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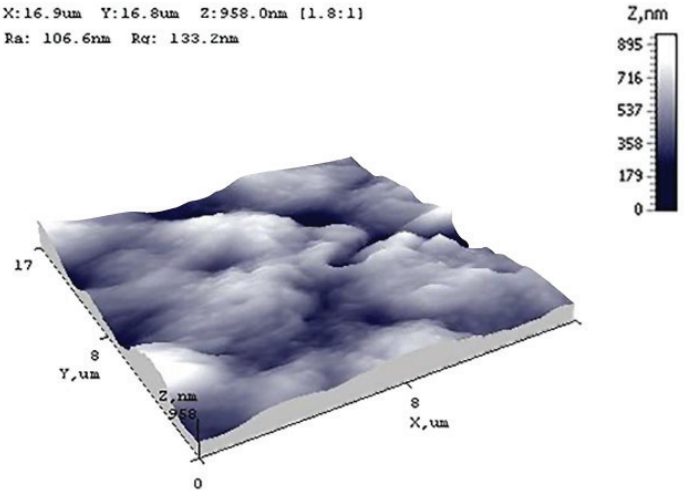

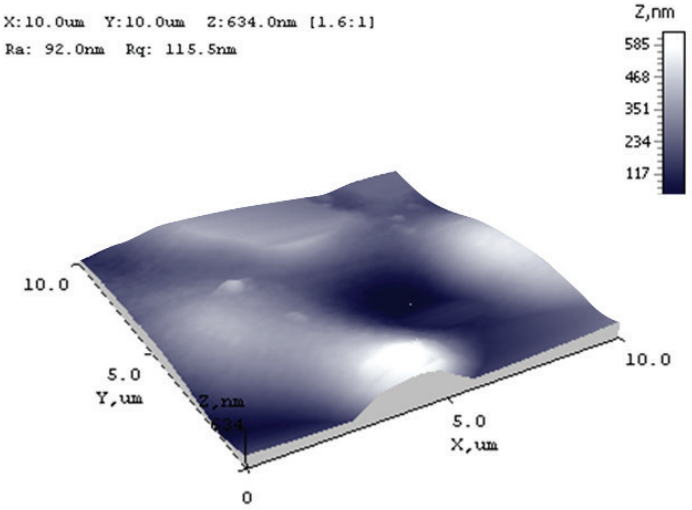

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Contents

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Visual effects and their importance in the field of visual media creation

ABSTRACT

The paper presents visual effects and their importance in the creation of visual media and film industry. After defining the field and the term visual effects, the reader is introduced to the techniques and approaches used to create visual effects, i.e., computer-generated Imagery, 3D computer graphics, motion capture, matchmoving, chroma key, rotoscoping, matte painting, and digital compositing. This is followed by a presentation of the history of visual effects from its beginnings to the digital age, taking in the most successful examples of film production such as Terminator, Toy Story, The Matrix, and Star Wars. As an example of the most representative production, the paper includes a more detailed description of the techniques, methods, and approaches used in the Lord of the Rings film trilogy, focusing on the creation of the visual appearance of the Gollum character, his movement, and facial expressions, the creation of crowds with autonomous agents and the introduction of digital duplicates. The review concludes with an overview of trends for the future of the field.

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Introduction

Let us take you on a journey to the world of visual effects (VFX). How do we define visual effects? What is the difference between visual and special effects? And why do we actually use them for?

For easier understanding of this particular topic, we will present the techniques most commonly used to create so-called »digital magic«. After that, we will focus on the history of visual effects, which will then be upgraded with a presentation of some examples of good practice. Those examples will be based on just one film trilogy, as it contains some key elements for a quality presentation of several different techniques and innovations in the field. Finally, we will briefly summarize some trends in VFX that are currently present and will probably occur in the future.

Visual effects

According to the established model of filmmaking, visual effects are primarily used to make the storytelling more believable. However, visual effects have often been treated as a less important area of film art and, therefore, also misinterpreted on several occasions. The reason for this misinterpretation is that visual effects are too often associated with tasteless spectacles, visually oversaturated hits, or fantasy adventures aimed primarily at young audiences. In some cases, they even seem to be more important than the storytelling itself. With the digital advancement and the creation of films, such as Avatar (directed by James Cameron, 2009), the traditional view of film production is changing. Such films place the visual effects at the very core of storytelling, as practically the entire visual image of the film is created digitally. However, such examples are merely

indicators of endless possibilities of visual creation. Furthermore, while it is true that visual effects can create a spectacle, they more often operate on a much more covert and less spectacular level (Prince, 2007).

Hand in hand – definition, differentiation, and connection between visual and special effects

To comprehensively address the field of visual effects in film, we must first clarify what visual effects actually are, and that is a subcategory of special effects (SFX or FX for short). And although the two areas are by no means mutually exclusive moreover, in most cases, they are even interconnected and complementary; they should by no means be equated (UKEssays, 2017).

Visual and special effects are often misunderstood to be the same thing. Such misunderstanding can occur due to the constant interconnection of the two fields in film art. In the past – that is before the development of digital technologies, the areas related to the creative process were very interconnected, as visual effects, as well as special effects, were often created with recording equipment on the film set. However, unlike special effects, which are made mainly with the use of various stage aids, visual effects have always been created with the help of optical processing, with the use of special photographic lenses, or the creation of optical illusions. In the digital age, the process of making visual effects has been moved completely to postproduction, while special effects are still being made during the actual live-action filming (Britannica, 2012).

At this point, the obvious question arises – what is the real difference between visual and special effects?

Visual effects include visual material made or adapted for use in a visual medium and cannot be created or recorded live. The art of creating visual effects in the digital age is usually performed in postproduction, that is after the basic capture of a recording. Visual effects are created using various techniques and added to the recordings with the help of computer programs. With technological development, digital equipment for the production and incorporation of visual effects into recorded material is becoming more and more accessible, so it has become a standard part of the filmmakers' equipment. Unlike visual, special effects cover all the effects that can be created during the actual recording of visual material – that is why they are also known as practical effects. The most typical examples of special effects are a recreation of rain and fire, the use of firearms, road races with various vehicles, and, after all, the use of the good old dynamite to simulate explosions. Visual and special effects have always gone hand in hand, but thanks to the progress that has been made in the field of VFX over time, mainly with the introduction of digital processing, the making of special effects has been able to evolve as well (Oknu & Zwerman, 2010).

The usefulness of digital magic

There are three main reasons for using visual effects in film art. The first is that certain scenes from the script simply cannot be recorded live in any way. Such an example would be the astronauts flying around the Moon in Apollo 13 (directed by Ron Howard, 1995). Another reason for using visual effects in a film is that a certain scene could be filmed live, but would endanger someone's life. An example of this would be the many death execution scenes in various films where, obviously, none of the actors is actually being killed. The third reason for using visual effects is primarily of a financial nature. In some cases, it is more practical and financially advantageous to recreate a specific space with the help of digital techniques than to shoot the scenes at the actual location. Some examples for that kind of usage of visual effects can be found in pretty much every modern production that contains scenes from a larger area of the landscape (Oknu & Zwerman, 2010).

Techniques, techniques, and techniques again

Before diving deep into the world of visual effects history and development, and for anyone's better understanding of the field, we will present some techniques that are most useful and, therefore, most commonly used for the creation of VFX.

Computer-Generated Imagery (CGI)

Computer-generated graphics is probably one of the most commonly used techniques for creating visual effects nowadays. The term is used for all the elements that are created and integrated into real shots with the help of a computer, whether that means only background elements, such as landscape, or movie characters that establish some kind of interaction with other parts of the scene. These elements can be two-dimensional or three-dimensional, but the term CGI is mainly used for the latter. Moreover, although a computer can do it all, in most cases, rather than resorting to this technique in its entirety, filmmakers use it only to upgrade the recorded material – for example, adding the audience to an actually empty stadium. The advantage of this particular technique is that everything created with it can be quite easily corrected and improved (Izmofx, 2019; StoryboardThat, 2020).

3D graphics

There are a few more techniques in the category of computer-generated graphics that definitely deserve an explanation. One of them, which represents a whole

extra field, is 3D modeling and animation. Simply explained, it is used to digitally create an object that doesn't really exist, or to recreate a scene that would be too difficult to build in reality (MasterClass, 2021).

Motion capture

Another commonly used technique that can be included in the field of computer-generated graphics is motion capture. This technique is mentioned here mainly due to the fact that motion capture is usually transferred to a computer-generated (in most cases a 3D) model. For this technique, a special suit with tracking points is used to capture the movement and facial expressions of a real person, which is then converted into the movement of a computer model. Thus, with the help of digital processing, actors' visual appearance can be partly or even completely changed (MasterClass, 2021; RedShark News, 2017).

Matchmoving

Another technique we can mention is matchmoving. This technique is used to place digitally generated elements in real space images. It is used to determine the space and movement of the camera in the image, which enables the correct integration of the 3D model into a certain space. The space in the image is marked with dots, based on which the computer calculates the movements. However, it can happen that, due to the ambiguity of the space, the points and their movements need to be determined manually, meaning each dot for each frame of the recording must be set by hand. The outcome of a successful matchmoving is that the integrated model does not move along with the digitally created camera but follows the location relative to the captured space. Simply put, a virtual camera follows the movements of the real camera (MassiveVFX Studios, 2020; Pluralsight, 2014).

Chroma Key

Chroma key or green screen, as it is more commonly known as, which, by the way, can also be blue (or pretty much any colour you want it to be, as long as it is different from the scene elements), is used for digital replacement of the scene background in postproduction. The color spectrum that the program overlooks during visualization is determined, which means that it can be digitally deleted or replaced with a different background. Nowadays, the chroma key is widely used, one of the examples being television weather forecasting (Izmofx, 2019; MasterClass, 2021; MassiveVFX Studios, 2020).

Rotoscopy

The idea of rotoscopy is similar to that of the chroma key, with one major exception – there is no green or blue background. Thus, it is necessary to create a mask over the object we want to keep on screen. That mask then follows the object's movement with the help of computer-generated points or the help of the manual work done by the mask editor. Everything around this mask is digitally replaceable (MassiveVFX Studios, 2020; Animation Boss, 2019; Future Learn, 2018).

Matte Painting

Using the matte painting technique, we can create a background drawn on a two-dimensional surface (using either 2D or 3D techniques), that gives us a sense of realistic environment. The background can stand physically on the set during the shooting itself, or it can be created digitally and then implemented in the recording (Izmofx, 2019; StoryboardThat, 2020).

Digital Compositing

Digital compositing means using all or just some of the previously mentioned techniques to assemble different parts of shots or images into a single visually uniformed scene. Various software allow us to replace parts of one clip with parts of another clip (replacing parts of the same clip is also possible). This technique is also known and used in other fields of digital art, such as graphic design or photography (where it is known as photomontage) (Izmofx, 2019; MasterClass, 2021).

A little bit of history

Old school effects

Have you ever wondered about how (or perhaps where) it all began and how the field of visual effects has evolved to the level we know today? Well, this chapter holds the answers to your questions.

At the beginning of the development of film art, special effects were strongly intertwined with visual effects. The two concepts only began to differ with the introduction of digital technologies and the proliferation of computer graphics. Various optical tricks that today are considered visual effects were used for different purposes in films at that time, but back then, they were still referred to as special effects. Therefore, at the beginning of this chapter, when we are talking about special effects, we are also talking about visual effects, as both terms meant the same thing at that point in film history.

The year was 1895 when a gentleman named Alfred Clarke used a certain trick that, at least to today's spectator, might seem rather simple. While filming the beheading scene in his short film The Execution of Mary, Queen of Scots (directed by Alfred Clarke, 1895), at the moment when the executioner raised his axe, Clarke

stopped filming and ordered the entire cast to hold still. Meanwhile, the actor who portrayed Mary was ordered to withdraw from the stage so that a doll could be placed in his place. Clarke then continued filming, and the executioner was able to cut off the doll's head. And this so-called stop-trick went down in history as the first film special effect (UKEssays, 2017; Gradišnik & Parkinson, 2000; Nuts Computer Graphics, 2018).

Around the same time, that being the end of the 19th century, a Frenchman named George Méliès, otherwise the owner of the Robert-Houdin Theater in Paris, where magic performances were staged from 1888 to World War I started to happen, accidentally discovered the same stop-trick effect. While filming on the streets of Paris, his film roll got stuck in the camera, and when he later developed it, he noticed that at one point the events in the footage were instantly changed. He later found that he accidentally filmed one shot over the other; thus, a particular visual effect was made. Méliès then began to uncover the possibilities of such tricks and continued to make films. He made almost a thousand short films between 1896 and 1914, but unfortunately, only 140 are preserved to this day. In making his films, he managed to develop various filming and processing techniques, such as dimming, darkening, overlaying and overflowing scenes, as well as hand-painting the film. Due to the development of these techniques, Méliès blurred the boundaries of how reality can be portrayed in films. That is well illustrated by his probably best-known work, The Voyage to the Moon (or Le voyage dans la lune, directed by George Méliès, 1902), which includes some extremely surreal images. Because of the use of special effects in this particular film, which include a combination of real shots and animation, as well as background painting, Méliès is considered to be a pioneer of the science-fiction genre in films. He is also known to be one of the first filmmakers who used storyboards to help him with planning and creating his films (UKEssays, 2017; Gradišnik & Parkinson, 2000; Nuts Computer Graphics, 2018).

Let us move a little closer to modern times, to a period closer to the middle of the 20th century. King Kong (directed by Merian C. Cooper and Ernest B. Schoedsack, 1933) is considered to be one of the pioneering productions in special and visual effects. A leading man of the special effects team was Willis O'Brien, who thought of combining separately filmed scenes in postproduction. With that, he led the path to the technique known as background projection, which later became the film industry standard (Britannica, 2010).

In Citizen Kane (directed by Orson Welles, 1941), many scenes were also adapted from postproduction footage processing, but due to their extremely precise production, they were barely noticeable when the film was released. The man responsible for creating those subtle optical effects was Linwood Dun, and the impressive background painting was done by the hands of Mario Larrinaga. Both had previously worked on visual effects in the production of previously mentioned King Kong. They did a remarkable job of combining different shots and images, mainly with the use of the optical projector. This is a device used for combining different shots of film, which means combining all scenes that contain any kind of special effects. The technique that is used to combine all these elements into a stylistically uniform image, however, is known as optical composition (FX Making of, 2014a).

Although at that time films were still mostly shot on black-and-white film tapes, color films also began to gain their popularity. The problem was that they were slightly more demanding in terms of visual effects, which had the greatest impact on the complexity of the background painting technique. The first major use of color background painting can be seen in the film Gone with the Wind (directed by Victor Fleming, 1939) (Nuts Computer Graphics, 2018; FX Making of, 2014b).

The main problem was the recording of background projections, as they were not bright enough for the cameras to capture them well. That was solved by introducing a new projection system, presented in 1940 by the Paramount studio. The technique of combined background painting, which combines scenes shot in different locations, also had to be adapted to add to the color film. The mentioned technique was first used in The Thief of Baghdad (directed by Ludwig Berger, Michael Powell, and Tim Whelan, 1940), where a blue-colored screen was used for the background on set, and the background environment that can be seen in the film was then added later in the postproduction. The Thief of Baghdad won an Oscar for special effects, one reason being the introduction of the technique in question (Nuts Computer Graphics, 2018; FX Making of, 2014b).

Despite progress and adjustments, the processing of color film still posed a significant financial burden for both filmmakers and production studios, so the use of black-and-white film tape still prevailed over the use of color tape (Nuts Computer Graphics, 2018; FX Making of, 2014b).

The line between special and visual effects became more apparent in the 1960s, when the first Oscars were awarded specifically for visual effects. Two films were nominated, Cleopatra (directed by Joseph L. Mankiewicz, 1963) and The Birds (directed by Alfred Hitchcock, 1963). The winner was Cleopatra, where mainly two techniques were used – glass painting and background painting. In The Birds, the technique of the so-called yellow background was used, where sodium vapor lights are used for the desired effect, in this case, the flapping of the bird's wings. Another film masterpiece of this era that deserves to be mentioned is 2001: A Space Odyssey (directed

by Stanley Kubrick, 1968), which was also awarded an Oscar for visual effects. Although the visual effects in the film were made with techniques that were already known and used before, the scene worth mentioning is the one with the stargate, where we see a traveling stream of colored beams. The effect was created with the Slit Scan device, an invention of one Douglas Trumbull, and can capture two seemingly infinite levels. Any additional effects for the scene were created using different color filters in aerial landscape photographs and with recordings of various chemical reactions (Heavy, 2010; Special FX, 2010; The 2001 Archive, 1999).

The field of special and visual effects has constantly been evolving over the years, making the effects more and more refined. The biggest technological change in the field of special and visual effects occurred with the introduction of the use of computers for the purpose of processing images. Computers not only made it easier for filmmakers to work by digitally editing film material, but they also made it possible to create digital 3D models that could be convincingly implemented into real shots (Gradišnik & Parkinson, 2000).

That being said, in 1972, Ed Catmull and Fred Parke took an important step in the field of computer graphics – they created the first computer-generated three-dimensional model. The hand model was made out of casting a real human hand, which was then marked with polygon points. Then a wire-like computer 3D model was created, which was, with the help of complementing and shading, transformed into a fairly realistic three-dimensional model of a human hand. Thus, the two men paved the way for the implementation of digitally created elements in film production (Knific Košir, 2018).

It was not long before a small revolution in visual effects happened; the reason is one of the first sci-fi saga masterpieces of popular film culture. The year was 1977 when the Star Wars: Episode IV – A New Hope (directed by George Lucas, 1977) shook the public with breathtaking visual effects. John Dykstra, the visual effects supervisor, designed a completely new computer-controlled moving camera system for the film, called Dykstraflex, which allowed mister Lucas to take accurate repetitions of shots with various elements, which were then assembled in postproduction (Thrillist, 2016).

Lucas used the same recording method in the sequel, Star Wars: Episode V – The Empire Strikes Back (directed by George Lucas, 1980), which contains a stop-motion animation of AT-AT robots models that were placed in a snowy landscape where the battle takes place. In addition to improving existing ones, ILM has developed many filming and processing techniques that have helped create the Star Wars saga. We can mention the use of VistaVision cameras for shots that were later used as scene backgrounds, or for shots that were used to replace the blue screen. VistaVision cameras were an older version of cameras that shot on a 35 mm film, but instead of vertically, the film ran horizontally through the camera, allowing the director to capture larger areas with miniatures and other elements, which subsequently meant better scene composition. And that is one of the reasons why, while watching the film, a spectator gets the feeling that the Death Star is actually floating in space, although most of the Death Star scenes were really filmed in the studio's parking lot (Thrillist, 2016).

Another film worth mentioning is one from the Star Trek franchise, Star Trek II: The Wrath of Khan (directed by Nicholas Meyer, 1982), which is one of the first films, that massively used computer graphics to create visual effects. A real star database was used for the creation of a digital simulation of star fields. In addition, film shows the first fully computer-generated scenes, one of them being the opening scene of a star system flight simulation and the other, probably the more famous one, being a demonstration of the Genesis device effect on an abandoned planet, which also introduced the use of computer-generated particle system technique.

Digital age

With the beginning of the widespread use of computer-generated visual effects in the film industry, quite a few films were recorded in the annals that had a significant impact on the development of the industry. In the 1990s, the film industry graced us with real treats. Visual effects became more and more realistic, as seen in movies like Terminator 2: Judgment Day (or. Terminator 2: Judgment Day, directed by James Cameron, 1991), for which the team created liquid metal for the robot T-1000. For the movie Jurassic Park (directed by: Steven Spielberg, 1993), they created a realistic T. Rex using a real model and a computer. And that's not all. In 1995, the first fully computer-generated feature film was released, the 3D animated film Toy Story (or Toy Story, directed by John Lasseter, 1995). At the end of the millennium, the public was driven mad by The Matrix (directed by The Wachowskis, 1999), using a combination of slow-motion, camera rotation, and digital projectiles that the year before in Blade (directed by: Stephen Norrington, 1998), was almost absurd. However, the new millennium has given us a slew of visual masterpieces, beginning with The Lord of the Rings trilogy (directed by Peter Jackson, 2001-2003). The production of the trilogy developed a good portion of the software that is still used in computer graphics today, and furthermore, some scenes are created entirely digitally (WatchCulture, 2014).

All this brings us back to Star Wars. Everything that has happened in the field of visual effects since the last film in the saga was important to the sequel. For the fourth film in the saga, Star Wars: Episode I- The Phantom Menace, directed by George Lucas, one of the first fully

digitally created characters was produced in 1999. Jar Jar Binks represents a milestone in motion capture technology, computer animation, and rendering, despite the endless derision of the character's immaturity that continues to this day from fans of the saga. Jar Jar Binks, however, is not the only innovation in Threatening Ghosts. For the racing scenes with floating race cars, it was necessary to depict a vast desert territory that ILM could not fully create with a computer alone (Thrillist, 2016).

Thus, they first photographed miniature versions of rock formations from different angles and then projected them onto simple geometric shells of the same formations in post-processing. This method allowed the camera more room to move, and they also achieved a high degree of persuasiveness this way. Hard to believe that the fifth film in the saga, Star Wars: Episode II: Attack of the Clones, directed by George Lucas (2002), was only the third film in history to be shot entirely with digital cameras. With Star Wars, ILM paved the way for the development of visual effects. The company not only developed technologies to create more convincing effects, but also changed the way of working in this field. Visual effects were thus not just part of film, but began to be seen as a field in its own right, requiring a coordinated set of different trades to function successfully (Thrillist, 2016).

The last twenty years have offered us a number of films with visual effects, most notably the film Avatar (or. Avatar, directed by James Cameron, 2009), which was created almost entirely using computer graphics. For some scenes, only the actors' movements were captured; everything else was created entirely digitally. Also, most of the movies with Marvel heroes, which have become very popular in the last decade, are known for a large number of visual effects, as this way of working has become faster and cheaper, and ultimately safer, with the development of computer graphics (WatchCulture, 2014).

Examples of a good practice

Here are some examples of good practice. And no, it is no coincidence that almost all the examples shown come from the Lord of the Rings film trilogy. These films, after all, represent a turning point in digital graphics and certainly set a milestone in showing what could be achieved with them in terms of visual effects.

The Lord of the Rings film trilogy, based on the book trilogy of the same name by J. R. R. Tolkien, became a cultural phenomenon shortly after the release of the first film in 2001. The reason for this was not only the masterfully told story on screen, but also the visual presentation as such. Groundbreaking software was created in the field of visual effects to meet the needs of the film, allowing for a visual spectacle that few could have imagined at the beginning of the third millennium. Below some computer-generated characters from the trilogy that was important not only to the advancement of visual effects creation, but also to the advancement of computer graphics in general are presented. It should also be mentioned that Weta Digital mainly used the computer programs Maya and ZBrush for their needs in creating the characters and scenes presented below (Aitken et al., 2004).

Gollum

You may have liked him, you may have hated him, but he certainly did not leave you indifferent. Everyone familiar with the Lord of the Rings film saga knows Gollum, who is probably the most visually stunning character in the film trilogy. And he is undoubtedly the character with whom the studio Weta Digital changed the way computer-generated effects are used in film. Gollum, represents a cinematic milestone because the creators of the visual effects had to use a computer to create a character that the audience could perceive as real. And, of course, they succeeded (Animation World Network, 2004; Vulture, 2018).

By the time the first film in the Lord of the Rings trilogy hit theaters, computer-generated characters had been featured in many films, but none of them were on the level of Gollum. The high level of detail with which he was portrayed was meant to make the audience actually see him as one of the actors, and not just another scary monster twenty years after the film's release. Several systems within computer programs were improved and even created for the needs of Gollum's depiction, including the object surface shader system now widely used in 3D programs, and with it the visualization of materials that scatter light below the surface and between surfaces (subsurface scattering), which even won the film crew an Oscar for technical achievement. However, let us go nicely in order. And we will start with the movement (Aitken et al., 2004; Animation World Network, 2004; Vulture, 2018).

Gollum's movement is created using the technique of "capturing movement", which is characterized by the fact that the movement of a character created in the computer follows the movements of a real person. In the first part of The Lord of the Rings: The Fellowship of the Ring trilogy (directed by Peter Jackson, 2001), the movement of the body was captured using a special suit, and the facial expressions of the 3D model were made entirely by hand. by animators who followed actual footage of the actor's facial expressions (Aitken et al., 2004; Animation World Network, 2004; Vulture, 2018).

Later, with the help of new technologies, it was also possible to capture facial expressions, but it was still necessary to adjust them manually. The computer model of Gollum used in the first film was actually a mapping of a puppet model that was then edited in

computer programs. However, for the purposes of the second film, Lord of the Rings: The Two Towers, directed by Peter Jackson (2002), they found that the scanning technique had too many shortcomings. Therefore, they recreated a computer model that met the requirements for the movement of the characters. They also improved the model's facial expressions since Gollum appears several times in this film, and the story also requires a more sophisticated emotional expression of the character. For this purpose, wrinkles and pores were painted on the character, and the wrinkle planes of the facial skin, especially on the forehead and around the mouth and eyes, were adjusted (Aitken et al., 2004; Animation World Network, 2004; Vulture, 2018).

The successful portrayal of the Golum movement in the second film of the trilogy prompted the creators to completely revise the managing directions of the Gollum computer model for the third film, The Lord of the Rings: The Return of the King (directed by Peter Jackson, 2003). The standard for building 3D models became the surface subdivision technique, which allowed greater control over the build, texturing, and movement of a computer character's body, something the creators took advantage of. One of the reasons Gollum looks so authentic is the structure of the computer model's anatomy. The skeleton that allows the animation of the movements is actually modeled after real human bones. Not only was the skin or the surface of the model attached to the fabricated skeleton, which was common until then, but also the muscles, taking into account the anatomy of the body since the figure of Gollum has an extremely thin skin through which one can see its shape (Aitken et al., 2004; Animation World Network, 2004; Vulture, 2018).

The extraordinary attention to detail in the visual representation of Gollum did not stop there. The material used for the skin was created completely from scratch. The use of semi-transparent materials for the passage of light made the skin on the model appear slightly translucent, allowing anatomical details such as veins to be seen on the model. Various scratches and bruises were also added to Gollum's skin, as well as a bloody nose and a bump on the head. One of the more difficult areas of creating Gollum was the hair, mainly because it is very sparse, meaning that any flaws in its structure and animation would be noticed sooner. Until then, the simulations of hair dynamics within the programs were quite limited, so it was necessary to find a separate solution for practically every scene. Additional problems were caused by the scenes where Gollum is standing on the edge of a cliff, as a wind simulation had to be added. However, the creators were able to overcome this obstacle as well by splitting the individual hairs into smaller segments that functioned more autonomously, thus preventing them from intertwining. All the little details, including the nail dirt, that the creators had in mind when creating Gollum allowed the audience to see him as a flesh and blood character, one of the actors, even though he was created entirely digitally. Gollum, however, deserves respect not only from the point of view of a successful portrayal of a character that can be seen by an ordinary viewer, he deserves it mainly because his revival on the big screen required the work of a great number of film geniuses, both in the field of 3D computer modeling and animation and in the field of visual effects (Aitken et al., 2004; Animation World Network, 2004; Vulture, 2018).

But the story of visual effects in the Lord of the Rings trilogy does not end with Gollum. Other digitally created characters also appear in the films, which required a lot of ingenuity on the part of the creators to create a successful script.

Crowds

In order to display the battles with a large number of participants, Weta Digital has developed its software, namely a crowd animation program called Massive.

The program for step-by-step animation of the autonomous agents (i.e., the individual building blocks of the crowd) uses various aspects of artificial life, i.e., it assigns each of the agents an artificial brain capable of basic logical reasoning. The agents are also assigned a basic ability to observe and listen so that they can respond to their immediate environment and to each other. In this way, scenes quickly create the sense that each agent is acting individually and that patterns of behavior are not repeated, allowing for a higher degree of realism. The creation of a new agent starts with the creation of a so-called movement tree. This tree determines the movement options available to the agent at any given time, and a typical combat agent has 200 different actions available. The motion trees are then gradually divided into individual scenes, and the motion for these scenes is basically obtained using the technique of capturing the motion of real people, and for those where this is not possible, classical animation with key thumbnails is used. In addition to capturing motion for a single agent, secondary dynamics, i.e., hair and cloth motion, are also obtained. The variability of the terrain is also taken into account, which is determined by three components: Level or Plane, Maximum Depth, and Maximum Height. The motion capture images are first digitally processed and then inserted into the Massive program according to the motion tree. Here, the motion of the joints in the limbs is converted into the inverse kinematics, which is used to animate the motion. The latter allows agents to vary in size, adapt to the terrain, and coordinate motion within the same scene. Agents are composed of basic geometric components, and they are also assigned variations in their size and component design. All information is then written to a file of each creature, which contains all possible variations in geometry, textures, and color shades of a given agent. Movement in an individual

scene is then determined with the help of the agent's brain, which uses basic logic and the senses to decide for itself how it will react to its environment. Upgrades are dual agents used with horses and riders. Despite the interdependent actions of such agents, each of them is still autonomous. The rider's brain determines the horse's position as well as the effect of the horse's movement on the rider's movement but it has no influence on the horse when the rider moves on it, for example, when shooting an arrow in combat. Using the captured movements of the horses, they created a library of 200 to 300 different movements. For some scenes, they also used multi-body agents, meaning that individual brains were operated by 25 soldiers. And another interesting fact: In the last part of the trilogy, 400 scenes were created with the help of the Massive program, in which over 200,000 agents acted (Aitken et al., 2004).

Digital duplicates

Because of the difficulty of recreating the action as envisioned by Mr. Jackson, the director of the trilogy, they had to create a few scenes entirely digitally. They had to create digital duplicates of the players for them, which they did with the help of mappings and photographic references. Digital models had to be improved during the making of the films, as some scenes also required close-ups where much more detail could be seen. Digital scenes are made in many layers, as they were very demanding due to all the events. Thus, they recorded or created several different layers separately, i.e., the scene, the main characters, the characters in the background, which they then combined into one scene with the help of digital assembly (Aitken et al., 2004).

Conclusions

What can we expect in the next few years? In the following, we briefly summarize some trends that we are already confronted with in the field of visual effects and that we probably will not be able to escape in the future- but don't want to.

There has never been a better time to be a visual effects connoisseur and creator. In the last decade, the number of superhero movies, science fiction movies, and other films that by their nature require a large amount of visual effects has increased, and with it the demand for people who can create such visual treats. There is also a growing demand for visual effects in advertising, educational content, and computer games. Technology is constantly improving, so we can expect new systems and programs to give us an even better visual experience. One example is the digital resurrection of actors who have already died, using CGI to resurrect them for the purposes of film, usually sparking debate about the quality of such attempts. Probably the most famous example in recent years is the resurrection of the late actress Carrie Fischer as Leia Skywalker and the late actor Peter Cushing as Governor Tarkin for Rogue One: A Star Wars Story, directed by Gareth Edwards, 2016). Of course, the whole thing is still very controversial, as there is also the question of exploiting the identity of already deceased actors at this point (3D-Ace, 2018; VFXV, 2017).

Despite the increased use and improvement in the appearance of digital visual effects, there is still a belief that they simply do not look the same as practical effects, i.e., physically created gadgets, models, and mock-ups. That's probably true. And that's why the usage of practical gadgets is returning wherever possible, but there's still the opportunity to enhance them digitally in postproduction. So- practicality remains relevant (3D-Ace, 2018; VFXV, 2017).

Virtual reality simulations already incorporate many visual effects, and according to the guidelines, it seems that their use will only increase as the technology develops and becomes cheaper. The logical consequence is that more and more workers will find themselves in the world of creating effects for virtual or augmented reality.

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Online learning during COVID-19 pandemic as perceived by the students of Graphic engineering and design

ABSTRACT

In this work we wanted to determine how students of Graphic engineering and design perceived online learning a year after the transition from traditional to online classes. The goal was to better understand problems, challenges, and good sides of online learning in this study field, and determine factors that impede knowledge transfer. The students' responses were collected via an anonymous online survey, which consisted of a series of questions that covered: conditions in which online classes are attended, communication channels, problems and how they are dealt with, understanding and motivation. The biggest challenges for our students were to sustain their attention and concentration during classes despite the distractors in their environments, and to keep their motivation despite the lack of direct interaction, social isolation, and too much computer time. Their technological and digital literacy were of great use in adapting to the online platforms and applications, as well as in solving technical problems that prevented them from following the classes. Even though online courses allow students to be more flexible and potentially combine work and study, most of our students do not think that their attendance and engagement in the studies increased in the last period. It is also undisputed that our students were dealing with a lot of stress and anxiety and that their emotional state highly influenced their perception of online learning. Hence, we firmly believe that apart from making online courses more engaging and interactive, it is of utmost importance to find a proper way to motivate and psychologically support students in the online learning environment, especially in times that require a high degree of resilience.

KEY WORDS
Covid-19, online learning, pandemic, online classes, engineering

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Introduction

At the beginning of 2020 the whole world had to stop. The limitations created by the Covid-19 pandemic affected everyone, and the fast adaptation to the "new normality" becomes the top priority. It goes without saying that the educational institutions were among those that were affected the most. Both students and lecturers had to show a significant amount of flexibility in the new, virtual learning environment. Distance education is not a new concept, and numerous studies have already focused on different ways of implementing it. Retaining the students in the online platforms was shown to be a challenging task even before pandemic (Panigrahi, Srivastava & Sharma, 2018) despite all the benefits this way of knowledge acquisition brings along (flexibility of time and place, cost-effectiveness, improving technical skills, time management, etc.) (Gautam, 2020; Arkorful & Abaidoo, 2014). It is also well known that effective online education highly depends on careful planning and sound instructional design, using a systematic model for design and development (Branch & Dousay, 2015; Hodges et al.,

2020). In the case of an emergency, like the one we all faced at the beginning of the pandemic, the fast reaction was essential, meaning that most online courses were not planned and organized systematically. Practically oriented courses were another problem, considering they could not easily be adapted to the online format. It most certainly affected the learning outcomes and other factors in students' perception of online teaching.

Many of the studies published during 2020 and 2021 were dedicated to the effect of Covid-19 on the educational sector. They covered the topic from the aspects of students' performance (Gonzales et al., 2020), their mental health and motivation (Copeland et al., 2021; Zacolletti et al., 2020), challenges, opportunities, and satisfaction (Adedoyin & Soykan, 2020; El Refae, Kaba & Eletter, 2021; Barrot, Llenares & Del Rosario 2021), their perception of online approach (Bączek et al., 2021; Cranfiedl et al., 2021), etc. The results often accentuate different factors, which is no surprise considering social and cultural differences, and the fact that each institution responded differently following the situation in its country. An international study conducted by (Cranfield et al., 2021) revealed that the most important differences are related to the learning environment, engagement, participation, and perception of impact on learning skills.

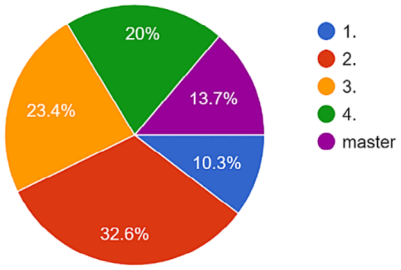
In the case of our institution, adaptation to the online classes was relatively fast and efficient. The online mode started in March 2020, and all the courses were synchronous (Arkorful & Abaidoo, 2014), following the pre-established timetable. Classes were initially held over Zoom, while everything else (sharing the materials and information, activities) was done via the University of Novi Sad Moodle-based online platform, developed long before the pandemic. From the winter semester of 2020/2021, a shift was made to Microsoft Teams and the new remote learning platform, thus creating a slight change in communication with the students – chat option in Microsoft Teams had become the predominant way of communication between students and lecturers.

Even though the adaptation to the learning management systems went smoothly for both parties, it was just one building block of the online teaching/learning process. As stated by (Hodges et al., 2020), lectures are only one aspect of the whole educational system, which is formed to support learners with formal, informal, and social resources. In the situation we were all in, it became clear that the support in all three segments was more than necessary.

Taking all into consideration, the purpose of this inquiry was to determine how students in our department perceived online learning during the Covid-19 pandemic. The goal was not to compare the online learning approaches or make a qualitative investigation on the difference between traditional and online classes, but rather to better understand all the problems and challenges they were facing and the advantages this new way of transferring knowledge has brought so far. The aim was also to pinpoint the factors that impede the knowledge transfer and those that could be changed to improve the learning process.

Method

To gain insight into our students' perception of online learning, we formed an anonymous online survey which was filled out on a voluntary basis. One hundred and seventy-six students, all aware of the purpose of the study, took part in it during April and May of 2021. Eighty percent of the students were female, and most were in their undergraduate studies (Figure 1). Only 8% of the students had prior experience with online learning (Google Classroom, different online courses, online conferences, workshops, etc.).



» **Figure 1:** *Distribution of respondents by the year of study*

The survey consisted of single-select and multi-select multiple-choice questions, where the latter were predominant and often allowed adding the missing answer. Predefined choices were determined on the basis of the studies dealing with the effect of the Covid-19 pandemic on higher education, overviews on e-learning (Gautam, 2020; Arkorful & Abaidoo, 2014; Adedoyin & Soykan, 2020; El Rafae, Kaba & Eletter, 2021; Barrot, Llenares & Del Rosario, 2021; Copeland et al., 2021; Zaccoletti et al., 2020; Cranfield et al., 2021), problems authors have noticed while teaching (Tomić et al., 2021), and their communication with the students during online classes. In addition, we used open-ended questions to allow students to elaborate preferences, describe problems more in detail, and give suggestions about possible improvements.

Questions evaluated different aspects of online learning: conditions in which online classes are attended, communication channels (including questions about platforms and applications used), problems and how they are dealt with, understanding and motivation.

In the first set of questions, students gave feedback about their learning environment and the equip-

ment they were using when attending online classes. Next, they were encouraged to reflect upon the technical and other problems they were facing, share the main distractors in their environment, and how they reacted when faced with those difficulties.

The second set of questions was formed to determine whether the students had any problems to adapt to different platforms and software and which software/platforms they preferred. Also, we wanted to determine which option they choose when communicating with lecturers (e-mail, chat, video calls, etc.) and why.

Questions in the third set focused on their understanding and motivation. We were curious to find out what were the main obstacles to understanding the teaching material, and how the students reacted when they fail to understand or to catch up with the classes. Also, we evaluated if our students struggle to motivate themselves in conditions that are not so common to them.

Ultimately, students were asked to evaluate their efficacy and activity in the previous period. They were also asked to give opinions about the advantages and disadvantages of online learning and to share their preferences.

Results

The results of the survey showed that the majority of our students (98.9%) followed online classes from their homes, where they mostly used laptops (48.9%), mobile phones (17.6%), and the mobile phone-computer combination (43.8%). More than one device was used in situations when they had to replicate what the lecturer was presenting.

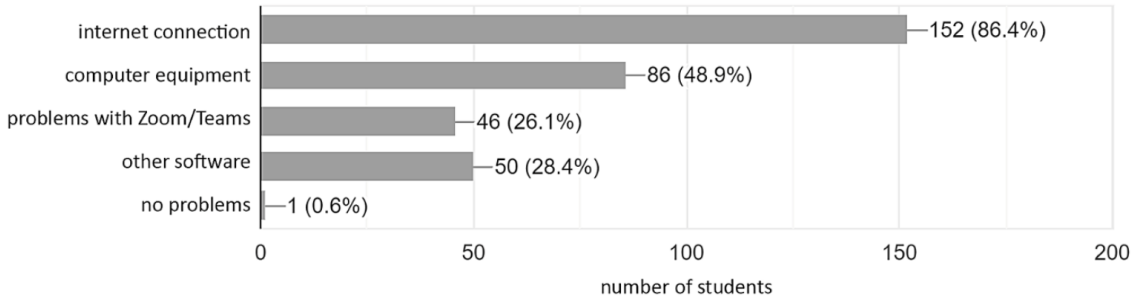
Students mostly encountered problems with the internet connection, with their own devices (memory, sound and camera issues, etc.), the software necessary for computer labs, and video conference software (Figure 2). Of all the technical problems, the issue with not having enough RAM to run both Microsoft Teams and other software was reported the most often. Our students try to solve the problems independently before asking for help either the lecturer, colleagues, or both parties.

Of problems not related to the equipment, the majority of the students reported lack of motivation (69.9%), lack of direct communication with their classmates (67.6%) and lecturers (33%), and the inability to concentrate due to the distractions in their surroundings (52.8% of students reported this problem).

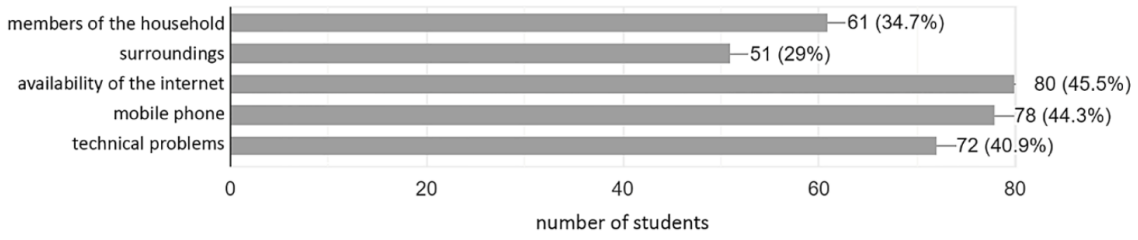
As the central distractor, they pinpoint the availability of the internet connection and the accessibility to their mobile phones, meaning they could easily access their social media, instant messages, etc. Technical issues, household members, and surroundings were also listed very high among the distractors (Figure 3).

When distracted, our students often try to overcome (67.2%) or ignore the problem and continue with the class (7.5%). However, an alarming number of students (21.8%) find it impossible to continue following their courses once they get distracted. We believe that the lack of motivation reported before, lack of self-discipline, and the overall feeling of lethargy lead to such a reaction.

Only 14.2% of our students reported problems adapting to the software used in online teaching (Zoom, Microsoft Teams), where 79% of them prefer Microsoft Teams over Zoom, and 15.9% have no preference.



» **Figure 2:** *Problems students encountered during online classes*

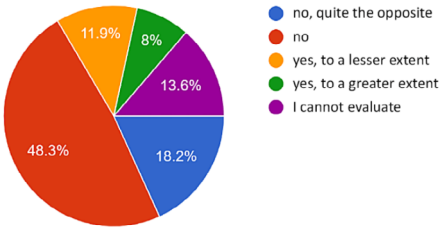


» **Figure 3:** *The main distractors, as reported by the students*

The main reason for choosing Teams over Zoom was "having everything in one place" – calendar with the timetable, chat, class files, etc. It is worth noting that since the introduction of Microsoft Teams, student-lecturer communication significantly shifted from e-mails to direct chatting via Teams. Students prefer this type of communication since it is more direct, and they obtain the answers much faster. On the other hand, there was no clear preference for one online platform over the other, and most of the students didn't report significant problems adapting to any of them.

Our students reported a lack of both motivation and concentration during online classes. Different reasons were mentioned for this, some of which are listed as follows: not seeing the professor face-to-face, technical issues, lack of interaction, too much computer time, social isolation. For 48.9% of them, the most difficult was to follow computer labs, 8.5% reported trouble focusing on laboratory sessions, while 31.3% had difficulty concentrating on lectures.

When estimating the attendance, efficiency, and information adoption, we disregarded the responses of first-year students since they were objectively unable to compare their performance before and after the pandemic. Nevertheless, almost half of our examinees think that the online regime did not increase their attendance to lectures and labs, while some even reported their attendance decreased (Figure 4).

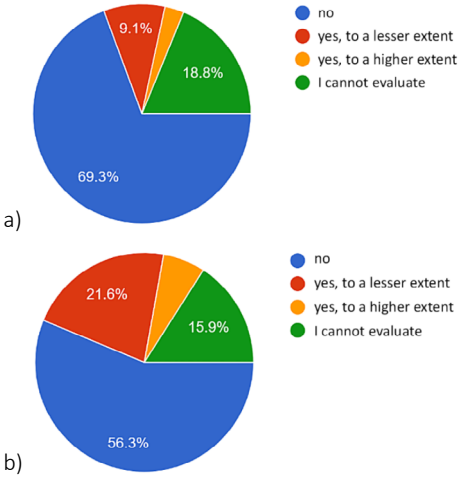


» **Figure 4:** *Students' opinions on whether the online regime increased their attendance to lectures and labs*

Also, most of them think that online teaching did not improve the information adoption during classes (Figure 5a), nor their efficiency in finishing tasks and projects (Figure 5b).

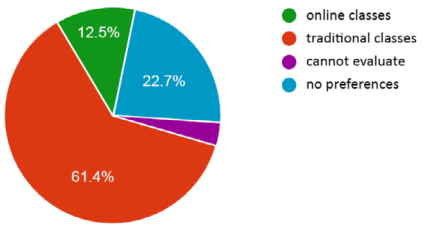
As the main advantages of online learning our students highlighted the possibility to attend classes from any location (77.8%), to adapt the learning environment to their preference (47.7%), and the feeling of privacy (27.8%). In addition, online classes enabled some of them to stay with their families and feel more secure, and others to combine work and study.

The drawbacks students highlighted were: lack of social connection (77.3%), lack of focus and motivation (73.3%), too much computer time (55.7%), feeling of isolation (42.6%), and the fact that classes can easily be interrupted due to the technical problems (76.7%). In this case, we believe their opinions on online teaching are highly influenced by their emotional state and the feeling of uncertainty they had to deal with. Responses to the open-ended questions confirmed our assumption. Multiple answers were focused on mental health and the necessity to deal with stress and anxiety. Some students suggested making classes more interactive, with more breaks and more communication, even unrelated to the topic of the lecture. Others highlighted the importance of video and interactive presentations and acknowledged the good practice of using class recordings and video tutorials.



» **Figure 5:** *Students' answers to whether the online teaching (a) increased the information adoption during classes, (b) increased their efficiency in finishing tasks and projects*

Taking all into account, it is no surprise that more than half of the students preferred the traditional form of teaching over online (Figure 6).



» **Figure 6:** *Students' preferences*

However, more than 20% is indecisive, stating that both forms of teaching have their advantages, while only 4.5% of students preferred online classes over traditional ones. The results do not change much if we exclude the responses of the first-year students (considering they didn't have any prior experience with conventional courses at our department).

Discussion

If we compare our survey results with similar reports, it is clear that our students do not differ significantly from the others. Their technological and digital literacy made them well prepared to handle online classes and easily switch from one software to another. Still, they were not less resistant to the stress and anxiety than all the others who were in the same situation. It is clear that the pandemic affected our students' attention and motivation, which was also acknowledged by other authors (Copeland et al., 2021; Zaccoletti et al., 2020).

The problems they were facing were also quite common, as well as the reported distractors (Barrot, Llenares & Del Rosario, 2021; Adedoyin & Soykan, 2020; El Rafae, Kaba & Eletter, 2021; Bączek et al., 2021). The study conducted by Tang et al. (2020) among engineering students showed that they are mostly dissatisfied with online learning in general, especially in the aspect of communication. Our students highlighted that they were missing face-to-face contact with their fellow students and lecturers; some even mentioned it affects their motivation. Limited interaction, lack of facial expression, and body language are the key challenges to distance learning (Georgiou, 2018) and are still to be overcome. Some of the main advantages of the online approach reported by other authors (Bączek et al., 2021; Adedoyin & Soykan, 2020) were also noted by our students: the ability to learn from any location, comfortable surroundings, and a sense of privacy. Same stands for disadvantages.

On the other hand, unlike the results of (Gonzalez et al., 2020), who reported a significant positive effect of Covid-19 confinement on students' performance, our results were just the opposite. Students reported lower performance in information adoption and efficiency, which was somewhat confirmed by the lecturers (Tomić et al., 2021).

Conclusion

In this inquiry, we wanted to find out the main challenges and problems students at our department have faced due to the transfer to online learning induced by the Covid-19 pandemic. Also, we wanted to examine the efficiency of the online learning approach in the current situation and its benefits in the long term.

First of all, we would like to point out that it is clear that the opinions of our students were highly biased by their psychological state. In the moments of uncertainty and pressure, a sense of social isolation had made many students feel unmotivated, with the lack of focus and drive for learning. The lack of concentration and attention can also be attributed, to some extent, to the distractors in their environment. The central distractor for our students were their mobile phones and the fact that they could easily access their social media and engage in other forms of out-of-class communication. Technical issues were also listed very high among the distractors, as expected, and the members of their household and their surroundings. Even though our students reported many problems with computer equipment and internet connection, they didn't have any issues adapting to online platforms or communication software, where it is clear that the majority prefer Teams over Zoom. Teams chat option almost entirely substituted e-mails and other forms of speaking with the lecturers since it is seen as a more direct way of communication. On the other hand, the lack of motivation seems to result from social isolation, lack of interaction, and too much computer time.

Our students think that the main advantage of online learning compared to the traditional form is the flexibility (connecting from any location and environment). The highlighted drawbacks were: lack of social connection, too much computer time, lack of motivation, and the feeling of isolation.

Students in our department reported less attendance to online classes, less information adoption during lessons, and a decrease in their efficiency in general. Furthermore, our lecturers confirmed that the students' performance in the last period did decrease to some extent compared to the pre-pandemic results (Tomić et al., 2021). Hence, it is no surprise that our students prefer traditional teaching over virtual.

Evidently, there is still a lot of space to improve the online approach and make it more attractive and engaging for both parties. We believe that the interaction should be imperative and that all future efforts on improving online learning should go in that direction. In addition to that, we are firmly convinced that it is crucial to motivate and psychologically support students in times like these, since it is clear that both their well-being and academic success depend on it.

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Effects of fine art print artworks on the art viewer in contemporary art presentation

ABSTRACT

The social and cultural changes brought about by industrialization and the Industrial Revolution highlighted the value of printmaking as a new means of expression in artistic presentation. The innovative mechanical production methods influenced their artistic production through the interest and experimentation of many artists, whose numbers should not be underestimated. On the other hand, the transfer of examples of traditional Japanese printmaking (Ukiyo-e) to Europe in 1700-1900 caused profound effects on Western art, beginning with Impressionism, one of the modern art movements. Especially in the last two decades, rapidly digitalizing technology has also provided radical changes in many social-cultural and economic fields. As a reflection of this, it has caused a change in the presentation of contemporary art and caused the formation of an innovative attitude that transforms-triggers the perception of the audience. Two effective factors are emphasized in the context of the effect of fine art print works on the phenomenon of art. One is the artist of the time, who uses all the media tools of his time with pure intuition to transform his artistic expression, his dreams into reality, and another is the audience of the artwork, who accepts only a part of his artistic presentation, which is helped by all technological tools, by discussing, and few of which will be praised by future generations. In this context, digital technology promises a free space to thousands of artists who produce screen presentations or artistic prints on many different media, enabling us to see them everywhere. It has indisputable that digital technologies are a new tool with a different line for artists, apart from the usual art presentation of contemporary art, which is in different quests with an innovative attitude in every period. From this point of view, in addition to the dynamic visual presentations in different places and platforms where the art audience can be involved and integrated into the contemporary art environment, the innovative attitude that fine art print artworks brings to the effect and behavior of the audience should also be considered. The purpose of this paper is to investigate how digital print technology and print works influence audience perception. The survey data analysis is interpreted in this article through excerpts from the dissertation titled "Effects of fine art printmaking on phenomenon of the art" which is still in progress.

KEY WORDS
Art audience in Turkey, fine art prints and audience, contemporary printmaking

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Introduction

The collaboration with painters to disseminate information through books and posters in the industrial revolution and cultural movements in 15th century Europe enabled the art to be watched with interest by the public. The dissemination of knowledge through printmaking supported a revolutionary, accessible, and powerful

democratization process, and the reflection of these developments and pursuits also found its place in the art movements. The artists of the period also found a new way of expression in this search, and by using the printmaking, which can be defined as the mass production tape method in art, they created a basis for an innovative art perception. When the capacity to share and disseminate information was combined with the characteristic of the art object, it has made possible the transformation of a new understanding for the artist and the audience (Crawford, 2021:p.2). The attractiveness of the cabaret and theater announcement posters in the entertainment world, which characterized the urban culture of the period, which were printed with mechanical mass production techniques such as lithography and wood engraving, made the art of printmaking popular. Thus, the art audience expanded, and the artists of the time, benefiting from the new production techniques, turned to new fields to present their innovative, original, and ideological ideas, expanding the means of production and incorporating the possibilities that the time offered to their artistic expressions. In other words, the artists who benefited from the new production technologies of the era exploited the era's possibilities to broaden the art audience and introduce them to the public through their work.

E. Gombrich points out the relationship between the spirit of the age and art movements by expressing that sometimes the age determines the art and sometimes the art determines the age (Gombrich, 1993:p.3). W. Benjamin, on the other hand, mentions that besides the enormous change that mechanical reproduction brought to literature, techniques such as wood engraving, metal engraving, and lithography in the Middle Ages brought the reproduction technique of art to a new level. He emphasizes that the mechanical reproduction of a work of art expresses something new and allows graphic art to take place in the market and that lithography, like Ukiyo-e, accompanies the graphic art of daily life with pictures.

However, with the invention of photography, the expression of the main artistic tasks in the pictorial reproduction process has changed- as it is perceived faster than the speed at which the hand can draw- the process of pictorial reproduction has accelerated immensely (Benjamin, 2008:p.20). Accordingly, it is suggested that printmaking is a social medium, that its social character and the role of social relations and power structures in the artist's negotiation of these dynamics should be considered. Given these interactions, it is emphasized that artists are prompted to question the power and significance of the art object, as well as reflect on their responsibility and ability to report and engage with current events. Also; It has been stated that artists have made this idea open to the public so that they can see it in their art practices and projects (Crawford, 2021:p.2). Today, the entrance of information into digital formats is changing human life with social and cultural changes, just as in 15th century Europe. The changing conditions of life due to digitalization have shaped our social and economic life and made it necessary for us to evaluate our cultural-artistic perspectives from a different aspect in an innovative light. Even though there is a dominant view that this change is destroying most of the inherited values of society, art persists stubbornly by transforming itself before it disappears. Computer technology enables us to track today's art easily and offers endless possibilities, such as monitoring and communicating all kinds of activities in virtual dimensions. In this vast comfort zone, the artist uses this easy presentation opportunity and treats it in an innovative manner, bringing it as close to us as a button press, nurturing the transformation of the perception in the minds and the innovative perspective. In the world of conscious deception, where art presentation is reconstructed, the artist adds new elements to the existing world with the help of information technology, as Gasset says, and further expands the world by adding a mythical continent to the present reality we perceive (Işık, 1998). As information technologies have taken over the entire dynamics of social life with the digitization of information, some contemporary artists have turned to artistic representations in which they adopt the interdisciplinary production relationship and use new virtual information in which no human is involved. These innovative information technologies have also enabled artists to expansions in their presentations. Examples of various artistic expressions called new media art are- starting with photography and video - Internet art, multimedia art, software art, intelligence happening, viral art, e-mail art, performance in virtual worlds or NFT, etc. This way, art is repositioning itself in the new world order by reaching a broader mass. In this direction, the view that art is now detaching itself from the traditional, that it needs to be redefined and regrounded, is gaining weight (Yıldırım, 2010). In the digital universe created, the artist remains loyal to the historical process and facilitates his artistic production, continuing to explore ways to reach a larger audience by expanding new presentation areas. One of the questions that need to be answered in this new field of presentation is how fine art prints, which are a new means of expression for artists, are perceived by the art audience.

This research paper, which seeks answers to such questions, consists of the analysis and results of the survey conducted to determine how audiences in contemporary art presentations today perceive fine art prints. This survey includes the analysis and interpretation by contrasting the views towards printed works through demographic information that clarifies the attitudes and perspectives of art audiences living in metropolitan cities, which are central to artistic presentation in Turkey, towards fine art prints.

Methodology

This research includes the analysis and interpretation of questionnaire prepared for adults interested in art, which is one of the factors influencing the phenomenon of art, as part of the ongoing doctoral research. The reliability tests of the prepared questions were conducted. However, with the COVID-19 pandemic process and the reopening of closed artistic events in May 2020, art events were followed and face-to-face meetings were held in accordance with the rules of social distance. In this research, which was originally planned to be conducted with 500 volunteer participants, difficulties in communication and invitation to participate due to the anxiety of the COVID-19 pandemic were observed. Therefore, a sufficient number of face-to-face surveys could not be reached. Social media, e-mail and digital communication channels were used to reach the targeted number, and this study was completed with the participation of adults who are interested in art. The art lovers living in metropolises such as Istanbul and Ankara, which are the centres of art in Turkey, constitute the target audience of this survey. Therefore, analysis and comments include comparisons of demographic information over the answers to the questions asked and results and part of comments only on the sample. In this study, the survey method, which is *"the method of obtaining data by responding to the questions created in a predetermined order and structure"* (Coskun, Altunişik & Yildirim, 2010), was preferred for data collection.

Findings and results

The widespread use of digital technologies, computers have become part of everyday life, and the development of vector image programs that facilitate production in industrial design has made it possible to produce art more easily in the digital environment. Whether using traditional methods such as brush, paint, or canvas or digital techniques such as video and sound programs, these are considered software or hardware tools that enable the artist to produce, and the result is no different. While in the 19th century, the artist produced his art with the possibilities of classical materials, he diversified his artistic expression by technological developments such as printing techniques, photography, television, and video, under the influence of the significant changes that have affected humanity in the 20th century. As one of the main reasons for this diversity, U. Eco, in his book "The Open Work," mentions the significant impact of the existence of an art audience, which the artist did not think of until the beginning of the 19th century, on the production process of his works for today's artist. According to Eco, in the art equation, the artist emphasizes that he cannot enjoy his work without the audience or the interpreter. (Eco, 2001:p.11).

When it comes to the 21st century, digital technology and communication channels, which are creatively involved in today's artistic productions, enable us to watch brand new presentations that will change the perception of art. Another approach to the use of digital technology in artistic presentation is hybrid technical artworks that combine traditional mediums with digital outputs such as film positives, plates engraved with CNC-type cutting machines, computer-engraved woodcuts as well as traces of scanned images. In contrast to conventional art presentations, some artists using digital technologies such as inkjet printers or laser printers have adopted entirely digital approaches in their artistic expressions. Fine art prints are now included in exhibitions and collections of comparable quality to traditional engraving, lithography and screen printing. Accordingly, it can also be said that virtual events on the Internet and exchanges on social media create a basis for the increase in interest and appreciation of edited fine art prints on a large audience.

Demographic findings

This survey aims to interpret the data through question and answer to determine the art audience's level of appreciation and views, which can affect the art phenomenon concerning edition fine art print artworks. To obtain better results, planning was made to think that working with a specific sample following the art activities under the pandemic conditions would be beneficial. In this context, 506 art-loving adults who visited contemporary art events during the pandemic between May and July 2020 were interviewed. According to the interviews, a questionnaire was applied to the respondents who were accessed face-to-face or through digital platforms until a quorum was obtained, and 506 questionnaire forms were considered since there were no such forms left unfinished to allow analysis. SPSS was used to analyze the data collected for the evaluation of the survey results. The questionnaire consists of 23 questions and consists of two parts. In the first part, the first six questions consist of questions for comparison, such as demographic information of the respondents, age, gender, education, and the sector they work in. The 17 questions asked in the second part are meant to investigate how often the respondents, as art viewers, watched art events, especially their perspectives and appreciation levels towards the print works they watched. In this survey, which was prepared to determine the level of appreciation of the art audience for fine art print artworks, questions were asked to ensure that the research could continue with suitable samples. The majority of the respondents follow art events, only 3% do not follow art events, and 52.8% of those pursuing art have received art education (Figure 1). In the light of the data, it is seen that the highest level of participation in art activities as spectators is those who have a high level

of education and employees (Table 1). In this context, the function of "having prior knowledge" and the content of the education gain importance as an incentive to participate in determining the culture and art audience.

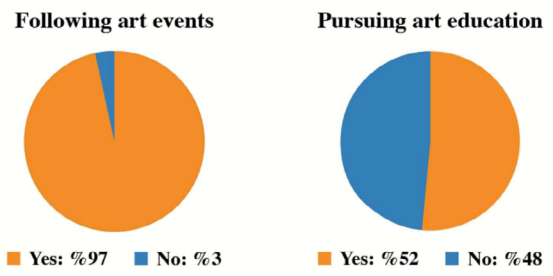

Figure 1: *Data analysis of the art audiences following contemporary art events and pursuing art education. Source: Adopted from the survey within the scope of the ongoing doctoral thesis titled "Effects of fine art printmaking on the phenomenon of the art"*

According to this data, there is a relationship between the level of education and the art audience, especially the art education received during the university period, which is one of the critical factors affecting being an art audience. The reason for the low participation of the pre-university education audience in the survey may be that the arts are not sufficiently included in the curriculum. For this reason, it draws attention once again to the importance of pre-university art education in terms of the function of "having prior knowledge".

Table 1

Table showing the education level of art audiences

	Frequency	Percent	Valid Percent
PhD	85	16,80 %	16,80 %
Master	95	18,80 %	18,80 %
Bachelor	273	54,00 %	54,00 %
High School	40	7,90 %	7,90 %
Under high school	13	2,60 %	2,60 %
Total	**506**	**100,00 %**	**100,00 %**

Source: Adopted from the survey within the scope of the ongoing doctoral thesis titled "Effects of fine art printmaking on the phenomenon of the art".

It is seen that the respondents mainly consist of those working in the education sector, and the majority of those who receive arts education are also in the education sector (Table 2). In another study similar to this one, which GfK commissioned in 2017 by İKSV in Turkey, it is pointed out that this value is higher in groups with a university or higher level of education in participating in cultural and artistic activities. In this context, the function of "having prior knowledge," which is an element that encourages participation, is once again emphasized while defining the culture and art audience. In this respect, the opinion that qualified culture and art classes in formal education positively affect the number of participants is also included in this report of İKSV (IKSV, 2017:p.29).

Table 2

The table shows the employees status of art audiences

	Frequency	Percent	Valid Percent
Workless	133	26,30 %	26,30 %
Health	20	4,00 %	4,00 %
Engineering	23	4,50 %	4,50 %
Academic	148	29,20 %	29,20 %
Finance	12	2,40 %	2,40 %
Art & Culture	69	13,60 %	13,60 %
Self-employed	55	10,90 %	10,90 %
Retired	46	9,10 %	9,10 %
Total	**506**	**100,00 %**	**100,00 %**

Source: Adopted from the survey within the scope of the ongoing doctoral thesis titled "Effects of fine art printmaking on the phenomenon of the art".

In the survey, conducted during the pandemic period, 68% are women, 30% are men, and 1% are those who choose not to state their gender.

Most respondents being women could be related to the high proportion of women among those receiving an arts education. Due to the pandemic period, it was seen that those who responded to the invitation to participate in the survey and in communicating, women were more participatory, and as those who followed the arts, the respondents were predominantly women. Studies conducted in Turkey also mentioned that the higher the level of education, the higher the participation rate of women compared to men, especially among those who follow cultural and artistic events in big cities like Istanbul (Gelişli, 2014).

According to the Gender Report in Turkey, prepared by the survey company Konda in 2018, the higher the education level, the higher the rate of women attending cultural events compared to men. According to the study, women with higher education participate in cultural events more frequently than men with the same level of education, and women with higher education attend cultural events more frequently than men with the same level of education (KONDA, 2019:p.49). One of the assumptions is that the pandemic process inspires more anxiety, and depression in men since they are generally the responsible for finances of the household, while women are less affected and have a tendency to become more social after the pandemic is over. Another is that due to high income level, ticket prices can be seen as a factor in accessing cultural and artistic activities.

The Gfk research conducted by İKSV, it was emphasized that audience participation in cultural and artistic activities is essential to have a certain level of financial savings

and that the high ticket prices are an obstacle for this (IKSV, 2017:p.40). According to Table 1, most of the 506 respondents graduated from university or higher education, this proportion is almost 90%, and only 10% have a lower education level than a college degree. Based on these ratios, it is seen that only 10% are at the lower college education level. The view that a high level of education is an essential factor for people interested in and visiting the arts, which impacts the distribution of income, is also discussed in the report presented by Gfk.

Results

Based on the survey results, it can be seen that the audience interested in the arts, with a rate of 68.75%, attended the concert as the top cultural and artistic activity. Theatre comes second with 67.34%, and contemporary art exhibitions come third with 64.52%. This data shows that concerts are the most commonly attended cultural activity for both men and women who attend contemporary art events. Theatre and contemporary art exhibitions, on the other hand, are the other highly rated events. The percentage of opera and ballet attendance among those attending cultural and artistic events is 2%, which is relatively low compared to concerts, theatres, and exhibitions. Prejudices influence the approach to different artistic disciplines and the great diversity of cultural and artistic audiences. Moreover, the effect of prejudice on selective perception is undeniable. Considering that this perceptual bias also guides going to cultural and artistic events, the views of potential audiences who state that they cannot "understand" artistically such as opera and ballet have no previous experience or- was not mean anything to themselves due to lack of knowledge- and curiosity has also can be caused these rates to be low (IKSV, 2017:p.34).

This research surveyed art lovers to determine their views and awareness of the fine art prints presented at contemporary art events and exhibitions. The data obtained from the responses show that 48.20% of the art lovers surveyed, regardless of whether they have an art education, have already attended exhibitions where fine art prints are displayed due to acquiring “prior knowledge” that is effective for perceptual selectivity. The percentage of those who have never visited an exhibition is 47.20%, and the percentage of those who have no idea about the subject is 4.60%. The fact that these findings are almost proportionally close to each other gains importance for the knowledge of the art production technique and awareness of the artwork he is looking at. The respondent is assumed to have a limited approach and awareness of the work they are looking at depending on how much “prior knowledge” they have of fine art prints- whether they have an art education or not. Even those who have never viewed fine art print before considered it a work of art and indicated that they might purchase the work if it fits their budget. This data was discussed based on responses to the question, "Would you buy fine art prints that you like?" The percentage of those who have never bought anything before is 29.60%, and those who previously have bought something is 13.20%. If they like it and it fits their budget, almost half of the respondents, 46.60%, say they could buy fine art prints.

In this context, this can be interpreted as that the viewer's approach to the artwork is only at the level of appreciation, especially since they have no specific idea about the artwork's structure. In another statement, respondents indicated that they agreed or partially agreed with the statement, "Fine art prints are as valuable as classical printmaking in today's artistic presentation," at the highest rate of 70%. The percentage of those who say they have no idea about the subject is 18.00%. The responses "I disagree" and "I do not agree at all," with the lowest percentage of 10.9% in total, illustrate the views of the art audience. As can be seen from this data, the opinion that fine art prints are as valuable as classical printmaking is the most widespread from the audience's point of view.

Analyses of quantitative data were conducted on adult art lovers in metropolises such as Istanbul, Ankara, and Izmir, the centre of contemporary art in the country. In this context, some of the responses to the questions and comments regarding the interest of 506 adult art lovers aged 15 years and older in cultural and artistic activities between March 2020 and July, as well as to determine their level of appreciation for fine art prints, are as follows:

- *"It is important that artistic fine art prints produced with digital printing technology take place as a new art genre in the contemporary art scene."*
- *"Wet-signed fine art prints printed with digital technology should be valued in today's art as much as printmaking printed with traditional processes”.*
- *"The fact that a work of art is printed using digital technology does not change my artistic value judgement of that artwork."*
- *Would you be interested in attending contemporary art exhibitions consisting of fine art prints?*

According to the responses to these comments and questions, the following odds was obtained;

- *"It is important that artistic fine art prints produced with digital printing technology take place as a new art genre in the contemporary art scene":*

This interpretation emphasised that fine art prints that are present in contemporary art events represent a new genre of artistic presentation. In particular, fine art printing is technically considered one of the original printmaking techniques such as woodcut, gravure and

linocut. This production technique, which has transformed into digital technology, is an artistic means of production with an innovative attitude. With this approach, the views of the art audience become more critical in the context of the art phenomenon. Table 3 shows the survey results determining the public's appreciation of fine art prints produced with digital technology. Depending on the data, whether or not they have an art education or not, the fine art prints produced with digital technology are watched with admiration by the audience, and the art lovers, as the audience, adopt diversity in artistic presentation. Therefore they find innovative digital production presentations interesting in the exhibitions.

Table 3

Proportional values according to the answers given by the art audience to the interpretation of *"It is important that artistic fine art prints produced with digital printing technology take place as a new art genre in the contemporary art scene"*

	Frequency	Percent	Valid Percent
Agree	246	48,60 %	48,60 %
Partielly agree	160	31,60 %	31,60 %
No idea	61	12,10 %	12,10 %
Disagree	30	5,90 %	5,90 %
Strongly disagree	9	1,80 %	1,80 %
Total	**506**	**100,00 %**	**100,00 %**

Source: Adopted from the survey within the scope of the ongoing doctoral thesis titled "Effects of fine art printmaking on the phenomenon of the art".

- *"Wet-signed fine art prints printed with digital technology should be valued in today's art as much as printmaking printed with traditional processes"*

Table 4

Proportional values according to the answers given by the art audience to the interpretation of *"Wet-signed fine art prints printed with digital technology should be valued in today's art as much as printmaking printed with traditional processes"*

	Frequency	Percent	Valid Percent
Agree	201	39,70 %	39,70 %
Partielly agree	180	35,60 %	35,60 %
No idea	54	10,70 %	10,70 %
Disagree	60	11,90 %	11,90 %
Strongly disagree	11	2,20 %	2,20 %
Total	**506**	**100,00 %**	**100,00 %**

Source: Adopted from the survey within the scope of the ongoing doctoral thesis titled "Effects of fine art printmaking on the phenomenon of the art".

There is a preponderance of opinion, with 75% of respondents agreeing or partially agreeing with this comment. The responses "I disagree" and "I disagree at all" are a close second with a total of 14.1%. The percentage of those who say they have no idea about the topic is the lowest at 10.70%. As can be seen from these data, they believe that fine art prints are as valuable as the printmaking ones (Table 4). In this context, it is assumed that the artistic value of fine art prints, as one of the printmaking production techniques, is seen as equivalent for the art audience.

- *"The fact that a work of art is printed using digital technology does not change my judgement on the artistic value of that work."*

Another comment that supports the response in Table 5 is, "The fact that a work of art is printed with digital technology does not change my artistic value judgment toward that artwork." The opinion with which the respondents agree or partially agree the most ranked first with 77.90%. On the other hand, "I do not agree, and I do not agree at all" ranks second with an overall percentage of 16.8%. Those who stated they had no idea about the topic had the lowest score of 5.30% (Table 5). According to these data, an understanding accepts taste and artistic value, reinforcing that fine art prints are as valuable as printmaking. Fine art prints, as one of the printmaking production techniques, the view that he accepts and adopts the artistic value for the audience is dominant.

Table 5

Proportional values according to the answers given by the art audience to the interpretation of *"The fact that a work of art is printed using digital technology does not change my judgement on the artistic value of that work."*

	Frequency	Percent	Valid Percent
Agree	209	41,30 %	41,30 %
Partielly agree	185	36,60 %	36,60 %
No idea	27	5,30 %	5,30 %
Disagree	68	13,40 %	13,40 %
Strongly disagree	17	3,40 %	2,20 %
Total	**506**	**100,00 %**	**100,00 %**

Source: Adopted from the survey within the scope of the ongoing doctoral thesis titled "Effects of fine art printmaking on the phenomenon of the art".

- - *"Would you be interested in attending contemporary art exhibitions consisting of fine art prints?"*

To determine the attitude of the culture and art audience participating in the survey towards the artwork, the question "Would you be interested in attending contemporary art exhibitions consisting of fine art prints?" was asked. In response to this question, which clarifies the views of the audience vis-à-vis the above comments, a large majority of respondents, 79%, indicated that they attend such exhibitions 'yes,' 'sometimes' or 'rarely' (Table 6). The percentage of those who answered "no" or "never" is 20.90%. These data show us that in

Turkey, art audiences participate in contemporary art exhibitions consisting of fine art prints with interest, a limited group does not participate, and an understanding that accepts the value of art with admiration against innovative presentations are in the majority.

Table 6

Proportional values according to the answers given by the art audience to the question of *"Would you be interested in attending contemporary art exhibitions consisting of fine art prints?"*

	Frequency	Percent	Valid Percent
Yes	213	42,10 %	42,10 %
No	76	15,00 %	15,00 %
Sometimes	112	22,10 %	22,10 %
Rarely	75	14,80 %	14,80 %
Never	30	5,90 %	4,90 %
Total	**506**	**100,00 %**	**100,00 %**

Source: Adopted from the survey within the scope of the ongoing doctoral thesis titled "Effects of fine art printmaking on the phenomenon of the art".

Discussion

According to the survey data, this research shows us that on art lovers' attitude and approach toward contemporary and innovative artistic presentations, regardless of whether they are produced by the classical method or digital technology, are approached with admiration and interest. This digitalized age offers the possibility to follow cultural and artistic events easily. Another result that underlines appreciation and interest is that the respondents find it attractive to view and buy fine art print, a new type of artistic production, according to their taste and purchasing power. It is a remarkable result to see this view in the responses of highly educated and professional art lovers. Considering this data, it indicates that the relationship between the level of education and the art audience, especially the art education received before and during college is an essential factor influencing the affiliation with the art audience.

Conclusion

This study addresses the survey results to determine the impact and level of appreciation of the fine art prints produced with digital printing technology by art audiences in the context of the art phenomenon.

According to an overview of this article, the Turkish art audience approaches contemporary art exhibitions consisting of fine art prints with admiration and interest. Moreover, income and education levels seem to play a significant role as well. The influence of income level due to higher education on the art audience's participation in cultural and artistic activities cannot be ignored. Another effect is the audience's level of awareness of the work they are viewing, according to the process of "prior knowledge", whether they have received art education or not. Based on the process of acquiring "prior knowledge", it can be said that he is aware of the type of artwork they are viewing, which affects their perception selectivity. In this context, it is evident that the audience with no art education approaches the artwork at the level of appreciation, mainly because they have no specific idea about the artwork's structure. This result reminds us once again of the importance of having curricula associated with the theoretical structure of education and practices and art.

According to the researchers, 506 adult art lovers living in metropolitan cities of Turkey during the pandemic period attended contemporary art exhibitions and events with fine art prints as art audiences, were very enthusiastic about innovative presentations, and showed a willingness to purchase art. This result can be considered one factor that encourages contemporary artists to include innovative means of expression in their artistic presentations. The contemporary artist is inclined to include new means of expression in his artistic presentations, thanks to his awareness that gives importance to the attitude and views of the art audience by following technological developments. In this context, as Umberto Eco mentioned in his book "The Open Work," the existence and views of the art viewer, effective in the artistic production process by adapting to the changes in the general nature of art, will continue to be a phenomenon that promotes production for today's artists.

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Quality assessment of offset thermosensitive printing plates

ABSTRACT

This article discusses the technological possibilities of assessing the quality of offset thermosensitive printing plates by studying the influence of the structural and physical properties of their construction layers, as well as the parameters of digital computer-to-plate recording on the quality of formation and reproduction of image elements.
The article presents an original conceptual model for determining the integral quality indicators of printing plates, taking into account their structural and physical properties, a set of modern methods for evaluating the quality of offset printing forms is presented, such as evaluating the surface morphology of polymer registering layers and a substrate – a basis of the printing form; assessment of the adhesion of polymer layers of offset printing plates to the substrate surface, taking into account the influence of image recording parameters; investigation of the influence of the chemical state of the registering layers of offset plates on the adhesion of printing elements to inks; assessment of the influence of the processes of thermal action of laser radiation and the temperature gradient on the surface structure of the polymer layer of a thermosensitive plate and the accuracy of the formation of the quality of discrete image elements on printing plates. These researches are aimed at determining the relationship between the structural and physicochemical properties of offset thermosensitive plates and integral indicators of the reproduction quality of raster and line image elements in a digital recording system.

KEY WORDS
Offset thermosensitive plate, printing plate, surface morphology, adhesion, reproduction-graphic properties

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Introduction

Determination of integral quality indicators of printing plates taking into account their structural and physical properties

Despite the rapid development of digital printing technologies, flat-bed offset printing using printing plates continues to occupy a significant part of the European market of printing products. The possibilities of using modern offset technologies allow printing high-quality paper and cardboard packaging, books, magazines, various graphic and advertising products, special products with signs of protection against counterfeiting and copying, which requires increased accuracy of graphic elements reproduction (Bobrobodro, 2010; Patlah, 2007; Khadzhynova & Havenko, 2020).

As is known, the physical parameters of the construction layers of the printing plates have a direct impact on the quality of reproduction of binary image elements on printing plates in the process of their digital recording in the Computer-to-plate system (Sevryugin, 2016). In particular, the thickness and chemical

composition of the polymer layers of printing plates, the morphology of the surface of their polymer layers and the substrate, the adhesion strength of the polymer layers to the substrate and the adhesion of printing elements on the plate's surface to the ink layers have a direct effect on the printing plate run time and the ink transfer process during printing.

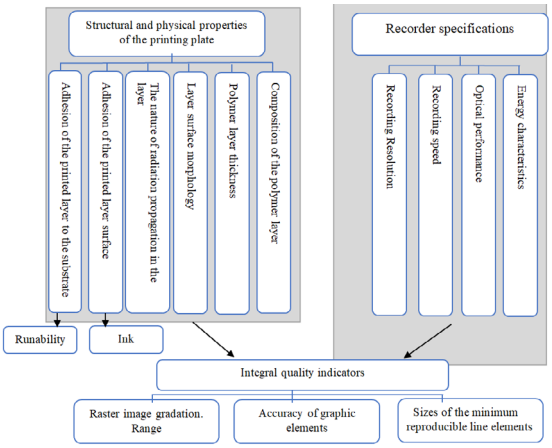
Along with the structural and physical properties of offset plates, the quality of image recording is influenced by integral quality indicators, in particular, the gradation transmission of the image, its range, the accuracy of reproduction of graphic elements, the size of the minimally reproducible line elements, etc. Integral quality indicators take into account not only the structural and physical properties of the construction layers of printing plates, but also their technological capabilities in conjunction with the platemaking equipment used for recording (Chepurna & Komarnytska, 2018).

Thus, the determination of the complex of physical, structural and integral properties of offset printing plates that affect the quality of finished printing plates is an important research process. Determination of indicators of these properties makes it possible to predict the quality of printing plates, which in turn makes it possible to make a targeted selection of plates for a specific production process at offset printing enterprises and to achieve optimal image recording quality in the "Platemaking device- printing plate" system.

The main characteristics of offset plates are determined by the sensitometric and reproductive-graphic properties of their polymer layers (Andreev & Sevryugin, 2012). The reproduction-graphic properties of the offset printing plate process are considered in (Kartasheva, 2008). The factors that determine the sensitometric and reproductive-graphic properties of the plates are the structural and physical parameters of the polymer layers that record the image: their thickness, nature and chemical composition, surface microgeometry. In particular, the thickness and chemical composition of the polymer layers determine the nature of the propagation of radiation in the layer, thus affecting the quality of the binary image recording. The morphology of the surface of the polymer layer of the plate affects the accuracy of the formation of image elements and the evenness of their edges. Comparison of the quality of the processes of recording images on light- and termosensitive offset plates, considered in the work (Andreev & Sevryugin, 2012).

The structural and physical properties of the polymer layers and the substrate of the plate also determine the technological capabilities of the printing plates in the printing process. The nature of the propagation of radiation in the polymer layer and the microgeometry of the wafer substrate surface also affect the degree of reflection of radiation and the adhesion of the printing elements to the substrate, therefore, determines the stability of the printing elements in the printing process and plate runability. The chemical composition and microgeometry of the surface of the polymer layer of the printing plate determine its surface energy and adhesion on the surface of the printing elements, therefore, influences the ink transfer process during the printing process.

Obviously, the main reproductive-graphic indicators of the quality of line and bitmap images reproduction on printing plates, such as the gradation transmission of the image, the resolution and excretory ability, the accuracy of reproduction of graphic elements, the sizes of minimally reproducible elements on recorded priting plates and others, are determined not only by the structural and physical parameters of their polymer layers. These quality indicators can be called integral, since they assess the quality of printed plates by a set of parameters. Integral quality indicators take into account the structural and physical properties of the construction layers of printing plates, their technological capabilities, together with the platemaking equipment used for recording (Figure 1).



» **Figure 1:** *Conceptual model for determining the integral quality indicators of printing plates, taking into account their structural and physical properties*

The above-mentioned indicators of image reproduction quality are also influenced by the parameters of recording systems – energy, optical characteristics, recording speed and resolution, etc. That is why it is so important to determine the integral indicators of the quality of printing plates, taking into account their structural and physical properties, which are characterized by the surface morphology of the layers of printing plates, adhesion of the polymer layer to the substrate and its chemical state under the influence of thermal effects.

Methods for determining the physical properties and integral quality indicators of offset printing plates

To determine the structural and physical characteristics of printed plates, it is advisable to use the following methods: atomic force microscopy (AFM) or surface free energy (SFE) method to determine the surface morphology of polymer layers and the adhesion force on the surface of the printing elements; the method of separating polymer layers using a needle (indenter)- to determine the adhesion strength of the polymer layer, and therefore the printing elements to the surface of the plate substrate; method of X-ray photoelectron spectroscopy (XPS)- to determine the chemical state of the surface of the layers. The nature of the propagation of radiation in a layer can be described using the method of physical modeling of laser processing of thin films, which makes it possible to assess the influence of the processes of thermal action of laser radiation and the temperature gradient on the surface structure of thin polymer layers and on the formation and quality of reproduction of image elements.

For the most detailed description of the **surface morphology** of the layers of printing plates, their microgeometry and roughness, it is necessary to use the parameters R_a – the arithmetic mean deviation of the microroughness profile, R_q – the standard deviation of the profile, and R_{max} – the maximum deviation of the profile height. To assess the morphology of the surface of the polymer layer and the substrate of the plates, we used the method of laser scanning on an AFM NT-206 microscope. According to the measurement results, profilograms of the surfaces of the layers and the arithmetic mean values of the R_a profile, the standard deviations of the R_q profile and the values of the maximum microroughness R_{max} were obtained (Margelevičius, Sajek & Kartasheva, 2015).

Determination of **adhesion on the surface of polymer layers** can be correctly performed using an AFM NT-206 microscope. As is known, the value of the adhesion force of the surface of printing plates is influenced not only by the properties of the microgeometry of the surface of the polymer layer, but also by its surface energy: the lower the surface energy, the weaker the wetting and adhesion on the surface of the printing elements of the plate. With increasing surface energy, wetting and adhesion increase. The magnitude of the adhesion force is largely determined by the properties and chemical composition of the polymer. Chemical elements in its composition affect the magnitude of the adhesion force, for example, the presence of sodium (Na) in the composition of the polymer in a certain amount increases its surface energy, and the presence of silicon (Si), on the contrary, leads to its decrease. Oxygen compounds on the polymer surface form oxide films with low surface energy. Chemical elements and impurities in the composition of the polymer layer of the plate determine the adhesion properties of the surface of the printing plate, which is in direct contact with the offset ink during the printing process (Margelevičius, Sajek & Kartasheva, 2015).

To determine the forces of **adhesion of the polymer layer to the substrate** of the printing plate, the method of layers separation was chosen in the framework of the research, i.e. scribing with a needle (indenter) with variable load and registration of normal F_N and tangential F_T load forces on the RA-120 device. When the indenter is deepened into a thin (1–2 μm thick) polymer layer of the Agfa Azura printing plate, at the moment of destruction of the coating, the value of FT becomes constant, i.e., the value of the indenter load is fixed, at which the coating peels off (Margelevičius & Sajek, 2010; Sajek & Kartasheva, 2017).

To carry out the process of analyzing **the chemical state** of the polymer layer of the studied plate, the X-Ray Photoelectron Spectroscopy XPS method was chosen using an ESCALAB-250Xi spectrometer. This is a quantitative and qualitative spectroscopic method for studying the elemental composition, as well as the chemical and electronic state of atoms on the surface of the investigated material. Broad (survey) and detailed spectra for qualitative and quantitative analysis of polymer surfaces were obtained by irradiating the surface of samples of Agfa EEP, Fuji VPS and YP-Q printing plates with X-rays (Sajek, 2018).

The method of studying **the processes of the influence of heat** and temperature gradient on the formation of graphic elements in the polymer layer of the printed plate was developed on the example of negative thermosensitive plates Agfa Azura. To study the effect of the type and parameters of thermal action on the structure of the latex surface on the platemaking device Heidelberg Supraseter A74 Agfa Azura printing plates with an IR laser power from 70 mW to 100 mW were recorded. Mathematical description of changes in the surface state of a layer of thin (0.5- 1 μm) latex film depending on the energy parameters of IR laser radiation- power and duration of exposure, is based on the physical model of laser processing of thin films.

The temperature of the film under these conditions (heat dissipation from the film of the polymer coating to the substrate is insignificant, the pulse duration is less than 10^{-7} s, layer thickness not more than 5 μm) is calculated using the equation:

$$T = \frac{q_0 A \tau}{\rho c h} + T_0 \quad (1)$$

where: q_0 – radiation power density, W/m²; A – the latex absorption coefficient $A=(1-R)$; R – the reflection coefficient; τ – the pulse duration, s; ρ – the density of

latex, kg/m; c – specific heat capacity of latex, J/kg·K; h – layer thickness, m; T_0 – ambient temperature, K.

When recording termosensitive plates, the largest part of the energy of thermal radiation is spent on the formation of an active printing element, but the edge of this element does not coincide with the edge of the distribution of thermal energy. Part of the energy is diverted outside the element, forming a blur zone and leading to its distortion. Obviously, the nature of the distribution of thermal energy has a direct impact on the accuracy of reproduction of active printing (in the case of a negative) and blank (in the case of a positive process) elements. The distribution of thermal energy in the layer proceeds from the areas exposed to thermal energy within the pixels towards the areas not exposed to laser radiation. This process is described using a temperature gradient:

$$T(x) = f(q, \tau, k) \quad (2)$$

where: $T(x)$ – temperature at point x, °C; q – the radiation power density, W/m²; k – thermal conductivity of latex W/m²·K; τ – the duration of the radiation pulse, s (Margelevičius, Vaitasius & Sajek, 2012).

Test objects are used to evaluate the reproduction of dashed details in a production environment. It should be noted that there is a variety of test objects and approaches to a set of fragments of the same type that are typical for each manufacturer. Evaluation of the performance of printing plates using these test objects does not give a complete picture of the quality of reproduction of image details of various sizes, and this is important and extremely necessary for the choice of printing plates when solving specific problems, regardless of the type of used platemaking device. Therefore, a universal characteristic is required that determines the reproduction of details of small sizes. This characteristic can be the modulation transfer function- MTF. It characterizes the dependence of the reproduced signal on its frequency and contains the characteristics of the reproduction of details of various sizes (Sajek, Kartasheva & Andreev, 2017).

Results

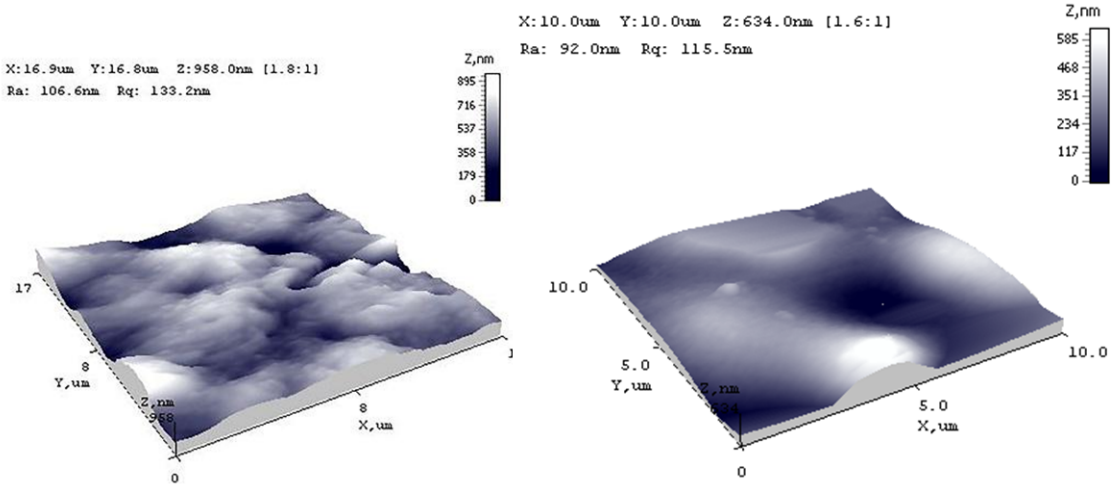
Results of the study of the physical properties and integral quality indicators of offset termosensitive printing plates

To assess the surface morphology of the aluminum substrate and the parameters of the surface morphology of polymer layers, samples of two types of thermosensitive printing plates – Agfa Azura (negative) and Agfa EEP (positive) – were studied (Figure 2). For the aim to compare different offset printing plates in general, Fuji VPS-E (photosensitive positive) and Huaguang YP-Q (positive plate with copy layer) were also evaluated. During recording, the polymer layer of the Agfa Azura negative plate was irradiated in the areas of the printing elements. The polymer layers of the remaining three positive plates were irradiated in the areas of the non-printing elements, and the printing elements (non-irradiated areas) remained in their original state. So, the surface areas of the unexposed polymer coating were evaluated on these printing forms. The measurement results are shown in Table 1.

Table 1

The main indicators of the surface morphology of the studied plates

Number	Plate	R_a, nm of polymer	R_q nm of polymer	R_{max}, nm of polymer	R_a, nm of aluminum	R_q nm of aluminum
1	Agfa EEP	92	115	150	200	300
2	Agfa Azura	106	133	324	200	200
3	Fuji VPS-E	34,1	42,9	75	100	200
4	Huaguang YP-Q	40,7	54,4	80	200	300



» **Figure 2:** *Three-dimensional models of the layer's surfaces of the plates in the zones of printed elements: 1 – laser-exposed layer of Agfa Azura latex; 2 – unexposed thermopolymer Agfa EEP*

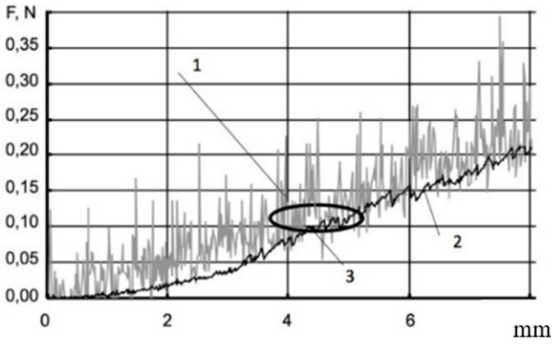
The results of studies of the **adhesion force of the surface** of the printing elements of the samples of printing plates Agfa EEP, Fuji VPS-E and YP-Q applying atomic force microscopy, are shown in Table 2.

Table 2

The magnitude of the adhesion force of the polymer layers surface of printing plates

Number	Plate	Adhesion force, nN
1	Agfa Energy Elite Pro	78,93
2	Fuji VPS-E	69,49
3	Huaguang YP-Q	51,05

Evaluation of the **adhesion force of the latex layer to the aluminum substrate** of the plate was carried out on Agfa Azura printing plates by scribing with a variable indenter load (Figure 3).



» **Figure 3:** *Distribution of normal F_N and tangential F_T scribing forces of the latex layer molten by laser action (q_0 = 100 mW): 1 – F_N, 2 – F_T, 3 – coating peeling zone*

The adhesion of the latex layer to the substrate surface changes after exposure to radiation, depending on the degree of melting of the layer. As can be seen from formula (1), the value of the temperature *T* of the latex layer when exposed to it by laser radiation is directly dependent on the power density of the laser radiation q_0, the pulse duration τ, as well as in inverse dependence on the characteristics of the material. In Figure 3 shows the distribution of normal F_N and tangential F_T scribing forces for the molten latex layer. It is obvious that the adhesion of the polymer layers of negative printing plates depends on the parameters of laser radiation, as well as on the physical and structural characteristics of the material (Margelevičius & Sajek, 2010; Sajek & Kartasheva, 2017).

Calculations of the relative adhesion force have shown that the relative adhesion of latex to the substrate depends on the type of radiation source. The value of the relative adhesion F_A of the latex layer melted by IR radiation and heated by a heat source is different: the adhesion of the layer heated with a heat source is one and a half times higher than the adhesion of the layer heated by IR radiation. This result can be explained by the influence of the temperature gradient in the zone of separation of layers during coating processing (Sajek & Kartasheva, 2017).

As a result of the XPS study of the **chemical state** of the surface of polymer layers, the zones of the printing elements were evaluated after recording the printing plates of Agfa EEP, Fuji VPS and YP-Q. On the ESCALAB-250Xi spectrometer, survey spectra of the surfaces of the polymer recording layers of the studied printing plates were obtained (Sajek, 2018).

With similar values of the surface morphology of the polymer layers (Table 1), its effect on adhesion on the layer surface in contact with the printing ink should be the same. With different values of adhesion (Table 2), it can be influenced by the chemical composition of the polymer layer and the concentration of chemical elements (for example, Na and Si). According to the results of the analysis of the spectra of Na and Si and the calculation of their atomic concentration (Table 3), it can be seen that the concentration of Na is practically the same on the surface of both photosensitive printing plates. No Na was found on the polymer surface of the Agfa EEP Na thermosensitive printing plate. The relatively low Si concentration on the surface of the Fuji VPS printing plate contributes to the presence of more surface energy than, for example, on the surface of the YP-Q printing plate, which is confirmed by the measurement results.

The surface morphology of the Agfa EEP thermosensitive plate is more rough compared to Fuji VPS and YP-Q printing plates. This state of the surface structure leads to an increase in the adhesion of the printing elements, despite the higher concentration of Si on the surface of the polymer layer.

Table 3

Results of calculations of the atomic concentration of Na and Si (%) from the XPS spectra of the surface of polymer layers

Printing plate	Adhesion force, nN	Chemical element	Bond energy, eV	Atomic concentration, %
Agfa EEP	78,93	Na1s	-	-
		Si2p	101,51	1,3
Fuji VPS	69,49	Na1s	1071.57	0,2
		Si2p	101.44	0.6
Huaguang YP-Q	51,05	Na1s	1071.18	0.3
		Si2p	101.75	4.2

To study the influence of the type and parameters of the thermal effect on the structure of the latex surface, it was calculated the temperature on the plate surface for specific recording conditions using formula (1). The results of calculating the temperature on the plate surface for specific recording conditions showed that the temperature of the latex layer, which is affected by the radiation energy density, is different. It has been confirmed that the power of laser radiation has an effect on the adhesion of latex to the substrate and on the stability of the printing elements.

The distribution of thermal energy in the latex layer of Agfa Azura plates was described using a temperature gradient. The values of the change in size (δ) of the diameter of the discrete element were calculated for a variable power density of laser radiation *q*, layer thickness *h*, for a variable diameter of the laser spot (Table 4) (Margelevičius, Vaitasius & Sajek, 2012).

Calculations of the change in the size of discrete elements showed that the power density of laser radiation and the density of the specific thermal energy of latex melting have practically no effect on the change in the size of the discrete element. At the same time, the greater the thickness of the latex layer, the greater the change in the size of the discrete element. Consequently, during digital recording of discrete elements on a thermosensitive latex layer, the change in their sizes depends to a greater extent on the diameter of the laser spot. The calculation results confirmed that the temperature distribution along the normal T_N is more efficient than its tangential distribution T_T. The relatively high temperature on the surface of the aluminum substrate, distributed in its volume due to the higher thermal diffusivity of aluminum in comparison with latex, increases the adhesion of the latex to the surface of the substrate.

To determine the **integral quality indicators** (image gradation, graphic elements reproduction accuracy, sizes of minimally reproducible line elements, etc.), the influence of modes and parameters of element-by-element recording on the reproductive properties of systems was studied: the position of image strokes relative to the recording direction (line and frame scanning), their spatial frequency, the rotation speed of the drum of the recording device, the radiation power and the resolution of the recording. Experimental results of assessing the reproductive properties of thermosensitive positive and negative offset plates are described: reproduction of line image details using the example of Fuji LH-PCE Brillia and Fuji LH-PJE plates, recorded on Creo Trendsetter 800 Quantum and CreoLotem 800 devices (Sajek & Valčiukas, 2021), respectively; gradation transmission of a raster image using the example of plate Agfa EEP, which was recorded on Screen Plate Rite 4300S (Sajek, 2014) and Agfa Azura, recordered on Heidelberg Suprasetter A74 devices. To assess the line details of the image, an original digital test object with lines from 10 to 150 µm wide was used (Sajek & Valčiukas, 2011).

As a result of the experimental data of reproduction of line details of the image and mathematical calculations, the MTF system of the "platemaking device-plate" was obtained for the Creo Lotem 800 device and Fuji LH-PJE thermosensitive plates and for the Creo Trendsetter 800 Quantum device and Fuji LH-PCE thermosensitive plates (Arutyunova, Kartasheva & Sajek, 2009; Sajek & Valčiukas, 2011). To assess the reproductive-graphic properties of the platemaking system, in which there is a certain blurring, the method of experimental evaluation based on the FPM was used, the parameters of reproduction quality of printing elements with different spatial frequencies and blurring in digital recording systems were determined. The research results showed that small strokes (10-15 microns wide, spatial frequency ν above 30 mm^{-1}), oriented perpendicular to the recording direction (frame scan), are better reproduced on these plates. Larger strokes (100 µm wide, spatial frequency ν- 5 mm^{-1}) are better reproduced in the recording direction (line scan) (Sajek, Kartasheva & Andreev, 2017; Arutyunova, Kartasheva & Sajek, 2009; Sajek & Valčiukas, 2021).

Conclusions

The article presents an original conceptual model for determining integral indicators of the quality of printing plates, taking into account their structural and physical properties; also selected methods for assessing the quality of offset thermosensitive printing plates based on the study of the influence of the structural and physical properties of their structural layers, as well as the parameters of digital recording on the quality of formation and reproduction of image elements.

Table 4

The values of the change in the size δ of a discrete element with a variable diameter of the laser spot

Diameter of the laser spot, $2r_o$, m	5×10^{-6}	10×10^{-6}	15×10^{-6}	20×10^{-6}
Latex layer thickness h =1.0 µm, power density q = 10^{11} W/m² · s (T = 185°C)				
Specific density of thermal energy, q_1, J/m²	$0,86\times10^{8}$	$0,43\times10^{8}$	$0,29\times10^{8}$	$0,22\times10^{8}$
Change in the size, δ, m	$0,22\times10^{-6}$	$0,44\times10^{-6}$	$0,65\times10^{-6}$	$0,85\times10^{-6}$
Latex layer thickness h=0/5 µm, power density q=10^{11} W/m² · s (T=185°C)				
Specific density of thermal energy, q_1, J/m²	$1,3\times10^{8}$	$1,5\times10^{8}$	$1,8\times10^{8}$	$2,0\times10^{8}$
Change in the size, δ, m	$0,11\times10^{-6}$	$0,22\times10^{-6}$	$0,33\times10^{-6}$	$0,43\times10^{-6}$

Within the framework of the research, the results of indicators of the surface morphology of the polymer layers and the substrate were obtained; adhesion of polymer layers of offset printing plates to the substrate surface, taking into account the influence of image recording parameters; the influence of the chemical state of the registering layers of offset plates on the adhesion of printing elements to inks was evaluated; the influence of the processes of thermal action of laser radiation and the temperature gradient on the surface structure of the polymer layer of a thermosensitive plate and the accuracy of the formation of discrete image elements on printing plates has been evaluated. The research results confirm the relationship between the structural and physicochemical properties of offset thermosensitive plates and integral indicators of the quality of image reproduction in a digital recording system.

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