Direct 3D Printing of a hand splint using Reverse Engineering

J Kechagias¹, K Kitsakis¹, A Zacharias¹, K Theocharis¹, K-E Aslani¹, M Petousis², N A Fountas³ and N M Vaxevaditis³*

¹University of Thessaly, General Department, Larissa, Gaiopolis, GR 41500, Greece.
²Hellenic Mediterranean University, Mechanical Engineering Department, Estavromenos, GR 71410, Heraklion, Crete, Greece.
³School of Pedagogical and Technological Education (ASPETE), Department of Mechanical Engineering Educators, Amarousion, GR 15122, Greece.
⁴University of West Attica, Department of Mechanical Engineering, Aigaleo, GR 12244, Greece.

*Corresponding author’s e-mail: vaxev@aspete.gr

Abstract. The present work is focused on the direct manufacturing of a hand splint using free-open access software and a low-cost three-dimensional printer (3DP). The hand digital model was created using panoramic photos by a common mobile phone camera. The photos were used as input to the “3DF-Zephyr” free software for creating the hand surface model. Then, the hand surface model was transferred into the “Autodesk fusion 360” free software and the surface model of the hand splint was generated and modified according to the design requirements. Sequentially, both hand and hand splint were translated to Stereolithography (STL) files and transferred to open access “MakerBot” 3D printing software in order to prepare the G-codes for 3D printing. A low cost 3D printer was used for building the models while Polylactic acid (PLA) was the material of the customized 3D physical models.

Keywords: 3D printing; reverse engineering; open software; hand splint

1. Introduction

3D printing and especially Fused Deposition Modelling (FDM) is one of the most widespread Additive Manufacturing processes for customized plastic parts directly from digital data [1]. Nowadays, FDM is known as Fused Filament Fabrication (FFF) and becomes more available to small firms or home users due to the low cost of the materials and the equipment used [2]. Reverse engineering refers to techniques that create CAD models from physical parts (damaged or broken) by data digitization method (MRI, CMM, photos etc.) [3]. These models are transferred into special CAD/CAM programs in order to create codes (similar to G-Codes) [4]. Finally, they are usually remanufactured with the use of 3D printing. Every 3D printing process comprises three stages: pre-processing of the STL-file, actual building and, post-processing of the prototype [5].
One of the most widespread 3D printing processes is Fused Filament Fabrication (FFF) [6]. This method generally uses polymers [7], while a large number of process parameters affect the final printed parts quality [4, 8].

In this project, direct manufacturing of a hand splint using free-open access software and an FFF 3D printer was attempted. A variety of studies related to 3D printing for fast production of customized three-dimensional-printed hand splints were found [9-11]. In our project, low cost 3D printing parts using free software is the main concept, as well as the evaluation of the proposed procedure as a sustainable choice. First, a hand digital model was created using panoramic photos of a common mobile phone camera. Then, the photos were used as input to the '3DF-Zephyr' free software for creating the hand surface model. After that, the hand surface model was transferred into 'Autodesk fusion 360' free software and the surface model of the hand splint was generated and modified according to the design requirements. Sequentially, both hand and hand splint, were saved as Stereolithography (STL) files and transferred to the open access 'MakerBot print' 3D printing software in order to prepare the g-codes for 3D printing. An FFF printer was used for models’ building. PLA was the printing material of the customized 3D physical models.

2. Materials and methods

2.1. Photogrammetry software
The program used to scan the hand was ‘3DF Zephyr’, which, although originally downloaded to the lite version, had to be upgraded to its Professional version. The upgrade was valid for one month. The tool used to photograph the hand was a common mobile phone. Another program that was proposed was the Autodesk Recap photo. The scanning process had to be repeated several times to achieve the desired result.

2.2. 3D design of the Splint
The scanned hand was inserted into the Autodesk fusion 360 software. Some other software tools such as Rhinoceros 5 or Meshmixer could have done the same process, too. Before the splint was designed, the triangles of the STL mesh file had to be lowered, to make the hand smoother on the 3D printer (Fig. 1).

Figure 1. Hand 3D model taken using 3DF Zephyr.
Initially, a tube was designed which was moved around the hand and using the ‘edit form’ command it came close enough to the curves of the hand. The command used to create the tube is: sculpt/create/cylinder. The next command utilized was “thicken” to give the required thickness. Then, after the splint took the shape of the hand, its buttons were designed, which are circular in the form of a groove, so that they can be closed using a washer. In order to facilitate the installation and the removal of the washer, recesses were designed that allow the placement of the finger (Fig. 2). The dimensions of the buttons are: Splint length: 13.78 cm; Splint thickness: ≈ 5mm; Button diameter: 20mm (outer) - 15mm (inner); Slot thickness: 5mm; Slot depth: 3.5mm; Diameter for finger on the clasp (Depth: 3mm, Tolerance: ± 0.3mm, the lowest point in oval shape). The number of buttons designed is four. Their location was chosen based on the ease of splitting, the splint was into two parts, which was then performed. Next, the object was divided into two parts. To do this, a line was drawn with a sketch that passes through the centres of all four buttons, and with the use of the “extrude” command, the line was drawn, so that it could pass through the object to be split. Finally, for the separation of the object, the “split body” command was utilized, in which the designed line was selected, and the object that will be divided into two parts was used. Afterwards, holes were drilled to ventilate the human limb and to save material. In order to open the holes, it was necessary to decide the suitable pattern. It was decided to design holes in the formation, of the part, with triangular and oval shape. For the formation of the holes, each hole was designed separately. After the design was made, the hole was moved near the splint, placed at the appropriate height and angle and with the use of the “extrude” command the opening was made. In order for the splint to have a smoother surface at the points where the holes were opened, the fillet command was used. All fillet commands were made with a radius of one millimetre (1 mm).

2.3. STL files preparation
The next step was the STL files preparation. First the hand was divided in two parts to facilitate the printing but also to fit the hand in the printer working volume. Then, part of the fingers was removed as this saved material and time, in addition they do not significantly affect the work, so with that in mind they were removed. After that, separation follows: the first part consists of the point where the fingers were cut and about 8.1 cm to the right, and the second was the part that remained.
After cutting, each section needed to be exported in a file format suitable for the 3d printer software (STL files). The program used for this was ‘meshmixer’, a software that will specify the format for exporting the file. With the same way hand-splint split into two parts with the same commands used for the hand and then exported to ‘meshmixer’. Prior to printing, the “sculpt” command was executed via ‘meshmixer’ to make the surface of the splint smoother in areas where many pixels appear.

2.4. Hand and hand splint printing
MakerBot Print was used for orientation and layer build style settings (Fig. 4). Wanhao Duplicator 4X FFF 3D Printer was used for printing the STL files (Figs. 5, 6, 7). The printer prepared with the following settings: Extruder temperature: 220° C; Platform temperature: 90° C; Travel speed: 150mm/s; Minimum layer duration: 5.0 s; Device settings: Low. Material used was PLA.

Figure 4. Hand and hand splint preparation for printing.
Figure 5. Hand physical models.

Figure 6. Hand splint physical models.

Figure 7. Assembly of hand and hand splint.
3. Results and discussion

The printing process of the hand and the hand splint was time consuming and, in some cases, required some corrections and reprinting from the beginning. The hand takes about four (4) hours for each part with the resolution setting at low. The difficulty encountered in this case was related to the extraction of the material by the extruders. During material delivery, as the extracellular material was moved, the material that was injected was carried away and detached from the printer base. This problem, in the end, was overcome by using hairspray, on the paper tapes that were already on the base of the printer as well as by increasing the base temperature so as not to entice the material with the movement of the extruder.

After the hand was 3D printed in two parts, it was then required to scrape the piece with a spatula, from the wrist to the fingers at the point of the thumb so that the piece would be smoother and the splint would fit better. After sanding the piece, the two parts were glued together with benzine glue so that the hand 3D printing process could be completed.

As for the 3D printing of the splint, the time it took was about four (4) hours for each piece. The difficulties in this case are related to the stability of the 3D print since there are holes in the splint. In order to overcome these difficulties, the parameter of the auxiliary material was selected during the processing of the 3D print settings in order to make the printing more robust. Moreover, during the 3D printing process, it was required to use the lacquer, so that the material does not come off the base. When the 3D printing of the two parts of the splint was completed, the auxiliary material was removed using the spatula, which was also used for smoothing in order to have the desired result.

4. Conclusions

In this project a hand splint and the hand prototype were 3D printed using FFF 3D printing technology and photogrammetry software. All software used in this project are open (free). Material used for 3D printings was the PLA biocompatible material. The procedure takes a lot of work to select the appropriate software for the manipulation of the panoramic photos (scanning data) and to translate them to STL 3D digital hand geometric model. Hand splint produced using appropriate software tools that produce CAD data from digital data (photogrammetry data). Finally, STL preparation for 3D printing and 3d printer settings are very important in order to have good quality physical models. Optimization of the process parameters is proposed as future work in order to have even better results.

Acknowledgements

The authors wish to thank the Special Account for Research of ASPETE for supporting this work through the funding program “Strengthening research of ASPETE faculty members”.

References

[1] Chaunier L, Guessasma S, Belhabib S, Valle GD, Lourdin D, Leroy E 2018 Addit. Manuf 21 220-233
[2] Kitsakis K, Alabey P, Kechagias J, Vaxevanidis N 2016 IOP Conf. Ser.: Mater. Sci. Eng. 161 012025
[3] Bagci E 2009 Adv. Eng. Sofw 40 407-418
[4] Tsiollikas A, Mikrou T, Vakouftsi F, Aslani KE, Kechagias J 2019 IOP Conf. Ser.: Mater. Sci. Eng. 564 012021
[5] Kechagias J, Maropoulos S, Karagiannis S 2004 Rapid Prototyp. J. 10 297-304
[6] Kitsakis K, Aslani KE, Vaxevanidis N, Kechagias J 2019 IOP Conf. Ser.: Mater. Sci. Eng. 564 012022
[7] Vidakis N, Vairis A, Petousis M, Savvakis K, Kechagias J 2016 Acad. J. Manuf. Eng. 14 87-94
[8] Valerga A.P, Batista M, Salguero J, Girot F 2018 Materials 11 1322
[9] Popescu D, Zacpuc A, Tarba C, Lapoiu D 2020 Rapid Prototyp. J. 26 134-144
[10] Chen PJ, Du YC, Shih JB, Xu ZF 2017 Development of a 3D printing system for hand splint by object mirroring and surface reconstruction technology Proc. of the 2017 IEEE Int. Conf. on Inf., Comm. Eng. (Xiamen) p 132
[11] Nam HS, Seo CH, Joo SY, Kim DH, Park DS 2018 Ann. Rehabil. Med. 42 634-638