ADAPTING GAME ENGINE TECHNOLOGY TO PERFORM COMPLEX PROCESS OF ARCHITECTURAL HERITAGE RECONSTRUCTIONS

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Introduction

'Technology is the answer… but what was the question?'[1] Cedric Price famously chose this provocative title for a lecture he gave in 1966, almost fifty years ago. His provocation remains valid to this day. It challenges us not only to critically assess the questions we expect technology to answer but also to explore whether a technology couldn't also be applied to uses it was never intended for.

It is in this spirit that this paper discusses and presents the possible integration and wider implementation of Game Engine Technology in the digital reconstruction of building processes in Architectural Heritage. While there are numerous examples of Game Engines being used to enable walk-throughs of architectural projects – built or un-built, including in Architectural Heritage – the focus of this project is not just the real-time visualization and immersive experience of a historically relevant building. Rather it demonstrates how the same technology can be used to document the entire development of a historically relevant ensemble of buildings through different stages of construction and adaptation over two centuries. Thus the project presented in this paper, which was developed as part of the primary author's Master Thesis, uses Game Engine Technology in order to document and visualize change over time.

Advances in Real Time Visualization

It is a well-known fact that computing power has been increasing exponentially since the late 1960ies[2]. Each year the computer industry is surprising users with novel possibilities, opening exciting perspectives and new horizons. The growing

[1] 'Technology is the answer… but what was the question?', Cedric Price, Lecture title, 1966.

[2] According to 'Moore's law': over the history of computing hardware, the number of transistors in a dense integrated circuit doubles approximately every two years.

speed of information technology also impacts the field of architecture. Computing has tightly woven itself into the fabric of what traditionally used to be a matter of craft. CAD and BIM systems have long become standard in practice, currently more specialized applications such as Augmented Reality are receiving broader attention. As a consequence, the field of architectural design is significantly expanding beyond its traditional borders.

A relevant part of this shift is driven by advances in real-time visualization. The graphics performance of standard computers is currently starting to blur the boundaries between reality and virtuality, not only for still images, where we have become accustomed to photorealistic renderings, but more and more also in real-time 3D applications. The main driver behind these advances is the gaming industry. The production of video games is now the biggest entertainment industry – ahead of movie or music[3]. The production of blockbuster games requires huge budgets and the sophisticated games that are produced in this high-powered fashion are gaining greater influence and recognition. Growing user expectations, especially related to the immersive quality of the real-time graphics, are constantly forcing the gaming industry to accelerate its development, setting the goals exceedingly high.

This constant "arms race" has led to the development of a variety of game engines. Among the most powerful engines currently available are: CryEngine (4th generation), Unreal Engine 4, Frostbite 3, Unity 5, Dunia Engine (2nd generation) and AnvilNext Engine. On the basis of these engines visually stunning games such as Crysis 3, Battlefield 4, FarCry 4 or Assassin's Creed Unity, are produced.

The latter, the latest installment of the Assassin's Creed saga, set a new standard for the visual quality and detail of its architectural and urban environments. The plot of the game is embedded within historic urban environments – cities like Jerusalem, Damascus, Constantinople, Venice, Florence, Rome or Paris – in different epochs and times. The level of detail achieved by those reconstructions – they can indeed be called thus – is captivating. Of course, even though a considerable amount of research went into their production[4] they are clearly not meant to be taken as proper scientific reconstructions. They are games, after all. Nevertheless, at this point we might well ask: why not make an effort and apply something so almost perfect for detailed real-time visualizations to the needs of a complex scientific reconstruction? Maybe these impressive game engines can not only be used to entertain us, but also to confront us with the complexities and uncertainties of scientific fact-finding? Maybe they could even make these scientific findings more entertaining? These are the question we are trying to answer with this paper.

Making scientific reconstructions more appealing not only to professionals but also to the broader public, who might well have an appetite for more than just stunning visuals, certainly seems to be a worthwhile goal.

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[3] http://www.fastcompany.com/3021008/why-video-games-succeed-where-the-movie-and-music-industries-fail

[4] http://edugamesresearch.com/blog/tag/assassins-creed-2-educational/

Game Engines in Heritage Reconstruction

The idea of implementation and utilization of Game Engine Technology in the process of visualizing cultural (architectural) heritage is not new. It has been addressed and discussed by numerous conferences and research projects. [e.g. Bertuzzi and Zreik[5], Hoon and Kehoe[6], Boeykens, Himpe and Martens[7], etc.] However, even though it is commonly known and acclaimed, somehow its potential isn't investigated more in depth. The use of computer game functionality seems to be considered as an add-on, but not as the main focus of any research. The reason for this might be its complexity, as stated by Boeykens[8]. Game Engines (GE) are not only powerful, they are also highly evolved specialist tools that require a long and often steep learning curve. This makes them intimidating, if not discouraging to the scientists in heritage reconstruction who are rarely familiar with gaming technology. Whether the project is a real-time adventure game or a cultural heritage reconstruction – proper work with GE typically requires an interdisciplinary team of specialists.

The most important piece of any GE lies in its programmability. This is what lets the bestselling games be so much more than just virtual models we can experience. The flexibility inherent in their programmability is also what makes it possible to apply GE to other uses than gaming. Though for many, their lack of programming skills may have been the first and sometimes definite obstacle that results in reducing the application of GE to its most basic functions. Therefore to produce appealing and foremost valid – from the scientific point of view – reconstructions, emphasis should be placed on creating interdisciplinary teams of experts with various backgrounds and abilities: architects, architectural historians and theorists, experts in urban theory and history, researchers, computer graphic artists, artists, programmers, IT specialists as well as others according to the needs and size of the project. It takes such an interdisciplinary team to get the most out of working on/at the intersection of physical and virtual reality.

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[5] Bertuzzi, Juan, Zreik, Khaldoun. "Mixed Reality Games – Augmented Cultural Heritage", in: *SIGraDi 2011* [Proceedings of the 15th Iberoamerican Congress of Digital Graphics]. Santa Fe. 2011, pp. 304-307.

[6] Hoon, Michael and Kehoe, Michael. "Enhancing Architectural Communication with Gaming Engines", in: *Connecting >> Crossroads of Digital Discourse* [Proceedings of the 2003 Annual Conference of the Association for Computer Aided Design In Architecture]. Indianapolis (Indiana). 2003, pp. 349-355.

[7] Boeykens, Stefan; Himpe, Caroline; Martens, Bob. "A Case Study of Using BIM in Historical Reconstruction: The Vinohrady synagogue in Prague", in: Achten, Henri; Pavlicek, Jiri; Hulin, Jaroslav; Matejovska, Dana (eds.), *Digital Physicality* – Proceedings of the 30th eCAADe Conference – Volume 1. Prague: Czech Technical University in Prague. 2012, pp. 729-737.

[8] Boeykens, Stefan. "Using 3D Design Software, BIM and Game Engines for Architectural Historical Reconstruction", in: *Computer Aided Architectural Design Futures 2011*. Liege. 2011, pp. 493-509.

Reconstructing the Franz Ramisch Textile Factory in Lodz

The project described here is not the work of a large team. It was developed by the primary author of this paper as part of his Master Thesis project. The thesis concerns the reconstruction of the spatial and architectural development of one of the textile factories in Lodz – Franz Ramisch Textile Factory.

The city of Lodz was founded in the 15th century but it was not until the beginning of 19th century that its economic potential was noticed and real development started. By decision of the state authorities Lodz was included into the group of industrial cities with the main scope focused on textile production. The city's natural conditions such as the land ownership status, which belonged to state, surrounding forests – availability of building material, and a lot of small rivers with steep drops which were ideal energy source for the machines , were favorable to this kind of activity. The first textile manufactures started to emerge as early as in 1823. This year is also known as the beginning of a period of rapid growth that led to the industrialization of the city. The first textile factory was erected in 1825 by the Saxon entrepreneur F. Wendisch, followed by L. Geyer (1828), K. Scheibler (1839), T. Grohmann (1845), I. Poznański (1852) and others. In a short period Lodz became the most important textile center in the Polish Kingdom and the industry itself became the beating heart of the city. In the second half of the 19th century Lodz was a thriving borough, maintaining mercantile contacts with Western and Eastern Europe, as well as with Asia, and constantly attracting entrepreneurs and ordinary people from all around Europe. The constant growth of its industrial importance resulted in an enormous growth in population. The city's' rate of population growth in the second half of 19th century was exceeding those of quickly growing Western European industrial cities such as Lyon or Manchester. Back then, due to its rapid development, Lodz was also known with as the "Polish Manchester". Initially, the development of the city was regular and planned: zoning laws had been adopted, separating parts of different usage. Everything changed in the mid '60ies of the 19^{h} century, when due to the lack of further administrative regulations, political crisis, as well as economic and social boom, the development reversed its direction from outwards of the city center to inwards. Industrial and civic tissues were mixed, intersected. Factories were built on practically every scrap of free land, even next to the main representative street – Piotrkowska. The Franz Ramisch Textile Factory portrayed in the thesis, is one of those erected in the very center of the city.

Rather than just focusing on the reconstruction of the factory at one point in time, the thesis focuses on its development through time – from when the very first dwellings were erected on the factories' plot of land in 1828 till the present times – 2014. This time mapping of the development is meant to enable a better understanding of the changes that have occurred in the factory as well as in the part of the city where it is located, and give deeper insight into the historic structure of the area. The 3D representation of reconstructed buildings is combined with information about relevant economic, social and political changes that have occurred within the given time period in the city itself, the country and the world. This information is crucial for creating an understanding of Architecture as not being an isolated discipline, but rather one depending on and being constantly shaped, changed, and complemented by factors and incidents in its context. The term 'context' here is not just referring to the physical surroundings, but rather to the entanglement of consequential factors influencing the decision making process of subjects that eventually led to the architectural creation.

The documentation of the development of mentioned factory was primarily made with the Unity game engine. Unity's functionality has been extended with the C# scripting language. This was used to create a 4th dimension in the interface: a timeline that allows users to experience the factory in both space and time. Highly detailed 3D models representing existing and non – existing pieces of architecture of the Factory were modelled with Autodesk 3dsMax. Emphasis was also put on the proper reconstruction of the construction elements. While modeling the entire city was outside the scope of a one-person project, the closest surroundings of the factory were modeled (also changing over time) to create a spatial reference of the urban context.

The resulting scene offers many of the viewing functions of the Game Engine, but on top of that it also offers a timeline, which enables the user to travel through time from the very beginning to the end of researched time span, observing all the changes occurring in the buildup of the factory. Users can orbit around emerging objects, zoom into the model and pan the camera to change the point of view and better inspect an individual area of interest. One of the core features includes historical analysis and dating of the plots' objects. It is achieved by coloring buildings, or parts, respectively to the year of creation.

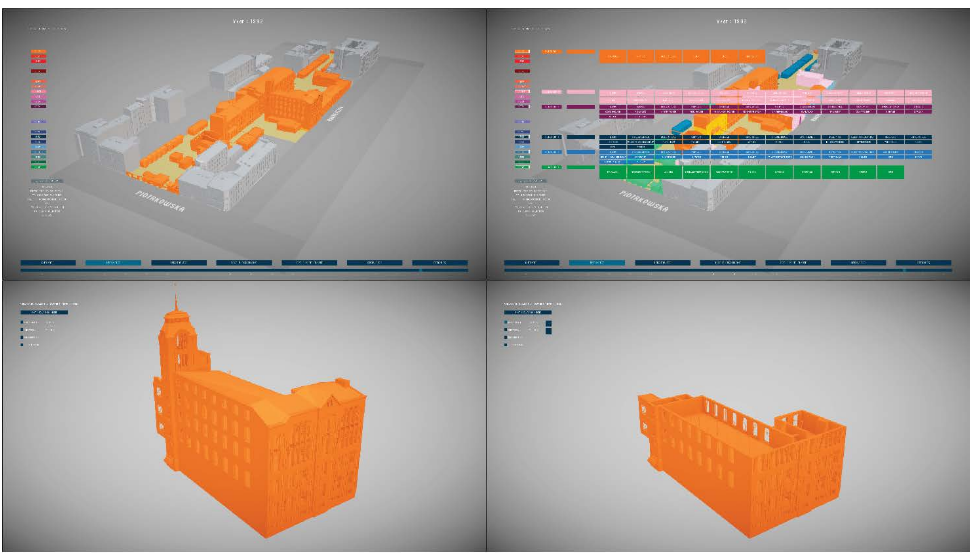

Fig. 1. Thesis program functionality depiction

Source: Work of the Author.

A similar principle was adopted for the analysis of the changing state of ownership of the factory's plot of land. Tracking of function change is also embedded enabling inspection of the changes occurring in the uses of the factory objects. The second crucial feature empowers to isolate selected building for better inspection, including 3D horizontal and vertical sections as well as detailed description of development phases including construction details. The program also includes links to historic data references in the form of a gallery. This enables users to relate the 3D data to archived plans, photos and other available documentation. Furthermore, the interface includes some minor functions such as camera matrix switch, disabling/enabling of surroundings, etc. for better representation of the whole on slower hardware. (Fig. 1).

Further Possibilities - Extension

The scope of this project is limited, but it documents an approach and a philosophy that can be extended. In order to truly capture the *genius loci* of an architectural form or place, a broader and more complex view is needed. For digital heritage reconstruction to come close to this ideal, open, extensible documentations are needed which can contain not only high quality 3D models that can be rendered and experienced immersively in real-time. They should also support the travel through time and through different historical – and perhaps only conjectured – versions of a historical ensemble as well as links to pictures, plans, photographs, texts that form its context. To be of relevance and to faithfully respect existing research this approach requires enormous effort. It cannot be achieved by a one-man-operation, but instead should involve, as mentioned earlier, interdisciplinary teams. In this way, truly valid and valuable reconstructions of architectural heritage could be created that could also be shared with a broader public. If these models are open, that is extensible, then such an effort would produce lasting results. New research could be added to it, so that its documentation would not become outdated, but grow to become more refined over time. With enough people working on it, such a project could well tackle not only single architectural objects, but whole cities.

The use of GE for such ambitious scientific purposes goes outside the commonly adopted boundaries, schemes and conventions. But it is actually rather straight-forward. The level of development of today's GE is very high and they have been tested with millions of users. Therefore, investing in the development of comprehensive and historically correct city models in game environments is not as outlandish as it might appear. In the following paragraphs we will describe some basic principles that we derived from the textile factory model, which could guide the development of much larger, comprehensive, open models for architectural heritage.

The main principle is that such models should be four dimensional (4D). The 4D representation supports the mapping of architectural and urban growth and development through time. Users can access data and embedded information on different levels of detail, likewise to narrow or expand the scope of interest, remaining, at the same time, aware of the ensemble. It is possible to move from general to specific cases and back. The basic units of such 4D models for urban and architectural reconstruction are single buildings, respectively architectural forms. Out of these units, groups could be formed as meaningful collections – districts, neighborhoods, etc. – they have an important role in creating an understanding of the changes occurring during development (as seen in the Ramisch factory example). The whole 4D model is then comprised of Units and Groups – the reconstructed city itself. The general structure of the reconstruction would look much like the one presented at the picture below (Fig. 2).

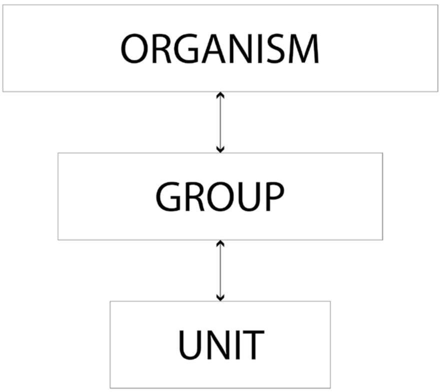

Fig. 2. Grand structure of the application
Source: Work of the author.

Further, each level is equipped with unique features that take care of high quality analysis possibilities adequate for selected standard. Such a gradation is required for better readability of the complex data structures, as well as for creating clear and transparent navigation and UI/UX[9] elements. We will present this additional data embodiment on the example of the simple Unit case – isolated building. Digital reconstruction of the single building is itself a challenge as for numerous aspect that could have been analyzed and included in the representation. What matters most at a very first glimpse, and what is exceedingly developed and important in computer games – what makes them so appealing and magnificent – is naturally the graphics. The visual attractiveness of an object marked by its fine details and high resolution textures and materials. Therefore the materiality of the building's exterior (and the interior) should be a matter of high priority. Not only because of the visual attractiveness, but mainly due to the requirement of creating valid and scientific representation of the reconstructed object. There are, of course, known problems with acceptable representation of materials during the visualization process, as already mentioned by Kępczyńska-Walczak[10]. Current GE though, as far as lighting and materials are considered, are equipped with up-to-date tools enabling real time execution of different light conditions for material testing. Nevertheless, as game engines were created in order to support formation of hyper realistic worlds in the first place, there is a temptation of using provided features to boost up and correct the reality. This should be avoided, as it would produce inaccurate and false interpretations and reconstructions. The 4D model should respect historical facts more than looks and rely on collected data in order to depict the past (which was

[9] UI/UX – User Interface/User Experience.

[10] Kępczyńska-Walczak, Anetta. "Performing the Past and the Present for the Knowledge of the Future", in: Stouffs, Rudi and Sariyildiz, Sevil (eds.), *Computation and Performance*. Delft: Delft University of Technology. 2013, pp. 453-462.

not always as picturesque and aesthetically pleasing as presumed) as faithfully as possible. Other issues to consider on the Unit level are the structure and construction of the building. The possibility of analyzing the sections of the building is very advantageous for architectural research. Each building undergoes changes in terms of structure, construction, used materials, functionality (functions served by it), is rebuilt, partially demolished, reconstructed, etc. From the historic and reconstruction point of view all those things are very relevant and important to present.

Of course our knowledge of the past is never complete and often it is impossible to fulfill all the expectations with valid, or any data. The problem is trivial – there just is not enough information available in the archives or sources we are working with. This lack of data has to be dealt with in a consistent fashion. Sometimes it will be acceptable to "improvise" in the sense of providing probable, though not scientifically assured, replacements. Such hypothesis resulting from research and consultations on the missing matter, should be involved as valid pieces of the reconstruction, however they should also be visibly marked in the model. The proper marking separating obvious from hypothesis would prevent the uncontrolled spread of probable truth as a definite truth according to the common rule of the visual society: "seeing is believing".

Already at this point the Unit level itself is extremely complex and encapsulates a lot of intersecting layers and information. As we aim at creating the application that would also provide educational value for a general public that is not necessarily familiar with the topic, there is an urgent need to introduce different levels of abstraction to present all this information in an approachable and understandable way (London Charter[11]). The levels of abstraction should consider visual appearance that corresponds with the exhibited topic. The versatility of the presentation layouts, though unified and kept together as a system, positively enforces the user and clarifies what may have been unclear.

After adding the new functionality to each of the application grand levels, supposed diagram may look like the one presented on Fig. 3.

To fully take advantage of the power of GE for projects in digital heritage reconstruction geared towards a wider audience, there is a need to create appropriate navigation and exploration system that would intuitively lead the users through the vast maze of included data. The ideal system we are outlining here should refer to, exploit and utilize existing and tested systems implemented in various computer games, as they have mastered this particular challenge very well. It should also, obviously, implement original ways of navigation appropriate for presented pieces of information. Furthermore switching from first person camera control – providing cognition of the environment in human scale, walkthrough modes, city or building

[11] London Charter, Principle 2: Aims and Methods, "2.3 While it is recognized that, particularly in innovative or complex activities, it may not always be possible to determine, a priori, the most appropriate method, the choice of computer-based visualization method (e.g. more or less photo-realistic, impressionistic or schematic; representation of hypotheses or of the available evidence; dynamic or static) or the decision to develop a new method, should be based on an evaluation of the likely success of each approach in addressing each aim."

exploration on regular, natural basis – to perspective/isometric 3D aerial views allowing perception of the Units, Groups and Organisms as a whole with additional features, should be considered and effectively implemented.

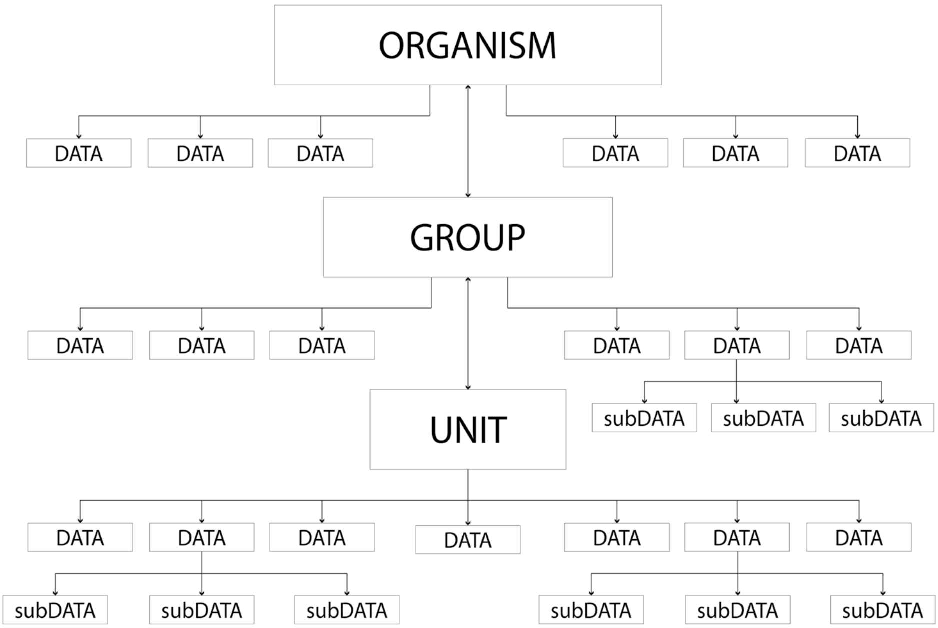

Fig. 3. Expanding the grand structure of the application
Source: Work of the author.

As our brief ideal outline makes clear, such a comprehensive system would entail challenges beyond those of a traditional computer game. Therefore the most important aspect of such a system cannot be stressed enough: it should be open to future improvements! The ideal 4D system we are envisioning should allow the contributions of many contributors, would allow the introduction of new features and elements and could be expanded – rather like a Wiki. Ideally it should also be developed in an open source fashion.

Summary

Dynamic advancement in the field of computer graphics, particularly in game engines technology creates great potential of its implementation in the scope of architecture, especially in reconstruction of Architectural Heritage. Integrating and taking advantage of the full potential those disciplines represent, would enable us to enter the next level of interdisciplinary work and integration between digital and non-digital worlds. As the prototype example presented in the paper, the Franz

Ramisch Textile Factory in Lodz, makes clear, this would enable us to perform procedural reconstructions not limited to the static depictions of Architecture at one particular point in time, but rather to embrace the change of and in Architecture throughout time dynamically. Taking the ideas presented in this prototype further, we can envision the dynamic reconstruction of urban complexes and eventually whole cities based on today's Game Engine technology and thereby acquainting a broader public with scientific knowledge about our past. While this would necessitate the collaboration of large interdisciplinary teams of specialists and would open up many questions regarding existing, as well as establishing new standards for scientific reconstruction of Architectural/Urban Heritage, such comprehensive digital 4D systems could become powerful means of educating our society about our past and empower us with new perspectives on our future. In this way, Game Engines can be used to produce much more than just games.