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# MODELING OF A VIRTUAL PRINTING MACHINE FOR INTERACTIVE E-LEARNING APPLICATIONS

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Abstract: *The advancement of interactive e-learning platforms requires developing sophisticated simulation tools to enhance the educational experience. This study focuses on modelling a virtual printing machine designed for integration into interactive e-learning applications. The virtual printing machine aims to simulate the functionalities and operations of a real-world printing machine, providing students with a hands-on learning environment. Using advanced software engineering techniques, the virtual model replicates mechanical processes, operational parameters, and troubleshooting scenarios typically encountered in printing technology. This approach not only aids in comprehending complex printing processes but also promotes active learning and critical thinking. The effectiveness of the virtual printing machine is evaluated through user feedback and performance assessments, demonstrating its potential as a valuable tool in technical education. The findings suggest that integrating such virtual simulations in e-learning platforms can significantly enhance the quality of technical training and education.*

Key words: Virtual Printing Machine, Interactive E-Learning, Simulation, Technical Education, Software Engineering

## 1. INTRODUCTION

Distance learning proved its importance during the 2020 pandemic, but its relevance extends beyond that period. It also highlighted numerous shortcomings, demonstrating the need for continuous improvement to ensure better learning outcomes. Distance learning is a form of education where the main elements involve the physical separation of teachers and students during instruction and various technologies to facilitate communication between them. It has primarily focused on non-traditional students, such as full-time workers, military personnel, and individuals with family obligations, providing them the flexibility to pursue education while balancing other responsibilities. (Berg & Simpson, 2024). It usually emphasizes the lack of personal contact between participants as the greatest shortcoming of this type of learning (Kalamković, Halaši & Kalamković, 2012)

Distance learning also serves as an excellent complement to conventional education, allowing us to define a subgroup involving virtual spaces and machines. Virtual learning, including access to virtual classrooms where students can supplement their theoretical knowledge, provides a significant contribution to a deeper understanding of the material. Also, virtual learning drives students to collaborate among themselves and with professors, which creates a positive correlation between technology-based learning and active learning (Kuh & Nelson, 2005). The use of technology to aid in information processing and communication is not new. In fact, over the past 50 years, numerous technologies have developed exponentially, primarily due to the invention of digital electronics (Bušelić, 2012).

This paper presents a solution for an educational tool designed to provide students with access to a digital printing machine in a virtual space. Students who may or may not be physically present in the classroom can virtually access elements they do not have adequate access to in the real world. Even when a physical machine is available, only a few students can gather around it, meaning others lack a clear view, cannot hear the instructor well, or are unable to approach the machine due to the presence of their peers, leading to a quick loss of interest. Virtual access to the machine allows a large number of students to have unlimited access to the necessary information simultaneously. In education, VR offers significant support for learning. By using such systems, students can visualize abstract concepts, observe events from different perspectives and scales (for example, atomic and giant scales), visit environments, and interact with events remotely (Machado, Costa & Moraes, 2006). Some studies, through informal interviews with students, have shown that most enjoy and appreciate 3D environments (Dickey, 2005).

As emerging technologies, Augmented Reality (AR) and Virtual Reality (VR) have been widely applied in the education of various disciplines. (Huang et al., 2021). VR possesses much potential, and its application in education has seen a lot of research interest lately. It has mostly been a part of experimental and development work rather than being applied regularly in actual teaching (Radianti et al., 2020). Today's VR systems can run on a relatively cheap system like a desktop personal computer. Such a VR system is commonly known as a desktop VR, where users can interact with the virtual environment using their keyboard, mouse, joystick, or touch screen (Lee, Wong & Fung, 2010). A key feature of the VR experience is the possibility of actively interacting with the created environment (Mantovani, 2001).

Today's students, often referred to as digital natives, have been using technological devices since infancy. Their brains have adapted to a fast-paced, hypertext-driven, interactive environment, leading to cognitive shifts that influence their learning methods (Prensky, 2001). They don't just seek information and solve problems online; they engage with digital content through exercises, simulations, games, and virtual worlds. Rather than passive observers, they are active participants, taking control of learning materials while managing their own time and pace. This fosters self-agency, autonomy, and problem-solving abilities and helps them stay focused (Alt & Raichel, 2020).

The paper presents the development of an educational tool for the Roland Versa UV LEC540 digital machine, featuring its basic functions, which are animated and integrated into a web application to maximize student access. The key animated actions include loading ink into the machine, printing, die-cutting, and cleaning the print heads. The machine's modelling process was conducted according to a precise schedule and well-defined components, considering the actual machine's operation, including the movements that need to be animated and the parts that would move and be displayed. Following the modelling phase, animation was applied, involving both the camera and the machine's moving parts. To enable interactivity within the application, separate 3D animations are created, which can be activated by the user through the web interface. The user selects which part of the machine to activate or which function to view. After viewing the animation, the user can repeatedly activate specific machine functions to understand the device's operation better. This method provides insights that are not easily achievable through traditional learning and are often difficult to comprehend. Additionally, the virtual machine cannot malfunction, pose any danger to the user, or consume expensive resources such as paper and ink to demonstrate its functionality.

## 2. DEVELOPMENT OF ANIMATION FOR EDUCATIONAL PURPOSES

The animation is divided into four main parts, which are integrated into a single educational tool, forming a unified whole that simulates the operation of the printing machine. Separate animations are created for loading ink into the machine, printing, die-cutting, and cleaning. Additionally, individual animations are made for the camera, which will provide the best view of the specific part of the machine performing its respective function at any given moment. Each camera for the selected machine operations follows a unique path, as shown in Figure 1.

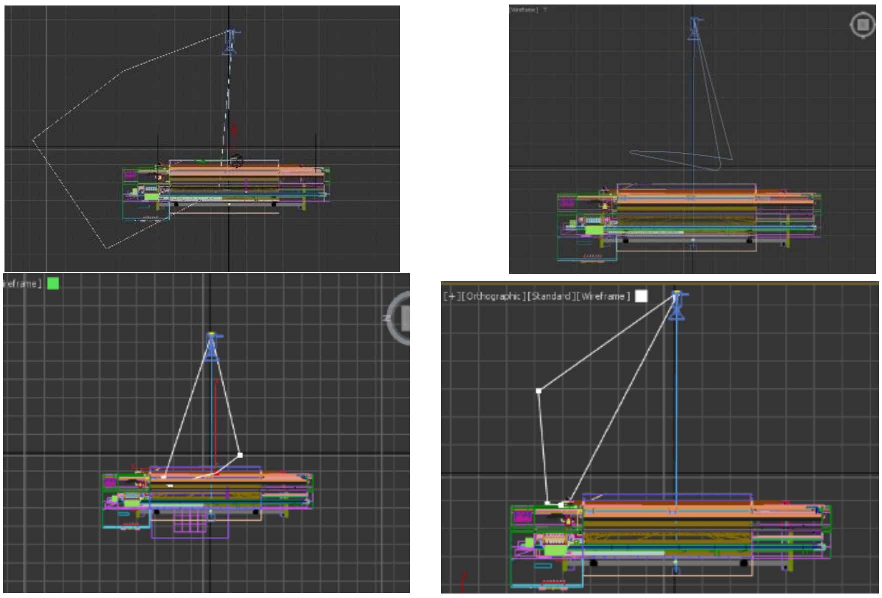

*Figure 1: The different camera paths are designed to provide a detailed view of the specific part of the machine performing a given function at the precise moment*

Video animations start and end with the same initial/final frame to ensure a smooth transition between animations without interruption (Figure 2). Special attention is paid to each camera path to avoid sudden turns and stops so that the movement does not appear abrupt or unexpected to the viewer.
Before starting each animation, it is necessary to set the appropriate number of frames, i.e., the duration of the animation in seconds. The initial frame count for each animation was set to 1,000 and was adjusted as needed, depending on the length of the machine operation being simulated, which is best assessed during the animation creation process. In addition to the animation duration, the frame rate must be set. Each second must display a minimum of 24 frames to ensure smooth movement. This frame rate is considered optimal for producing a natural and pleasant sense of motion for the viewer. For these animations, the frame rate was set to 30 frames per second. Each animation segment is planned so that none of them are excessively long, maintaining the viewer's concentration at its peak.

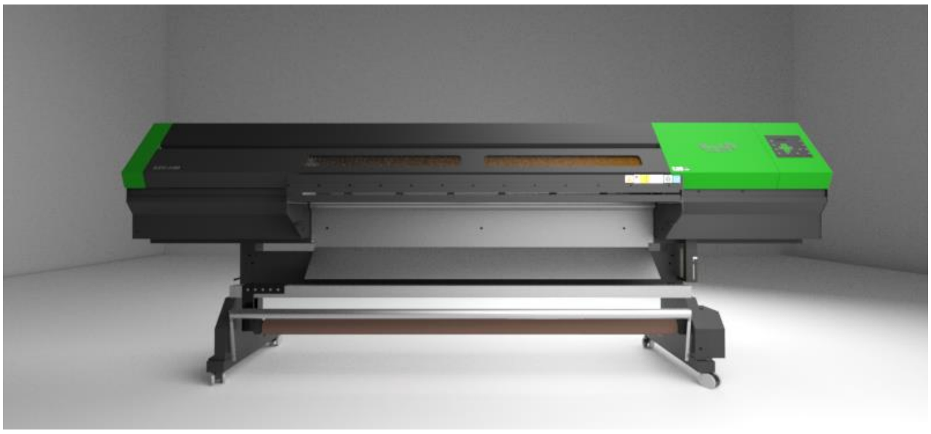

*Figure 2: Display of the initial and final frame of each animation*

Each animation has something unique that sets it apart from the others, whether the duration or the animation technique used. The first animation is the shortest and relatively simple compared to the others. The camera has only one stop and focus point. It pauses at the rear part of the machine where the ink is loaded, remaining stationary until the ink-loading sequence is complete. The rear doors open, and their rotation is animated around a single axis. Like the camera, they stay open until the ink is inserted. The cartridges are animated to move into the machine, and once the doors close, the camera returns to its initial position.
The second animation is notable for depicting the printing process. To show the printing or the gradual appearance of the image with each pass of the print head over the paper, an additional animation is created to display the image progressively. This is done in a separate program that produces a 2D animation, where the logo appears incrementally every 10 seconds (Figure 3).

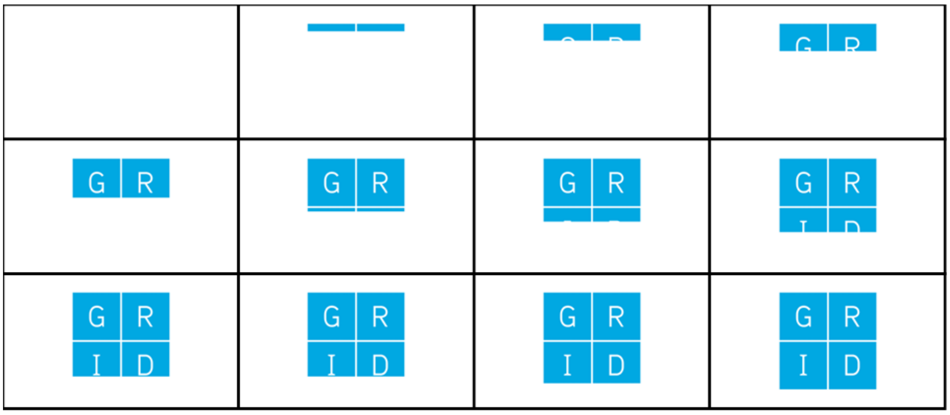


*Figure 3: Animation of print appearance on paper*

The 2D animation created in this manner is imported into a 3D program as a material. In order to be used as a material, it must be saved as a sequence of images. Once the animation is obtained in the form of a material, it is applied to an object representing paper. Throughout the entire printing animation, the camera focuses on the printing table, where, before displaying the paper itself, the stopper's placement is shown. During the printing animation, care must be taken to position the print head above the paper at the appropriate moment, making it appear that the image is being printed as the head moves across. It should also be noted that once the paper animation is imported into the 3D software, it cannot be modified, meaning the 3D animation must be adapted to the paper animation.
The die-cutting animation is similar to the printing animation, except in this case, the gradual appearance of the image is not animated, it already exists as the bottom layer beneath the printed image. It is essential to demonstrate what is achieved through die-cutting, precisely how the paper is partially cut. In this case, the process is shown through an animation where separate objects, the paper and the sticker, are created. These objects appear connected during the tool's scoring process, after which it becomes easier to show how the two models separate. It is crucial that they maintain the same position and that their movements are synchronized so as not to reveal any difference between the objects.
For the printhead cleaning animation, the right-side door must be opened. Under normal circumstances, this door typically remains closed since the cleaning process can only occur when the machine is sealed. It is important to emphasize that this function cannot be observed live during operation, as it takes place within a closed system. The camera focuses on the printheads, and to demonstrate the cleaning process, the protective barrier over the printheads is also removed.
The cleaning process involves sponges within the machine being raised to absorb excess ink from the heads, after which they must be lowered (Figure 4). Once the sponge has absorbed the excess ink, the printhead moves to the squeegee located next to the sponge. The squeegee moves back and forth to thoroughly clean the printheads. To adequately represent the motion of the squeegee, it is not sufficient to merely adjust the camera's target position; the camera itself must be rotated during the shot. The printheads are cleaned two at a time, so the animation should be structured accordingly.

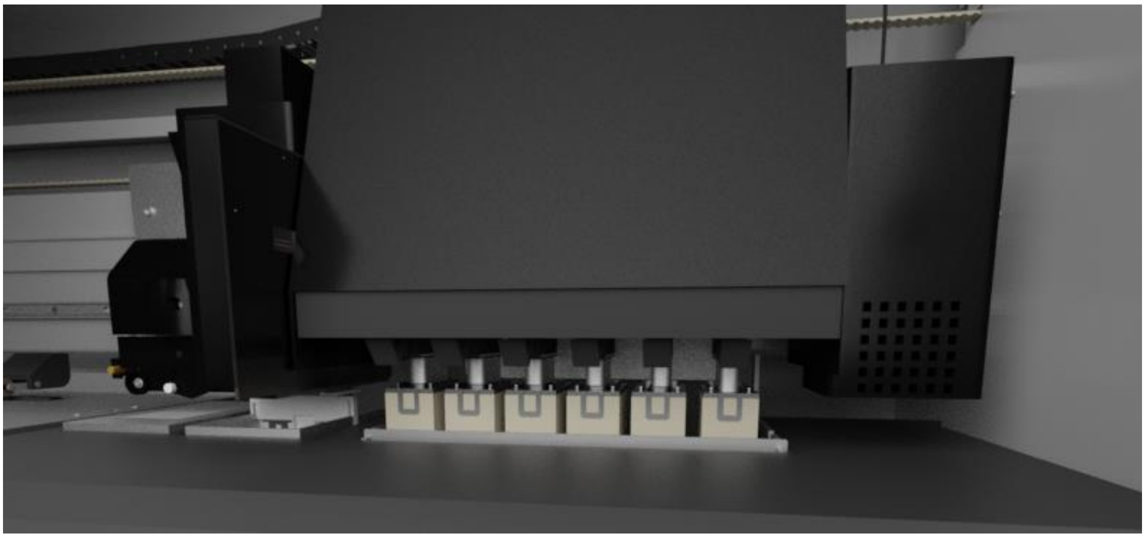

*Figure 4: Display of printheads during cleaning*

After cleaning, the camera moves down towards the waste container where the excess material is collected, showing the path the ink takes during the cleaning. The camera remains focused on the container for a few seconds before returning to its original position, during which the doors and screws are also returned to their proper places.

## 3. INTERACTIVITY

The animation is rendered from the 3D program as a sequence of images, which are then combined into a video using Adobe After Effects (Tables 1-3). The individual videos are rendered separately and then

combined in the web application. It is important to ensure that the beginning and end of each animation align perfectly to avoid discontinuities in the video sequence.
In the program, a composition is created with the same dimensions as the animation (800x600), and the frame rate is set to 30 frames per second. The image sequence is imported into the program and placed within the created composition. The resulting video is then added to the render queue to be processed in the appropriate format. The format generated this way is .avi, and additional software or extensions are required to convert it into .mp4 format.
Once each animation has been converted into a video, it must be merged into a single interactive video, which begins in the same way as each animation – with the first frame. The application is formed by defining a reference to a tag in the HTML itself, *initialVideoRef,* and the HTML will always display the initial frame of the animation, as later shown in the code as: *<video ref={initialVideoRef} controls={false}>.*

*Table 1: Reference creation for the initial tag*

```
const [video, setVideo] = useState<string>('');

const initialVideoRef = useRef<HTMLVideoElement>(null);
const stampaVideoRef = useRef<HTMLVideoElement>(null);
const bojaVideoRef = useRef<HTMLVideoElement>(null);
const ciscenjeVideoRef = useRef<HTMLVideoElement>(null);
const ricovanjeVideoRef = useRef<HTMLVideoElement>(null);

const playVideo = (name: string) => {
   setVideo(name);

   switch (name) {
    case 'stampa':
      stampaVideoRef.current?.play();
      break;
    case 'boja':
      bojaVideoRef.current?.play();
      break;
    case 'ciscenje':
      ciscenjeVideoRef.current?.play();
      break;
    case 'ricovanje':
      ricovanjeVideoRef.current?.play();
      break;
    default:
      break;
   }
 }
```

In addition, four more video tags are defined, one for each animation. The displayed portion of the code also includes a div tag containing buttons necessary for starting the animations. When each button is clicked, the *playVideo* function is called, which receives the name of the animation to be played as a parameter. Upon the completion of each animation, the *endVideo* function is invoked, setting the state so that no animation is active. Based on whether a specific animation is active, the CSS class of the video tag (*className*) is applied to determine whether the animation should be displayed or hidden.

*Table 2: Display of the animation code*

```
const endVideo = () => {
   setVideo('');
  }
 return (
   <div className='container'>
     <div className='image'>
       <video ref={initialVideoRef} controls={false}>
         <source src='./videos/Stampa-1.m4v'
type='video/mp4' />
       </video>
       <div className='button-container'>
         <button onClick={() =>
playVideo('boja')}>Ink</button>
         <button onClick={() =>
playVideo('stampa')}>Printing</button>
         <button onClick={() =>
playVideo('ricovanje')}>Die-cutting</button>
         <button onClick={() =>
playVideo('ciscenje')}>Cleaning</button>
       </div>
     </div>
     <video ref={stampaVideoRef}
onEnded={endVideo} controls={false}
className={'video ' + (video === 'stampa' ? 'show' :
'hide')}>
       <source src='./videos/Stampa-1.m4v'
type='video/mp4' />
     </video>
     <video ref={bojaVideoRef} onEnded={endVideo}
controls={false} className={'video ' + (video ===
'boja' ? 'show' : 'hide')}>
       <source src='./videos/Boja-1.m4v'
type='video/mp4' />
     </video>
     <video ref={ciscenjeVideoRef}
onEnded={endVideo} controls={false}
className={'video ' + (video === 'ciscenje' ? 'show' :
'hide')}>
       <source src='./videos/Ciscenje-1.m4v'
type='video/mp4' />
     </video>
     <video ref={ricovanjeVideoRef}
onEnded={endVideo} controls={false}
className={'video ' + (video === 'ricovanje' ? 'show' :
'hide')}>
       <source src='./videos/Ricovanje 1-1.m4v'
type='video/mp4' />
     </video>
   </div>
  );
}
```

To achieve the desired appearance of the animation, CSS code is created to define the properties of the HTML elements. The position of the buttons is set relative to the top of the animation, and the animation itself is centred in the window, which is reflected in the code with justify-content: centre and align-items: centre;

*Table 3: Display of animation setup in the window and css code*

```
.container {
  width: 100%;
  height: 100vh;
  display: flex;
  justify-content: center;
  align-items: center;
}

.container .image {
  width: 800px;
  height: 600px;
  position: relative;
  border: 1px solid black;
  z-index: 0;
}

.container .video {
  width: 800px;
  height: 600px;
  border: 1px solid black;
  z-index: 2;
  position: absolute;
}

.container .show {
  display: flex; }

.container .hide {
  display:

.container .button-container {
  width: 650px;
  position: absolute;
  top: 95px;
  right: 71px;
  display: flex;
  justify-content: space-evenly;
  align-items: center;
  z-index: 1;
}

.container .button-container button {
  height: 40px;
  width: 140px;
  border: 2px solid white;
  background: transparent;
  color: white;
  font-size: 24px;
  cursor: pointer;
  border-radius: 10px;
}
```

After all the previously described steps, the final appearance of the interactive animation, which runs locally, is obtained. The initial frame of the animation is shown in Figure 5.

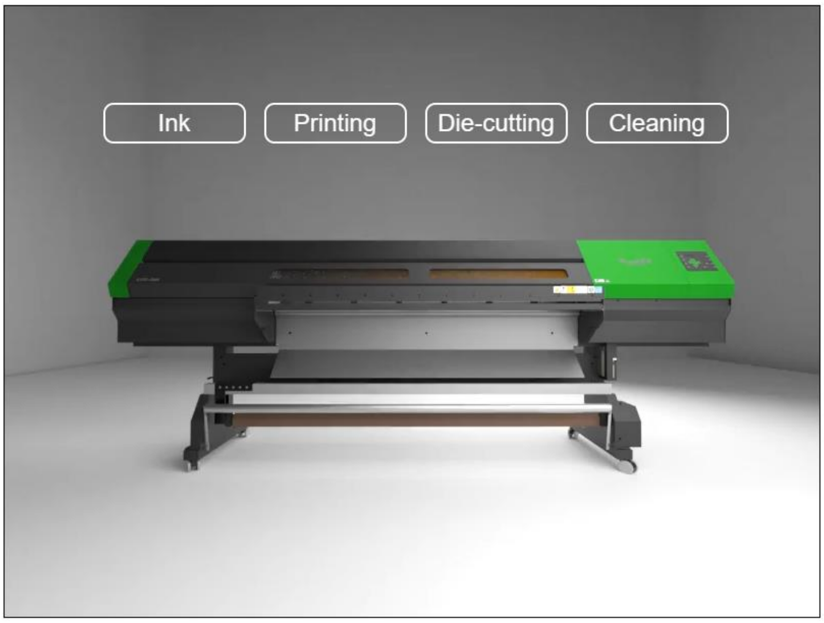


*Figure 5: Initial frame of the interactive web application*

The previous steps create an interactive web application that can be run locally or on a publicly hosted website with a domain. When the application is launched, the initial screen displays either the first or last frame of the animation. Above the machine, buttons are indicating which animations can be started, and clicking on a button triggers the desired animation. This allows each video to be played unlimited times, making them appear as a cohesive unit within the application.

## 4. CONCLUSIONS

The animation of various jobs, sciences, and engineering fields provides access to objects that people do not typically have the opportunity to observe in their daily lives. This paper focuses on the principles of digital printing technology and its operation animation. By visualizing the functioning and features of digital inkjet printing machines, the animation offers many individuals the chance to learn and gain a deeper understanding of how such machinery operates.

Through these animations, users are enabled to acquire a clear insight into how different components and processes work together. This enhances users' comprehension and knowledge and contributes to improved training and preparation for working with complex technologies. Moreover, animation enriches the learning process and opens new avenues for exploration and innovation.

This application, as defined, allows for online deployment without requiring installation on personal computers. The number of visitors is limited only by server capabilities, enabling unrestricted use in educational settings and as a supplementary resource for home learning.

Future work will include optimization for mobile platforms, which are expected to become the preferred mode of learning over traditional computers among younger users

## 5. ACKNOWLEDGMENTS

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