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Technology for developing educational films on medicine using highly realistic computer graphics and animation

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Abstract

The article discusses a project to create educational films in the field of medicine, using 3D technologies. Possible technologies, the impact of audiovisual content on the viewer, and technical features of the production of educational films are highlighted.

Keywords: medicine, surgery, maxillofacial surgery, education, educational film, 3D graphics, visualization, public relations, distance education.

I. INTRODUCTION

The article discusses a creation of educational films in the field of medicine, using 3D technologies. The project is being implemented by the Herzen State Pedagogical University of Russia together with the Pavlov First State Medical University of St. Petersburg. The description of the features of creating medical content and its implementation in the educational product is carried out on the example of the created pilot film.

1.1. The Pilot Project

The pilot issue is a learning film on surgery, which reveals the preparation and conduct of surgery to correct the bite mesiocclusion in the case of dento-maxillofacial disorder (DMFD), as well as further treatment and rehabilitation after the operation. The film is based on a real-life and documented operation at the Research Institute for Dentistry and Maxillofacial Surgery of the Pavlov First State Medical University of St. Petersburg.

II. Project Goals

The main goal of the project is, of course, education and the educational process. But this process can take a different form and be presented to a very different audience. This can be either full-time lecture-based education at a university, in which case the films can serve as the demonstration, or online training courses for medical personnel, including Junior medical staff. The issue of distance learning is particularly acute during and after the global COVID-19 virus pandemic. But the project's potential is not limited to education alone. Films can also serve as a public relations tool, providing the public and patients preparing for surgery with up-to-date medical information or guidance on how to act in difficult situations. This, once again, becomes particularly relevant in the context of the pandemic.

2.1 Conveying information

Of course, the key task of such educational films is to convey information about the operation. In the format we selected, information about the operation can be divided into three categories. **First category**. General information about the disease and treatment methods. This includes not only the operation itself, but also preparing the patient for it, planning the operation, rehabilitation and further treatment after the operation. It is reasonable to transmit this information using schematic 2D graphics. We can use such as a flowchart, a timeline showing the days and weeks that have passed since the operation, and so on. **Second category**. Information about the specific anatomical modifications for which the surgery is performed (what is moved and where, where the incisions are made, and how it is all sewn up). Here it is reasonable to use 3D graphics, since it allows you to clearly demonstrate the trajectory of cuts, saws and splits, as well as the direction and degree of displacement of anatomical structures in space. 3D graphics technology gives a huge advantage since it allows you to see the necessary anatomical structures through others. For example, the skull and lower jaw through soft tissues (skin, periosteum, mucous membrane). The **third category** includes information about the operation technique. In what order, by what methods, and with what devices, the required corrections are implemented. This includes, for example, screwing an additional screw into the patient's skull, which serves as a reference point for precise positioning of the upper jaw using a caliper; or a technique for fastening the patient's bite (closed dental rows) with additional screws and rubber rods. Of course, this is an accurate simulation of all surgical instruments used during the operation, and their use. A special advantage of the chosen technique is that it allows you to simply and easily reveal the essence of the operation, without missing a single step, in a period of time from 3 to 5 minutes, while the operation itself can last 4, 6, or even 8 hours.

2.2 Innovative Activity of Our Customers

The pilot film was created on the example of one of the operations performed at the Research Institute for Dentistry and Maxillofacial Surgery of the Pavlov First State Medical University of St. Petersburg. This Department conducts operations that are currently breakthrough and unique in their complexity. Even though such operations are described in the upfront scientific literature, there is a shortage of educational materials for students, clinical residents, surgeons, and medical professionals. Our project allows documenting, organizing, analyzing, and providing such operations for the educational process, thereby facilitating and speeding up the assimilation of advanced knowledge in the field of surgery by the Russian and international medical community. Mainly, it helps to spread not only the information about the operation itself, but also the direct visual experience of operating surgeons, which is extremely important for the training of specialists in the field of surgery. The project can also serve the purpose of popularizing advanced scientific knowledge among the general public.

2.3 Psychological Training

Any surgical operation is a mental stress for the surgeon. The success of the intervention depends directly on how the surgeon handles stress. Anticipation of the upcoming operation can cause two types of emotions: sthenic (emotional rise, self-confidence, cheerfulness) and asthenic (decline in energy, lack of concentration, uncertainty) [1]. Obviously, the development of sthenic mental reactions and reduction of asthenic ones is an important task in the psychological training of surgeons. Our product allows maximum virtual dipping into the operation process, while programming the surgeon for a successful result and clear flow of all processes, thereby forming a positive experience of a surgery. Unlike other analogs that reveal the essence of surgical operations in 3D, our project aims to create the illusion of presence in a real operating room. For this purpose, the patient is positioned horizontally, simulating not only the part of the patient's body that is undergoing surgery, but also the entire environment, including the operating room, the fabric covering the rest of the patient's body, the operating table, lighting, all tools, additional elements such as a bracket system, etc. Special attention is paid to the photorealism of the image. To achieve this, PBR materials (Physically Based Rendering) are used [2]. Visualization is performed on the PBR real-time render engine Eevee (Blender). In addition to the 3D graphics itself, you can insert fragments

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of actual footage from the operating room to illustrate the corresponding actions. Here, it is important to match what is seen in the video and in 3D, so that a closer connection with real surgical practice is formed and the effect of presence is enhanced. For this reason all the instruments and equipment is precisely replicated in 3D in the exact scale (fig. 1).

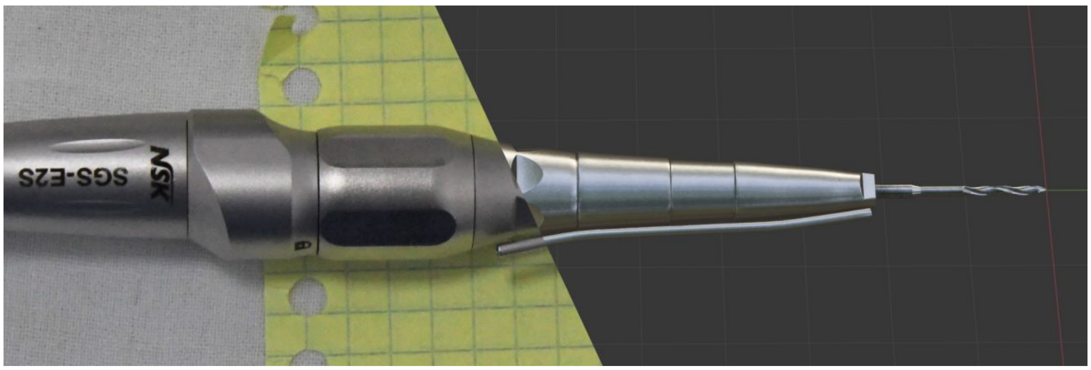

Figure 1. Precise modeling of instruments used in surgery

2.4 Emotional Impact

Audio-visual content has the ability, in addition to simply informing, to convey unconscious motives and values that can contribute to the correction of a possible crisis situation or to the improvement of society as a whole [3].

2.5 Image Creation

The appearance of the product, the messages embedded in it and, of course, the quality of the film are a hallmark in the professional environment and for the general public. One of the most powerful tools for creating an image is design [4]. The core messages embedded in the appearance of the learning film: "progressiveness, innovation"; "clarity, openness"; "high professionalism"; "good taste"; "creativity"; "care for the audience" (fig. 2).

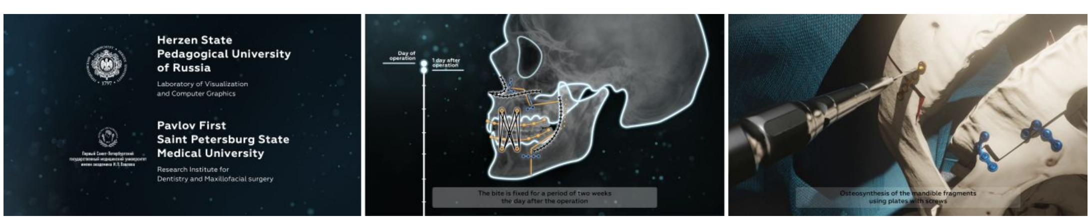

Figure 2. Design example

III. Target Audience

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3.1 Narrow Target Audience

The narrow target audience of the project is, of course, medical staff and students. Thus, when working for this audience, our product can be considered as an accompanying specialized educational guide. The maximum accuracy of medical aspects is essential here. This includes both the operation itself and the actions that take place in it, which should have maximum universality and acknowledgement in the scientific community. The same applies to the accuracy of phrasing and unambiguity. When monitoring the quality of this aspect, priority is given to consulting with leading industry experts [5]. When working for such an audience, the level of complexity is also important. The material can be used as an experienced surgeon for self-education or dipping into a new field of surgery, as well as a teacher of a specialized University while teaching students. Educational films should be understandable to all potential audiences. Visibility is a key aspect in achieving this goal. For example, the phrase: "a sagittal split osteotomy of the mandible is done above the neurovascular bundle and vertically between the first and second molars of the mandible", which an experienced specialist can perceive by ear, was necessarily accompanied by a visual demonstration of this action during the phrase, so that students and doctors could form a clear idea of the meaning of these words. In order to make learning more efficient at a wider audience, the entire sounding is dubbed with subtitles since it is more convenient for some people to memorize the information in this way, as well as because it may not always be technically possible to play the sound.

3.2 Wide Target Audience

As has been already mentioned in this paper, the project may not be limited to working for the professional medical community. When working for a wide audience, it is better to avoid professional vocabulary or decipher it, use diagrams and animation to illustrate all processes, use "friendly" color, graphic and musical solutions, and use an attractive and trustworthy voice and tone of the speaker. In addition to that, it is extremely useful to test content on ordinary viewers before the release of the film (working with focus groups).

4. Features of Working With Disturbing Content

The sight of a human body being cut up, as well as manipulating it with rather crude tools (chisel, hammer, saw), has a depressing effect on the human psyche and can even traumatize it. In this regard, it is necessary to think about the degree of naturalness that we offer to different categories of viewers.

4.1 Need for Special Color Correction

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The most problematic element in this sense is fragments of video footage of the operation. If surgeons are used to such a spectacle, then in the case of creating a film for a wide audience, it is necessary to develop a solution that allows you to reduce the naturalness. There are two ways to achieve that. The first is the complete elimination of video fragments from the film. The second is a special color correction. The meaning of the last solution is to completely or partially remove the color of blood from the screen. To demonstrate how this can be done, figure 3 shows 4 variations of the same frame. The first is untouched, the very depressing visual that we want to get rid of. The second is the same, only translated into black and white in the simplest way. And here we face a problem. We are losing all the visual information that was transmitted through color in the first version. To solve this problem, we make the color component of the image (chroma) affect the brightness value of the image (luma). For instance, red areas are now getting darker. This way, more visual information is revealed. In the last version, we selectively add colors that do not cause the viewer to be disturbed.

Figure 3. Stages of color correction

To give the most flexibility when marketing the product, the final version of the film is composed of three versions: a full-color version, a version with special color correction, and a version with completely excluded video footage.

5. Features of Working With Anatomy in 3D

In this part, we will review the technical solutions that have been found for the specific needs of the project.

5.1 The Technology Used in the Making of the Film

All 3D graphics were made using the mesh modeling technique, in which the surface of objects is defined by a mesh consisting of vertices, edges, and polygons [6]. This technique is used to define the surface of the skull, soft tissues of the mouth, skin, sutures, instruments, mucous membranes, etc. (Fig. 4). The main technical limitation when editing such a geometry is the number of vertices that are simultaneously present in the scene, i.e. they are located in the computer's RAM. If there is a lot of such information, working on it is complicated by the lowered performance of the computer.

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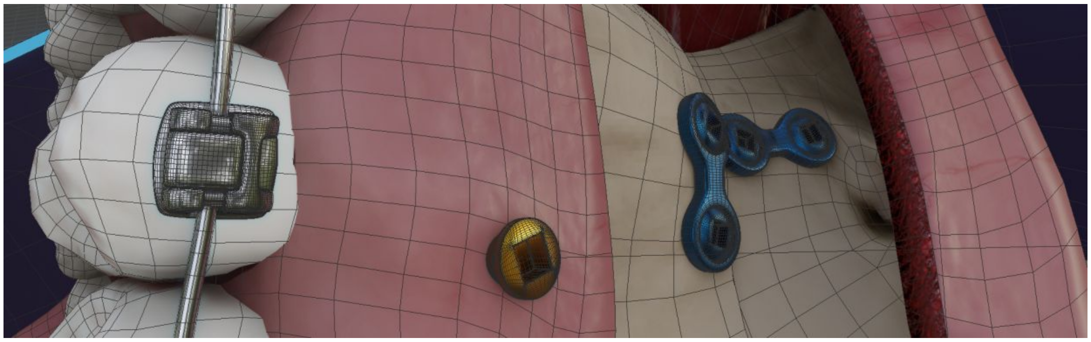

Figure 4. Polygons that define the surface of objects

Complex operations that overlap the geometry in real time, such as trimming one object with another (boolean), adding thickness, and so on, can also slow down the computer's response.

5.2 Technical Requirements of the Project

The purpose of the operation is to change the position of the bone sections relative to each other. For instance, a fragment is detached from the bone tissue, moved to a new position, and fixed. But elastic soft tissues (skin, mucous membrane, periosteum) and additional elements (sutures) are constantly attached to these bones, which should be stretched accordingly between the mobile parts of the bones. This means that the movement of the bones in all directions should move the soft tissues and sutures accordingly. But the bones to which the elastic elements are attached are not present in the scene all the time. When a single bone is cut into two fragments and they start moving independently, a single solid 3D object is replaced by two separate ones, unnoticed by the viewer. Binding soft tissue and sutures directly to the bones in this situation is complicated by two aspects. The first is that to edit such a system, you will have to load all the associated geometry and operations on them into RAM, which will significantly increase the computer's calculation time. The second is that the areas of the bones to which soft tissues are attached are constantly replaced by splitted parts of the same bones. In addition, this system makes it difficult to independently edit related objects, which is constantly necessary when correcting surgical actions during production.

5.3 Motion Blueprint

The solution found is to isolate the "blueprint of movement" of all the fragments of bone tissue into a separate file. This file contains "empty" objects (which do not include any surfaces, but store the position, rotation, and scale of objects). They are then used for all the animation of bone tissues. Then these objects are linked to all files which contain movement of any anatomical structures or additional objects (screws, osteosynthesis plates, sutures) and all mobile surfaces (including bones) are

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linked to them. Since "empty" objects do not contain any surface geometry, they do not slow down the computer's response while editing the scene. This approach has a special advantage in editing the animation of movement of bone sections, since the animation is automatically transmitted to all necessary objects, from the bones themselves to even the stitches.

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