Design of a Parameterized Mannequin Using Rapid Prototyping Technology

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Abstract. This research addresses to a mannequin design in a parameterized mode similar to a four years old child. The designed mechanical system will be integrated in an active exoskeleton, especially designed for children with locomotion problems. Thus there will be performed measurements for a four years old child, in order to acquire the anthropometric data which will be used for mannequin segments design. The mannequin will have a similar design with the ones used in automotive industry at Euro NCAP tests. The finalized prototype will be obtained based on 3D- printing technology.

Keywords: rapid prototyping · 3D printing technology · mannequin · exoskeleton

1 Introduction

Nowadays rapid prototyping technology has a fast evolution due to 3D printers and scanners which are used for designing personalized objects. Involving this technology, will help designers to obtain products at fair prices and in a short period of time.

By referring to 3D printing technology, there is well known that there are several methods to print an object. From these methods it can be remarked the use of melting or softening the material in order to develop layers. Most popular methods are selective laser sintering – SLS and fused deposition modeling – FDM, according with [1–4]. Another familiar method is called stereo lithography – SLA which is more precise than the other two.

In this research case it will be used the FDM technology. This technology use a plastic filament in an unwounded form and supplying this to an extrusion controlled nozzle. This nozzle is heated at a controlled temperature in order to melt the material and can be moved in both horizontal and vertical axes of a global coordinate system allocated on 3D – printing workspace. These motions are numerically controlled through a mechanism made of at least three stepper motors, connected directly to 3D printer motherboard. This motherboard has a direct or indirect connection with a computer, based on a computer aided manufacturing software package (CAM) according with [5–7].

I. Dumitru et al. (Eds.): ICOME 2022, AHE 15, pp. 27–35, 2023.
https://doi.org/10.2991/978-94-6463-152-4_4

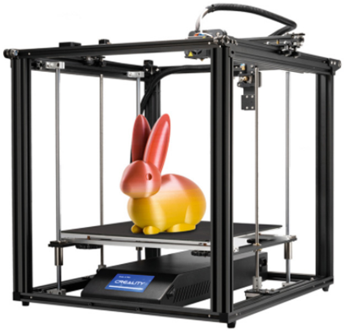

Fig. 1. Creality Ender – 5Plus 3d printer [11].

The 3D printed object will be obtained by extruding melted material in a layer forms and the melted layer will hardens immediately after nozzle extrusion process.

This technology was invented by Scott Crump near 80's and it was patented by Stratasys Company in 1988 according with [10].

This technology is widely spread due to the fact that use cheap material like ABS (Acrylonitrile Butadiene Styrene) or PLA (Polylactic acid) according with [4].

By having in sight the FDM technology, and by using a 3D printer, the research was focused in building a 3D mannequin model in a parameterized form according with a four years old child. The purpose of fabricating this mannequin represents a starting point for designing parameterized exoskeleton used in children locomotion rehabilitation. Thus the proposed research consists on presenting the technology for manufacturing this, and presenting the 3D printer with the proper setup for obtaining this exoskeleton according with second part of the research. In third part of the research there where acquired anthropometric data in order to design the proposed mannequin. Some particular aspects during 3D printing process and the obtained product are presented in the last part of this research.

2 3D Printing Hardware and Setup

In order to reach this research objective, as a starting point it is represented by the 3D printer setup. At one of the Faculty of Mechanics – University of Craiova laboratories it was acquired a 3D printer from Creality 3D Company [11]. This is a Creality Ender-5Plus 3D printer as it can be remarked in Fig. 1.

This has the following technical specifications: printing size of 350 × 350 × 400 mm; modeling technology based on FDM; cubic chassis size of 632 × 666 × 619 mm; stock nozzle of 0.4mm; Print Accuracy: ± 0.1mm; maximum hot end temperature is lower than 260 °C. It has some features like: auto-bed leveling, strong power support and smoother transmissions based on power screw and belt transmissions and thermal runaway protection. By having in sight this hardware, the workflow is schematized in Fig. 2. Thus has the following phases: designing the proposed 3D printed model by using a 3D modeling software (1); creating an export interface for exporting the printed model in an *.stl file (2). Transferring and importing this file in Cura Ultimaker software

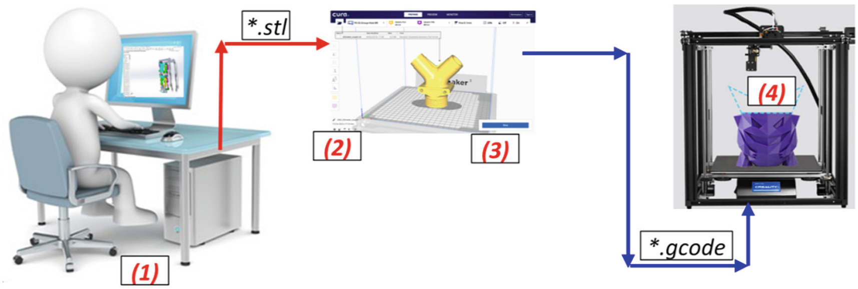

Fig. 2. 3D printing workflow.

Fig. 3. A child volunteer for acquiring the anthropometric data.

for final adjustments (3) and sending a gcode file to Creality Ender 5Plus motherboard hardware; printing the desired 3D model (4).

3 Designing the Parameterized Mannequin

In order to print a 3D model of the desired mannequin, it was used in a voluntary mode a four years old child for acquiring the anthropometric data. These were obtained experimentally with the aid of a ruler according with Fig. 3. The measured dimensional parameters were presented in Table 1. Other parameters such as segment thickness were measured.

In order to transfer this anthropometric data to a 3D mannequin, it was used a design model similar to the one used in automotive crash tests – Euro NCAP according with [8, 9]. Thus, it was used SolidWorks software in order to model each segment in a parameterized mode according with the acquired data in case of the used child as a volunteer. Some snapshots during modeling the mannequin segments are shown in Fig. 4 and in Fig. 5 it is presented the entire mannequin.

Table 1. Child anthropometric data.

Segment length	Value [mm]
Femur	174,12
Tibia	164,79
Foot&Ankle	47,34
Torso	320,47
Upper limb	357,95
Neck&Head	112,92
Total height	793,02

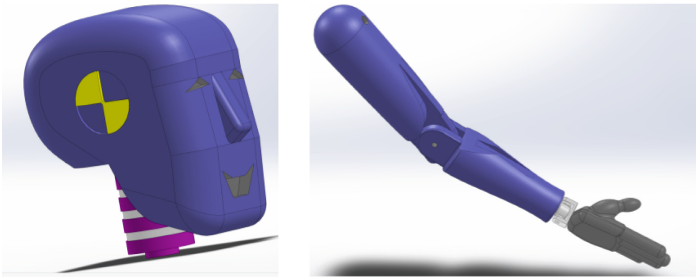

Fig. 4. Virtual models of the head and neck and a upper limb.

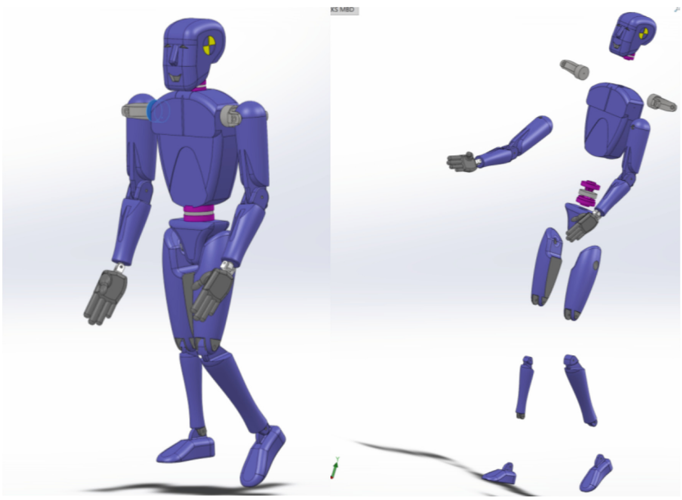

Fig. 5. Virtual model of the parameterized mannequin.

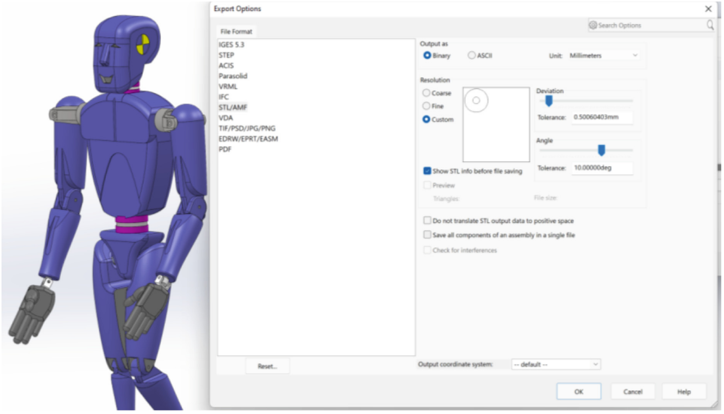

Fig. 6. Export options for the *stl format.

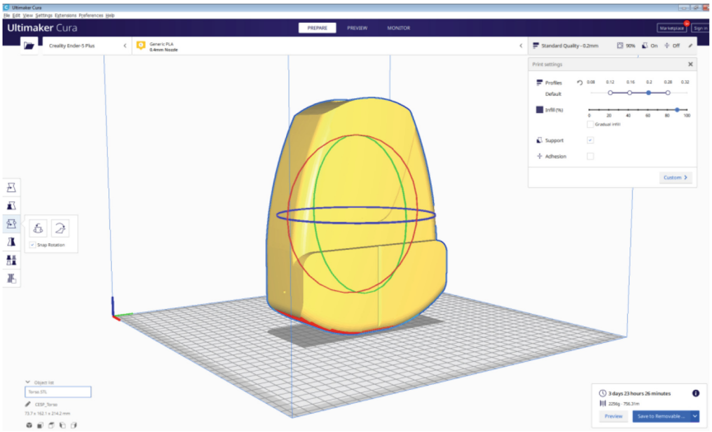

Fig. 7. 3D model imported in CURA Ultimaker environment.

4 Experimental Printing Process

The experimental printing process was done according with the workflow presented in Fig. 2. Thus each parameterized mannequin segment was saved in an *stl format with the proper tolerances like in Fig. 6.

The imported file was opened in Cura Ultimaker software [12] as it can be seen in Fig. 7. There were performed several settings onto 3D printer parameters like the ones presented in Fig. 8. Thus the important parameters were very important in printing process by using PLA material like: nozzle heat at 200 °C, bed temperature at 70 °C and printing speed at 70mm/s. Other parameters were setup by having in sight the texture structure modes, infill gradient and support adhesion according with Fig. 8.

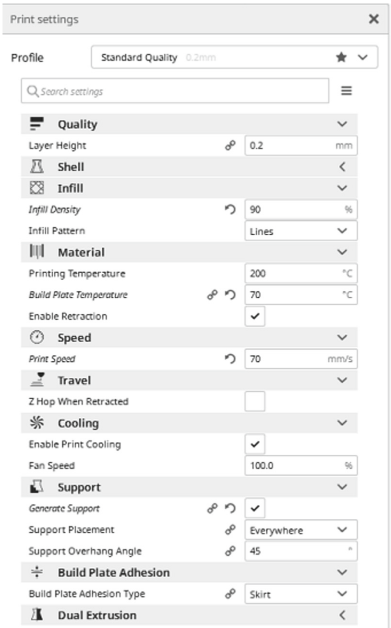

Fig. 8. 3D printer settings with CURA Ultimaker software.

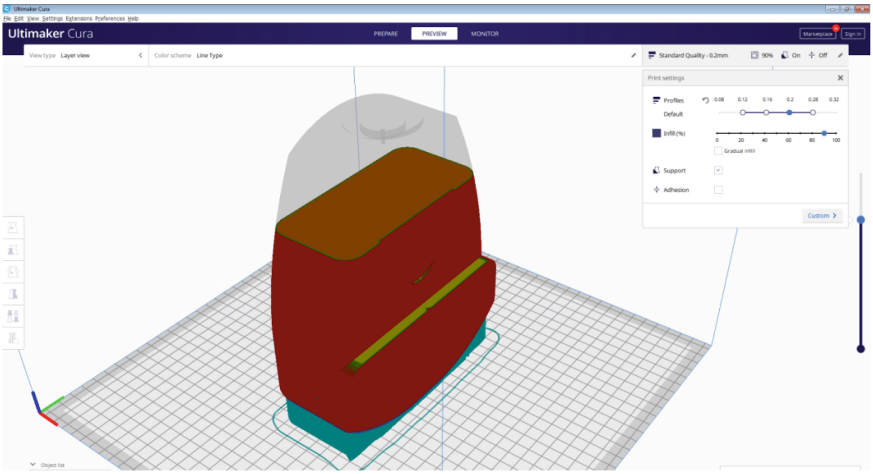

Fig. 9. Virtual simulation of the sliced model in CURA Ultimaker software.

After a complete setup, the entire segment was sliced, in order to obtain the proper gcode file. A preview of a simulation printing process was done, according with Fig. 9. There were printed away 72 segments for assembling the desired mannequin (Figs. 10, 11, and 12).

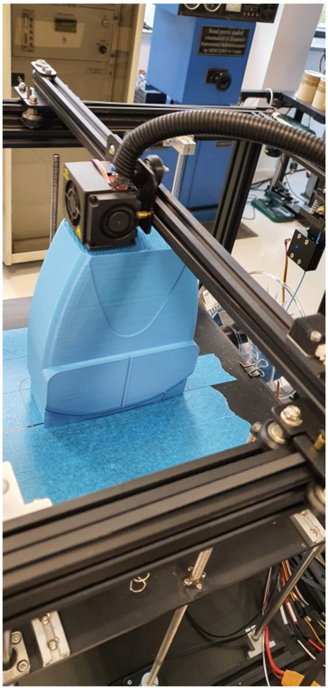

Fig. 10. Torso printing view.

5 Conclusions

Through this research it was obtained a parameterized mannequin which can have in future applications an exoskeleton prototype design. The purpose of this mannequin in future applications allow us to avoid using children as volunteers in experimental tests of prototype exoskeletons. It is also remarked that there are presented important information regarding a 3D printer setup among the mannequin fabrication. On the other hand the printing process use FDM technology which is very cheap in comparison with other technologies, but the manufacturing time is very long.

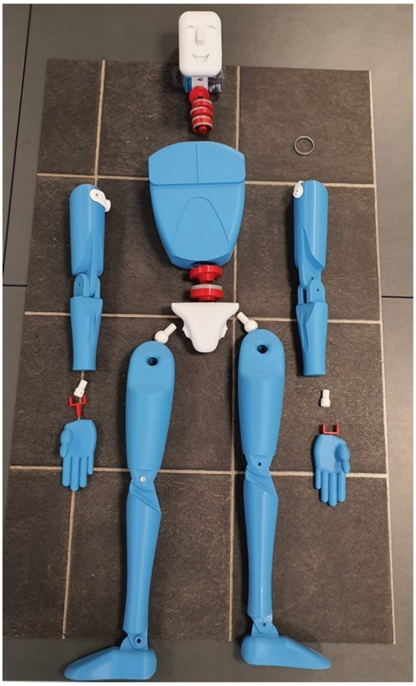

Fig. 11. Mannequin exploded view with the desired printed parts.

Fig. 12. The assembled mannequin prototype.

Acknowledgement. This work was supported by the European Social Fund within the Sectorial Operational Program Human Capital 2014–2020 and by the grant of the Romanian Ministry of Education and Research, CCCDI – UEFISCDI, project number PN-III-P2-2.1-PED-2019-0937, within PNCDI.

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