TÉCNICO LISBOA

Digital Project

Three-dimensional Modelling in Architecture

Fuzeta village virtual model

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Extended Abstract

Dissertation for Master Degree in

Architecture

Jury

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The present dissertation constitutes a report on the development of technologies that aid in the simulation and demonstration of works of architecture and engineering, particularly on the application of three-dimensional modelling tools in the production of virtual models, as well as the exploration and analysis techniques to be implemented on them.

For this purpose an exhaustive account is established, in which is explained the detailed process modelling and development of a three-dimensional model of the Vila da Fuzeta, located in Algarve, Portugal, as well as the problems raised during the execution of the project and alternatives opted to solve them.

Then, in the context of future developments, different interconnections between the main modelling, visualization and analysis technologies available are inferred, as well as their influence on the current process of Architecture, with special emphasis on the main benefits of these changes.

Lastly, it is noted that the development of this case study functions as a support tool for a Doctorate's dissertation, still in development, on the main traditional construction typologies present in Vila da Fuzeta, allowing the validation of the proposed modelling project.

The technologies used for virtual modelling and projection of construction works are becoming more and more noticeably used in the fields of Architecture and Engineering. In fact, resorting to virtual modelling is an event occurring not only in these working fields, but as well as in the vast majority of working fields that involve the production of objects with artistic value.

In comparison, the use of hand drawn sketches or handmade models possesses advantages when compared to three-dimensional modelling, especially when applied to areas such as Traditional Crafting or Fashion. But in other fields such as that of Architecture, Engineering and Design, one usually acquires many more benefits from three-dimensional modelling, as well as having those same benefits constantly being improved in order to make project execution faster and better.

For instance, rendering realistic three-dimensional models is perfectly executable to a quality which makes such render almost indistinguishable from photography, since the three-dimensional model allows a much flexible and reliable method of obtaining photorealistic imagery, without sacrificing quality, at the same time this process is much more facilitated than it would be to acquire photograph of a building, mostly because the modeller is capable of controlling certain components in order to create a scenario, components such as weather effects. Also, technicians can take advantage of these technologies, independently of their expertise, to create models as a single piece with hallow insides, since such pieces can be modelled and printed all at once.

Fig. 1: Example of printed object using the three-dimensional modelling. Due to its complexity, it is not possible to manually creating it as a single piece. (Source: Proto3000.com (2013))

The same way different fields benefit with the use of three-dimensional modelling, this technology is also resorted to in Architecture. Amongst some of the advantages in using virtual models, when compared to more traditional methods of model building or bi-dimensional sketching, are:

- Project visualization is much more flexible, effective and more quickly delivered
- Possibility of verification of conception and execution errors before they may arise during construction phases
- Improved perspectives and viewpoints of interior arrangements (such as kitchens, bathrooms and offices)
- Creation of virtual walkthroughs
- More efficient marketing and publicity tools
- Application and rendering with customized components
- Shortage of error accumulation during project revision processes
- More efficient coordination and communication tools between architects, engineers and landowners
- Improved testing and visualization of textures and construction materials
- Reduction of overall project costs

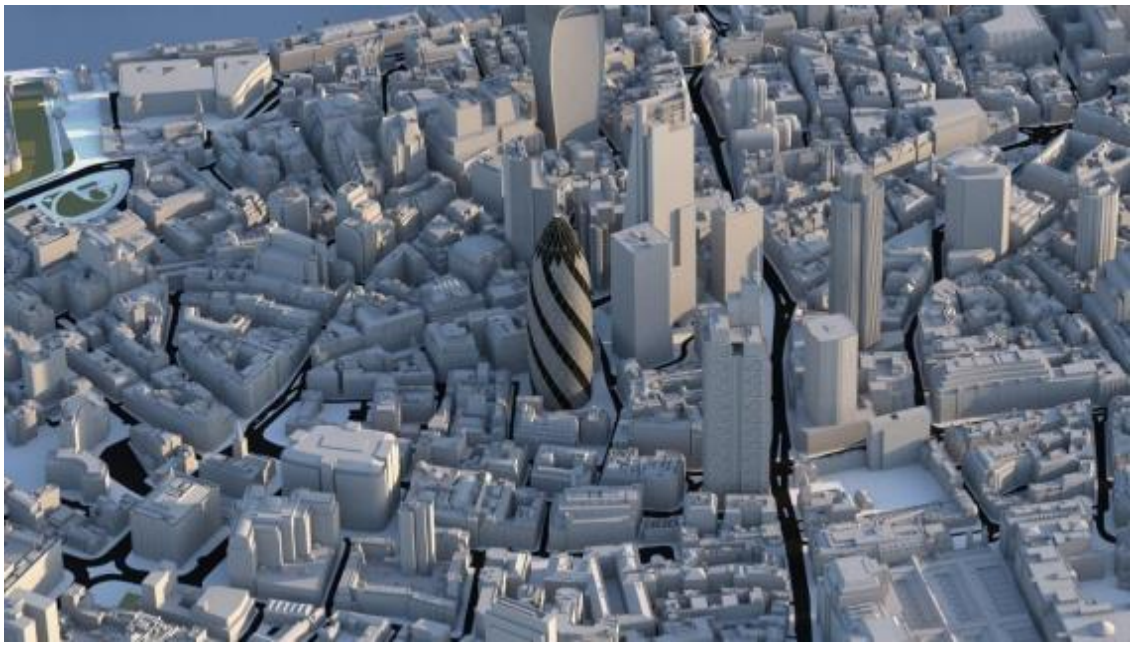

Fig. 2: Example of a virtual model, more specifically the city of London, UK. (Source: Vertex Modelling (2013))

There are more than enough reasons to justify the increasing use and spreading of this technology. Being so, when I was suggested to develop a city model as part of my thesis, I figured that this would be an excellent opportunity to learn more about these methods, where the process of modelling could be used as a discussion and learning topic for future projects and works.

The content of this thesis demonstrates an example of the process of urban modelling, more specifically that of Fuzeta, located in Algarve, Portugal. Throughout the dissertation I will explain the modelling of specific housing typologies and their insertion in a modelled urban environment resorting to three-dimensional modelling tools, as well as the possibility of exploring and using other softwares with several different purposes within three-dimensional modelling and virtual simulation, as a context for future developments.

Table 1: Critical description of the main software used in the modelling process

SOFTWARE	DESCRIPTION	ICON	VERSION
Autodesk® AutoCAD®	Tool design and 3D modelling in CAD (Computer Assisted Design) format.		Architecture 2013 Version G 55.0.0
Autodesk® Revit®	Software specialized in designing and modelling in BIM (Building Information Modeling) format.		2013 - Build 20120221_2030(x64) 2014 - Build 20130722_2115(x64)
Adobe® Photoshop®	Editing, modification and image enhancement software.		CS6 Version 13.0 x64
Google® Earth®	Ensures access to satellite images of locations across the globe.		7.1.1.1888

As such, the following thesis was structure so that: the first chapter is composed of a small introduction to the project; the second chapter will describe the process of modelling the project, which in turn was separated according to the different components built, which include terrain, buildings, architectural components, section aggregation and other details; the third chapter will analyse the main advantages and limitations of the process, mainly in terms of file conversion and usage with other softwares that allow for specific analysis of the three-dimensional model, including structural, environmental, spatial analysis and simulations; the fourth and final chapter will describe the conclusions obtained with the project.

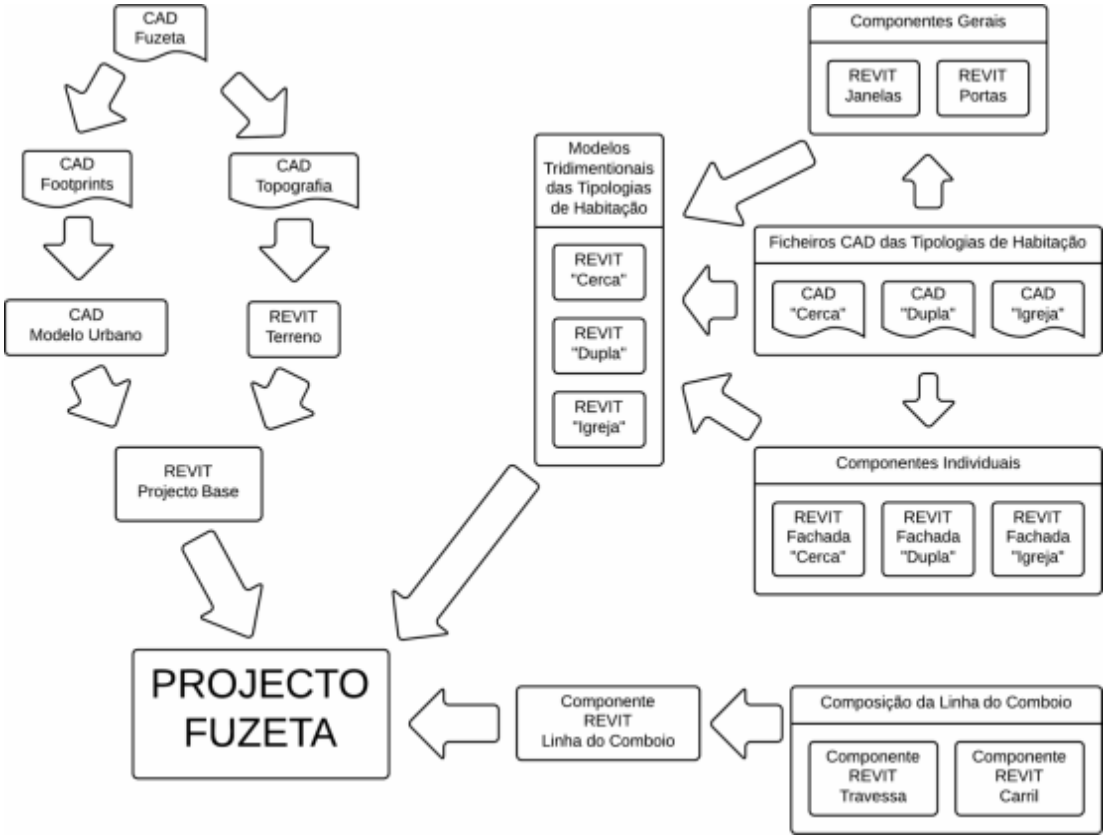

Diagram 1: Schematic workflow of Fuzeta Project.

The Vila da Fuzeta is located within Algarve's leeward, more precisely 20 kilometres East of the city of Faro. Fuzeta presently stretches between an area South to Estrada Nacional 125 and North of the sea, however its historical nucleus corresponds to an area limited by Estrada Nacional 125-5, by Rua General Humberto Delgado and by the local railroad tracks.

Fig. 3: Historic core of the village of Fuzeta. The demarcated streets are: Manuel da Silva Ramos (blue), Magalhães Lima (green), and Dr. Virgílio Inglês (yellow). (Source: Google Earth (2013))

For modelling purposes, and since the project focused on the different habitation typologies built between the 19th and 20th centuries, it was opted to first sketch the limits inside the urban plan putting special emphasis on its historical nucleus, which also leans towards the objectives set out for the doctorate dissertation that focuses on the analysis of the different existing habitation typologies in Fuzeta.

The modelled urban plan, essentially composed of an orthogonal grid formed by identical lots, corresponds to the Historical Nucleus, where the existing building typologies have been developed around what has been classified as “Cerca”, “Igreja” and “Dupla”. The “Cerca” typology distinguishes itself for being a laterally distributed narrow lot, inserted in terrain with an irregular morphology; the “Igreja” typology is similar to the previously mentioned “Cerca”, however it as much more length and is inserted in regularly levelled terrain; the “Dupla” housing possesses a much larger front, and is of central distribution.

The main objective of the virtual model is to supply people with a representative base of the urban plan of Fuzeta, as well as a tool that allows simulation studies with the built housing typologies, which in turn allow for a further visualization and analysis of different historical intervalls, all of which is part of a continuously developing project.

Since it was intended to have a multifunctional model which combines graphics with other writers of text elements, without the need of specific programming languages, it was decided to develop the model in Revit.

One of the great advantages of having a virtual model is to be able to experiment at different levels, from the architectural design to performance simulations of the building before it is built, such as evaluating thermal behaviour, the behaviour of the structure when subjected to loads and stresses, etc., according to the software used.

With this goal, several different possible conversions of the Fuzeta model were analysed so these can be used with other softwares much more widely used amongst designers, and in this context, we analysed the advantages and limitations of both the conversion of the model or the characteristics of the program, from the point of view of user. The chosen softwares are representative of different types of uses: disclosure on the web, georeferencing, conversion to BIM software, structural analysis and simulations, energy performance, evaluation of the urban context, experimentation and presentation of projects.

Table 2: Summary of descriptions, applications, advantages, and drawbacks of different technologies for three-dimensional modelling and analysis

FORMATS	DESCRIPTION	COMPATIBILITIES	ADVANTAGES / LIMITATIONS
DWF	Compressed safety format for public sharing	AutoCAD DWF readers PDF readers	(+) can be viewed using the free programs and accessible to the general public (+) Files with reduced dimensions (+) Publicly accessible information are defined by the author, enables secure intellectual property (-) Files are for display only, cannot be edited
Klm/Kmz DAE	Formats for assigning data to geo-referenced three-dimensional models	Google Earth Google SketchUp Pro Blender 3D	(+) insertion coordinates for better coordination and location of projects (+) georeferencing allows collecting information on the insertion site of the project, such as meteorological and topographical data
IFC	Format that provides all the information project compiled in text form	BIM software (Building Information Modelling)	(+) of reduced information at a basic text format projects (+) allows different software to access different information without compromising other data (+) format that can be read by virtually any software or three-dimensional modelling BIM
gbXML	Format used for calculations and simulations of HVAC systems, lighting, ventilation and other energy factors	DesignBuilder Autodesk EcoTech	(+) great compatibility with different BIM software (+) collects information materials and other areas defined software to perform calculations and analysis quickly (+) automatically corrects design errors, such as empty or wiring fault (-) Modified flexibility of reduced models
FORMATS	DESCRIPTION	COMPATIBILITIES	ADVANTAGES / LIMITATIONS
Robot Structural Analysis	Analysis and calculations of infrastructural systems models of buildings	IFC Revit	(+) great compatibility with BIM programs (+) computes efforts and structural stresses for all types of buildings and structural bases (+) permit modification of construction materials (-) of little use in areas outside of Structural Engineering
ArcGIS CityEngine UCL DepthMap	Modelling and analysis of urban-scale models	IFC AutoCAD	(+) allows for three-dimensional modeling to scale urban faster (+) for terrain modeling, elevation of buildings, insertion of roads and railways, all possible information from topographic and urban plans (-) requires an understanding of a specific programming language to be able to work with several of the tools available
Unity3D	Game engines for modelling and visualization of models with very high level of detail, textures, lighting, etc.	3DS FBX	(+) great tools that allow complexity to improve each and every detail, from imperfections in texture and even weather effects (+) very high quality renderings performed in very short time (+) might be virtual, interactive tours and first-person (-) reduced compatibility with other software (-) software for high-quality game engines are usually pricy

In this dissertation, I aimed at the exploration of virtual models in architecture design. To this end, the case study of Fuzeta was used to develop a virtual model so as to simulate the urban and architectural space in question. Computer programs such as AutoCAD, Revit and Photoshop were used in order to develop the three case studies proposed, corresponding to the types of housing "Cerca", "Dupla" and "Igreja" and the urban space in which they live were used . The model was developed allowing space and update at any time, to test the impact of other settings by activating the link created between AutoCAD and Revit. Thus, it allows the evaluation, in real time, of various occupations of that space.

Once created, the digital model of Fuzeta will provides a basis on which hypotheses for future development can be experimented on. The export of data to other software model is a tool for analysis and experimenting with future developments, and choose what best is suited to the location. On the basis of this choice are the viewing options to meet the architectural space and its context, and other dynamics associated with the dynamics of the software where the model was exported. Thus, it allows, for example, quantifying the environmental performance of buildings, optimization of public spaces, and simulation of urban expansion, a strategic tool.

With the development of this work it was found that the expansion and development of digital technologies in architectural design tends to result in more effective constructive planning. In a rapidly expanding market, where it is necessary to be equally quick to perform various different tasks associated with the Architecture and Urban Planning, the virtual models will be fundamental to the development of design tools. The technology of three-dimensional modelling is a key tool in these work areas.

In addition to the general benefits mentioned above, this model has an immediate application in the doctorate thesis in the concept that constitutes a three-dimensional digital basis, since, for the first time, it is possible to test the concept of architectural types present in a three-dimensional digital representation of Fuzeta. Thermal performance related measurements and analysis of each of these types will be made.

In a society where construction projects are based on documents usually presented in the form of two-dimensional drawings on paper or shared CAD files containing plans, elevations, sections, technical details, lists of construction materials and other relevant information, such information not only defines the geometry and distribution of the interior spaces of buildings, but also plays a very important role in costing and implementation and publication of the final product. This documentation, when performed with conventional methods - beautifully executed hand raised, with more or less stringent equipment - requires more effort to work whenever you want to make changes to the initial project - in order to set the appropriate direction information. Subject particularly important because, to be successful in today's competitive environment of the construction area, is of great importance to

be able to provide effective documentation and high quality within a short time and with minimum costs.

On appeal to the two-dimensional drawing, the architectural plans were implemented predominantly through manual processes and not only do these techniques take a long runtime, errors of functional and constructive coherence tend to accumulate, sometimes being only detectable at later stages of construction, with all associated problems. This sort of problem is very likely to occur when handling two-dimensional information.

The use of the CAD format and three-dimensional modelling techniques has the advantage of optimizing the time and effort while two-dimensional drawings are created. However, it still allows the creation of three-dimensional models of great use to fulfil the requirements for documentation and dissemination that the work needs.

A three-dimensional architectural model in digital format in itself powers all of the information , - materials , drawings and documents - necessary to help the architect understand and produce two-dimensional elements - elevations, plans, sections , details , price estimates and detailed lists of materials constructive - consistent construction of the property . As this three-dimensional model developed in information-based (BIM or Building Information Model), allows the architect to test several alternative hypotheses and instantly verify the impacts and costs of your changes in the construction of the final product. The result of the application of new technologies represents better enforcement and more efficient in the use of the project: the model can be viewed from different perspectives endless , to better demonstrate to customers what to expect from the final product and may even be possible to make virtual visits to buildings prior to construction.

With the constant development of three-dimensional modelling technology, as well as other tools to work allied to the areas of Architecture and Engineering, the challenge to think about how what can the future of these same features be is launched. For example, combined with gaming engine software, it is considered the hypothesis of first-person exploration of virtual environments through the use of virtual reality technology equipment to provide the public with more interactive and effective demonstration of architectural projects. Another hypothesis is based on the possibility of visualizing virtual models using the three-dimensional holographic projection technology. Can the use of traditional architectural models become superfluous in the near future?

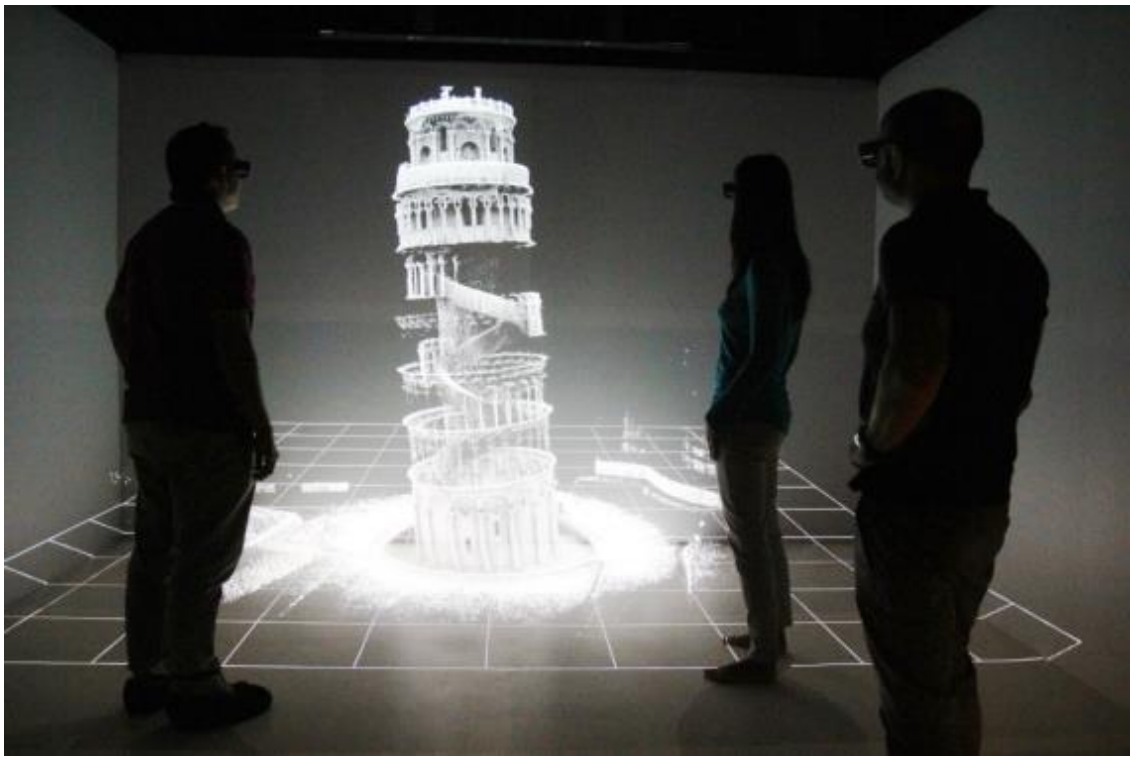

Fig. 42: Holographic projection of a three-dimensional model of the Tower of Pisa. (Source: Csiro (2013))

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DIGITAL PROJECT

Modelling Vila da Fuzeta

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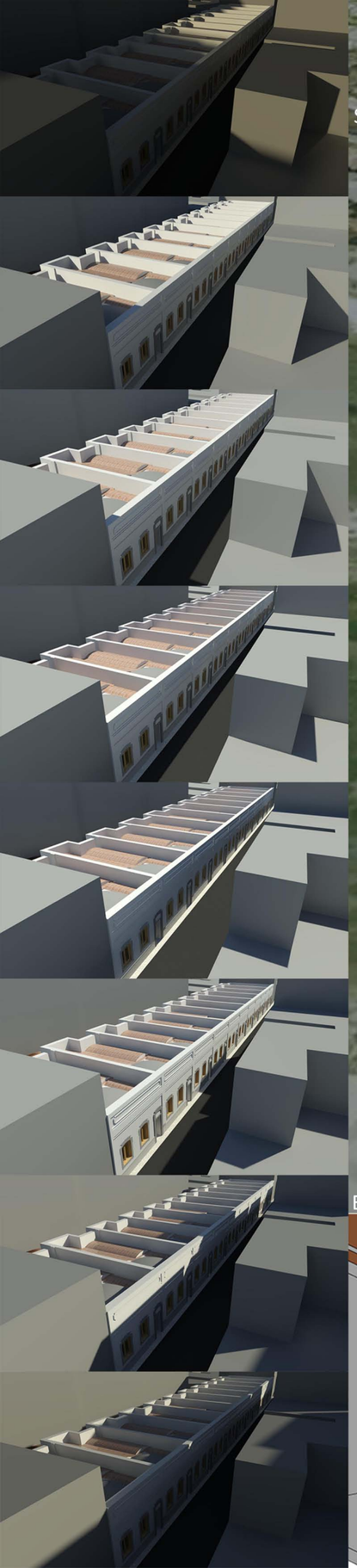
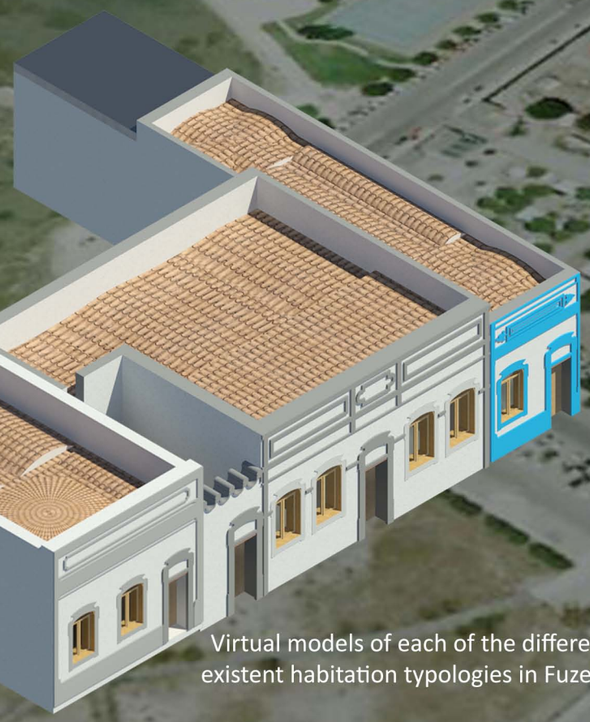


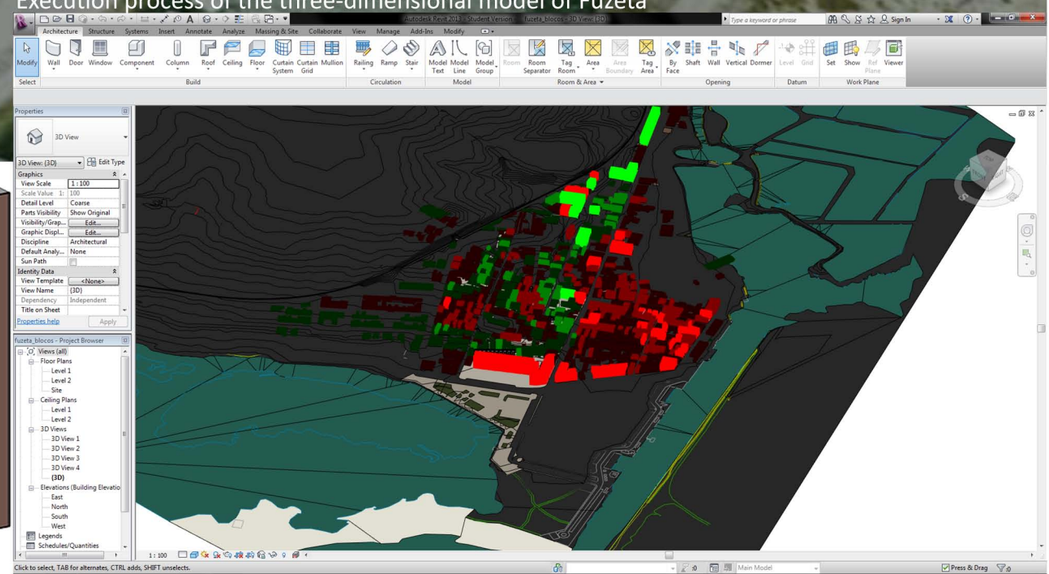
Simulation of a solar cycle during a Summer day on Rua Dr. Manuel da Silva Ramos

Background Image:
Render of the finalized
three-dimensional model of Fuzeta



Virtual models of each of the different
existent habitation typologies in Fuzeta

Execution process of the three-dimensional model of Fuzeta



Examples of different roofing solutions adopted in the “Cerca” housing typology