

Mathematical 3D Modelling and Real-Time Simulation of Tesla's Wireless Controlled Vehicle - Boat

Dedicated to Professor Slavoljub Aleksić on the occasion of his 60th birthday

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Abstract: This paper presents the basic principles of the mathematical 3D modeling and simulation of the Tesla's wireless controlled moving vehicle Tesla boat. This is one of the most complex Tesla's inventions. We have constructed detailed 3D model of the invention and added most of the functionality to the model according to the original patent.

Keywords: 3D modeling and simulation; Tesla wireless controlled moving vehicle

1 Introduction

THE project Computer Simulation and 3-D Modeling of the Original Patents of Nikola Tesla has begun in April 2009, carried out at the Faculty of Electronics in Niš, in the laboratory CiitLab. The team of engineers and students from the Faculty of Electronic Engineering has accomplished great success and results, which are implemented in the presentation systems at the Nikola Tesla Museum, so that museum visitors have the opportunity to see modern animation of Tesla's inventions. In this way, through the project, the two institutions, Nikola Tesla Museum in Belgrade as an institution of national importance, that preserves Tesla's legacy and Faculty of Electronic Engineering in Niš as a development institution, were linked in a common project.

During the project development team was formed of a number of permanent and temporary personal, modern equipment was purchased for 3-D modeling, and

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a separate laboratories within CiitLab were established, which deals exclusively with high-tech projects in the field of 3-D modeling and simulation [1, 2]. The environment in which the project is developing guaranteed a high quality of work in the future.

The aim of the project Computer Simulation and 3-D Modeling of the Original Patents of Nikola Tesla realized by the Faculty of Electronic Engineering in Niš as a producer and the Nikola Tesla Museum in Belgrade as a participant are numerous. Basically, it is digital and detailed 3-D modeling of the original patents of Nikola Tesla, which are the part of a Museum's archives.

Using 3-D models, further objectives are rendering, animation, simulation and visualization in real time and space shaded by wire (3-D stereo) model. Naturally, first developed and detailed model of the fountain is realized, which contains about 500,000 points in space with accompanying 3-D engine used to visualize and simulate physical movement, which was presented to the experts from the Museum. An agreement was reached that in this technological project, in collaboration with the Museum, ten models of Tesla's patents from the four research areas will be realized by the end of 2010.

One of the most complex Tesla's inventions that we have modeled is Tesla boat. The original patent was pended in application filed July 1, 1898. The full specification of the invention: TESLA PATENT NO. 613,809, METHOD OF AND APPARATUS FOR CONTROLLING MECHANISM OF MOVING VESSELS OR VEHICLES.

This paper presents some basic details about the patent specification that was the base for our work. After analyzing of the specification and two-dimensional schemes the vehicle itself, we have manually transferred the blueprints to 3D. In later phases, we added some functionality to the model, and use it in most complex 3D environment.

2 Tesla's Basic Patent

Tesla completed the application for the patent on July 1st, 1898. As we have mentioned, the patent name is METHOD OF AND APPARATUS FOR CONTROLLING MECHANISM OF MOVING VESSELS OR VEHICLES, NO. 613,809 in the US patent office. The patent application is very complex and revolutionary for the time when it was pended. In this Section, we will present main details from the Tesla's specification that was the forming part of Letters Patent No. 613,809, dated November 8st, 1898 [3]. According to Tesla's original description from the specification, we are able to precisely define the aim of the patent:

"... The problem for which the invention forming the subject of my present application affords a complete and practicable solution is that of controlling from a

given point the operation of the propelling-engines, the steering apparatus, and other mechanism carried by a moving object, such as a boat or any floating vessel, whereby the movements and course of such body or vessel may be directed and controlled from a distance and any device carried by the same brought into action at any desired time. So far as I am aware the only attempts to solve this problem which have heretofore met with any measure of success have been made in connection with a certain class of vessels the machinery of which was governed by electric currents conveyed to the controlling apparatus through a flexible conductor; but this system is subject to such obvious limitations as are imposed by the length, weight, and strength of the conductor which can be practically used, by the difficulty of maintaining with safety a high speed of the vessel or changing the direction of movement of the same with the desired rapidity, by the necessity for effecting the control from a point which is practically fixed, and by many well-understood drawbacks inseparably connected with such a system. The plan which I have perfected involves none of these objections, for I am enabled by the use of my invention to employ any means of propulsion, to impart to the moving body or vessel the highest possible speed, to control the operation of its machinery and to direct its movements from either a fixed point or from a body moving and changing its direction however rapidly, and to maintain this control over great distances without any artificial connections between the vessel and the apparatus governing its movements and without such restrictions as these must necessarily impose.”

This introducing description is enough to define the domain of the patent. Tesla intended to protect not only the idea of the first wireless controlled vehicle but also the first boat-robot with the elements of artificial intelligence! On the following drawings (also excepted from the original Tesla's patent) the whole device is constructed:

These drawings (Figure 1) define basic elements of the Tesla's boat. All fundamental mechanisms of the future robots like control mechanism, servomechanisms, remote control, gyroscope, DC electrical drive etc. are presented. The boat is a complete device that could be operated remotely as well as autonomously, when it is out of radio control.

Some details about Tesla's vision of the remote controlled boat are shown in Figure 2 (left picture). It is easy to comprehend that Tesla constructed 3 independent radio circuits that are controlled by the radio waves, from the small radio station on the coast. Using the first logic AND circuit driven by the alternating current, it was able to control not only 3 but also 8 independent servo operations. Servomechanisms themselves were constructed using the small electro motors driven by DC and electromagnetic relays Figure 2 (right picture). Receiving circuit was solved using high-sensitive coherers.

The key-points of Tesla's patent should be best presented by the original claims

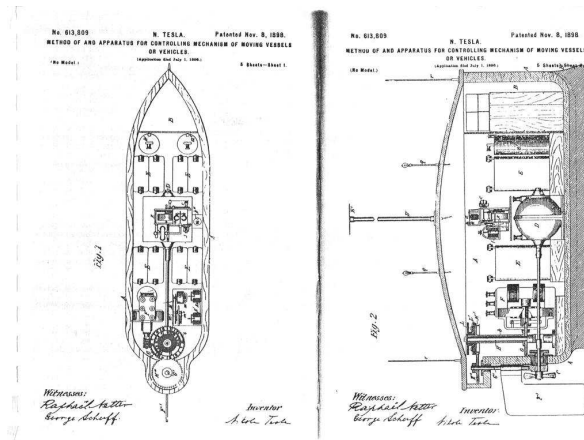


Fig. 1. Basic drawings of the Tesla's vehicle - boat.

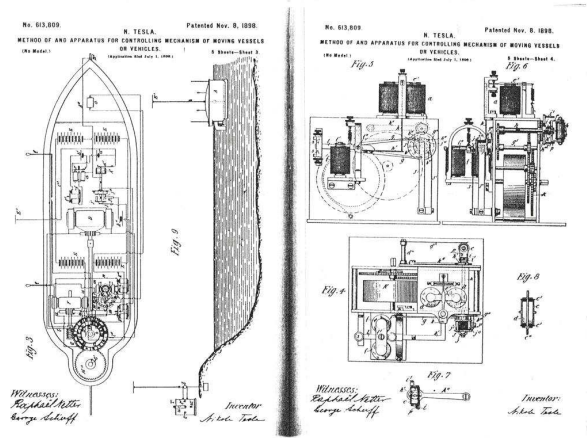


Fig. 2. Wireless control of the boat and some detail about the servomechanism.

from patent application:

" ...

Having now described my invention, what I claim is-

1. *The improvement in the art of controlling the movements and operation of a vessel or vehicle herein described, which consist in producing waves or disturbances which are conveyed to the vessel by the natural media, actuating thereby suitable apparatus on the vessel and effecting the control of the propelling-engine, the steering and other mechanism by the operation of the said apparatus, as set forth.*

2. *The improvement in the art of controlling the movements and operation of a vessel or vehicle, herein described, which consists in establishing a region of waves or disturbances, and actuating by their influence exerted at a distance the devices on such vessel or vehicle, which control the propelling, steering and other mechanism thereon, as set forth.*
3. *The improvement in the art of controlling the movements and operation of a vessel or vehicle, herein described, which consists in establishing a region of electrical waves or disturbances, and actuating by their influence, exerted at a distance, the devices on said vessel or vehicle, which control the propelling, steering and other mechanism thereon, as set forth.*
4. *The improvement in the art of controlling the movements and operation of a vessel or vehicle, herein described, which consists in providing on the vessel a circuit controlling the propelling, steering and other mechanism, adjusting or rendering such circuit sensitive to ways or disturbances of a definite character, establishing a region of such waves or disturbances.*
5. *The combination with a source of electrical waves or disturbances of a moving vessel or vehicle, and mechanism thereon for propelling, steering or operating the same, and a controlling apparatus adapted to be actuated by the influence of the said waves or disturbances at a distance from the source, as set forth.*
6. *The combination with a source of electrical waves or disturbances of a moving vessel or vehicle, mechanism for propelling, steering or operating the same, a circuit and means therein for controlling said mechanism, and means for rendering said circuit active or inactive through the influence of the said waves or disturbances exerted at a distance from the source, as set forth.*
7. *The combination with a source of electrical waves or disturbances and means for starting and stopping the same, of a vessel or vehicle, propelling and steering mechanism carried thereby, a circuit containing or connected with means for controlling the operation of said mechanism and adjusted or rendered sensitive to the waves or disturbances of the source, as set forth.*
8. *The combination with a source of electrical waves or disturbances, and means for starting and stopping the operation of the same, of a vessel or vehicle, propelling and steering mechanism carried thereby, local circuits controlling said mechanisms, a circuit sensitive to the waves or disturbances of the source and means therein adapted to control the said local circuits, as and for the purpose set forth.*
9. *The sensitive device herein described comprising in construction a receptacle containing a material such as particles of oxidized metal forming a part of the circuit, and means for turning the same end for end when the material*

has been rendered active by the passage through it of an electric discharge, as set forth.

10. *The sensitive device herein described, comprising in combination a receptacle containing a material such as particles of oxidized metal forming a part of an electric circuit, an electromagnet in said circuit, and devices controlled thereby for turning the receptacle end for end when said magnet is energized, as set forth.*
11. *The sensitive device herein described, comprising in combination a receptacle containing a material such as particles of oxidized metal forming part of an electric circuit, a motor for rotating the receptacle, an electromagnet in circuit with the material, and an escapement controlled by said magnet and adapted to permit a half-revolution of the receptacle when the said magnet is energized, as set forth.*
12. *The combination with a movable body or vehicle, of a propelling-motor, a steering-motor and electrical contacts carried by a moving portion of the steering mechanism, and adapted in certain positions of the latter to interrupt the circuit of the propelling-motor, a local circuit and means connected therewith for controlling the steering-motor, and a circuit controlling the local circuit and means for rendering said controlling-circuit sensitive to the influence of electric waves or disturbances exerted at a distance from their source, as set forth.*
13. *The combination with the steering-motor, a local circuit for directing current through the same in opposite directions, a controlling-circuit rendered sensitive to the influence of electric waves or disturbances exerted at a distance from their source, a motor in circuit with the steering-motor but adapted to run always in the same direction, and a local circuit or circuits controlled by said motor, as set forth.*

...

This claim itself contains the fundamental principles of different directions in robotics and wireless controlled devices that were a very good base for the further development.

3 Basic Procedures of the 3D Modeling

Basic procedures in the implementation of the project objectives could be described as follows [4]:

1. On the basis of selected original patent by Nikola Tesla, one made its digitization and transfer to the virtual 3-D model [5].

2. After receiving 3-D model, its processing and finalization are done in appropriate 3-D editors, programs for processing and rendering of three-dimensional model.
3. Using different 3-D applications, we perform rendering of the model, which can be seen from different angles as well as the animation models from the desired motion parameters model.
4. We perform a reduction of the basic model for the needs of interactive engine. Reduced-model is converted into an internal domain for interactive OpenGL engine, developed as an original application, means that models can be rotated in real time and run models in virtual space.
5. The reduced model can be used as input to the 3D stereo engine that enables stereoscopic vision three-dimensional model.
6. Animations, rendering of images in high resolution, and other materials are integrated into a unified presentation program that is installed in the Museum of the appropriate equipment, which means that visitors of the Museum have continuous access to the project results.

Following these steps, we completely solved the problems with 3D applications of the Tesla-Robot Boat (U.S. Patent 613.809 Method of and Apparatus for Controlling Mechanism of Moving Vessels or Vehicles) completed the modeling and the movement in water, operation mechanism and management of real-time functions.

The first steps were connected with the modeling of the boat itself. The boat is modeled manually, but all proportions and details were based on original schemes from Tesla's patent. Using the details from the patent specifications, our team was able to precisely and completely construct the 3D model of the boat. We believe that the model in all aspect is very similar to the original model of the boat. The total mechanism of the boat, as a 3D model is presented in Figure 3:

When we remove the glass plate of a boat, we are able to see the inner 3D structure of the model. All basic elements of the modern robots are presented - the accumulator, main drive motor, servo motor, control relays and control system, effectors, signal lamps, HF radio circuits for radio control (Figure 4a-4c).

After the static 3D modeling, we add functionality and transfer the model to real time environment that was mentioned before in the paper.

4 Modeling of the Tesla's Boat

We modeled textured Tesla's boat in AutoDesk Maya. AutoDesk Maya is a program that is used for modeling, animating and rendering virtual objects. After that,

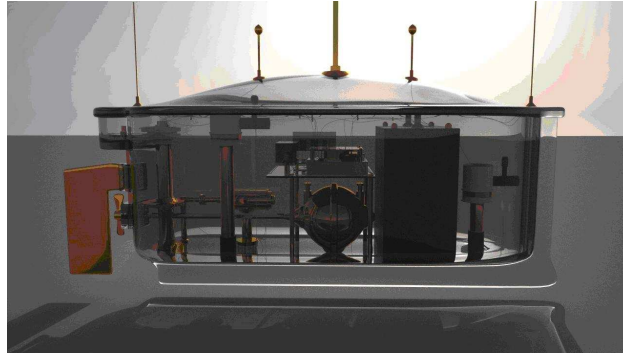


Fig. 3. Complete 3D model of a Tesla's boat.

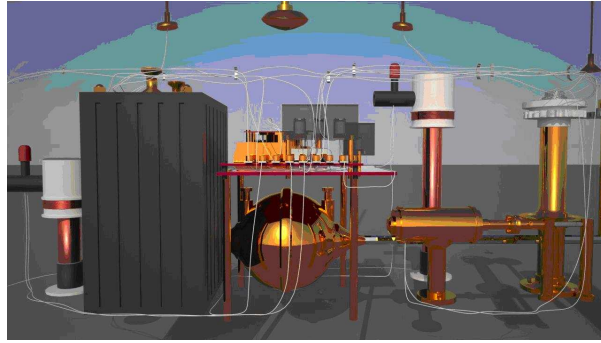
the boat was exported into a real-time engine Unreal Development Kit (UDK). In UDK, the boat was rendered for Real Time performance. UDK is using Lightmass for rendering engine, which gives very good results for a shorter time of rendering. Lightmass is using Light Baking technique for Real Time performance. Light Baking means that, when we render the scene the results are written into textures so there is no need to re-render for every frame. UDK also can show Real Time shadows, which are computed for every frame. The great thing is that we can mix those techniques until we get good visual quality with minimal processor usage.

Nikola Tesla was also modeled and textured in AutoDesk Maya, but exported in AutoDesk Motionbuijder. AutoDesk Motionbuijder (MB) is a program for character animation only. MB has many advantages; one of them is its Real Time environment (there is no need for scene render for seeing animation at a good frame rate), Automated Rig Creation that has Forward/Inverse Kinematics manipulation rig that is automatically created based on the size and proportions of our character. Animated Tesla was exported into UDK for rendering and scene placement.

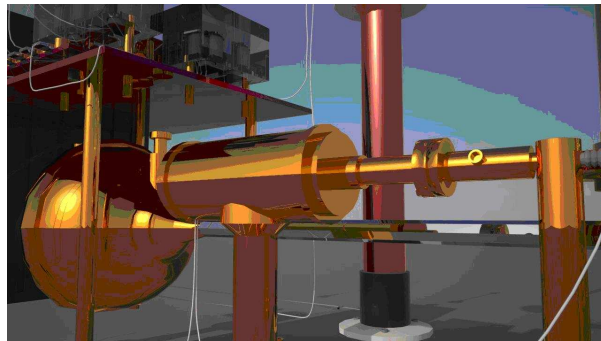
Nature environment was made in UDK with Terrain Editor and Speed Tree. Terrain editor is a part of UDK that allows us to do very believable terrain with foliage on top of it. We have been using Speed Tree for tree placement into the scene and its animation.

The control of the boat was done in such a way that the user could control the movement of the boat. Kismet is a part in UDK where we do visual programming. In Figure 5a-5d one can see the events that we made for the movement of the boat, lamps that are switching on and off, depending on the boat movement and waves that are showing around the boat. Some of the details about the Kismet programming are presented in the following pictures:

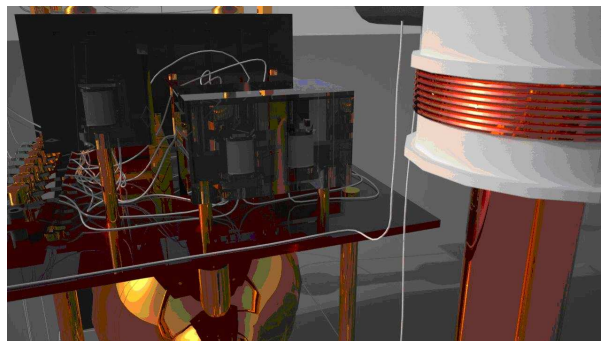
So, therefore we programmed movement of the boat in Kismet, which is controlled by the user. Lights on the boat are changing when the user change direction



(a) The inner structure of a boat.



(b) Servomechanism.

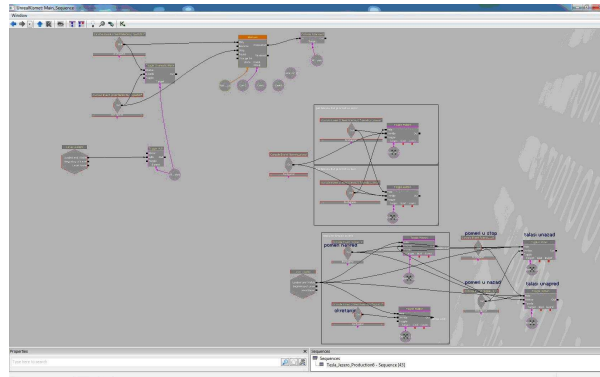


(c) Control circuits.

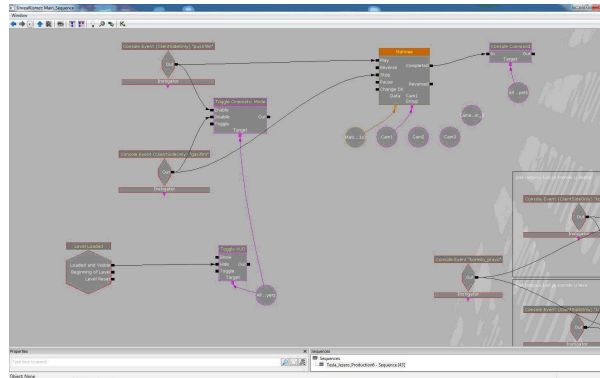
Fig. 4. Inner structure of the model.

of the moving boat.

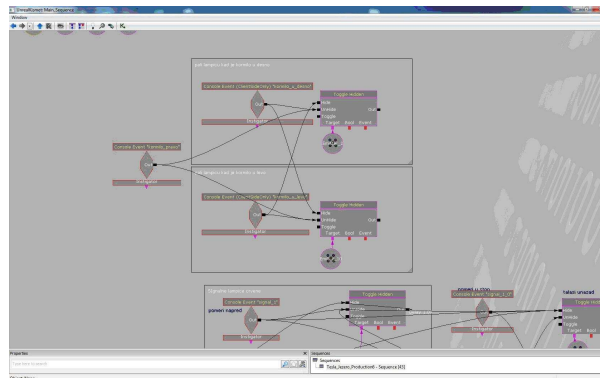
Matinee is the application where we control camera animation, which is used for a render scene (Figure 6). Camera control is very good, almost like in professional animation programs such as Autodesk Maya. The animation of the camera



(a) Kismet visual programming of the Tesla Boat-details.



(b) Kismet visual programming of the Tesla Boat-details.



(c) Kismet visual programming of the Tesla Boat-details.

Fig. 5. Kismet visual programming of the Tesla Boat-details.

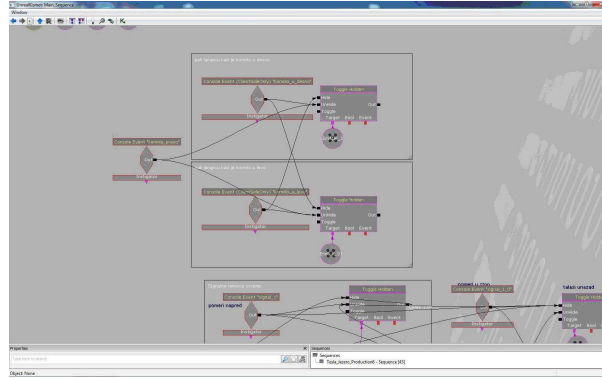


Fig. 5. (d) Kismet visual programming of the Tesla Boat-details (continue).

was rendered in .avi file. Rendering is ultra fast because we are using Real Time environment and there is no need for recalculation of the scene.

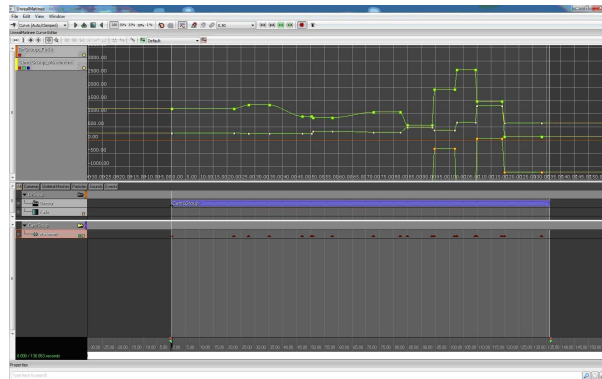


Fig. 6. Matinee - control camera animation, which is used for a render scene.

Real Time environment and placeholders for various Real Time effects: lights, wind, sound, place where character will spawn etc. (Figure 7).

Camera movement control is very important for final animation rendering. It can be controlled by Matinee (Figure 6) as well as by direct Manuel movement. The software enables to visualize camera movements, that are very useful for control of the animation direction (Figure 8).

Finally, Tesla's boat was modeled, textured and animated in AutoDesk Maya. Virtual character Nikola Tesla was also modeled in AutoDesk Maya and animated in AutoDesk Motionbuilder program for character animation (Figure 9,10).

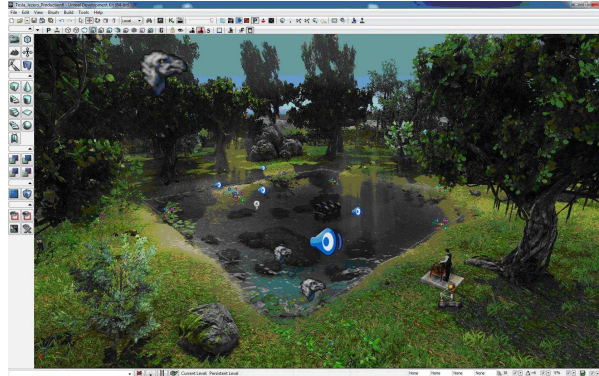


Fig. 7. Real Time environment.

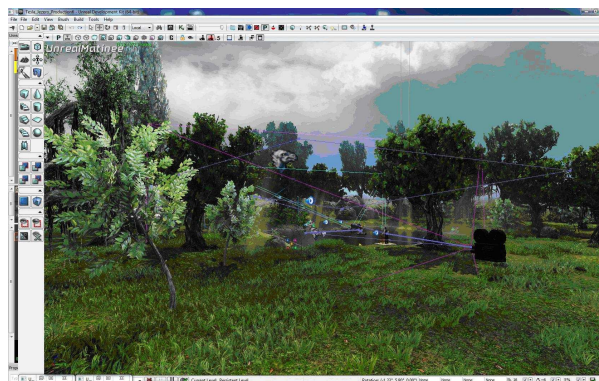


Fig. 8. Visualization of the camera animation in the Real Time environment.

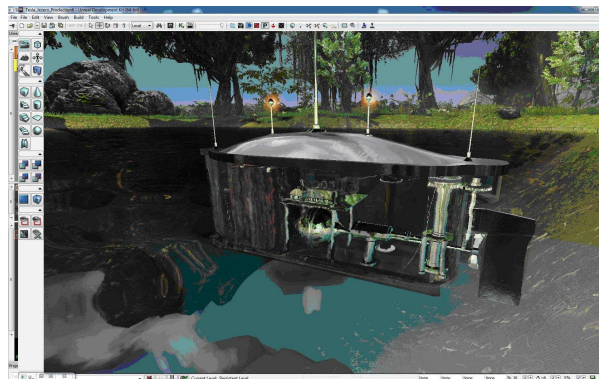


Fig. 9. Model of Tesla boat - integrated in 3D environment.

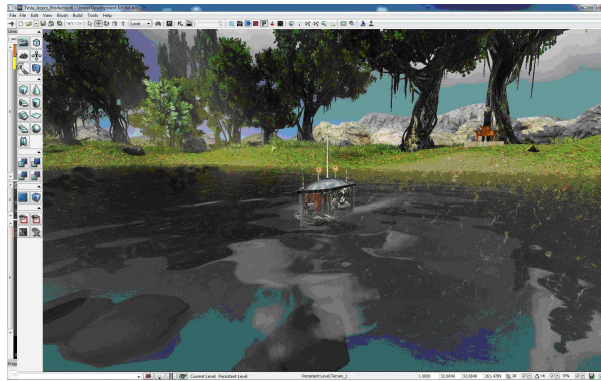


Fig. 10. The complete models of the robot-boat with Tesla in the background.

5 Conclusion

This paper presents details about the 3D modeling and real-time animations of the Tesla ship - one of the most complex Tesla's patents. We presented the full procedure from the original patent to the real time model. There are many steps in this procedure, all of them described. Finally, our model of the boat is one of the most complex and detailed models made till nowadays. Real time application, with a combination lake and a boat, is the first one of that kind, as far as we know [6].

This model is a part of our work on a project realized at Faculty of Electronic Engineering in cooperation with the Ministry of Science and Technology and the Nikola Tesla Museum from Belgrade. We believe that the realization of the project is very important for both institutions, especially the Nikola Tesla Museum in Belgrade, which has a special status of the institution of national importance, so that the results of the project were implemented immediately in direct support for the work of this major institution.

As a direct project outcome we can point the implementation of dozens of animation, computer models, rendered images and other material, which are installed in a unique presentation system at the Nikola Tesla museum and are in constant operation. The project had a number of promotions, seminars, and media attention. To crown the success is a joint appearance with the Museum of Nikola Tesla at the World Exhibition in China in 2010 at the central stand of the Republic of Serbia. 3-D movie made especially for the occasion was seen by some 200,000 visitors.

Acknowledgements

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References

- [1] M. M. Woolfson, *Introduction to Computer Simulation*. OUI Oxford, ISBN-10: 019850425X.
- [2] H. Alexander, *Practical Guide to Computer Simulations*, pap/cdr ed. World Scientific Publishing, June 21, ISBN-10: 981283415X.
- [3] N. Tesla, "Method and apparatus for controlling mechanism of moving vessels or vehicles," U.S. Patent 613,809, July 1, 1898.
- [4] N. Stojanović and V. Vučković, "Inverted pendulum 3d engine," *Facta Universitatis, Series Electronics and Energetics*, vol. 23, no. 3, pp. 299–309, Dec. 2010, ISBN 0353-3670. [Online]. Available: <http://factae.elfak.ni.ac.rs/fu2k103/4nikola.pdf>
- [5] V. Vučković, "Virtual models of tesla patents," in *Proc. of 17th Telecommunications Forum TELFOR2009*, Nov. 24–26, 2009, pp. 1335–1338, ISBN 978-86-7466-337-0.
- [6] M. P. Allen and D. J. Tildesley, *Computer Simulation of Liquids*, new ed. Clarendon Press, June 1, 1989, ISBN-10: 0198556454.