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FROM SKETCH TO ANIMATED 3D MODEL: THEATRICAL COSTUME DESIGN

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Abstract: *Theatre costume design is a demanding process that requires the collaboration of the play's creative team, including the director and performers. Traditionally, the process involved phases such as sketching, tailoring, sewing, and fitting. Nowadays, these phases have been transformed through digital reconstruction, clothing simulation, and motion-tracking tools. This paper aims to illustrate the theatrical costume design process using Tibor Vajda's play Pygmalion as a case study and to explore how modern technology can breathe new life into the process. The study examines the costume design workflow, from the initial sketching to crafting costumes that meet the play's specifications. The characters' costumes were redesigned using Marvelous Designer, and the movement of Miljana Kravić's character Eliza Doolittle was recreated using motion-tracking achieved with Wonder Dynamics. The result of this approach was a Blender animation that could serve as a costume-fitting preview for the creative team. This study provides insights for future projects, including the potential for three-dimensional theatrical productions emphasizing performers and scenography along with costumes, especially for plays that have been withdrawn from the repertoire.*

Key words: Theatrical Costume Design, Eliza Doolittle, Marvelous Designer, Wonder Dynamics, Blender

1. INTRODUCTION

This paper explores different points of view on theatrical costumes, explores the process of gathering and digitizing costume sketches and emphasizes a successful collaboration with the Theatre Museum of Vojvodina and its curator and former director Zoran Maksimović. Furthermore, it discusses the digitalization of the costume and its subsequent reconstruction using Marvelous Designer, a 3D garment simulator. Following the costume recreation, an authentic video clip featuring the costume was obtained and utilized to track the movements of the actress Miljana Kravić wearing the costume. Tracked movement was then remapped to the 3D costume recreation. The outcome of this process is an animated portrayal of the costume. The paper concludes by outlining the motion tracking and retargeting results and provides suggestions for future research.

We were wondering about the effectiveness of using low-quality video material for motion detection. Additionally, we were curious about Eliza Doolittle and how their character development impacted the costumes they wore. Specifically, the character of Eliza Doolittle in the play Pygmalion endures a transformation upon meeting the phonetics professor, Henry Higgins. They embark on an experiment where the professor teaches Eliza the proper accent and posture to present them as a 'lady'. During the first act, Eliza is attired in a more modest yet dynamic costume, which gradually transforms into a more refined one throughout the play. The literary piece was written by George Bernard Shaw and has undergone theatre and film adaptations, the most famous being *My Fair Lady* starring Julie Andrews as Eliza Doolittle and Rex Harrison as Henry Higgins, featuring costumes designed by Cecil Beaton. Andrews once expressed: '*It wasn't until I had Eliza's shawl on my shoulders and her silly broken hat on my head that I knew how I was supposed to act'.* Their statement accentuates the significance and influence of Eliza's costumes.

2. LITERATURE REVIEW

Costumes have attracted academic interest over the years (Barbieri & Pantouvaki, 2016). However, authors noted that the field is still in the early stages of development compared to the established ones. Moreover, authors pointed out that Elizabeth Goepp brought up the issue as early as in 1928, particularly emphasizing the ambiguity surrounding the field's terminology. In their research, Barbieri and Pantouvaki separated costuming from the practice of everyday dressing, reclaiming costuming as a preparation of the performer specifically for performance, echoing Goepp's view of costume as 'the stuff of which drama is made'.

Costume is described as a performance articulation tool and a challenge to assumptions (Petranović, 2022), its 'critical' role was emphasized in questioning the relationships between body, design, and performance (Hann & Bech, 2014). Authors further explored this idea, viewing costume as an 'act of revelation and concealment' and agreeing with Aoife Monks that 'the costume is a body that can be taken off' (Monks, 2010). The costumes of the main characters are considered an important element of the stage performance (Bezruchko et al., 2024), they manifest the characters' personalities and backgrounds. In addition, costumes affect the portrayal of the characters and establish the tone of the play. Along with integrating the performer into the scenography (McKinney & Butterworth, 2015), the costume distinguishes between the performer and their environment. Furthermore, costumes are described as visual narrators shaping characters to serve the narrative (Academy of Motion Picture Arts and Sciences, 2004). Moreover, the interaction with lighting and scenography is highlighted (Macintosh et al., 2018), which contributes to the creation of the character's image. It is pointed out that the costume designer should work closely with the director, actors, and creative teams to achieve effectiveness. The imperative of 'performativity' is imposed on the costume in every production phase, from the rehearsal to the performance and even after (Barbieri, 2013). Opulence should not come at the expense of the performance. Furthermore, costume is considered a cultural phenomenon (Dembich, Zyrina & Fatkullina, 2021) that conveys and reinforces ideas and concepts. Value-communicating aspect of costume is highlighted (Wilson, 2003), arguing that when we dress, we carry an inscribed combination of art, social order, and personal statements on our bodies.
The progress of three-dimensional simulation technology for conducting garment simulations has been made (Porterfield & Lamar, 2017). The five main procedures typically involved in clothing CAD systems are: 2D pattern design, pattern prepositioning, virtual sewing, simulation, and 2D or 3D design modification. When the film industry started to show interest in 3D computer-generated imagery in the 1980s, research on virtual clothing 'began to gain momentum' (Spahiu, Shehi & Piperi, 2014). Currently, one of the most important examples of collaboration between IT and the fashion industry is the three-dimensional garment simulation (Kim, Kim & Park, 2017). The technique involves creating a 3D garment shape by applying different sewing conditions to flat pattern pieces. Additionally, the use of software to simulate three-dimensional clothing can accelerate the development of new garment pieces. Designers can visualize how a garment will look like on an avatar by digitally 'sewing' together 2D patterns, to reduce the need for prototyping and enhance team communication (Porterfield & Lamar, 2021). Motion capture is described as a process of recording the motion, processing it, and mapping it onto a virtual character (Reuter & Schindler, 2023). In this paper, a video clip of a play provided motion information, the task was to detect the main character and track their motion. Motion detection and tracking are often based on background estimation and subtraction (Uke & Thool, 2014). It is necessary to separate the moving objects from the background in each frame and consider variables involving object textures (Wang, Doherty & Van Dyck, 2000). The concept of digital theatre has been adopted, symbolizing the coexistence of performers and digital media (Andreadis et al., 2010).

3. METHODOLOGY

3.1 Phase One: Costume design sketches

During the first visit to the Theatre Museum of Vojvodina, several theatre costumes were discovered, including a collection donated by theatre director Tibor Vajda and costume sketches drawn by Tibor's associate, Anamarija Mihajlović. In 1976, they worked together on Tibor's play 'Who's Afraid of Virginia Woolf?' for the first time. Pygmalion was their final production together since Anamarija passed away in 2003. This was Anamarija's final engagement of this type, while for the then-young actress Miljana Kravić, who portrays the play's lead female character, Eliza Doollitle, it was their first role in the Kikinda theatre.
Anamarija Mihajlović is considered one of the first professional clothing designers in Yugoslavia. Mihajlović has designed fashion and stage wear since the 1970s. Anamarija was a member of the Association of Artists of Applied Arts and Designers of Vojvodina, which stated the following:

'*Anamarija Mihajlović always had a tendency to experiment, beginning each new project in their creative endeavors by reimagining the social purpose of clothing. The aesthetic never aspired to surpass the function of clothes. Because of these lasting qualities, their work is still highly valued*'. (UPIDIV, 2014)

During the second visit, photographs shown in Figure 1 of the costumes and costume design sketches were taken under the supervision of Milisanda Milović, curator of scenography, costumes, puppets, and art objects, to whom we owe a great debt of gratitude, as well as to Zoran Maksimović, the curator of the Theatre Museum of Vojvodina. Photographs were shot using a Nikon D3500 (18–55 mm) in daylight and without flash.

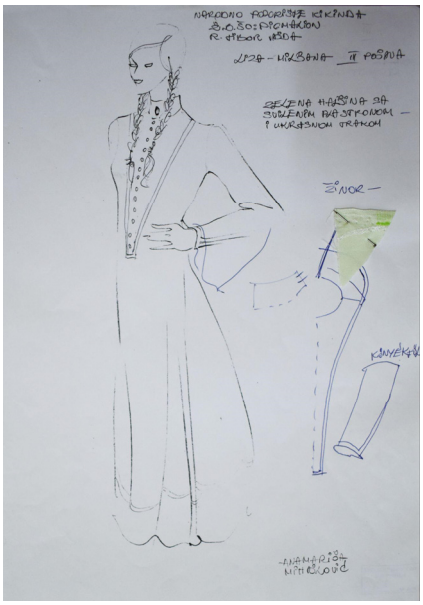
a  b 

Figure 1: Anamarija Mihajlović's a) costume sketch and b) a costume made for Miljana Kravić

3.2 Phase Two: Costume construction and redesign

For costume construction and redesign purposes, the Marvelous Designer 12 software (Marvelous Designer, 2024) was used, which enables the creation of 3D objects based on two-dimensional sketches. First, the contour line of the skirt was digitally drawn to recreate the left part of the costume, and a symmetrical duplicate was generated. Then, the plastron, which was going to be attached to the left and right elements of the outfit, was digitally reconstructed as a separate segment.

Subsequently, three distinct segments were created to function as the left pair of sleeves. To create the illusion of a puff sleeve, the bottom edge of the upper segment of the sleeve is wider than the upper edge of the middle segment. The ratio is the same between the middle and lower segments. The segments were symmetrically duplicated for the matching pair of sleeves. At this stage, the front of the costume was finished, and the back part was made as its modified duplicate. This was followed by the digital segment sewing. There is a counterpart for each selected edge, with which it is joined. Points have been added to divide the lengths into segments adequate for sewing. The detailed construction process and motives for the redesign were published in the thesis (Ilić, 2024), and the results are shown in Figure 2.

Figure 2: Reconstructed costume a) front, b) back, c) worn - front, d) worn - perspective, and e) worn - back

3.3 Phase Three: Theatre play video

A 'Pygmalion' play video clip was found on Miljana Kravić's YouTube channel, so we emailed them with the request to utilize it. Miljana approved our request and directed us to the existence of the entire video owned by Radio Television of Vojvodina, although it couldn't be obtained due to the digitization process. With its quality and the fact that all costumes are presented, such a video would influence the costume choice for redesign and animation. In this case, the costume with the most 'screen time' was picked (Kravić, 2011).

The costume of interest is in the frame from the sixth minute and 37th second to the ninth and 28th second, and in the tenth minute, from the 34th to the 40th second. Among the costumes that have been digitized in the Theatre Museum, this is the longest and provides the most video material to be manipulated with. The total presence of the costume is 177 seconds. The background and the movements of the camera also influenced the choice. The shots of the other costumes mostly involved a broad shot, more actors entering into interactions, and more complex scenography.

In the After Effects 2019 software (After Effects, 2024), it was first necessary to stabilize the video, utilizing the Warp Stabilizer effect, which neutralizes the shaking of the footage that occurs due to the absence of a tripod, handheld video recording, or slight camera movements. This step was taken to bring more stable footage to the platform and to make it easier to detect the actress in each frame and track their movements. The sharpening of the video was done utilizing the Sharpen and Unsharp Mask effects. The video segments were also subjected to colour corrections; to make a better distinction between foreground and background, the dominant tone on the frames was neutralized, and the exposure, contrast, and saturation were adjusted, as shown in Figure 3.

The recording was subjected to a free video upscaling solution, Video2X (Video2X, 2020), to increase the number of pixels available for motion detection.

Figure 3: 'Pygmalion' play video clip a) before and b) after the enhancements

3.4 Phase Four: Motion tracking

The costume was exported from Marvelous Designer along with the avatar wearing it. A generic avatar was utilized, as shown in Figure 2, and its armature was also exported for Blender 3.4 (Blender, 2024). Marvelous Designer allows avatar's measurement modifications. However, asking Miljana for their measurements was deemed inappropriate, particularly since this paper does not focus on that aspect. The costume and the avatar were imported in Blender, to get validated by The Wonder Studio Character Validator.

The Wonder Studio Character Validator add-on is installed in Blender 3.4 for motion tracking purposes. Its main function is to validate and ensure the model is compatible with the Wonder Dynamics platform (Wonder Dynamics, 2024). Selecting the character's skeleton is a mandatory validation step in the Select Body Elements section. The validation process consists of three steps: cleanup, validation, and warning. The Character Validation section manages the validation process and identifies potential problems. After the validation is passed, the add-on creates metadata and saves it in the metadata.json file, located in a folder named 01_wonder_studio_character_data, along with all the textures used to create the model. A validated character is then integrated into the Wonder Dynamics platform, accompanied by a video presenting the costume for motion detection and tracking.

After importing the video into the project, it is required to perform a frame scan in search of actors whose movements will be detected and used later. The platform detects and frames the recognized actors. Upon detection, the imported character is assigned to the actress by simply selecting it from the character list. The project is executed digitally and downloaded for further use. The motion detection results are imported into Blender as an .fbx file type, as shown in Figure 4. Facial expressions were not tracked, as the actress is engaged in a conversation and is facing Colonel Pickering.

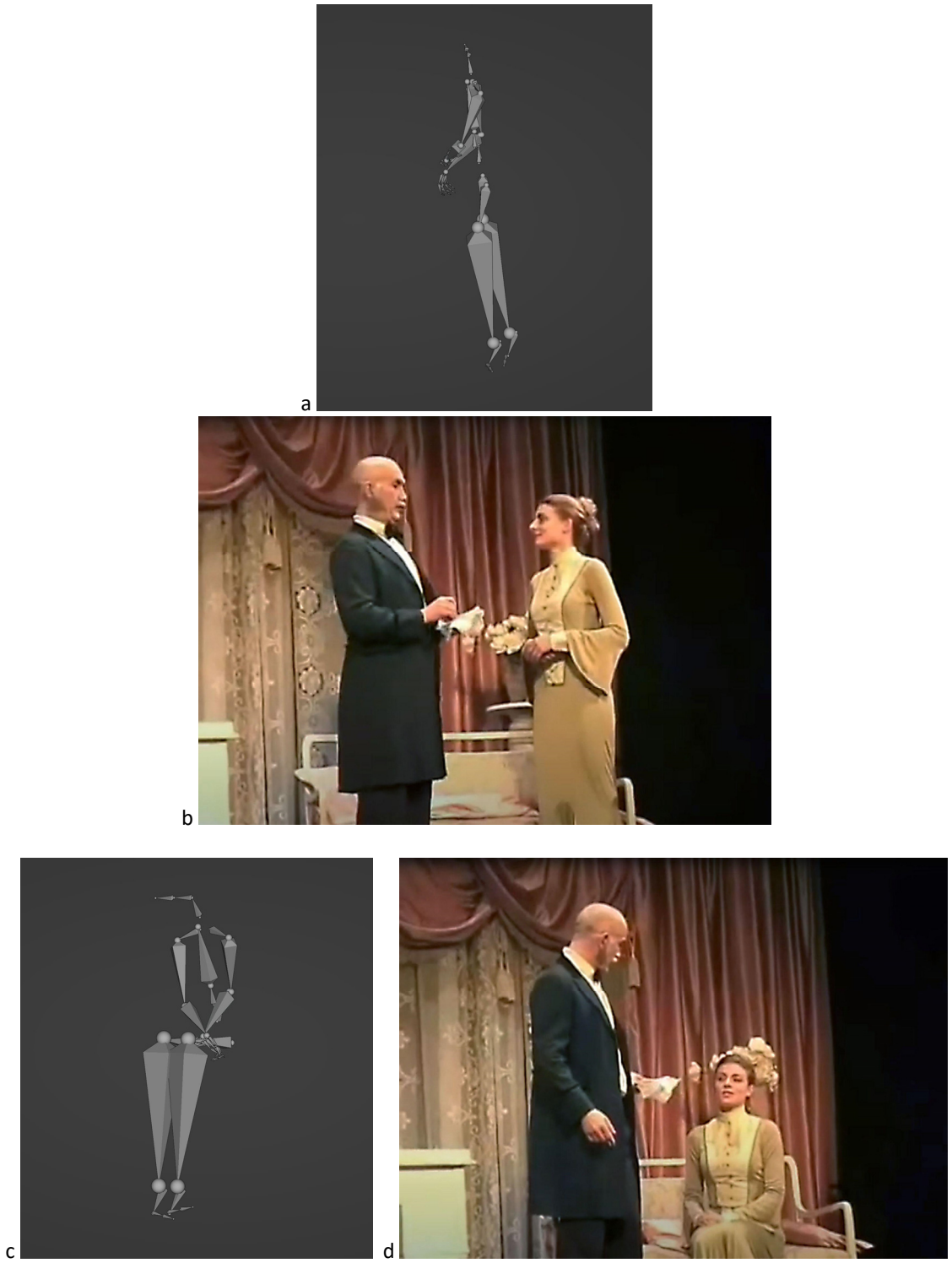


Figure 4: Wonder Dynamics results and references while a) and b) walking and c) and d) sitting

3.5 Phase Five: Animation

The movement redirection was done in Blender using the Auto-Rig Pro add-on that allows rigging and retargeting. It requires the import of a rigged model as the motion-remapping target skeleton and the import of the reference skeleton as the source.
The add-on allows matching them based on size, and within the bones section, it identifies the source and target bones. If the naming conventions don't match or the add-on makes an incorrect assumption, the bones can be manually adjusted. It is possible to exclude certain bones from the procedure, in this case,

fingers and facial bones. The sleeves covered most of the fingers, and facial bone movement wasn't tracked in the first place. The results of the remapping process are shown in Figure 5.

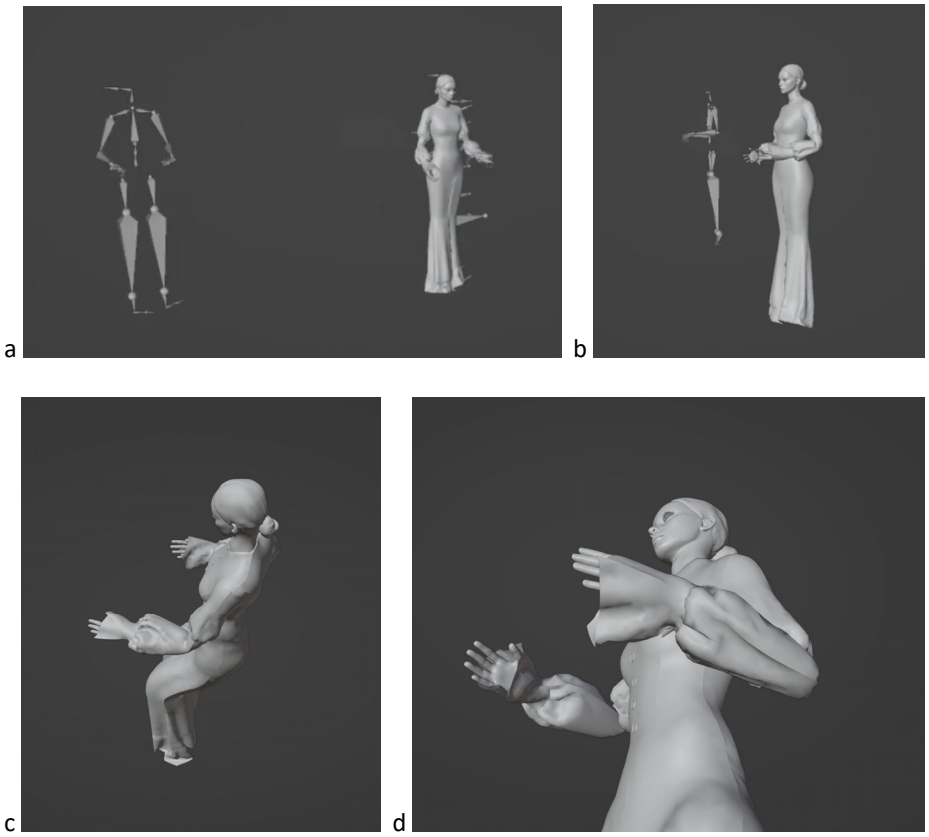


Figure 5: Remapping results a) side by side, b) side by side, c) above, and d) below

4. RESULTS

The final results include 400 frames of animated material in which the actress is continuously in the frame and is shown conducting a conversation in which her hands are the ones that move the most. The moments where Eliza and Colonel Pickering decide to sit down do not make it into the final animation, as the actress sits down holding the actor's hands. The actor's movements were not detected, so their interaction is excluded. The accomplishment of the Wonder Dynamics platform and the Auto-rig Pro add-on is shown in Figure 5. The remapping process went efficiently, considering that the same naming convention and the skeleton were used for tracking motion and then remapping it to the same but static skeleton of the avatar. However, the imperfections in tracking are noticed, shown in Figure 6, particularly on the right hand. These imperfections are assumed to be caused by the actress's position in the frame, shown in Figure 3. The actress is dominant in the frame, with their arms bent, gesturing during the discussion with the actor. The selected costume was chosen for this process because it appeared for the longest in the frame and was part of a simple stage setup. However, the results lack a distinction when the background and foreground of a video have similar colour tones. Additionally, the detection of the fingers was poor due to their distance from the camera and their size relative to the overall video. Stiff and motionless fingers detract from the authenticity. In the conversation between Eliza and Colonel Pickering, the actress's fingers were straightened and tense. In the final results, they are static and do not reflect active discussion. Furthermore, the lack of facial expressions enhance the impression of stiffness.

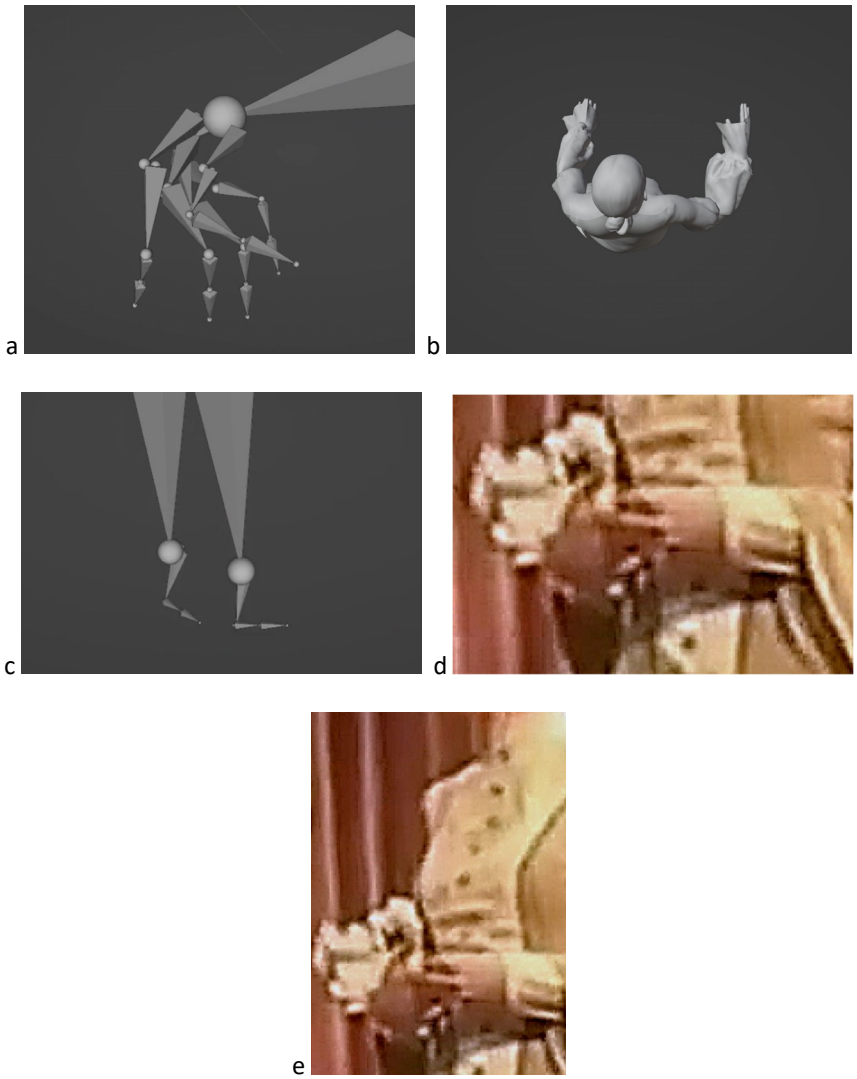


Figure 6: Imperfection shown on the a) fingers, b) right hand, c) feet, d) background and foreground (fingers), and e) background and foreground (right hand)

Since keyframes are remapped onto the costumed avatar, it is possible to manually modify the animation in Blender software to achieve better results. Especially in the case of the right hand shown in Figure 6, for which the platform predicts that it is further away from the body than it actually is. In the case of fingers, it is necessary to use a higher-quality video for motion detection and tracking, and they should be closer to the camera for better distinction. The same applies to the facial bones.

5. CONCLUSION

The lack of exhibition space forced the Theatre Museum of Vojvodina to store costumes in sacks, which was a key motivation for writing this paper. The paper deals with costumes that have already fulfilled their main purpose, aspiring to breathe new life into the play withdrawn from the repertoire. The employees are trying their best to maintain the museum's legacy through various projects and exhibitions, this was just our way to contribute to their cause.

The entire process was driven by the idea that it is possible to detect and track movement in a low-quality video. The results show that the outcomes differ depending on factors such as video quality, character movement, background and foreground, distance between the character and the camera, distance among the characters, etc. There is an opportunity to acquire a high-quality video of the performance from Radio Television Vojvodina in the future and repeat the procedure. It is also anticipated that the actress Miljana Kravić may be invited to provide insights on Eliza’s character.

In the future, examination of the minimal video requirements that can undergo motion detection, the impact of the background on motion detection, and identification of patterns that would optimize detection on smaller bones could be undertaken. The potential to experiment with creating various costume constructions in Marvelous Designer arises, along with the opportunity to use designed models to interact with lighting and cameras to create interactive experiences. Additionally, exploring the parameters for restoring old theatre recordings in After Effects, assessing the background and foreground in terms of contrast and sharpness, and studying the impact of colours on motion detection could be pursued in the future. Testing the parameters of motion detection in Wonder Dynamics and evaluating the platform's success in detecting characters without human skeletons, can be explored. Furthermore, assessing the success of motion detection under varying lighting conditions, and scrutinizing the relationship between characters and their environment, as well as detecting fluid or unconventional shapes, can be considered. This paper opened up technical questions and possibilities for the future and told the story of the costume that once lived.

6. ACKNOWLEDGMENTS

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