3D Technologies in Individualized Chest Protector Modelling

Paula MILOSEVIC, Slavica BOGOVIC*

University of Zagreb Faculty of Textile Technology, Department of Clothing Technology, Croatia

*slavica.bogovic@ttf.hr

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ABSTRACT

The application of 3D technology increases every day by discovering new ways of usage, which can make everyday life easier. It is most used in production of individualized items that become more accessible and fully customized to personal needs. 3D technologies such as 3D scanning, 3D modelling and additive technologies (3D printing) are used in various areas of human activity such as medicine, architecture, the movie industry, etc. In the clothing's industry, 3D scanning the human body is digitalized, which is after that used in computer software packages for custom-made clothing. Except for the fashion industry, there is a need for individualized protective work clothing and equipment production in other industries as well. The possibility of applying new technologies such as 3D scanning and 3D modelling of protective elements that can be made by using 3D printers is presented in this paper. In order to design a field hockey chest protector, male and female subjects were scanned using a 3D body scanner in several different positions specific to the sport. The chest protector was constructed and modelled based on the digitalized images. Software packages were used which enable point clouds preparation of the digitalized human body for constructing the protector, its modelling and preparation of virtually designed protectors for 3D printing. An individualized chest protector is modelled using a software program called Bender. The protector is integrated into the clothing item, completely follows the body shape and provides the necessary protection.

KEYWORDS

3D body scanner, 3D modelling, 3D printing, chest protector

INTRODUCTION

The development of 3D technologies as well as finding new ways of application has largely increased in the last several years. 3D technologies include 3D scanners, 3D modelling software and 3D printers. By using 3D body scanners, human bodies are digitalized, thus forming spatial coordinates of point clouds suitable for further computer processing. 3D human body digitalization is carried out by various techniques depending on the type of sensor used [1, 2]. Point clouds of the human body obtained in such a way have different applications and are used in the clothing industry, film industry, ergonomic research, aesthetic surgery, etc. [2]. In the clothing industry, 3D body scanners have been used for many years and enable custom-made

clothing production, virtual simulation of clothing and measuring fabric surface geometry [1, 2]. Point clouds obtained by scanning are used when taking measurements or for a virtual representation of clothing fit, where a parametric model of the human body was made previously [3, 4]. Such clothing provides good fit and, in the case of producing functional custom-made protective clothing, provides better protection [1, 5]. The production of individualized protectors which are part of the protective equipment includes additive production or 3D printer. An object that is produced using a 3D printer needs to be designed using a software package. In this way, the 3D model is constructed or can be made based on a scanned object. Today, there are a number of CAD programs on the market that allow precise computer modelling of the object [1, 6].
In order to produce computer designed objects using a 3D printer, it is necessary to store them in a file that is suitable for printing. STL (triangulation file) is the most common type of a 3D model file in which the surface consists of triangles. Each triangle has an internal and external side that is called a normal. In well formed STL files, all normals are facing outwards and together make a continuous surface [6, 7]. The 3D model is made using a 3D printer that arranges the polymer in layers. The layer thickness is defined depending on the purpose and required strength of the object being produced. The printing process may take several hours to several days depending on the size and the type of product [6, 7]. The most commonly used polymers for 3D printing are: polylactic acid (PLA), acrylonitrile butadiene styrene (ABS), polyethylene terephthalate (PETT), nylon by Taulman 3D, etc. The easiest to use is PLA, and the strongest is ABS [1, 8].
During 3D printing, layer height, object filling and wall thickness can be defined. Wall thickness, the form of filling, and density are defined prior to printing as well. The exterior appearance and firmness of the object depends on the wall thickness. Items are most often printed at 10% fill, while a 15 % fill is used for prototypes and in architecture, and 20 % fill for usable objects [8].
Individualized protective clothing and equipment have been used in various sports for a long time. Such clothing and equipment may, in addition to protection, provide better sport results [9]. In order to design equipment and clothing intended to protect athletes, it is necessary to know characteristics of the sport in which it will be used. It is important to know which body parts should be provided protection and at what level, what are the rules prescribing the equipment, as well as human body measurements and shapes, specific positions of the body, and similar [1, 9].
In some team sports, hockey included it is important to know the position of the user in the team, because the type of protective equipment to be used depends on it [1]. What is required adequate clothing and equipment varies between ice hockey and field hockey. Due to greater dynamism of ice hockey, its equipment consists of: helmets, neck protectors, upper body protectors, elbow pads, leg protectors, hockey gloves, trousers and jerseys. Such elaborate equipment, with the addition of hand and leg protectors, is worn only by the goalkeeper in field hockey [1, 10].
Protectors for field hockey are made of polymeric materials with high firmness and durability. Textile materials should also be used to ensure adequate protection. Textile materials adhere to the body at the appropriate locations. Custom-made protectors are made of various polymeric materials and textile composites, thus achieving high firmness, impact resistance and other properties [11].
Figure 1 shows the needed protection for field hockey goalkeepers. The protection is layered and made from different materials. Next to the body, there is protection made of foam material (b) that relieves impacts and can be of various thicknesses and firmness. Strong polymeric protectors (a) are used for the protection of the chest and the shoulders. Both types of protectors are integrated into the clothing item.

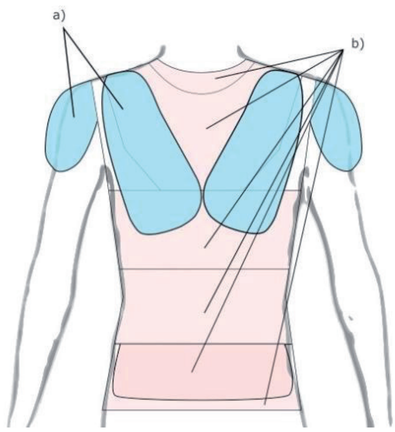


Figure 1. The sketch of positions of body protectors used by field hockey goalkeepers
a) strong polymeric protectors, b) protection made of foam material

EXPERIMENTAL

The modelling of a chest protector for a specific purpose has been carried out in three related steps:

- 3D body scanning in specific positions,
- Preparation of point cloud for 3D chest protection modelling and
- 3D modelling and preparation for 3D printing.

3D body scanning

For an individualized protector production, male and female subjects were scanned in specific positions when using the equipment (Fig.2). The scanning was performed using the VisualSmart 3D body scanner installed at the University of Zagreb, at the Faculty of Textile Technology's Department of Clothing Technology. A system of 8 CCD cameras and laser beams was used and the scanning lasted 10-12 seconds, resulting in a point cloud containing about 500 000 spatial coordinates. Data processing took approximately 40 seconds and created a point cloud used as the etalon for measuring and extracting shapes of the human body using the ScanWorx software package. The scanning area was 1000x800mm by 2040 mm tall.

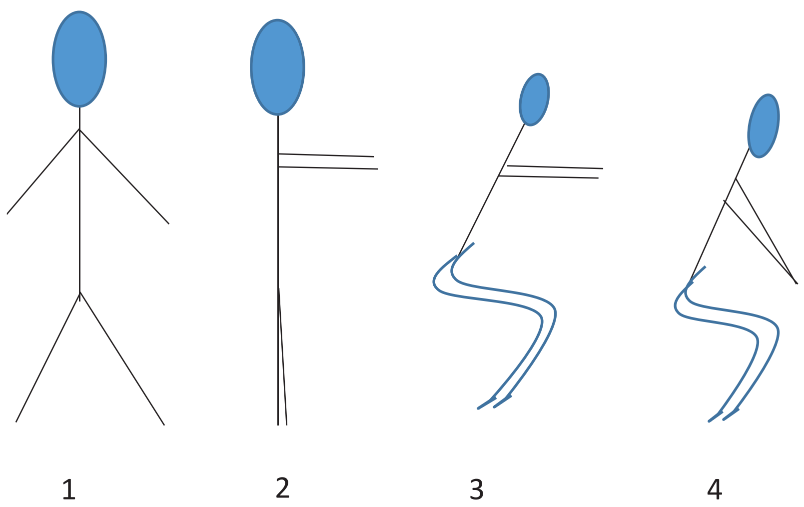


Figure 2. Specific body positions in which the body is scanned [1]

Point cloud preparation for 3D modelling

Point cloud preparation for 3D modelling was performed for the purpose of closing the point cloud, thereby reducing the number of points. The MeshLab software package was used due to its suitability for processing and editing of unstructured 3D data after 3D scanning. Automatic software package filters were used to clean the meshes including removing double, undefined, unexposed edges and peaks, and so called zero surfaces. The tools supported a high quality of mesh simplification. Using different types of surface divisions and surface reconstruction algorithms, the point cloud can be completed [1, 12].

3D modelling and preparation for 3D printing

The Blender software package was used for the 3D modelling of the chest protector as it supports 3D modelling, animation, simulation, assembling, motion tracking, video editing, and games creation [13].
Performing different 3D modifications on the object can be accomplished by object processing in two ways: in Object Mode and Edit Mode. In Edit Mode, the object is processed by adding or reducing the number of points, edges, or surfaces. These elements can be positioned individually or in a group with a high accuracy in forming a 3D object. Both data processing modes allow adding 2D and 3D objects, lines, and meshes on the surface, etc. [1, 13].
When constructing an individualized chest protector, different 3D modelling methods can be applied, depending on the software package and input data used in 3D modelling. When it comes to human body digitalization, the obtained data are not fully structured. It is necessary to find 3D modelling methods that will ensure shapes suitable for 3D printing. Therefore, it is possible to define a simple geometric body with finite object dimensions which is then modelled. A cube, cuboid or sphere are usually used as the base [1].
Another 3D modelling method is a construction of the base that is modelled according to a scanned object. In other words, it has its own shape and volume which is multiplied and built in layers into a 3D object. The third possibility of modelling is constructing a structured mesh that fully follows the scanned 3D object. When defining the area for which the protector has to be made, the volume of the protector is determined. The aforementioned 3D modelling procedures result in a structured 3D mesh that is suitable for 3D printing.

RESULTS AND DISCUSSIONS

Based on the experiment plan, the 3D human body point clouds in different positions were obtained (Fig. 3).

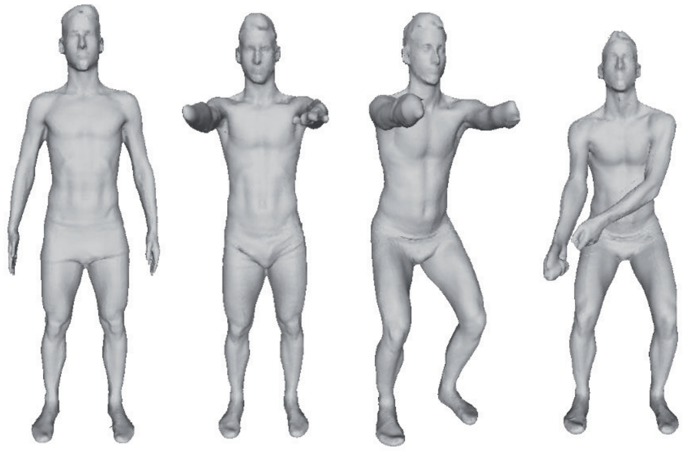


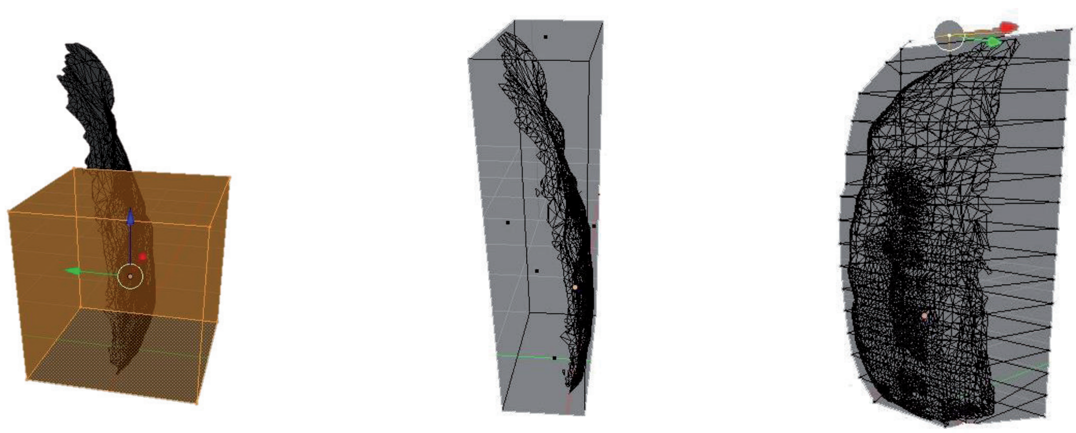
Figure 3. 3D scanned point clouds of male body in specific positions

After the scanning, the point clouds were closed and unified. The MeshLab software package was used for unifying the point clouds and the Poisson's surface reconstruction algorithm was used for closing the point clouds. This way, parameters that allow even and precise surface modelling of the scanned object were defined. The first parameter defines the depth of reconstruction i.e. the depth of the point cloud that the reconstruction will capture. The point cloud of the scanned human body has four layers. By reducing the number of points, a unified point cloud is obtained. Figure 4 shows the point cloud of human body obtained by 3D scanning (Fig. 4a) and closed point cloud (Fig. 4b) prepared for 3D modelling. As described above, all the scanned point clouds are prepared which enables taking accurate measurements and defining a body shape for which the protective element will be constructed [1].

a) b)

Figure 4. Point clouds of the digitalized human body: a) point cloud obtained by 3D scanning; b) point cloud prepared for 3D modelling

3D modelling of the protector was carried out according to the sketch of the chest protector shown in Figure 1. A cuboid which outlines the protector was defined for the chest protector production by 3D modelling. The cuboid was defined by scaling of the cube (Fig. 5a) and according to the chest protector's external shape template (Fig. 5b). The number of edges increased within the defined cuboid which makes it possible to form a structured mesh defining the chest protector's external shape (Fig. 5c).



a) b) c)

Figure 5. Chest protector modelling: a) Defining the cube; b) remodeling the cube into the cuboid according to protector's dimensions; c) Creating a structured mesh for chest protector modelling

The protector's external shape is constructed as described above, and integrated into a cuboid with defined height which corresponds to the protector's thickness.
The next step in the chest protector construction was the modelling of the protector's inner side so that it precisely follows the body shape As it cannot be achieved by conventional methods, it was modelled according to the scanned part of the point cloud. As a result, functions which enable modelling of protector structured mesh by "imprinting" part of the point clouds into the prepared chest protector shape were used (Fig. 6). As the etalon, the point cloud of 3D scanned human body was used in the standard scanning position (pos. 1, Fig. 2).

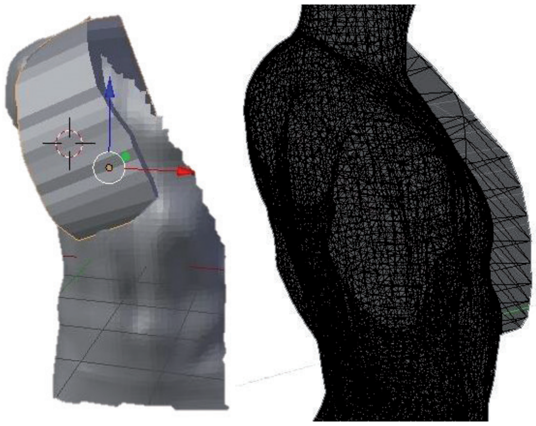


Figure 6. 3D chest protector modelling according to the scanned body

The chest protector modelled as described is prepared for 3D printing by defining a smooth and even surface of the chest protector's external layer. By multiplying the number of points, the number of mesh edges and the mesh surface elements, the fragmentation of 3D object mesh construction was achieved (Fig. 7).

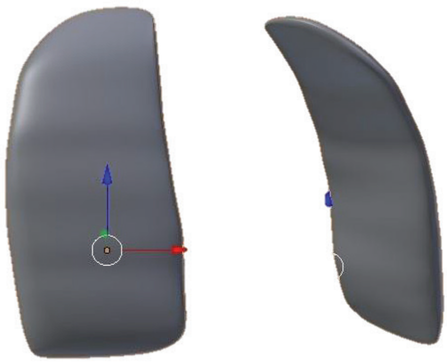


Figure 7. Smoothened surface of 3D modelled chest protector

After modelling the right chest protector, the chest protector covering the left side of the body was modelled. It is not possible to define the left side of the chest protector as mirror image of the right part due to the asymmetry of the body, which is determined by a virtual fit testing. Therefore, the left part of the protector was corrected according to the body shape. Figure 8 shows 3D protectors in static body position.

Figure 8. 3D modelled chest protectors for male body

The chest protectors for the female body were modelled in a similar manner showing that the inner side of the protector differs from the inner side of the male body protector due to the anatomical differences of the female body (Fig. 9).

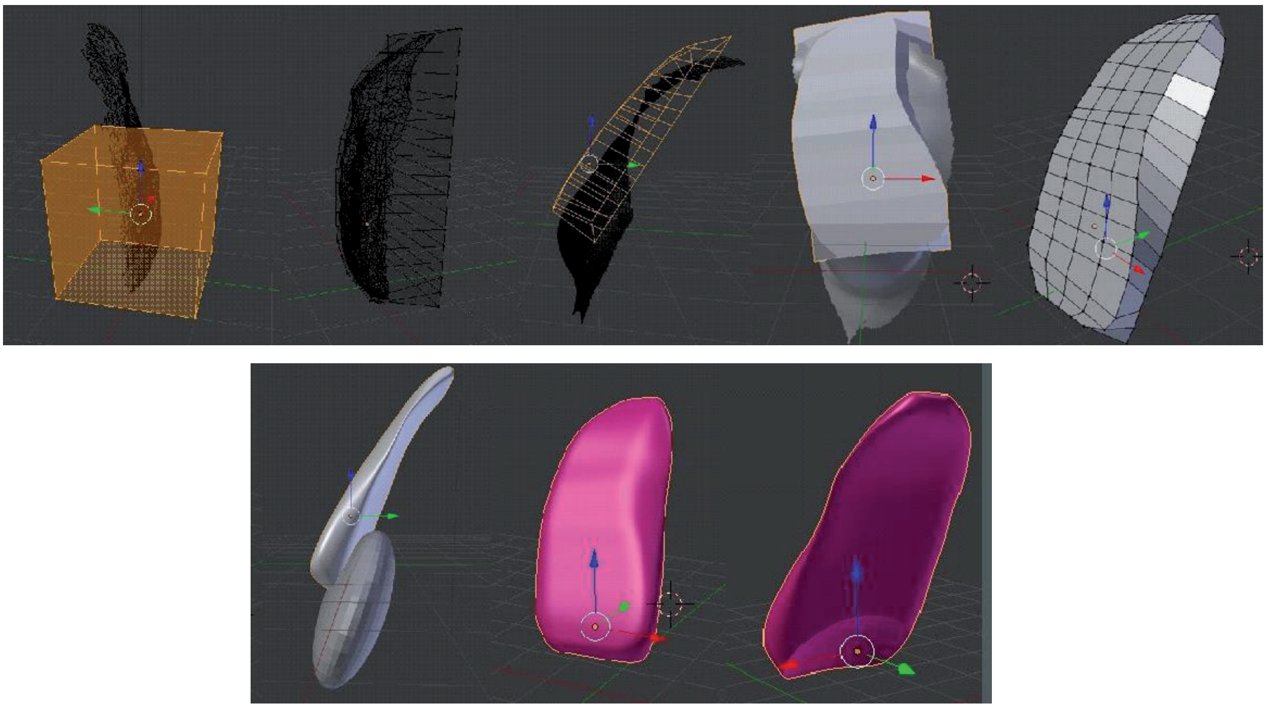
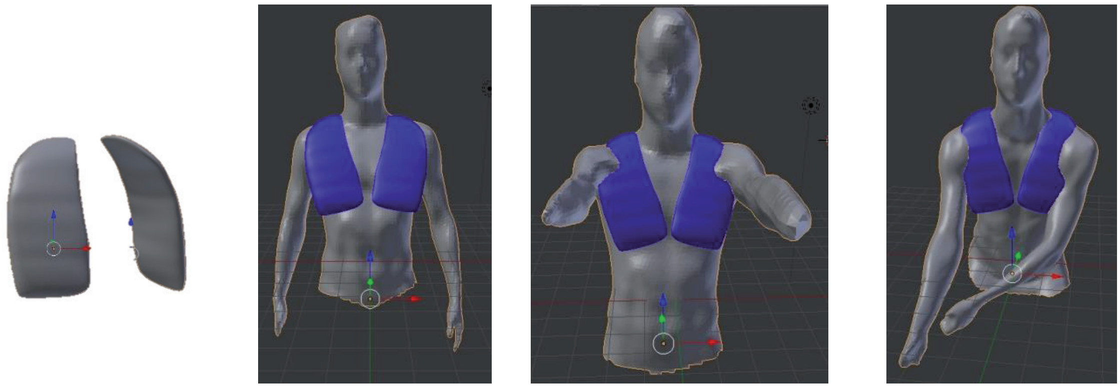
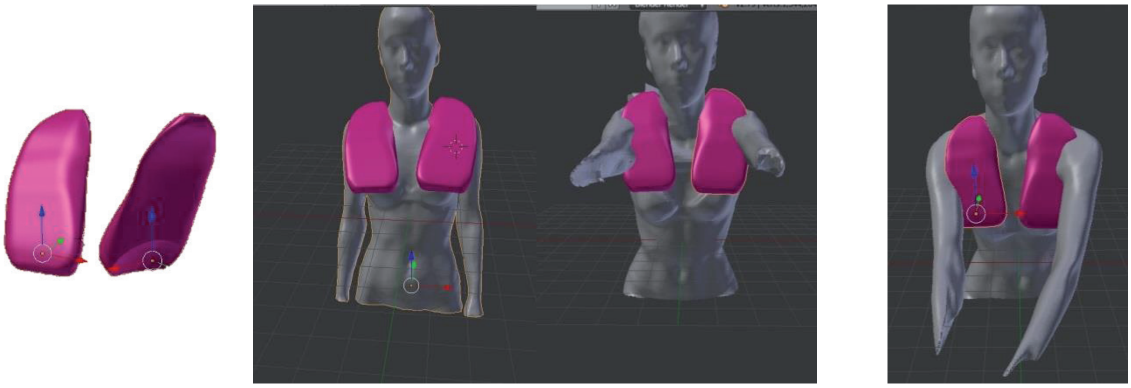


Figure 9. Chest protector modelling custom- made for female body [1]

3D chest protectors were virtually tested for the purpose of fit testing in specific body positions (Fig. 10). The need for further protector modelling was established in order to provide adequate protection [1].



a)



b)

Figure 10. Chest protector fit testing in specific body position: a) male body; b) female body [1]

Considering the occurrence of overlapping of point clouds of the human body and the 3D modelled chest protector, it is necessary to model new 3D objects in the sleeve area is following the body shape. In the case of the chest protector intended for the female body, it is necessary to make additional protector modelling in the neck area. Thecustom-made chest protectors for male and female bodies are shown in Figure 11.

Figure 11. Chest protectors for male and female bodies made to measure and prepared for 3D printing [1]

The difference in shape of the chest protector for the male and female bodies does not appear only in the inner part of the protector, but on the external shape as well. The chest protector intended for the female body moves to the neck in specific position sue to the anatomical differences of the female body. The major cause is the shoulder width and the angle at which the protector lies on the chest of the female body.

CONCLUSIONS

The common methods of shaping protective clothing and accessories, as well as elements that integrate into a garment item, are conceived in body measurements and are made on the basis of a national manufacturer's standard in several sizes. Such equipment does not provide adequate protection and security to users. Therefore, research, application of scientific technical and engineering knowledge, creativity and the use of new technologies are of great importance for the design of individualized functional protection elements. Based on the results presented in this paper, it can be concluded that 3D technologies can be successfully used in the modelling of protection elements for the human body 3D scanning, 3D modelling, and 3D printing require knowledge of 3D technology and its use in order to develop objects for individual purposes. 3D chest protectors modelling according to real body shapes and specific purposes indicate the need for using sophisticated equipment that will provide adequate protection. Modelling of protective elements can increase the level of protection, as shown, because body asymmetry can be taken into consideration during development, as well as the specific body positions in which the protection is used. The method of using 3D technology presented in this paper can be used for other purposes of protecting the body. In this manner, various protectors can be produced to be implemented in clothing items for different purposes.

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