Digital Mockup: Touching the 3rd Dimension

Final Report

Simulacros Digitais: Modelando a 3ª Dimensão

Relatório Final

INESC-ID Technical Report # **vimmi/02/2016**	
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Data: Date:	30/06/2016

Reference: PTDC/EEI-SII/3154/2012

Project WWW Site: https://tecton3d.wordpress.com/

Contents

Summary

In this section we relate the actual performance of the tasks throughout the years of the project with the task description and expected results as established in the project proposal. Overall, there were no significant changes as compared to what had been outlined during the application. The project results largely exceeded the expected results, which became possible during the second and last year of execution. That goal was attained through an increase in both the number and the nature of collaborations. Concretely, by increasing the research team with more MSc students (2 in FAUL, 2 in INESC), establishing connections with industry partners, namely ARX and EMBAIXADA and finally cross-pollinating this research with other ongoing research projects at INESC-ID and FAUL.

Objectives

Current architectural visualization software based on virtual environments (VEs) supports mainly 3D animation and automatic navigation. Despite the growing popularity of VEs, they still need to go a long ways to replace or even augment desktop CAD systems in the modeling of 3D scenes. To address this problem requires developing new techniques for multimodal interaction based on hand gestures, more suitable for tasks of traditional 3D modeling devices and make more attractive mixed reality techniques. These techniques, combined with procedural modeling, address the lack of expressiveness or naturalness of conventional CAD operations. To this end we want to create a new design framework combining stereoscopic viewing with modeling, simulation and reactive content. To this end we will work on recognizing bi-manual gestures using 3D sensors acquiring information from follow up body posture using commodity sensors. Such interaction techniques combined with procedural based modeling primitives which extend shape grammars, will allow incremental changes to exploit the advantages of direct 3D manipulation in richer ways.

SUMMARY OF ACCOMPLISHMENTS

Please refer to end of report for detailed accounts. The aggregate figures are listed here

Publications:

	Complete	Ongoing	Planned	Dev (+ongoing)
Books	1	(due 2016)	1	0%
International Journal Papers	10	7	6	+66% (+166%)
Internat. Conference Papers	20		9	+122%
National Conference Papers	9		1	+800%
National Journal Papers	1			=100%

Advanced Degrees:

MsC Theses	**7**	**3**	**2**	**+133% (+214%)**
PhD Theses	**4**	**6**	**3**	**+33% (+233%)**

Dissemination:

Keynote Talks	**9**
Seminars / Invited Talks	**15**

1 REQUIREMENTS ANALYSIS

The project Tecton 3D Task 1 was a requirement analysis, aiming to gather relevant information that could support the creation of the desired virtual reality system, which has the goal of improve the conceptual design phase in the architectural design process. This task had three distinct objectives, which were organized into three different sub-tasks. Sub-task 1.1 consisted in identify the benefits of virtual reality and the needs of the users in the field of architecture, taking into account their workflow. Under this sub-task, were developed a Generic Characterization of Users and Tools (through a survey to architects by internet), a Review of existing 3D Modelling Software (analyzing its most important features) and a Case Study Analysis, the architectural office ARX Portugal (where were made an interview with one of the office founders and the monitoring of the office activities). Sub-task 1.2 intended to define the modelling and editing operators required for an architectural project, and how they can take advantage of interactive procedural techniques to increase efficiency in modelling tasks. Sub-task 1.3 served to define the metaphors of interaction and usage scenarios that best fit the needs, preferences, expertise and capabilities of the users in a viewing environment in mixed or virtual reality, such as a table for stereoscopic visualization or a virtual reality glasses. For the accomplishment of sub-tasks 1.2 and 1.3, when sub-task 1.1 was being executed, preliminary prototypes were developed, that allow to sketch, model and explore three-dimensional shapes in an immersive virtual reality environment. These preliminary prototypes, such as Air Sketching, World Builder, Walking-in-place and City Wave, allowed to test initial ideas on how is that virtual reality could bring benefits for the initial phase of the design process in architecture projects. They served as reference for the prototypes developed in the following project tasks.

1.1 MAIN RESULTS

The main results of Task 1 and of sub-tasks 1.1, 1.2 and 1.3 allowed to realize that architects prefer tools that allow them to explore ideas in three dimensions in an easy, fast and appealing way.

Architects prefer to use traditional tools like Sketch by Hand and Mockups in the creative and conceptual phase of the project, because current software operates according to a WIMP (Windows, Icons, Menus and Pointers) logic that has limitations in the type of interaction that provides to the user, restricting their creative freedom when compared with Sketch by Hand and Mockups. As such, a virtual reality system that can apply the added value of these traditional tools in a computer system is important. Another important observation is that many of current software allow procedural modelling (creation of surfaces and solids by defining procedures such as algorithms and shape grammars) through textual scripting and through toolboxes. However, is almost unexplored the use of visual processes like Shape Grammars. Shape Grammars allow to establish visual procedures of transformation of shapes for the modelling activities (for example, a square is transformed into a sphere), which is more similar with the creative process of the architects than the use of textual scripting and toolboxes. As such, it is relevant their application in modelling software.

1.1.1 KEY EVENTS (PUBLICATIONS, CONFERENCES, WORKSHOPS, ETC)

Task 1 results can be found in a submitted list of publications (Number 13 of "International Journal Papers", Number 8 of "Papers in International Conferences" and Number 4 of "National Conference Papers"), the last two presented in conferences. It were also included in the list publications (Numbers 14 and 18 of "Papers in International Conferences") in the context of a PhD research thesis that seeks to address energy as a requirement to be taken into account in the conceptual phase of the architectural project, allowing the design of shapes of building envelopes (roof and facades) that are more efficient regarding their energetic performance. In the end of Task 1 a Workshop was made, on 11th November of 2014, in the rooms 2.6 and 2.8 of IST in Taguspark. Took part on it students of architecture and informatic engineering. During the morning, there was a conference session regarding the conceptual process in the architectural project and the potentialities of the contribution of virtual reality in that process. In the afternoon, a serie of experiments were realized, where students were able to experience and give their opinion on some of the preliminary prototypes developed. It was also made a brainstorming session with some of the researchers of the Tecton 3D project, about which modelling operators could be applied in a virtual reality immersive environment. Both sessions, experiments with students and brainstorming, served together with the results obtained in the sub-tasks of Task 1, for creating a set of guidelines for the next steps to follow in the development of the prototypes.

2 PROCEDURAL TECHNIQUES AND SHAPE GRAMMARS

The objective of Task 2 was to make the most out of both procedural techniques and shape grammars as modelling tools in service of the project's objectives. Two modules have been produced as a response to Task 2.

The first subtask focused on the application of shape grammars to curves and curved surfaces. Subtask 2.1 was carried out in the scope of both the Tecton 3D project as well as an ongoing PhD research on "Mass Customization of Ceramic Tableware". Such system encompasses an automatic

design module supported by a shape grammar, whose design rules were partially implemented into Unity as an editable parametric model of a tableware collection . Therefore, it was necessary to implement a set of C# functions that enable Unity to generate at run-time the double-curved surfaces of tableware elements such as plates and cups.

The following subtasks included the implementation of shape grammar methods onto the visualization prototypes developed within the scope of the project. Such implementation was carried out in the scope of both the Tecton 3D project as well as an ongoing PhD research entitled "Onto-Grammars - from description to design", as a module called Virtual Grammars. The main objective of this subtask was to enable the prototype's user to both create simple design rules, and later to use those rules to edit the conceptual model. Besides, considering the Shape Grammar formalism, the Virtual Grammar prototype took into account the interaction paradigm, reflecting on which gestures would be more suitable for actions such as creating and recalling rules.

3 EXPLORING THE VIRTUAL MOCKUP

Even during the initial conceptual stages of digital architectural mockups, interviews with architects suggests the need to explore and navigate through the design models. Therefore we developed a technique that takes advantage of a wall-sized large scale display and natural gait movements to navigate through virtual environments, called Walking-in-place (WIP).

WIP is a locomotion technique that allows people to travel in a linear manner in virtual environments (VEs) without significantly changing their physical position on the floor, and consequently, the combination of large scale display with a more natural way of locomotions provides for an improved feeling of `being there` that traditional Desktop plus WIMP cannot afford. Furthermore, our approach utilizes one Microsoft Kinect depth camera to track people's body movements which makes the setup and apparatus cost effective and portable.

Results from usability evaluations with architects suggests that our approach successfully provides an appropriate user experience for architectural review of digital mockups. While, at the same time, maintains the perception of distance and the architectural mockup size and proportions. Despite that, architects felt that the interaction design were too overwhelming for demonstrations to possible clients and shareholders of large architectural projects. Therefore, we developed a 3D Model Inspection Tool for design and review meetings, where participants can travel through virtual mockups using the Thumbcam navigation technique in a personal handheld tablet devices while sharing a common point-of-view using a large scale display.

Our WIP technique manuscript is currently under review on the International Journal of Human-Computer Studies, while Thumbcam was accepted as a poster at the ACM Interactive Tabletops and Surfaces(ITS2014) conference.

4 DIRECT MODELING VIRTUAL MOCKUP

An interactive 3D modeling environment, called Maquetteer, was developed to assist the design of early stage maquettes using virtual reality technologies. Since the focus was on conceptual modeling, the Maquetteer environment allowed users to perform 3D sketches of buildings without intricate and complex details. We took advantage of a constrained modeling metaphor which consists of snapping parallelepipeds to a rectangular regular grid, similar to the Minecraft video game but far more effective. Content could be created with or without an urban environment. The user could view the model on a 1:1 scale, providing an immersive experience to the user, which can explore the content by walking inside the virtual space, limited only by the physical dimensions of the room.

Interaction techniques can be considered as being simple but not simplistic. The user holds a drawing device enabling him/her to draw in mid air, evoking rectangular prisms or blocks of various dimensions, shapes and orientations. Content could be created/deleted, scaled, rotated, translated, copied, duplicated in such a way that patterns could be easily. In other words, these tools are a set elementar procedural modeling operators for direct manipulation of 3D content. Once the Maquetteer application was concluded, we developed a stand-alone executable that was used for demonstrations for any academic, industrial or professional visitor.

All the software was developed in Unity 3D with scripts written in C# and GLSL shaders.

The major results from this task are a fully functional software prototype for early stage concept modeling in Virtual Reality, a demonstrator for exhibiting the application, and a public presentation for a Workshop on Virtual Reality in Architectural Concept Modeling.

A manuscript which was initially accepted as a poster paper at a top venue (ISMAR 2016, A* CORE conference) which was strengthened and submitted to a more impactful venue, namely Automation in Construction (Q1 journal).

5 USABILITY STUDIES AND USER EVALUATION

Usability studies were conducted to test the Maquetteer interactive 3D modelling environment, which were divided (initially) in two stages: one with lay people and the other with professional architects. Close to the end of the Project, we conducted new usability studies with professional architects to evaluate the Maquetteer environment in collaborative work sessions, with multiple architects interacting simultaneously while immersed in the same VR 3D modelling session.

The main goal of the usability studies with lay people was to assess the adequacy of the Maquetteer environment to the creation of simple conceptual 3D architectural models. Users were asked to evaluate the system's precision, ease of use, its interface and how comfortable it was to use. This study consisted in the comparative evaluation of Maquetteer versus Trimble's Sketchup, a WIMP 3D modeller commonly used in architecture, testing the user's' performance in the replication of simplified 3D architectural models. The promising results from the study confirmed the validity of Maquetteer and were used to further develop the Maquetteer environment, prior to the usability studies with professional architects.

Internationally renowned professional architects were invited to evaluate the Maquetteer environment in two distinct usability studies. The first group of studies followed the Maquetteer's development after the studies with lay people and its goal was to evaluate if Maquetteer – and the direct creation of 3D models in VR – would be a desirable and useful tool in architectural practice. Results from the study confirmed its adequacy as a complementary tool for professional use, especially well-suited to quickly create conceptual models of a project, evaluate designs and test design strategies and various scales.

The most relevant topics from the results of the previous study were then implemented and the system was converted to allow multiple users immersed in the same VR session – only made possible with the acquisition of additional head-mounted displays (Samsung Gear VR). Results from the second group of usability studies involving professional architects confirmed the collaborative sessions to be indispensable in Maquetteer, for it to be applicable in the professional realm.

As mentioned in the previous topic, the results from usability studies with lay people and the first group of studies with professional architects were meanwhile submitted for publication in Automation in Construction (Q1 journal).

6 PROJECT MANAGEMENT + DISSEMINATION

Project Management was greatly facilitated by the use of collaborative Tools, including DropBox for Document Sharing, GoogleDocs for Collaborative Editing and Minute Taking during meetings, Skype for distance collaboration, Doodle for scheduling meetings and events, Wordpress for website and content management, and Trello for deadline and workflow management. The project was structured in a Steering Committee, including the most senior people, an executive committee and a general assembly. All these boards met regularly, at least once every quarter (Steering Committee), every month (General Assembly - all hands meeting) and every other week (executive committee). The project documentation includes a document repository in GoogleDocs (3Gb+) a shared DropBox folder **One of the strong components of the project was the dissemination and organization of International and National events. One highlight is the Springer Book on "Collaboration Meets Interactive Surfaces", edited by Anslow, Campos and Jorge, related to the** CMIS Series of Workshops (2013, 2014, 2015) Co-located with ITS, with one more workshop planned for Q3 2016 (co-located with ACM ISS)

Conferences

We organized or helped organized many scientific events related to the project. Among them we can list the following:

1. **Co-Program Chair**, Eurographics 2016 (Lisbon, Portugal), Joaquim Jorge
2. **Chair**, 31st Spring Conference on Computer Graphics (SCCG) Smolenice, Slovakia 21-24 Abr 2015, Joaquim Jorge
3. **Co-chair** Workshop on **Shape grammars in product design and engineering**, Kyoto Institute of Technology, Kyoto, Japan, March 10th-11th, 2015. J Duarte (with Andrew Li).
4. **Co-Chair** International Conference on CAD and Graphics, Xi'an China 26-28 de Agosto 2015, Joaquim Jorge
5. **Co-Chair** SMI/SPM Shape Modeling International Joint Conference with SIAM Solid and Physical Modeling, HKUST, Hong Kong, Outubro de 2014, Joaquim Jorge
6. **Co-Chair International Program Committee**, International Conference on CAD and Graphics, Hong-Kong China Nov. 2013, Joaquim Jorge
7. **Chair** 2nd Sustainable Intelligent Manufacturing, SIM 2013, Faculty of Architecture, University of Lisbon, Lisboa, Portugal, June 26-29, 2013. José Duarte
8. Tecton 3D Closing Workshop, May 31st 2016, Organized by Rui de Klerk and Eduardo Castro e Costa

Keynote Talks

1. J Jorge, Full Contact: Beyond 2D Interactive Surfaces, ACM/ITS Collaboration meets Interactive Surfaces, CMIS Workshop, Funchal, Madeira 15 November 2015 (25pp),
2. J Jorge, Game Over? New Approaches to Teaching Engineering Courses, SIGGRAPH/Asia Education Symposium, Kobe, Japan, 2 November 2015 (80pp),
3. Duarte, J.P. Inserting new technologies in architectural curricula: from research to practice, and to teaching, ASK conference, Faculty of Architecture, Technical University of warsaw, Warsaw, Poland. February 27, 2016.
4. Duarte, J.P. Inserção de novas tecnologias nos currículos de arquitectura: da investigação, ao ensino e à prática (Inserting new technologies in architectural curricula: from research to practice, and to teaching), V Congresso Internacional de Conhecimento Científico sobre "Inovação, Planejamento Urbano e Tecnologia", Instituto Superior de Ensino do Centro Educacional Nossa Senhora da Auxiliadora - ISECENSA, Campos dos Goytacazes, RJ, Brazil. September 10, 2015.
5. Duarte, J.P. Inserting new technologies in architectural curricula: from research to practice, and to teaching, Keynote Address, National Symposium of Computational Design and Architecture on Sustainable digital ecologies: digital design, material and performance, Faculty of Architecture, Özyeğin University, Istanbul, Turkey. June 25, 2015.
6. J Jorge, Game Over? New Approaches to Teaching Engineering Courses, 9th International Conference on Computer Graphics, Visualization, Computer Vision and Image Processing, Las Palmas de Gran Canaria, Spain (50pp), 22–24 July 2015,
7. J Jorge, Multimodal Interfaces for Content Creation, 31st Spring Conference on Computer Graphics (SCCG), April 2015, Smolenice, Slovakia 21-24 April 2015 (60pp),

8. J Jorge, Touching more than three dimensions: having fun with surfaces, EPCG 2014, Encontro Português de Computação Gráfica, Leiria, Portugal, 13 novembro de 2014 (40pp)
9. Duarte, J.P.; Inserting New Technologies in Architectural Curricula, ADU 2020 Conference on Innovation and Diversity: Challenges and Opportunities in Architecture, Design and Urbanism, Rio de Janeiro, Brazil, November 26-28, 2013.

Seminars / Invited Talks

1. J Jorge & D Lopes, Challenges and Approaches to Interactive 3D Visualization in Clinical Applications, Invited Talk, Congresso Internacional do CiiEM - Centro de Investigação Interdisciplinar Egas Moniz 28 de Nov 2015 (90 pp)
2. Duarte, J.P. Alberti Digital: do tratado à materialização física (Digital Alberti: from the treatise to physical materialization), Public Lecture, Universidade Federal Fluminense, Rio de Janeiro, RJ, Brazil. September 8, 2015.
3. J Jorge, Multimodal interfaces for Shape Exploration: Beyond 2D Sketching, Symposium on Expressive Modelling: New Advances towards the Seamless Creation of 3D Content, Organized by Marie-Paule Cani, Collége de France, 08 June 2015 (110+ people) http://www.college-de-france.fr/site/en-marie-paule-cani/symposium-2014-2015.htm
4. Duarte, J.P. Mass Customization: models and algorithms, Public Lecture, 1st Workshop Beyond Shape, Universidade Lusófona de Humanidades e Tecnologias, part of the research program "New Architectural Approaches to Urban Space Fragmentation" (ARCH@USF), Lisboa, Portugal. May 18, 2015.
5. Duarte, J.P. Alberti Digital: do tratado à materialização física (Digital Alberti: from the treatise to physical materialization), Public Lecture, Universidade Federal Fluminense, Rio de Janeiro, RJ, Brazil. September 8, 2015.
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8. Duarte, J.P. Mass Customization: models and algorithms, Public Lecture, School of Architecture and Landscape Architecture, College of Arts and Architecture, Penn State University, State College, PA, USA. May 11, 2015.
9. Duarte, J.P. Mass Customization: models and algorithms, Public Lecture, Digital Darq: Encontros entre o Passado e o Futuro da Arquitectura, Colégio das Artes, Faculty of Science and Technology, University of Coimbra. April 30, 2015.
10. Duarte, J.P. The ULisboa Faculty of Architecture, Dean's Interchange Meeting on "Us in the world and the world with Us", ETH Zürich, Switzerland, April 15, 2015.
11. Duarte, J.P. The ULisboa Faculty of Architecture, Lecture to Staff, Kyoto Institute of Technology, Kyoto, March 9, 2015.

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14. J Jorge Acrescentando um novo toque a interacção com superfícies, PlayNESTI, Universidade dos Açores, Ponta Delgada, 18 de Março de 2015, (80pp),
15. J Jorge, Adding More than Two Dimensions to Tabletop Interfaces. Univ Macau, 31 Oct 2014

7 CONCLUSIONS

Overall, we consider this Project a resounding success since all objectives were either met or largely exceeded both in terms of scientific output (17 Journal papers, 20 international conference papers, one Springer book and two dedicated workshops) as well as advanced degrees (four PhD theses and seven MSc Theses completed) not to mention the ongoing and fruitful international collaboration between Universidade de Lisboa the Architecture Firms EMBAIXADA and ARX and PUC-Rio. Of special mention it is important to highlight the ongoing and future work (five PhD Dissertations ongoing and three MSc slated to complete in 2016) as well as seven Journal Submissions (under review) at the time of this writing.

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