Non-Verbal Communication for a Virtual Reality Interface

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Abstract. The steady growth of technology has allowed to extend all forms of human-computer communication. Since the emergence of more sophisticated interaction devices, Human Computer Interaction (HCI) science has added the issue of Non-Verbal Communication (NVC).
Nowadays, there are a lot of applications such as interactive entertainments and virtual reality requiring more natural and intuitive interfaces. Human gestures constitute a great space of actions expressed by the body, face, and/or hands.
Hand Gesture is frequently used in people's daily life, thus it is an alternative form to communicate with computers in an easy way.
This paper introduces a real-time hand gesture recognition and tracking system to identify different and dinamic hand postures. In order to improve the user experience, a set of different system functions into a virtual world had been implemented so interaction can be performed by the user through a data glove device.

Keywords: Non-Verbal Communication, Human Computer Interaction, Virtual Reality (VR), Computer Graphics.

1 Introduction

Some time ago scientists predicted the impending transition in the ways humans would experience the communication of information. Virtual Reality (VR) has allowed the creation of interaction's environments that facilitate new contexts of exchange and communication of information. Currently, VR applications consist in user immersion into a computer-generated environment, resulting in a natural idea to improve the impression of living in a simulated reality [1][2].

It is well known that the use of VR techniques does not alter the physical body, however affects perceptions and interactions of the human being operating in a virtual environment in real time using their senses and natural abilities. At the beginning, VR used the classical interaction devices such as joystick, keyboard, mouse, among others; in the same way they were used in video games. Nowadays, technological advances have resulted in the need for evolution of existing devices and consequently, the emergence of new simple and intuitive devices to improve user interaction with VR environments [3]. In this context, *Natural User Interfaces* (NUI) appears as an attractive solution to the need raised.

These interfaces are a new paradigm in HCI for a system or application, where the main goal is making use of a natural communication to humans. In fact, capturing information must be in real time achieving a direct interaction without using a peripheral as an intermediary for the entry of information [4]. In consequence, this paradigm exploits the skills that most users have already acquired through living an experience in an everyday world while interacting with other humans [5]. This interaction is what the world knows as *Non-Verbal Communication* (NVC).

While Verbal Communication (information exchange using words) is important, humans had relied on NVC for thousands of years before they developed the capability to communicate with words. The NVC takes many forms or modalities like *facial expression*; *gaze* (eye movements and pupil dilation); *gestures*, and other *bodily movements*; *body posture*; *bodily contact*; *spatial behaviour gesture*; *clothing* and *appearance*; *non-verbal vocalizations*, and *smell* [6].

The main NVC related research areas are *Proxemics*, *Kinesics* and *Paralinguistics*. *Proxemics* analyses the chosen body distance and angle during interaction. *Kinesics* is the study of what is called body language, all body movements except physical contact, which includes gestures – movements of the limbs, postural shifts and movements of some parts of the body like hands, head or trunk. Finally, *Paralinguistics* comprises all non linguistic characteristics related to speech like the selected language or the tone of voice or voice inflexions, among others [6][7].

At the moment, VR implements the NVC by using virtual characters so that the user can interact with environment. Considering that a developed VR system must collect gestural, positional, sound and biometric user information; the use of more sophisticated devices must be done, achieving a NUI system. Thus, the virtual participants respond to the sensory data as if it were real, where response is at every level from physiological through to cognitive one [8][9].

In this context, this work presents a VR system based on NUI principles. The system allows the simulation of gestures and animations of a human hand based on the recognition of their movements, using a data glove as an input device. A recogniser and tracker system methods enables to provide a natural interaction for the user.

2 Concepts on the Generic Non-Verbal Communication Framework

NVC is the main channel through which is experienced inner life of others. Is a significant and ubiquitous aspect of life, so it is not surprising to observe that computing technology expects to integrate seamlessly the daily life and naturally identify the automatic understanding and synthesis of NVC, i.e, as adept computers to the natural modes of human operation and communication [10].

Thus, to get an interface between computers and some of the most important aspects of human psychology such as emotions and social attitudes.

In particular, the gesture interaction is one of the research topics that belong to the scientific eld of HCI and have been examined thoroughly within the past years. Their objective is to recognise meaningful expressions of humans with any part of their body (hands, arms, head, upper body). The spectrum of applications have given significant results in many areas such as artificial intelligence, robotics, medicine, sign language, video games, performing arts, among others [11][12].

2.1 NUI based on Virtual Reality

All interactive system should provide the user with an interface through which it can move and interact in the virtual environment. The interface's design should include features like functionality, ease of use, intelligence and adaptation; so it is reasonable to think that the same user can personify a character in the environment together with other objects or virtual characters. In order to achieve the above, it is necessary to understand before some basic VR environments personification's concepts like as *user perspective*, *modelling*, *rendering* and *physics*.

First Person (FP) view, the most common *user perspective*, allows the user to perceive the environment through the eyes of the character, observing his around up-close, giving a clear view of the scenario in front of him. This FP feature establishes a "user-character" relationship to provide the most immersing feel and improving learning abilities stimulating his visual and auditory capabilities [13].

The VR applications development process require to support scientific *modelling* and *rendering* processes. Both processes are designed to ensure that the final product is appealing and, as much as possible, is real to the user's eyes, allowing the developer focusing on the target instead of centering his attention on environment aspects.

Considering the *physics* aspect, objects in any VR application should behave as in reality including their physical characteristics, so it is necessary to simulate aspects like gravity and collision avoiding crossing between solid objects, then achieving a behavior like the impact of a ball on the ground and soft objects deformations, among others.

All of the above concepts should not affect the performance, in particular *real-time*, since the user acts according to what it is displayed while interacting with the application. Taking into consideration the performed user action, the graphical application refreshes the display, returning a feedback to the user.

Formally, experts in NUI approve that an interface is natural if it obeys the following considerations [14]:

- Create an experience that gives the feeling of being an extension of the body.
- Create an experience that is natural for both expert users and new users.
- Create an experience that is authentic to the environment.

– Create a user interface that takes into account the context, been aware of right metaphors, visual cues, feedback and input and output methods.

Most of current computer games and VR applications usually employ a "person" within the scenario who unfolds through commands specified by the user through a device. This "person" is called *Avatar* and consists of a character whose behaviour is explicitly controlled by an external animator using control commands.

Considering VR applications, NUI concepts and finally Gesture Interaction, the interface should provide to the user with certain facilities for a more bearable interaction, i.e., using the gestural medium to develop within the scenario. In the interaction through an avatar, each gesture is a control command associated to a process trying to match the incoming data from data glove with the modelled avatar [15][16]. In general, gestures can be used for both as symbolic language and as multi-dimensional control tools. Within the standard primitives for the virtual behavior, the following multi-dimensional control tools were defined by [17][18]:

– **Navigation**, the displacement of the user in the virtual space and the "cognitive map" he/she builds of it.
– **Selection**, the action of user pointing to an object.
– **Manipulation**, the user modification of an object's state; and
– **System control**, the dialogue between the user and the application.

Added to the defined Navigation and System control tools a *gestural protocol* is needed. Theoretically, a protocol is defined as a set of rules set out in the communication process between two systems. In an HCI protocol, the user and computer are the two involved systems where communication is carried out by means of human gestures.

There exist a diversity of methods, techniques, interfaces and applications that are used for several purposes. In every instance different equipment is used, requiring specific hardware and software to get and process the needed data based on the strategy of the researcher and the needs of each project.

Many existing works use specific devices for gesture recognition and hand's movements tracking, nevertheless one of the most interesting ways to get what was mentioned is by using data gloves [19].

3 Gestural Interface System Features

Gesture recognition and hand movements tracking technology consists of devices capable of tracking the human body movements and communicating the data to computer [20]. Its potential is to change the way users interact with computers by eliminating input devices such as joysticks, mice and keyboards and allowing the unencumbered body to give signals to the computer through gestures (such as finger pointing) or movements.

At the beginning, many works of the mentioned issues used a regular camera as a device for its developments, based on image processing technique [20]. However, nowadays, there exist special equipment that the user can attach to his body.

This study focuses on the gestural interface of a system where the interaction device is a data glove consisting of an integrated sensor textile glove. This device has been chosen under the need for natural interaction by the user using the hands into a virtual world [21][19]. The system's interface allows a real-time interaction where the user communicates through an *avatar*.

The following explains the basic features offered by the system to give more sophistication and naturalness to the interface. It has been developed according to the mentioned multi-dimensional control tools (Section 2.1), excepting the selection tool.

- **Navigation**. Most of the known and implemented navigation options used by game and VR applications developers are: "walk", "stop", "run", "jump", change different views of the scenario, among others. Particularly, this system has implemented the "walk", "stop" and change of view of the scenario (See Fig. 1 a)). All of them are associated to a set of gestures (protocol) that performs each action. As an extra functionality of the system, it is possible to remotely control an air-plane toy included in the scenario (See Fig. 1 b)). As it is possible to do two different types of navigation (avatar navigation and air-plane navigation), it is necessary to perform a gestural protocol to swap between them.
- **Manipulation**. While a user interacts naturally on scenario, has also the need to perform handling actions in it. Basically, these actions are to be able to touch the virtual elements and grab them. Some involved factors for implementing this functionality are: physics treatment, proximity to objects (to grab) and avatar hand position. (See Fig. 1 c))
- **System Control**. This control tool relates to the user-application dialogue (Section 2.1). In this approach user-application dialogue implies to control the system by using simple and natural gestures. This feature is achieved through navigation and manipulation tools.

As a consequence of the personification of an avatar by the user it would be nice to be able to visualise user hands and avatar hands as synchronised as possible. Thus, this system implements the next feature:

Real-time Imitation. This involves that avatar's hands can mimics user's hands through a refined model management, physics treatment and rendering tuning (frame rates) (See Fig. 2). Realistic visualisation of the replicated gestures needs the model representation of hands and mapping of human hands' motion into the model which is not straight-forward due to different sizes and joint structures of bones for the human hands. It is necessary to consider that some movements are not feasible by the user then the avatar should not be able to do it.

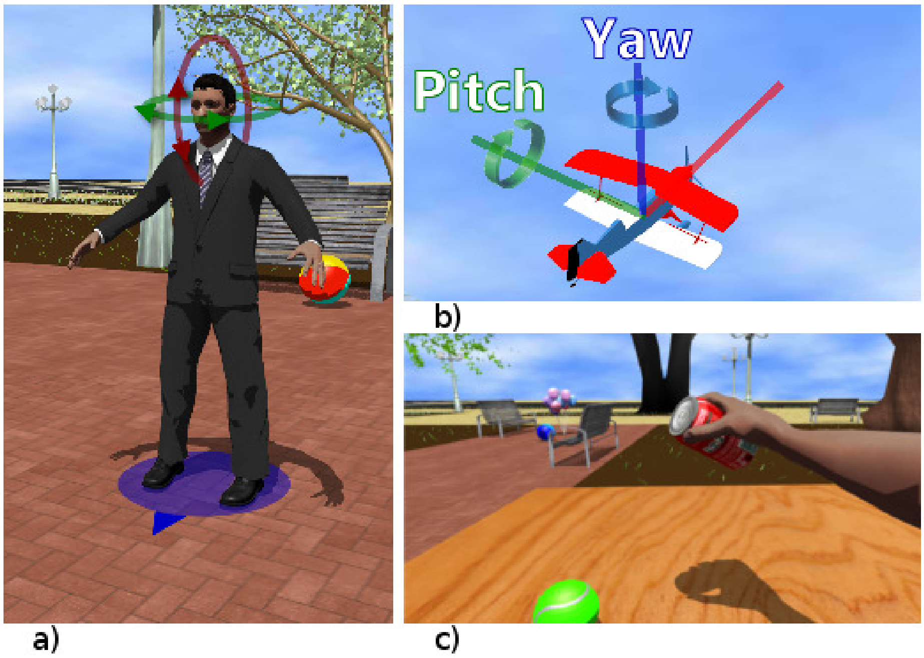

Fig. 1. System's Features: a) Change of View Avatar, b) Airplane Navigation, c) Grasping in a work's table.

Fig. 2. Real time Imitation Feature.

4 Issues Concerning the Interface

The developed system is a system that operates in real time. Since the interaction should appear as natural as possible, it is necessary to consider certain particular features of the operating modules, which will make the proper and efficient operation of the system.

The used input device was an integrated sensor textile glove *DG5 Vhand Data Glove 2.0* distributed by *DGTech Engineering Solutions* [22].

4.1 Data Acquisition (Sampling)

The data glove is a sensor device with five embedded bend sensors which enables to accurately measure the finger movements, while embedded 3 axes accelerometer allows to sense both the hand movements and the hand orientation (roll and pitch). Direct acquisition is performed by the different sensors to capture performer actions. On figure 3, the three former columns show the captured values for the fingers sensors.

4.2 Data Processing (Mapping)

The mapping procedure consists in a function going from bending, orientation and acceleration domains to values within the avatar model domain. Acquired data are matched to model data getting a transition from physical detected movement (real domain) to model avatar image movement (virtual domain). On figure 3, the last column shows the resulting values from the mapped captured values on third column (input data).

Data Glove Fingers	Domain	Input Data	Hand mesh (output)		
			Proximal phalange	Middle phalange	Distal phalange
Thumb	[0.0 – 100.0]	17.87	(0.99, -0.04, 0, 0.08)	(0.99, 0, 0, 0.08)	(0.99, 0, 0, 0.08)
Index	[0.0 – 100.0]	24.90	(0.99, -0.06, -0.06, -0.06)	(0.99, -0.06, -0.06, -0.06)	(0.99, -0.06, -0.06, -0.06)
Middle	[0.0 – 100.0]	53.01	(0.95, 0.21, 0.21, 0.30)	(0.95, 0.21, 0.21, 0.30)	(0.95, 0.21, 0.21, 0.30)
Ring	[0.0 – 100.0]	43.75	(0.97, 0.10, 0.10, 0.20)	(0.97, 0.10, 0.10, 0.20)	(0.97, 0.10, 0.10, 0.20)
Pinky	[0.0 – 100.0]	33.59	(0.99, 0.04, 0.04, 0.09)	(0.95, 0.21, 0.21, 0.30)	(0.99, 0.04, 0.04, 0.09)

Fig. 3. An instance of Input Data and Deviation for Avatar Fingers Real-Time Imitation.

4.3 Gesture Recognition

Each gesture is determined by tracking mapped data. Gesture recognition takes place by matching the tracked data with some gestural values set. Valid gesture values are previously stored on a data base.

4.4 Gestural Protocol Detection.

The real time interface is responsible for controlling whether the user has executed any of the developed protocols. Each gestural protocol provided by the system arrange a set of gestures that are important for its detection. These gestures should be performed sequentially. Thus, once the gestural protocol was determined, the system will generate a particular event. Some of the implemented protocol are: forward walking, back-forward walking, stop walking, revolver, grasp, among others.

5 Conclusions and Future Works

Virtual Reality has became a commonplace in our increasingly technological world in recent years. An explosion has occurred in our understanding of Virtual Reality, Virtual Environments and in the technologies required to produce them in the last decade. Virtual Worlds and Virtual Environments are produced for people, for users to interact with computer and with complex information sets.

In Human-Computer Interaction, the development of avatars has significant potential to enhance realism, automation capability, and effectiveness across a variety of issues. As a form of communication, a theoretical model delivering new insights on the process of 3D avatar's design must consider verbal and non-verbal communication.

Particularly, NVC meets all the requirements of the HCI phenomenon, such as a functional, procedural, dynamic, irreversible, and meaningful character, and a presupposed systematicity which qualifies it for scientific study. Thus, non-verbal behaviour appears to be a primary factor in human-avatar interaction as much as it is for human-human interaction.

In particular, in human-avatar interaction, gestures add a welcome feeling of activity to the otherwise joyless ones of pointing and clicking. Gestural interfaces point out the invisible nature of gestures as a simple medium of NVC.

At present time, we are working on adding user technology that enables the use of human body as interface. This work is aimed to offer a form of natural interaction, based on the knowledge and practice of human beings through the several and numerous movements you can do with your hands.

The use of hands as an interaction medium requires a series of processes that naturally added immersion and interaction to the involved VR system.

Specifically, the development is based on the use of data gloves in order to incorporate attractive features for interaction within the virtual world. The conducted research and work is mostly based on gesture and real-time movements hand recognition. The included features are: hand tracking, navigation on stage and object manipulation.

The system allows the specification and recognition of dynamic gestures defined by sequences of dynamic and static hand poses (in order to expand the expressivity potential of the user and not to feel restricted). Each gesture has its own recognition process that tries to recognise the gesture using the incoming pose data. The recognition processes for each gesture operate in parallel.

The detected gestures are very easy to learn and do not require any special attention from the user.

By the moment, some systems aspects are beta version. Thus, future works will be oriented to improve environment issues, such as hardware platform. Even though the system allows a user interactivity in real-time, meaningful feedback and learning through an interface. We consider that the system should provide the necessary multi-VR media [23] and multi-platform structure and optimise the handling of 3D objects in the scenario using new libraries of physics or reprogramming of existing ones.

We think that the path leading to a natural and realistic inclusion of nonverbal communication in virtual environments is long and challenging, but crucial for the quality of interactions within these environments.

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