Modeling university environment:
means and applications for university education

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Abstract. In the paper, we establish an investigation on the development of university 3D-model and its possible applications for educational and research fields. We assume that 3D-model of university can help in various scenarios and should be used to adopt modern immersing technologies into to university processes. Different means are employed for the development of the model. Bottom-up approach for using these means and their connection with each other are shown in the work. Then, details of the 3D-model design process are provided with peculiarities related to the university building location and corpuses positions. Finally, assembled models of university are shown in 3ds Max and Unity environments. In the final part of the paper, we suggest scenarios of model usage for educational and research fields. Universities can gain various benefits from integrating their research efforts to employ new technology and identify new development opportunities for both science and education in university. In case of the developed 3D-model, it is planned to use it in the projects connected with client-server applications, Internet-of-Things, Smart Grid, etc. In the educational process it will be a part of case-studies for learning 3D-modeling, development in Unity environment, training for emergency situations.

Keywords: 3D-model, university, education, technology, development.

1 Introduction

Usage of modern information-communication technologies (ICT) is a crucial point for a successful university education system. ICT present in literally every field of life and knowledge and effective work with ICT is becoming more and more valuable. Students and enrollee are attracted by possibility to gain new knowledge about new technologies and their practical applications. Nowadays, they are surrounded by new technical means and those means are highly involved in the lifestyle. For instance, smartphone has become indispensable part of communication. However, when it comes to education process, those devices are not employed up to their full potential. We emphasize the following reasons to explain that condition:

1. Velocity of technology improvement process is much higher than capability of adaptation to new challenges in educational environment. By the time when technology is implemented for education process, it might be outdated already.
2. Deficiency of technical means in educational institutions.
3. Lack of systematic approach to this issue. No framework has been developed to join education system with rising technologies as they appear.

Therefore, we can conclude that to cope with the problem educational institutions and specifically universities should not wait for opportunity to integrate new technology. They have to establish general idea of the development in form of framework and integrate immersing technical achievements into educational process fluently.

In this work, we share experience of modeling university environment of Petro Mohyla Black Sea National University in the Computer-Aided Design (CAD) software. The developed 3D-model can be used in different scenarios and in tight cooperation with other modern technologies.

2   Review of scientific sources

In general, digitalization of educational process is one of the main trends in educational process nowadays, especially in higher education [6]. Both students and lecturers are ready to use modern technologies and devices for the classes. Moreover, one of the peculiarities is that students are prepared better for the technologies usage on a basic level than lecturers are. Virtual Reality (VR) and Augmented Reality (AR) can be considered as the most promising technologies for education. They provide advanced learning experience have almost unlimited possibilities for application. For instance, VR can be used for development of virtual labs [3], while AR is an effective tool for enhancing existing learning materials [12]. However, AR is still an adequate choice for development of new courses. These technologies provide gamification of education [11] that increases students' engagement into the process [6; 11; 13].

From the research perspective, convergence and synergy of multiple emerging trends are very prominent [9]. They can be used together to provide benefits to all involved directions. In this work, we consider how 3D-model of university can be used in research topics such as IoT [7], AR [12; 13], Smart Grids, etc. Publications [15] aimed to develop the generalized approach for AR infrastructure for educational purposes. However, this work established general solution while peculiar cases might have significant deviation from the common software architecture. At the same time, subject-specific educational software [8] does not suppose possibility of extension to other fields. To conclude this part of the review, it can be stated that AR-application that exploits 3D-model of university building requires integration with software architecture to execute target functions.

Let us consider in more details main environment for bringing new functions to 3D-model of university. Unity [14] is a state-of-the-art toolkit for the task of 3D-modelling and game development. It provides high-level programming interface to developers and reduces time to release of the final version of the product. In comparison with native interfaces for specific platforms, fewer code instructions are

necessary to achieve desired functionality. Unity supports deployment to multiple platforms. Thus, designs based on Unity automatically gain advantage of being able to work on various devices with different operating systems like Android, Windows, and MacOS. The list is not limited to the mentioned platforms. Developers can switch target platform and easily get application for new device without changing software side. However, the main drawback of such universality is high-resource usage of the device. Output file with compiled program code usually exploits much more device's resources, especially disk storage capacity.

Unity includes environment for modeling scene in 3D-view. You can import models into scene editor and combine them according to the needed location, positions of light sources, etc. However, it is not a Computer-Aided Design (CAD) program and it is more convenient to use other software tools for model development. We consider tools that assisted us during development stage in the main part.

The last but certainly not least to mention feature of Unity is cohesion with other modern technologies like VR and AR. The first one supposes that person wears special equipment (glasses or helmet) with integrated means for displaying virtual image and can interact with virtual environment via gestures. VR exploits the idea of creating new reality with clear margin between existing and virtual objects. In contrary, AR is trying to provide new experience by augmenting real world. Objects of AR "appear" in our own environment and interact with it. For now, AR requires markers to be present on the scene and when device recognized markers, it brings new objects into the scene. Regarding connection VR and AR with Unity, both technologies can use models created in Unity. Moreover, Unity supports inclusion of a few AR-libraries so AR-features can be designed directly from Unity infrastructure. As VR does not depend on technology behind the curtain, any modeling tools can be used for scene generation. However, Unity is a mainstream technology and this is the reason why VR-projects include Unity as a basic instrument for modeling.

Many universities develop 3D-models of their building and location or panorama views. Those designs give students the opportunity to be acquainted with university space, find necessary places, etc. However, the idea behind the model of university can have much more practical applications. It may be a complex platform for studying process, research environment, and investigation of contemporary technologies. But university building relates to the complex structures [5] with multiple details and developed model of university should be relevant to employ it in all the related activities.

3   Results

3D-model of university is a complex composition of multiple objects with different properties. Some of them comprise large number of nodes in space (e.g. university buildings) and other might be quite simple for design (e.g. part of interior design). During designing model of the university, we used bottom-up approach, e.i. start from low-complexity parts and then add more details, improve quality of each model, etc. Eventually, this approach leads to the state when design satisfies expected criteria

(dimensions consistency, texture selection, number of polygons for object detalization, etc.).

Bottom-up approach supposes that a combination of different tools is harnessed for design process. We can distinguish next steps for retrieving 3D-model:

1. Design of low-polygonal models.
2. Improvement of models created at first step by adding additional polygons in their representation.
3. Texture application and editing.
4. Preparation of light sources.
5. View cameras setup and adjustment.

The following software products have been used during development of the university 3D-model:

- Blender [4];
- SketchUp [1];
- 3ds Max [2].

The selection of the aforementioned software tools is explained by the availability of the extensive instrument set for 3D-model design with employment of different techniques. Moreover, the software tools are available under terms of free license for educational institutions.

SketchUp is a lightweight software for designing of 3D-models. It is available in form of native application and can be used in web-browser. Because SketchUp is suitable for fast design of low-polygonal models, this software has been used for the university model. The basic models were created in SketchUp and then they have been improved in other modeling environments.

Blender is another instrument to work with 3D-models. Its main purpose is creation of 3D-objects animations. The great advantage of Blender is that it has a free license and can be used even in commercial projects.

3ds Max is probably one of the most advanced instruments when it comes to modeling complex 3D-objects. During development of the university model, 3ds Max was employed to enhance detalization level of the models from the previous step. Autodesk provides special free educational license for university for three years.

3ds Max was also involved in the work with texture. It contains material editor that facilitates wide variety of configuration for the work with texture objects. To create as much realistic model as it is possible, textures have to be obtained first. They have been collected as storage of photos made around and inside the university. Only photos of the most important and visually notable objects were taken.

Because models are stored in interchangeable format, output from one software can be used as an input model for other one. Thus, model can pass through different instruments before appearing in the final scene. It may be considered as a software pipeline for 3D-models that aims to improve quality of object with each next step or to bring new functions to available models. Fig. 1 demonstrates interconnections between software tools in terms of model processing.
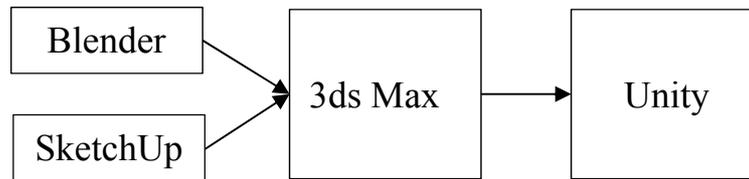
Fig. 1. Structural flow interconnection between modeling tools

The design of university 3D-model started from information available at the photos and blueprints of the university buildings. In general, main university building consists of four university building. At the location where university placed, slope can observed clearly. This fact produces one of the main difficulties for designing complex 3D-model. All components of the model should be in conformity state with each other to ensure that geometrical proportions match in joint points. Another complexity issue is concerned with architectural solutions for the building. Different floors of the university has different geometrical parameters and they vary significantly. Thus, we cannot just use cloning operation to obtain model of all stores in the corpus. Moreover, constructions in the main building have different number of floors and adjacent buildings are not equal by this parameter. Some of the photos that demonstrate outside facade of the university and internal space surrounded by the university are shown in Fig. 2.

Fig. 2. Outer view and internal space of the university

As blueprints contained almost no information about height parameters and proportions of the inter-corpus connection, they have been reproduced from photo materials and direct measurements obtained using a laser range finder.

Basic low-polygonal models have been developed in SketchUp modeling environment. Different views of university corpuses are illustrated in Fig. 3. This way outer frame of the corpuses has been visualized. From this moment, 3D-model is ready for further detalization and enhancement.
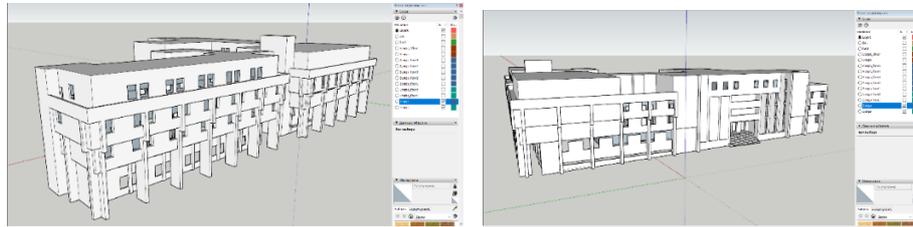
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Fig. 3. Modeling university in SketchUp

From the Fig. 3, you also can see that model is described only using straight line and can be composed of as a union of rectangles. With outer frame, we can move on to the next stage that is design of internal parts. We modeled each floor separately. Afterward, all designed floors were embedded into the outer skeleton. The preview of combined floors models is shown in Fig. 4.
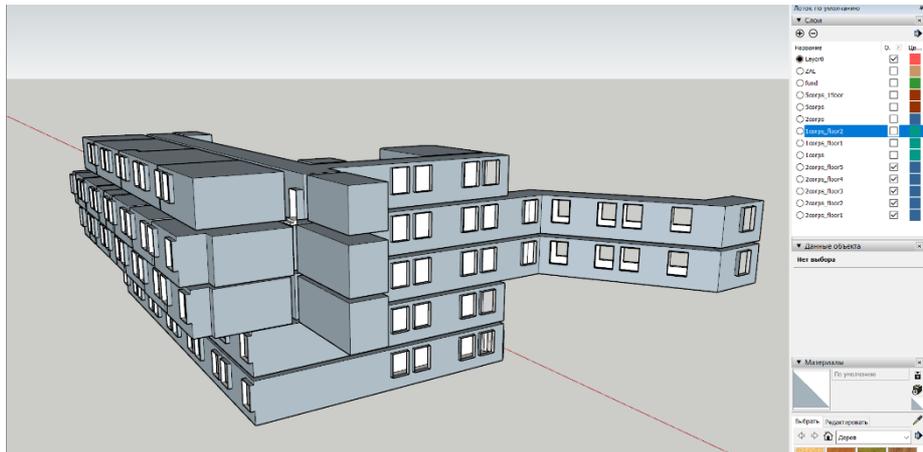

Fig. 4. Models of stories of the university building

It demonstrates floor models for one of the university buildings. You can visually notice that floors have different level of extension to the outer side. Additionally, two of the floors shown in Fig. have connection with other university structures. Stories of each building have been modeled individually because it makes construction modular and easier to change. However, this approach conceals a problem of consistency. Elements of the stories from different buildings have to be connected at the same level and no geometrical forms of connection should infer appearance of artifacts in the model (obstacles in passages, disconnected surfaces, etc.).

At the next stage, prepared 3D-models are exported to the environment with wider instrument set. In this case, we perform export to 3ds Max 2019. With export done, we can perform rendering of the model from a different point of views to retrieve high-quality image of the model. One of the rendering results is demonstrated in Fig. 5.
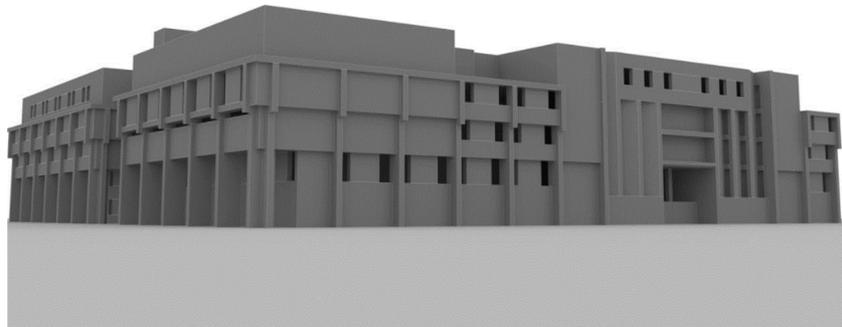
Fig. 5. Rendering results of university model in 3ds Max

At the next stage, we perform texture overlay and set up light sources for rendering of the ready 3D-model. However, to achieve high-quality results and to build final model with texture as maximum close to the original as it is possible, we need to collect those textures and apply them in the modelling environment. The results of this stage will be available in the next publications on the topic.

Although, the model does not contain more details and full set of textures, it is ready for usage in development of the programming projects. We can import assembled model into Unity environment and organize preview using embedded functionality of Unity editor as shown in Fig. 6.
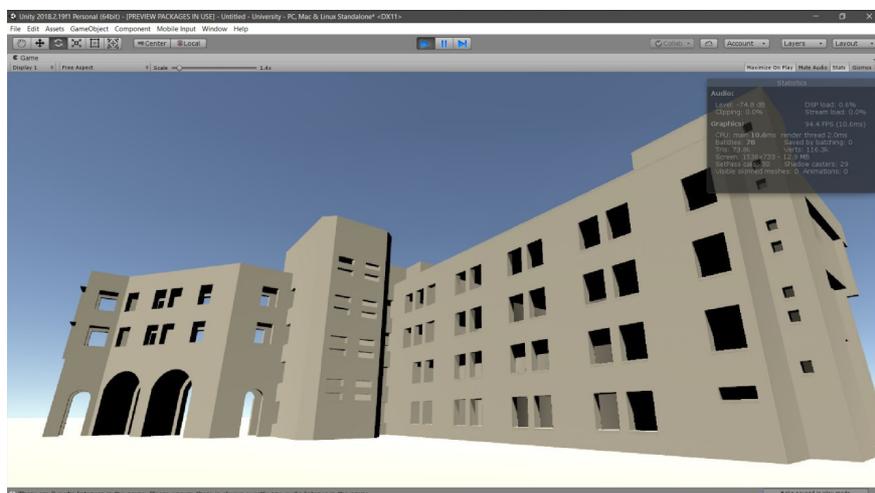

Fig. 6. Representation of developed university model in the Unity environment

As the model, has been imported into Unity, we can engage it into development of complex systems with combination of different technologies. Unity environment assists a lot in the software products development that includes 3D-model. It

conveniently separates visual presentation of the model and model's behavior that is described in controller using programming language (C# or JavaScript). Unity features all conventional instruments (camera view, textures, light sources, model transformations, etc.) for programming 3D-models. However, it provides additional level of abstraction that results in reduced amount of code developer needs to write. It also provide notable advantage for testing because its integrated environment allows running developed solution immediately on the developer's machine.

Let us consider further how model of university can be used with other trending technologies for practical projects and researches. Internet-of-Things (IoT) [10] is very promising conception that supposes very high level of integration for modern devices to the global network. IoT is not limited by any specific application sphere and can be used in almost any activity. In context of 3D-model of university, it can be a complex solution that unites sensor network, network technologies, application server, and client application with support of 3D-graphics. Nodes in the network collect information from sensors and send measurements to the server. Server processes information and notifies connected clients about changes in state of the sensor system. This way client in real time can monitor microclimate in the classroom, identify presence of students, state of the equipment, etc. User can instantly "move" to the necessary place in application and react to the notification. Actions available to user depends on peculiarities of the system.

For instance, we consider Smart Energy Grid (SEG) technologies. First of all, university have to occupy the role of prosumer (producer and consumer of electricity at the same time). Having large areas and huge demands for electricity resources, it makes sense to deploy at least basic photovoltaic (PV) infrastructure. If solar panels are installed on moving platform, operator can adjust their position in real-time using interface of 3D-environment. Consequently, it will result in higher level of generated energy and reduction of payment bill. Another example of electricity management is automatic light control system. If presence of activity is detected in the classroom, the light can automatically turn on. In opposite, if no activity is detected, it goes off. In this case, network node does not need to send all acquired measurements to the server but can just notify server when state of the light is changed.

Another instance of 3D-model use is an interactive 3D-application. The application is responsible for visualization, navigation, and interaction with 3D-model. Thus, it is possible to perform a virtual tour over university. This feature can be employed for solving problem of the positioning in space, finding the route to the target point, and acquiring information about the object. Due to the high level of realism of the developed model, an effect of immersion can be achieved.

Considering applications of the 3D-model in educational process, we can state that they are very promising.

First, the model can be used in the courses connected with development of AR and VR software. Ready-to-use model significantly simplifies development process and allows formulation of the tasks. One thing all applications will share in common is active movement inside the modeling building. Thus, it is suitable for teaching concepts of camera in 3D-environment and its correct adjustment. An example application that employs that functionality is interactive guide for university

environment where user moves over the model and gets hints on what is the purpose of each room, who works inside, working hours, etc. Eventually, some part of electronic documentation might be moved into such application. However, this scenario does not limit possible practical benefit of 3D-model for programming purposes. In fact, many programming tasks are becoming more comprehensible and interesting for students when they are connected with programming 3D-models.

Second, 3D-model of university can be effectively used for emergency training. For instance, preliminary training on the actions in case of fire situations can be held in 3D-environment. Various cases are available for such training to guarantee complex approach to the problem. Tested person verifies his/her action in the virtual environment and gets more acquainted with possible critical situations. It helps a lot when it comes to real training or even critical situation because person has visual experience and recalls recommended plan of actions faster.

Third, the final 3D-model and its by-products are actually a good point for learning CAD-tools with emphasis on 3D-tools. They serve as an example of successful design and can be used for further improvement of the model. Tasks related to these disciplines include modeling of interior environment (view of the classrooms), perspective planning for further renovation of the building and evaluation of the proposals for this purpose. They can be visually evaluated and feedback for the project will be given much faster than without visual representation.

Concluding this part, we can allege that proposed use cases do not form a full list of outcomes for research and educational fields of activities. Moreover, new applications should be found as modern technologies appear.

4 Conclusions

In this paper, we provide results of the development of Petro Mohyla Black Sea National University 3D-model. Four main software tools were occupied in the process. Bottom-up approach has been used for 3D-model design where outputs from one application served as inputs for another. It allowed improve detalization level systematically and combine simple models into complex ones. The designed model can be used in a set of various cases for educational and scientific processes. It can be especially effective solutions with rich visual experience and has many perspectives for further extensions.

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