SCIRES it
SCIentific RESearch and Information Technology
Ricerca Scientifica e Tecnologie dell'Informazione
Vol 6, Issue 1 (2016), 79-86
e-ISSN 2239-4303, DOI 10.2423/i22394303v6n1p79

A FRAMEWORK FOR REMOTE 3D INTERACTION WITH HANDHELD DEVICES: APPLICATION TO A 3D HERITAGE GALLERY PROTOTYPE

Alejandro Rodríguez, Alejandro León**

* Virtual Reality Lab, University of Granada– Granada, Spain.

Abstract

In this work we present a framework for fast developing of remote controlled 3D applications of digital heritage. The framework relies on standard technologies and does not have special hardware requirements since just a smartphone, a remote 3D application and a wireless connection are required to set up the system, making it ideal for live environments where attenders can use their own smartphone to interact with remote 3D digital content.

The framework provides a set of single-handed interaction techniques for smartphones and also provides with connection capabilities allowing to remotely interact with 3D content by combining the modern 3D sensing capabilities of these devices with touch-screen inputs. The prototype was set up and presented at the Digital Heritage 2015 Exposition, where attenders were able to remotely interact with 3D heritage models.

Keywords

3D interaction, Smartphone, Interactive Graphics

1. *Introduction*

Over the last years, heritage is being transfigured into new digital representations of the available information. Much of this new content comprises 3D information that can be easily explored and manipulated using new proposals such as 3D reconstructions and virtual environments, which raises their position in accessibility. This is the case for many previous works, such as the work of Webel, Olbrich, Franke and Keil (2013), exploring low-cost virtual reality setups of cultural heritage artifacts, the web-based visualization tool proposed by Manferdini and Remondino (2010) or the multimedia cultural heritage content presented by Beraldin, Picard, El-Hakim, Godin, Valzano and Bandiera (2005), showing three real cases with a very practical view. In the case of interactive approaches, it is required a set of 3D interaction techniques to allow the users to intuitively manipulate and explore the 3D content.

Many devices have been introduced to perform 3D interaction intuitively. Some examples are found on the work of Wingrave, Williamson, Varcholik, Rose, Miller, Charbonneau, Bott and LaViola (2010), exploring the use of the Wiimote for remote 3D interaction, and the work of Held, Gupta, Curless and Agrawala (2012), where a Kinect device is used to produce 3D animations by interacting with physical puppets.

Although these devices provide useful interaction metaphors, the non-standard hardware and software components of the proposed setups lead to a poor scalability for live environments where many attenders want to interact with many different virtual reconstructions and costly setup requirements.

In this work, we present a remote interaction framework for smartphone devices, providing a set of single-handed interaction techniques described in the work of Rodríguez and León (2015) and the required connection capabilities for an easy setup on live environments. Currently, the framework allows to easily develop an Android application to connect and control a remote 3D application. The interaction metaphors require no external tracking and most modern smartphones can be used to perform the interaction, allowing thus the users to interact with their own devices.

A 3D gallery prototype has been developed to showcase the different interaction techniques combining the 3D sensing capabilities present in modern smartphones with the touchscreen inputs to issue 3D commands to the remote application.

1.1 Motivation and related work

The addition of multi-touch input and 3D capabilities to mobile devices has motivated many works regarding their use for 3D interaction tasks. Some examples can be found in the works of Steinicke, Hinrichs, Schöning and Krüger (2008), discussing the use of mobile multi-touch devices for 3D interaction tasks, and Telkenaroglu and Caping (2013), revisiting existing techniques for touch-based 3D interaction and proposing a new set of techniques adapted to mobile devices. The works of De Souza, Carvalho, Barth, Ramos, Comunello and Von Wangenheim (2010) and Katzakis, Hori, Kiyokawa and Takemura (2011) propose the use of the built-in sensors to perform 3D related interaction tasks.

The use of these interaction techniques has been proven successful in different contexts. Mossel, Venditti and Kaufmann (2013) apply smartphone interaction metaphors to manipulate augmented reality applications. Medeiros, Teixeira, Carvahlo, Santos and Raposo (2013) apply external tracking to a tablet device to provide with an interaction tool for immersive environments with engineering applications. A cross reality system is proposed by Davies, Miller and Allison (2013), also relying on device tracking to explore virtual reconstructions of cultural heritage sites.

The prototype presented in this work is aimed to show the suitability of smartphones as remote 3D interaction tools due to modern 3D input capabilities provided by the built-in sensors and their widespread use. While the idea of using smartphones as remote 3D controllers is not new, the proposed techniques have been designed to intuitively cover all the canonical 3D inspection tasks, established by Bowman, Kruijff, LaViola and Poupyrev (2004) with single-handed operations, thus allowing to ergonomically control the application while holding the device in its natural holding position.

The developed framework is built based on standard technologies and no special hardware is required aside from a smartphone, therefore an easy setup is possible even in live environments such as an exposition, where the visitors can use their own device to interact with digital 3D content.

1.2 Innovation

In this work, we demonstrate that a Smartphone can be used as a remote 3D interaction device applied to remote digital heritage content. The implemented interaction techniques provide enough richness to perform all the canonical 3D interaction tasks in an ergonomic and intuitive way, and the developed framework allows a very simple setup for live environments.

The proposed 3D gallery prototype was presented at the Digital Heritage 2015 Exposition. Attenders were able to interact with the 3D gallery using their own smartphones and gave positive feedback regarding the proposed techniques.

The developed framework, together with some demos showcasing its features, is freely available at "wdb.ugr.es/~alejandrora/s3di/". Its modular implementation allows to easily include new interaction techniques or communication protocols.

2. Framework implementation

The proposed framework sustaining the presented prototype is responsible for both the handling of the device 3D inputs and the communication between the device and the remote application. Fig 1 shows an overview of the framework structure.

2.1 Device Interaction module

The device interaction module implements all the interaction techniques proposed by Rodríguez and León (2015). By using the sensors present in modern smartphones, the *orientation manager* performs a continuous tracking of the current orientation of the device by means of sensor fusion techniques, providing an updated rotation matrix which express the current orientation. This orientation, calibrated as explained in (Rodríguez & León, 2015), is combined with touch inputs to provide an intuitive interaction metaphor, including translation, scaling and rotation operations.

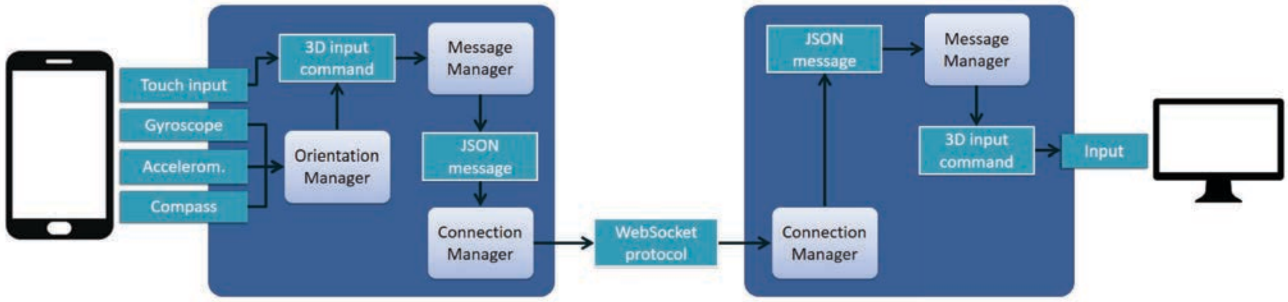

Fig. 1 Overview of the developed framework. The different managers are independent and can be easily replaced for other implementations if different technologies want to be used.

2.1.1 Translation

When the user's finger moves over the screen, a 2D vector is generated using the x and y finger displacements. This vector is transformed into a 3D vector (with a zero z coordinate) and rotated by composing it with current rotation matrix.

This 3D vector is sent to the remote application, which will replicate the 3D movement of the finger onto the virtual object. Fig. 2 shows an example of different results produced by the same touch input when the device is held with different orientations.

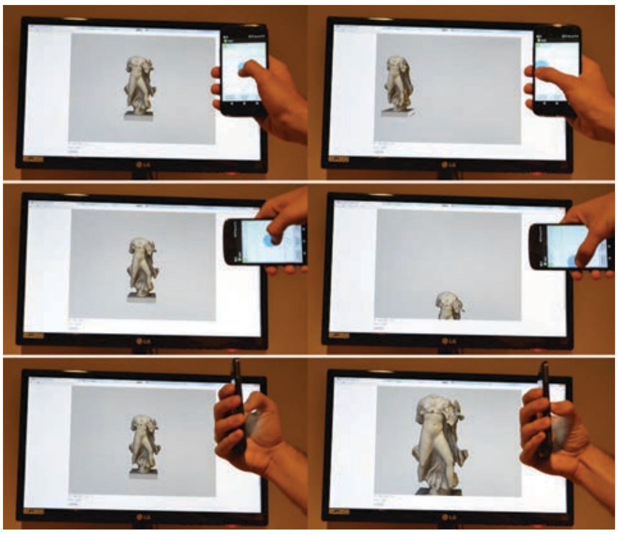

Fig. 2 The same touch input while holding the device in three different orientations produce different 3D displacements of the virtual object.

2.1.2 Scaling

We have limited the scaling interaction to uniform scaling since the main objective of scaling during inspection is either to zoom in and capture details on the virtual objects or zoom out to obtain a more general view.

A slider-type touch interaction is enough to enable these operations by simply obtaining a scaling factor $0 < s < 1$ for left displacements in the slider and $s > 1$ for right displacements, as can be seen in Fig. 3.

2.1.3 Rotation

Two different approaches have been implemented to perform rotation operations. First, the rotation that the device is undergoing can be directly applied to the virtual object, imitating the way a real object would be rotated by the user (see Fig. 4).

While this metaphor is very natural, it can lead to uncomfortable wrist motions in order to reach some rotated configurations. Also, very subtle rotations can be difficult to apply due to the noise introduced by the sensors or the user's motions.

Therefore, the *weighted rotation mapping* metaphor (Rodríguez & León, 2015) has been implemented in order to maintain the natural, intuitive benefits of this metaphor and increase the ergonomics and precision during the rotation.

Through a slider touch input, the user defines a weighting factor α in a similar way as the scaling factor was selected. This weighting factor decreases or increases the amount of rotation applied to the remote object, allowing to increase the accuracy when required and increase the range of rotated configurations obtained through small motions of the wrist, as can be seen in Fig. 5.

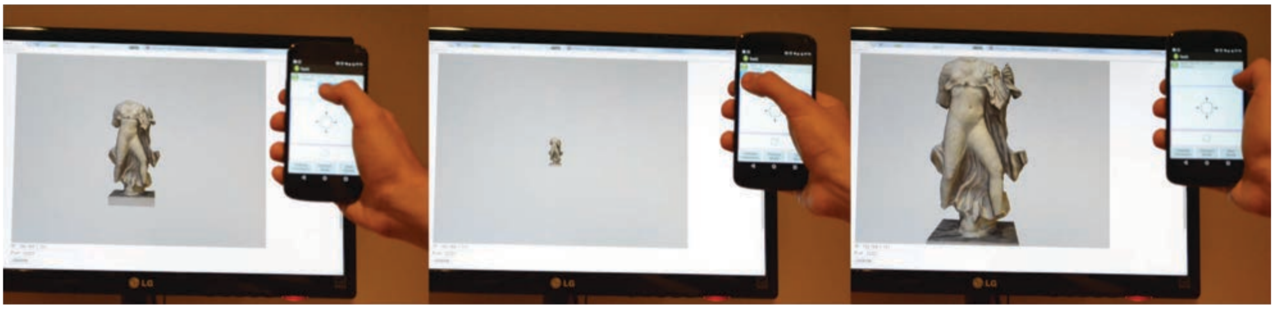

Fig. 3 A simple slider-type interaction allows to remotely modify the scaling of the object.

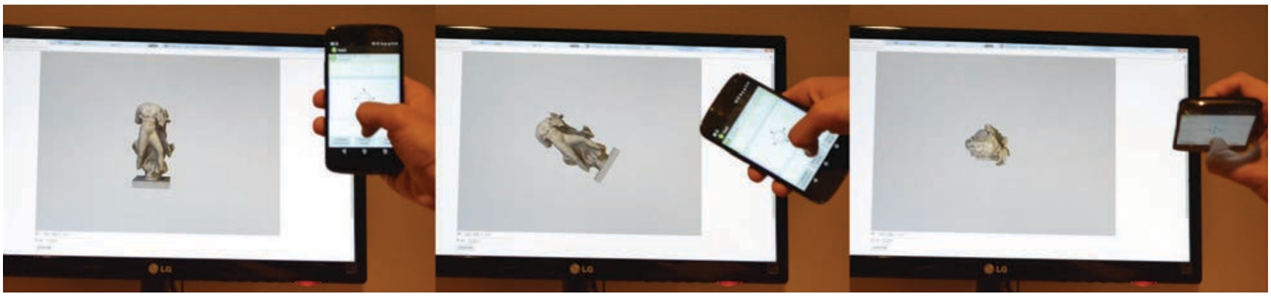

Fig. 4 The direct rotation mapping naturally transfers the rotation of the device to the remote object. Although the interaction is very intuitive, uncomfortable wrist movements are required to reach certain rotated configurations, limiting the use of this metaphor.

2.1.4 System control

Aside from direct interaction over the 3D content, a means of issuing commands to control the application state is required for any general 3D interface (Bowman et al., 2004).

As smartphones allow to design and display any customized widget-based interface, remote system control is trivially handled by connecting the displayed interface with the remote application API.

The proposed framework allows to easily perform this connection. For instance, the system control of our gallery prototype simply consists of two buttons, each issuing a remote command that let the user switch between the models in the gallery, going to the next or the previous one.

2.2 Communication module

The communication module is designed to provide a multi-platform, multi-language communication channel between the device and the remote application. Since the proposed prototype is a front-end web application, the WebSocket protocol is used by the *connection manager* to stablish and maintain the communication. For the message formatting, the JSON protocol is used by the *message manager*.

Both the WebSocket protocol and the JSON protocol are standard and available in many platforms and languages. The device side is implemented in Java for the Android O.S., and the application side is implemented as a Javascript module of the web application.

This module can be easily adapted to other standard or non-standard protocols attending on the specific demands of each setup. For instance, the standard TCP/IP Sockets or the Bluetooth protocol are both implemented in Android and their use is straightforward.

2.2.1 Device-application connection

To avoid manual connection of the device to the remote application, a service discovery protocol must be used (Helal, 2002), and depending on the constraints of each specific setup, a server-based, centralized approach such as DHCP or a distributed approach such as SSDP will enable fast and automatic remote connection.

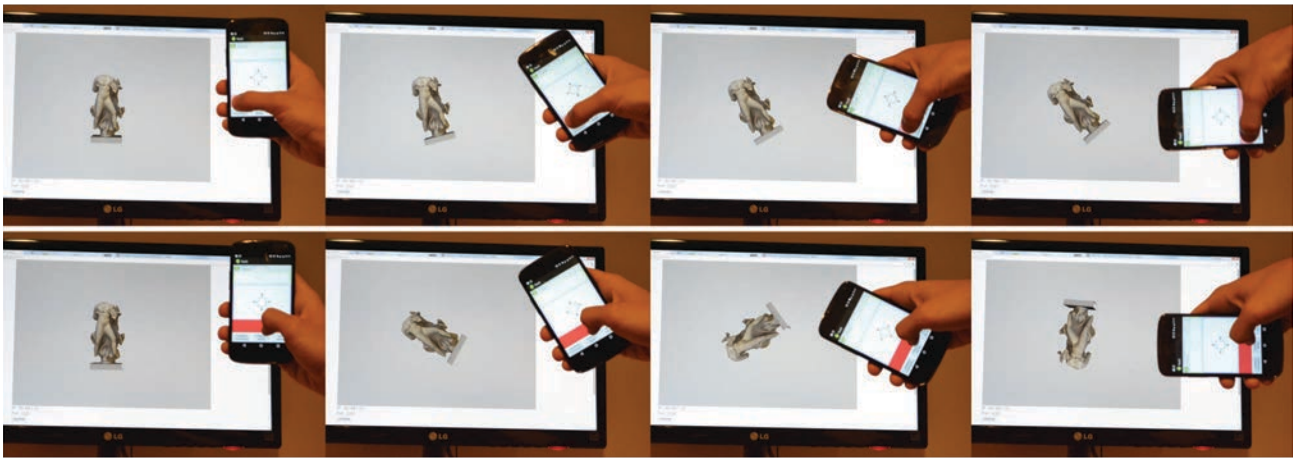

Fig. 5 Through the use of the weighted rotation mapping, the same ergonomic wrist motion can lead to precise rotations of the remote object (top) or highly rotated configurations (bottom).

3. 3D gallery prototype

The proposed framework was used to interact with a 3D gallery prototype to explore different digitized heritage artifacts. The prototype was implemented as a Javascript front-end web application using WebGL, and the models were obtained from Sketchfab (sketchfab.com).

No special back-end features are required for this application, and all the technologies used are standard, thus any web server provides support for its deployment.

Moreover, the front-end application avoids any installation requirements and only a modern web browser is required, thus a large-scale deployment is performed in a straightforward manner.

3.1 System setup

Our prototype features a single application and multiple devices, similar to what could be used on live environments where attenders would interact with one or more remote applications.

When a single application is available, a client-server approach for the connection would be the easiest approach for an automatic connection. However, front-end web applications cannot create socket servers due to security issues.

To avoid the use of a dedicated connection server, we invert the role in the connection protocol. The socket server is created by the device when the Android interaction application is launched, and the 3D gallery application actively searches for active devices until a candidate is found. A simple service discovery protocol was implemented on the gallery application side to detect new devices, based on simple iterative LAN IP pinging.

If more than one application is available, a dedicated back-end server could monitor all the active applications and devices and perform the required connections, enabling an easy large-scale, installation-free deployment.

3.1 Live exhibition and feedback

The developed prototype was presented at the Digital Heritage 2015 Exposition. For the setup, only a standard PC and a Wi-Fi network were required.

On the PC side, a web application was launched, prompting the attenders to download an Android application and use their smartphones to interact with the system.

When a user launched the Android application, it was automatically detected by the service discovery protocol and the 3D interaction prototype was launched and connected to the user's smartphone.

Many attenders were able to test the proposed prototype. The users were asked to perform all the implemented metaphors to explore the gallery models. All the users successfully performed the different tasks, and the general claim was that they found the system easy to use and were able to test all of its functionality.

The most salient feature highlighted by the attenders was the intuitiveness of the proposed rotation techniques, and the precision obtained by the *weighted rotation mapping* method.

4. Results and conclusions

In this work, a remotely controlled 3D gallery prototype has been presented, showcasing the use of smartphones as remote 3D interaction devices for digital heritage applications. The developed framework allows an easy setup of a system using this strategy in live environments without any special hardware requirements, where attenders can use their own smartphones to interact with remote 3D applications shown in standard screens.

The developed framework implements a set of single-handed interaction techniques, general enough to cover all the main 3D manipulation tasks, designed to allow intuitive, ergonomic interactions, avoiding the use of any external tracking support.

The source code of the framework, together with some demos can be downloaded from wdb.ugr.es/~alejandrora/s3di/.

An informal evaluation of the setup yielded positive feedback from many users; however, a proper, formal evaluation and validation must be performed before making formal claims regarding the performance of the proposed metaphors with respect to other, existing techniques.

The developed framework suffices to perform basic 3D interaction tasks, however, more advanced applications could be enriched by adding output capabilities to the device, for example, showing additional 2D and 3D content in the smartphone screen. Moreover, the framework is developed following a modular approach, and could be extended in several ways, for instance, by implementing more application-specific interaction metaphors for a more complex and rich user experience, or by handling several remote devices interacting in a collaborative environment.

Acknoledgements

This work is supported by the “Formación de Profesorado Universitario, Plan Propio de Investigación” program of the University of Granada. This work is also supported by the project TIN2014-60956-R of the Spanish Ministry of Economy and Competitiveness with FEDER funds.

REFERENCES

Webel, S., Olbrich, M., Franke, T., & Keil, J. (2013). Immersive experience of current and ancient reconstructed cultural attractions. In A. Addison, L. De Luca, G. Guidi, & S. Pescarin (Eds.), *Digital Heritage International Congress (DigitalHeritage)*, Vol. 1, (pp. 395-398). Denver, CO, USA: IEEE.

Manferdini, A. M., & Remondino, F. (2010). Reality-based 3D modeling, segmentation and web-based visualization. In *International Congress on Digital Heritage 2010* (pp. 110-124). Berlin-Heidelberg, Germany: Springer.

Beraldin, J. A., Picard, M., El-Hakim, S. F., Godin, G., Valzano, V., & Bandiera, A. (2005). Combining 3D technologies for cultural heritage interpretation and entertainment. In *Proceedings of SPIE 5665, Videometrics VIII*, (pp. 108-118).

Rodríguez, A., & León, A. (2015). Smartphone-based remote 3D interaction for digital heritage applications. In *International Congress on Digital Heritage 2015 (Digital Heritage).* Denver, CO, USA: IEEE.

Bowman, D. A., Kruijff, E., LaViola Jr, J. J., & Poupyrev, I. (2004). *3D user interfaces: theory and practice*. Redwood City, CA, US: Addison-Wesley Longman Publishing Co

Steinicke, F., Hinrichs, K. H., Schöning, J., & Krüger, A. (2008). Multitouching 3D data: Towards direct interaction in stereoscopic display environments coupled with mobile devices. In *Proceedings of AVI Workshop on Designing Multi-Touch Interaction Techniques for Coupled Public and Private Displays* (pp. 46–49). New York, NY, USA: ACM.

Telkenaroglu, C. & Capin, T. (2013). Dual-finger 3D interaction techniques for mobile devices. *Personal and ubiquitous computing*, 17(7), 1551–1572.

de Souza, M., Carvalho, D. D. B., Barth, P., Ramos, J. V., Comunello, E., & von Wangenheim, A. (2010). Using acceleration data from smartphones to interact with 3D medical data. In *23rd SIBGRAPI Conference on Graphics, Patterns and Images* (pp. 339–345). Denver, CO, USA: IEEE.

Katzakis, N., Hori, M., Kiyokawa, K., & Takemura, H. (2011). Smartphone game controller. In *Proceedings of the 74th HIS SigVR Workshop,* □ □ □ □ □ □ □ □ □ □ □ □ □ □ □35(25), (pp. 55-60).

Mossel, A., Venditti, B., & Kaufmann, H. (2013). 3DTouch and HOMER-S: intuitive manipulation techniques for one-handed handheld augmented reality. In *Proceedings of the Virtual Reality International Conference: Laval Virtual*. New York, NY, USA: ACM.

Medeiros, D., Teixeira, L., Carvalho, F., Santos, I., & Raposo, A. (2013). A tablet-based 3D interaction tool for virtual engineering environments. In *Proceedings of the 12th ACM SIGGRAPH International Conference on Virtual-Reality Continuum and Its Applications in Industry* (pp. 211-218). New York, NY, USA: ACM.

Davies, C., Miller, A., & Allison, C. (2013). Mobile cross reality for cultural heritage. In *Proceedings of Digital Heritage International Congress* (Vol. 1, pp. 331-338). Denver, CO, USA: IEEE: IEEE.

Wingrave, C. A., Williamson, B., Varcholik, P. D., Rose, J., Miller, A., Charbonneau, E., Bott, J., & LaViola Jr, J. J. (2010). The wiimote and beyond: Spatially convenient devices for 3D user interfaces. *Computer Graphics and Applications*, 30(2), 71-85.

Held, R., Gupta, A., Curless, B., & Agrawala, M. (2012). 3D puppetry: a kinect-based interface for 3D animation. In *Proceedings of the 25th annual ACM symposium on User interface software and technology* (pp. 423-434). New York, NY, USA: ACM.

Helal, S. (2002). Standards for service discovery and delivery. *IEEE pervasive computing*, 1(3), 95-100.