtual Human inside a mobile device. For all of the following examples of potential applications, a special network infrastructure should be built.
Several authors have focused on this problem: [13], [20].

Data can be streamed to the PDA in different ways depending on the application scenario (different amounts of data and update frequency required).

Besides the network infrastructure, design tools to create the virtual humans and animate them must be updated to fit the needs of the mobile platform. While we have tested our prototype with a 3D model designed for desktop applications, the performance of the application could be raised with models adapted to this kind of applications.

We believe these are the main categories of applications where our Personal Virtual Human could be an efficient assistant:

-**Digital guide to museums and expositions:** related to the content presenter application. Visitors on a museum could use their PDA as an interactive guide to the contents of the exhibition, with on-line explanations from their personalized virtual assistant. Put an "intelligent" dialog manager with a knowledge database on a server and the virtual assistant can turn into an "expert" on any subject.

**- Digital personality for games and leisure applications:** The market for 3D games for PocketPC platform is growing very fast [1], [2]. An animated 3D character can always find its place on a game application.

**- Digital instructor for physical activities:** It could be an interesting didactic support. On your PDA you could store 3D animations of exercise routines, special movements for sports such as aerobics or martial arts, etc. Hopefully, the virtual human will never substitute the real instructor, but it could help when the real "coach" is not around.

- **Digital salesman - Content presenter:** as an extension to the applications that already exist on the web. The virtual human in the mobile device could be used to present and even drive the user through the advantages of the product to sell. Potential clients could load on their PDAs (either on real-time or for off-line use) the virtual salesman who would describe the products of interest. Mobile devices have already been considered as "shopping tools" [3], we believe the presence of a personal virtual human could positively increase the efficiency of commercial applications.

Many other applications could make use of the technology we are proposing. Their main characteristic will be to use the PDA as a smart interface and provide an interesting way to communicate with the user through a virtual human.

Now, in the last part of this paper we present a second prototype application which gives a slightly different use to the handheld: we use the PDA to control the virtual humans and their 3D environment.

## 6 The PDA as an remote interaction tool

An interesting application area for these devices is the remote control and monitoring of processes (process management of remote or local workstations), systems (remote control for electro-domestic devices such as Audio and Video equipment) and applications (view and interaction with the host system: MS Terminal Services Client).

Another area currently on exploration is the use of PDAs as all-in-one remote interaction devices: the potential applications range from secondary screens for monitoring applets to fully functional remote controls.

The PDA can work as a remote control which integrates all the traditional interaction devices (keyboard, mouse, and monitor) and puts them all in the palm of the hand. This characteristic makes easier to realize operations which are neither intuitive nor easy to learn, such as camera management or navigation in a 3D virtual environment.

This brings us again to the 3D virtual environments inhabited by virtual humans and other creatures and objects. We can use a handheld to ease the interaction with complex 3D virtual environment applications. The rest of the paper describes a tested application developed to test the feasibility of using mobile devices as integrated remote controls for 3D navigation and interaction.

The virtual reality or virtual environment applications we are addressing belong to the partial-immersion kind, and can be used on regular monitors or projection screens. Full-immersion requires the use of special equipment like Head Mounted Displays (HMD), data gloves, etc. But such devices are still too invasive and hence uncomfortable for daily use. In our target applications, the user stands in front of a screen or a projection surface where he/she can see and explore the 3D world, by means of “classic” interaction devices and now, with the remote control implemented in the PDA.

## 7 System architecture of the remote control prototype

The idea of the PDA as an assistant tool was implemented in a testbed application featuring the following characteristics: The main application is a 3D virtual environment where the user can navigate and interact with a virtual human by means of sending specific commands to it. For the 3D rendering we have adapted a previously developed mpeg-4 viewer for web-based applications [11]. In addition to the scene controls available in the viewer (essentially mouse-driven interaction), we developed another user interface embedded in a mobile device.

The figure 4 shows the main system components and the way they are related to each other. The three main components are:

**Control applet on the mobile device.** This allows to manage the camera and change the viewpoint in the scene; lets the user select any object in the 3D scene and execute some action with it, such as focus the camera on it, or in the case of the virtual human, display some animation (walk, dance, show some emotional gestures, etc.).

**Central message management server.** This application acts as the intermediary between the 3D application and the mobile interface. Its function is to manage and exchange infomation between the other components.

**The 3D virtual environment application.** The front-end and main interface, this is where the user can view the 3D virtual environment and interacts with it simultaneously with both the workstation interface devices (mouse, keyboard) and the PDA.

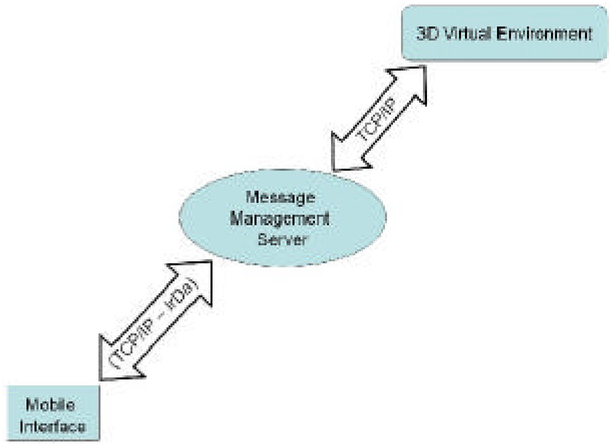


**Figure 4:** Main Components of the developed application.

An important characteristic we wanted to implement was the flexibility of communication methods. We exploit three of the main communication means available in state-of-the-art Pocket PCs: infrared data transfer, wireless (IEEE 802.11) and wired network (Ethernet technology). The communication media can be selected at the beginning of the session on the mobile interface and on the central server. Actually, the three altematives use TCP/IP sockets communications, through the use of Infrared Sockets (IrSock) interfaces and "classical" socket implementations for both network types.

The control applet on the mobile device was implemented using Embedded Visual Basic 3.0. It allows to specify the connection parameters (central server address, connection type: infrared or "classic" network) and has two main components: a camera management module to navigate the scene by means of zooming, panning (camera translation) and rotation. The commands to the 3D application are sent as soon as the user selects the camera movement and presses the arrow keys on the PDA (hardware buttons).

The second component presents a menu loaded with data coming from the 3D application and allows selecting objects in the scene (furniture, virtual humans) and executing actions with them. In the case of the static objects, the available action is to focus the camera on the selected object. For the virtual humans, some preset animations are available for the user to choose.

The central message management server is essentially a multi threaded socket server (implemented in Visual Basic), capable to handle communications coming from two clients (mobile device, 3D applet). The server uses the IP address of the computer where it runs from and two port numbers for the TCP sockets are configurable to receive connections from the clients. The server processes the messages coming from the clients and redistributes them according to the message type. There are two main types of message:

- **information request:** for the mobile device to learn about the 3D scene objects and actions.
- **action to execute**: camera movement, ID of a selected object, action to perform on the last selected object.

Concerning the data frames, we're currently using a straight forward syntax which only specifies the device ID, the action to execute and the time stamp. By identifying the device, the system can be extended to allow the interaction of multiple mobile devices over one virtual environment. In this case, the application will become a true distributed system.

The 3D virtual environment application, for this prototype we adapted a MPEG-4 virtual human animation engine previously developed. This is a java applet capable to render and animate 3D virtual humans (MPEG-4 compliant). The applet can load standard VRML scenes as well. The application has a conventional interface built inside the web page and allowing the user to select some animation sequence for the virtual human. Scene navigation is achieved using the mouse. This functionality was replicated with some enhancements in the mobile interface (icons to select camera operations and a more detailed menu for object interaction). We added a socket client module to the main java applet to enable communication with the central server.

The figure 5 shows the actual look of the mobile interface and snapshots of the central server and 3D application.

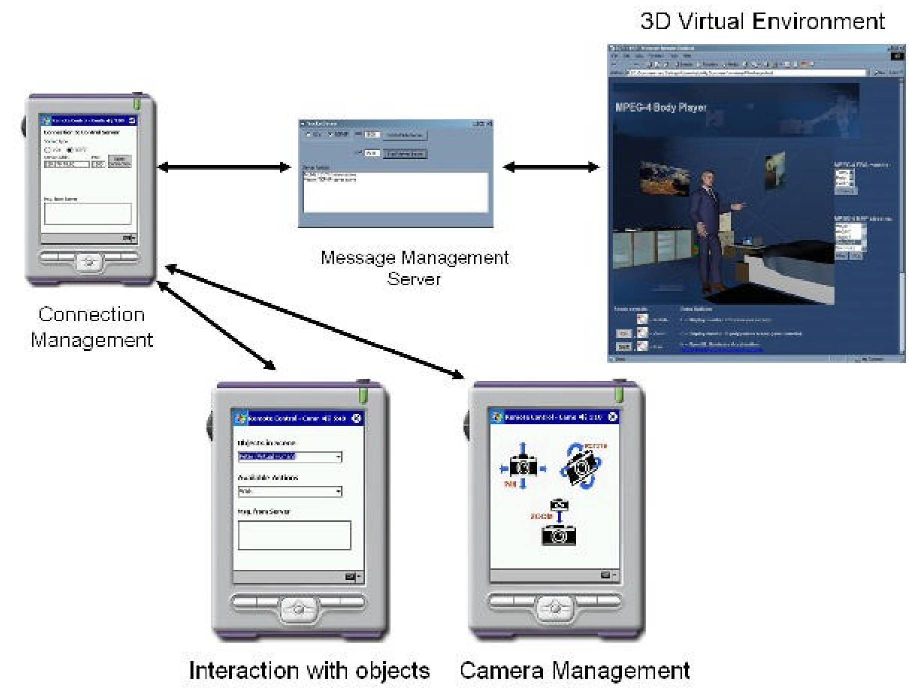


**Figure 5:** Snapshots of the prototype system.

In the following section we discuss the ease of use of the new interface and the future work to extend the paradigm of mobile interfaces.

## 8 Discussion of results and future work on remote control interfaces

The developed prototype allowed us to make a feasibility study on the capabilities and potential applications of mobile devices as complementary interfaces for 3D applications.

The main advantage we found was the possibility to provide additional information to the user without overloading the main interface (3D environment window). Navigation and interaction in a 3D world require a big amount of interface controls, moving the camera to explore the environment and pinpointing objects to execute actions on them are just some examples. State-of-the-art games and virtual reality applications allow the user to execute complex operations such as dialogs with characters and manipulation of complicated objects. As we already mentioned, there is the possibility to use full-immersion devices such as data gloves and HMD, but it would be very useful to have an intermediate device. This additional dispositive shouldn't be as invasive as a HMD, but must have enough interactive features to help the user with complex tasks.

The PDA seems to be a good candidate for this intermediate device aimed to discharge the main user interface. In our prototype, the PDA was useful to represent additional information in a compact way and eased the execution of some operations.

Example of this is the camera management. The PDA iconic interface plus the hardware arrow keys proved to be more efficient than the combination of keyboard mouse, which was the only mean to move the camera in the 3D application. A similar interface component could have been implemented in the java applet, but this would overload the main screen and we would go back to the problem of having too much information on the same place.

In the case of object interaction, the advantage is the same, we avoid main screen overload and gain an extra place to display and use additional information on the PDA screen.

Future developments include the design and implementation of a low detail viewer on the PDA, capable to present a conceptual view of the 3D scene. This additional view could be a map showing the points of interest in the whole scene, allowing the user to know what's beyond or behind the fully detailed 3D scene currently being rendered on the main screen.

On the communication issue, the update speed can be improved to provide a smoother interaction. For this, a more efficient central server must be implemented, the use of visual basic as prototyping platform was a good idea, but for better performance, C/C++ language must be used. The communication speed on the mobile device could be improved as well by means of implementing the communication routines as pre-compiled Dynamic Linked Libraries (dll's). The message syntax will have to be extended to allow more complex operations and interaction. The use of XML is an option we're considering to implement a better syntax and communication protocol.

Experiments with other 3D virtual environment applications will be carried on. The web-based MPEG-4 player will be replaced by a more capable rendering engine to test the PDA as a remote control in games or similar scenarios.

## 9 Final Conclusion: Virtual Humans went mobile, but handhelds can still control them

We have developed a first prototype of a virtual human animation engine for mobile devices. The software is capable to render a 3D model of a realistic virtual human and animate it using MPEG-4 compliant data streams.

A prototype system to experiment with the use of mobile devices as remote control interfaces to assist users in the control and navigation of 3D virtual environments was implemented as well.

The MPEG-4 based animation engine will be used as the main component of a multimodal interface for mobile devices. We believe the metaphor of a virtual human inside a personal computer system such as the current PocketPC PDAs can lead the way to the creation of novel mobile applications.

Another direction of research and development focuses on the fact that the developed prototypes have been truly helpful in the task of redistributing the information and interface controls. Handhelds can reduce the overloaded user interfaces (main screen). PDA devices can avoid the use of invasive or classical interaction devices.

Mobile devices can bring an important advance in the search for the final personal assistant: a software agent or entity capable to process, present and handle information. Intuitive interfaces and original ways to communicate with the user are promising applications for the new hi-tech mobile devices. The new handhelds can be an excellent home for virtual humans, from within this ubiquitous platform, they will help us in our daily tasks and help us interact with them and their virtual worlds.

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