Multiple Degrees-Of-Freedom Input Devices for Interactive Command and Control within Virtual Reality in Industrial Visualizations

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ABSTRACT

The aim of this research is to present a new multimodal interaction mapping framework for 3D object manipulation within the virtual reality (VR) realm, by leveraging the advantages of having multiple DoF (Degree of Freedom). In this new software engineering designed framework, interaction devices such as the keyboard, mouse, joystick, and specialist devices for 3D interactions; the Wing [5] [4] and the 3D connexion spacenavigator, can all be combined to provide a more intuitive and natural interaction command system. This can be applied to many different specific systems including industrial applications within the petroleum, geology and materials sciences.

Key words: Virtual Reality, 3D Interactions, Input Devices, Human-Computer Interactions, Human Interface Device, Multimodal Interaction, Degrees of Freedom, Ontology

1. INTRODUCTION

With advances in technology, VR has become a powerful tool for interactive visualization and immersion of the user in 3D virtual spaces [1] [3] Despite having many 2D and 3D input devices for the exploration of large-scale 3D datasets, it is still difficult to navigate in unknown visual landscapes and access information simultaneously [2] (from a menu for example). Unfortunately, not all combinations of input and display devices can work together in a suitable and useful manner, either because they are not capable of 3D input or because, for instance, they need a hard table surface to work properly.

Therefore, the purpose of this study is, firstly to provide an overview of existing technology and to identify combinations of input and display devices that have proven to work well. Then, based on this ontological overview [4], we are designing a new framework that allows users to switch between different modes of functions depending on the combination of the input devices. In this framework, we offer multiple actions for monitoring 3D structures which best fit the reality allowing operators to perform multiple activities in the industrial field such as exploration of 3D environment reconstructions to observe at various positions or to find out where possible hydrocarbon is below thousands of feet below the earth surface.

Specifically, we are exploring various 2D and 3D interaction paradigms and their utility in analysing the 3D scanned structure used by petrochemical industry to generate tessellated surfaces from point clouds. This has been chosen as it incorporates complex navigational tasks that require more than six degrees-of-freedom user input and is a typical example of an application where multiple renderings of an object from various angles and viewpoints may lead to new insights.

Finally, this project will also study aspects of human-computer interaction and the human brain response behaviour when the operator is managing multiple combinations of inputs devices for 3D manipulation, determining if the operator is able to complete the task effectively and evaluating the means for a user to transmit information to a computer through these combinations.

2. METHOD AND APPARATUS

We are designing a novel component that will consider the current user context and an ontology of the 3D input devices, with semantic integration component, to create an interaction matrix of functions. These map object-oriented specific

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functions that manipulate input values to an application. Thus, the system can understand the user intention and assist him in achieving his goal in the handling process.

Our new framework is split into five layers and based upon the Open Systems Interconnection project (International Organization for Standardization ISO), identification IEC 7498-1.

2.1 Physical layer

This is the lowest layer of this framework where a method for implementing USB communications providing user interface measurement and detection is executed. After all the input devices are connected to the system, they are given a unique ID and then these values are saved in an array called "INPUTDEVICELIST" as seen in Figure 1. This array will be used in the next layers to map all the possible movements to do in the 3D software with the input devices recognised in this level.

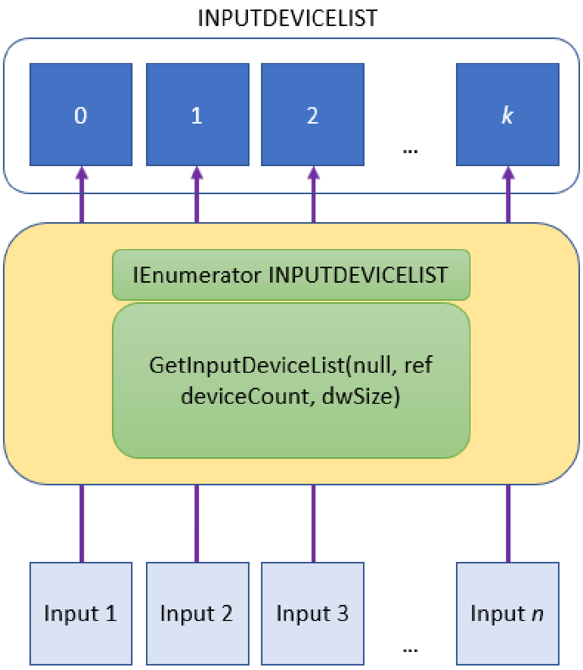

Figure 1: The identifying and recognition subprocess where an array called "INPUTDEVICELIST" saves the PATHFILE name for each component to be used in the next layers of the framework.

2.2 Driver layer

In this second layer, the devices are auto-calibrated to examine each input request for certain qualifying criteria, for example, to eliminate noise. Once the devices are calibrated, our framework is responsive enough to feed and process the data collected from the input devices connected to the system and map it to the USB HID class specification of the operating system. This is to set all the attributes of the devices and enable all the axis and properties of the input devices.

Then, our framework sorts the devices based on their movement. With this, the framework can determine which fields play important roles in what circumstances and in what combinations. For instance, if the user connects two device inputs (having two mouse devices, one smaller than the other), the first mouse to move becomes “input 1” and the additional mouse is added as “input 2” and so on.

2.3 Transport layer

Our framework needs to be responsive enough to listen for USB input device events, so that the transport layer will be responsible to map all the operator movements to the visualization software. This layer takes application messages and transmits those message segments into the presentation layer. Once the receiving side has these segments, they are reassembled into messages and passed on to the application layer. The connections are identified and tracked using port numbers that range between 0 and 65,535 and the messages are sent according to the set of instructions of each visualisation software structure.

2.4 Presentation layer

Based on the information saved in the “INPUTDEVICELIST” array, in the presentation layer, our framework sets to each input device a specific action. As an example, let a 2D device be defined as "input 1" and a 3D input device defined as "input 2”. A transfer matrix is also defined where "input 1" is represented in yellow and "input 2" in green, as seen in Figure 2.

In this example, according to the values saved into “INPUTDEVICELIST”, “input 1” can only do movements in x and y axis, whereas "input 2" can enable 6DoF for a 3D exploration. Then, our framework sets all the transfer functions that each device can use for the 3D object manipulator.

The next step is to set for "input 1" all the linear movements in axis x and y that are coloured in yellow, whereas for "input 2", the matrix also sets movements for axis z and includes all the rotational movements pitch, yaw and roll that are coloured in green.

As a result of doing this, our framework allows to use the additional 2D movements for other purposes to compliment the exploration, therefore this algorithm is enabling 8 DoF at once, in addition to the multiple buttons that each device has. It is important to mention that the only limitation for the transfer matrix is related to the set of instructions the application software uses for exploration.

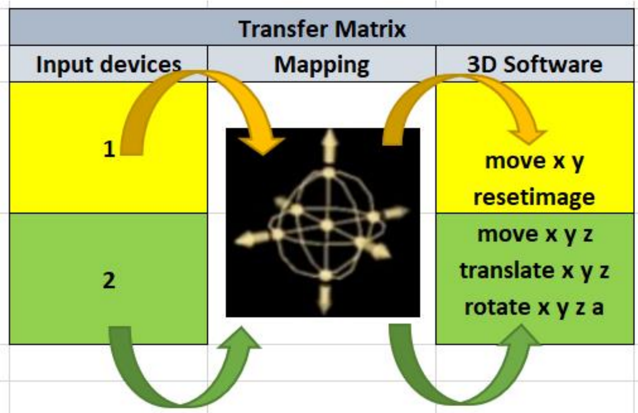

Figure 2: Matrix representation for the integration of a 2D device and a 3D device into the system. In this example, "input 1" is represented in yellow and "input 2" in green. Also, for this example, the matrix will set for "input 1" movement for the camera around the object and to fill the background with "input 1" buttons; whereas "input 2" to translate, rotate and move the camera to the x,y,z position. As a result, we have 8 DoF.

2.5 Application layer

This is the final layer that relies on all the layers below to allow users to interact with the 3D object. In this layer, as the presentation layer delivers information to the application layer for display, the user can use multiple movements in the visualization software. Finally, this layer determines the protocol and data syntax rules at the application level and ensures agreement at both ends about error recovery procedures.

3. CONCLUSION

To deepen our understanding of input devices, particularly those with high degrees of freedom, this research will explore device influence on the user's ability to coordinate controlled movements in a 3D interface. Additionally, a new framework to enable multiple input devices at once based on movement efficiency, is proposed and applied to the evaluation of various 2D and 3D devices.

4. AUTHORS AND COLLABORATION

This is a Computer Science focused research project sponsored by CONACyT-SENER Hidrocarburos and applications for this new framework, will be within the UAV control environment, 3D volume analysis for Materials Scientists and data analytics for the petrochemical communities; all with links to groups at the University of Manchester.

5. REFERENCE

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