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MANUFACTURING OF 3D HUMAN FACIAL MODEL THROUGH FUSED DEPOSITION MODELING (FDM)

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ABSTRACT
AM is increasingly becoming popular as a technology for producing highly accurate 3D human facial models. In this paper, we discuss the fabrication of the 3D human facial model using Fused Deposition Modelling (FDM). Firstly, a number of high-quality images of human faces were taken. These images were modelled on Blender to create a 3D human face. Then, the obtained STL file was sliced by slicer software in order to obtain the optimum printing parameters as well as the appropriate tool paths for printing a 3D human face with PLA material. The produced 3D human facial model was printed using a Bambu Lab FDM machine. The proposed method is able to provide accurate and effective production of a complex 3D human facial model. These customized faces can be utilized for various applications including medical simulation, prosthetics, forensic reconstruction, animation, education, and customized product design.

Keywords: FDM, human facial model, 3D Printer, PLA, digital manufacturing.

I. Introduction
Currently, the three dimensional (3D) printing or additive manufacturing (AM) becomes highly popular as an innovative method for the production of custom-made elements with complex geometry and relatively high accuracy [1-3]. The number of AM techniques is rather wide, yet the Fused Deposition Modelling (FDM) technique is more often applied because of its cost-effectiveness, economy of resources and capacity to create complex objects from layers according to digital models. The innovations in computer-assisted image modelling and design have provided the opportunity to create highly realistic 3D models of human faces used in medicine, prosthetics, forensics, biomedicine, and education [4–8]. Although FDM technology has evolved rapidly, modelling realistic human face geometry has still proved to be difficult due to several factors, including the impact of layer height, print temperature, printing speed, and orientation, among others [9]. It is clear that optimizing modelling and printing parameters is critical to creating realistic 3D models of human faces. Raza et al. reviewed the effect of various parameters used during the FDM process, such as layer thickness, raster angle, and orientation of construction on the mechanical properties of different polymers like PLA, ABS, Nylon, and PEEK. It further addresses some optimization approaches like Taguchi method and response surface methodology [10]. Salentijn et al. studied on the use of FDM technology in manufacturing micro-machines and LOC elements for the purpose of bio-analysis. The research explores the printability, properties of the material, biocompatibility, and applicability of different types of FDM materials used in creating microfluidic channels and micro-fabrication devices [11].
In the current study, high-quality facial images were analyzed via the Blender program to create a 3D geometry of the face, and then the resulting face geometry was printed by a Bambu Lab 3D Printer via fused deposition using polylactic acid (PLA). The suggested process of digital modelling and subsequent physical prototyping can reduce both the material usage and printing time.

II. Methodology

Methodology involved in the development of the human facial model in 3D is shown in Figure 1. Firstly, high-quality human facial images were captured under appropriate lighting conditions and further processed in Blender software for creation of realistic 3D geometry of the human face. The obtained model was optimized and exported in STL format for fabrication process. Then, the STL model was sliced for setting appropriate printing parameters like layer height, speed of printing, and melting temperature of PLA plastic. At last, human facial model was printed using FDM technology.

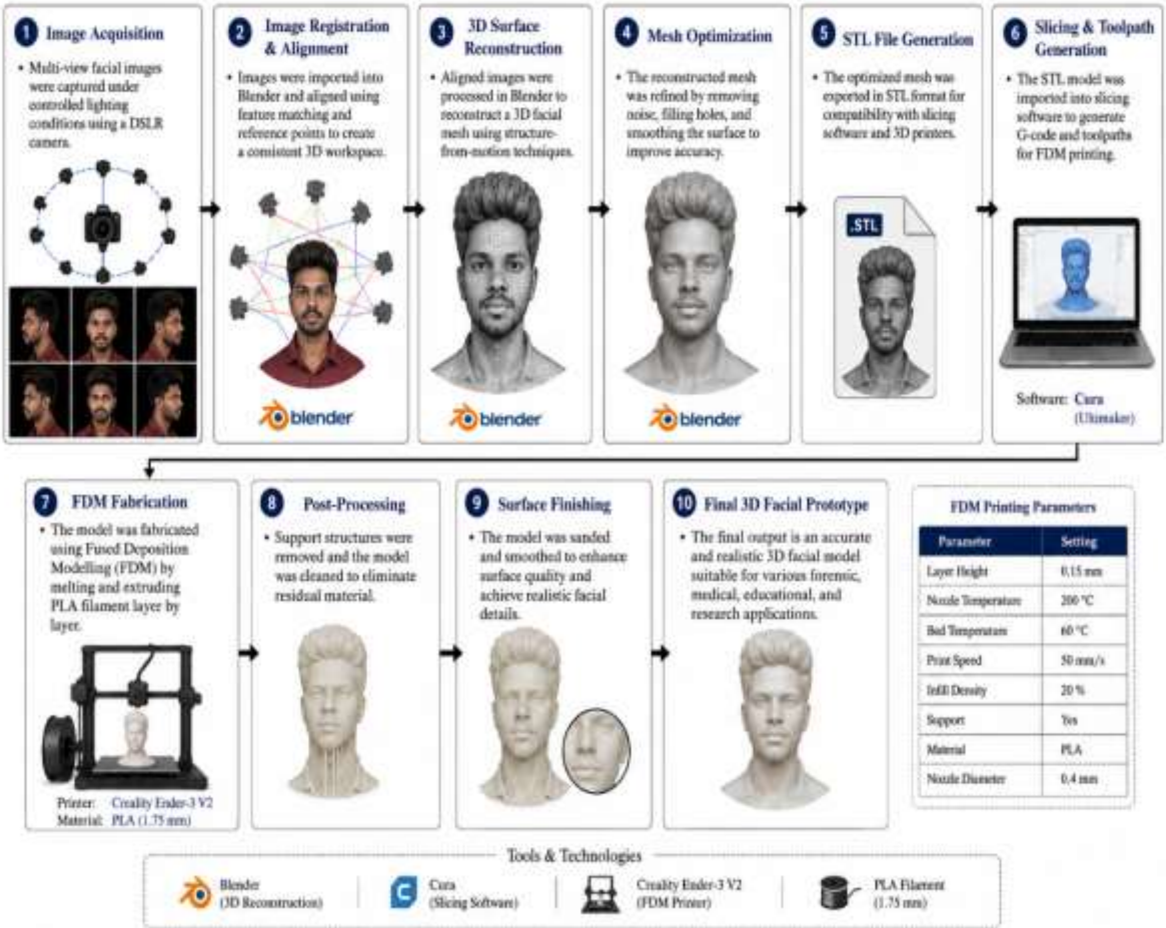

Figure 1 : Step-by step involved in the human face formulation

III. Results and Discussion

The manufactured fake facial model can be seen as having accurate dimensions and surfaces when compared to the digital facial model. It is clear that surface complexities were accurately captured, thus, confirming the efficiency of the method. Also, small surface deformities that characterize FDM were identified and corrected after post-processing.

3.1 Step 1: Face Image Acquisition

Firstly, six photos were taken from different directions, such as a front view photo, a left side view photo, a right side view photo, an upside view photo, a downside view photo, and a three-quarters view photo of a face. Photographing the face at different angles assisted in capturing accurate geometrical features of the face image. All photographs taken from different directions were stored in the JPEG file format for convenience when using the modelling software. These images are presented in Figure 2.

Front view	Left profile view	Right profile view
		
Top view	Bottom view	Back-side view
		

Figure 2 : Multi-view images in JPEG

3.2 Step 2: Bringing the Images into Blender

The face scans were imported to Blender as reference planes for the frontal, lateral, and top views of the faces. This configuration helped ensure the accuracy of the dimensions and spatial positioning of facial structures that will be used in modelling. Blender was selected based on the powerful mesh modelling and sculpting capabilities of the software. The setup of the reference images in Blender is illustrated in Figure 3 below.

3.3 Step 3: Modeling the 3D Facial Features

The polygon modelling and sculpting functionality of the software Blender was used to create and perfect the facial mesh through the use of reference pictures. Facial parts including the eyes, nose, lips, jaws, and cheekbones were correctly modeled; furthermore, subdivision surfaces helped to smooth the mesh while leaving its geometry intact. This can be seen more clearly in Figure 4.

3.4 Step 4: Modification of Parameters and Model Optimization

Following the creation of the initial 3D facial model, optimization was achieved through the modification of mesh density, vertices, edges, and smoothing levels, in order to improve the quality of the surface without affecting the face details. Any non-manifold edges and inner surfaces were removed to guarantee a watertight model and avoid errors in printing. The model's dimensions and angles were optimized for proper proportions.

Front view	Left profile view	Right profile view

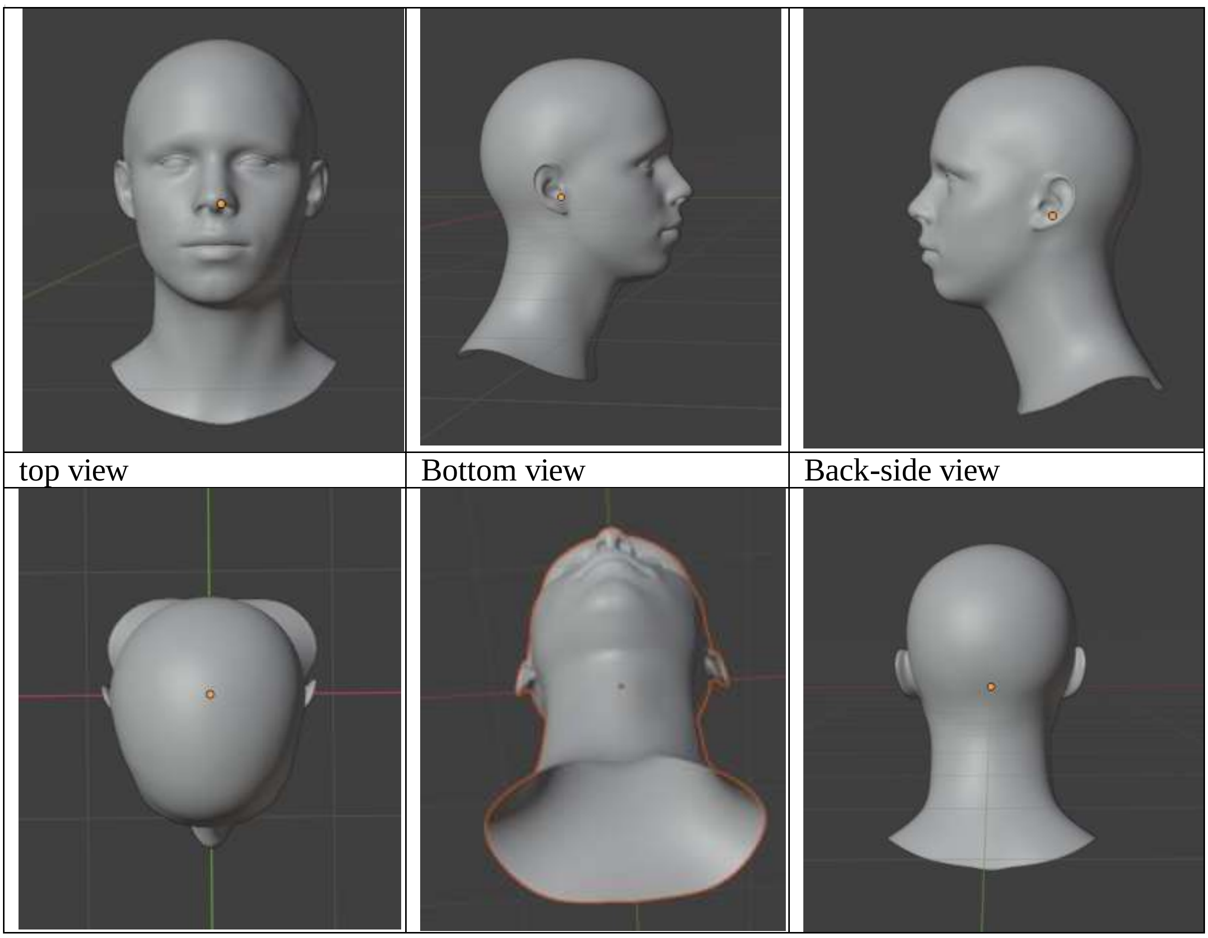

Figure 3 : Reference images in blender

3.5 Step 5: Exporting to STL File

Upon completion of the 3D facial design, the 3D model was converted into a stereolithography (STL) file format that can be used by slicer software and fused deposition modeling machines. It was checked for any defects including non-manifold edges, negative surface normals, overlapping triangles, and open boundaries to ensure there were no errors during its printing.

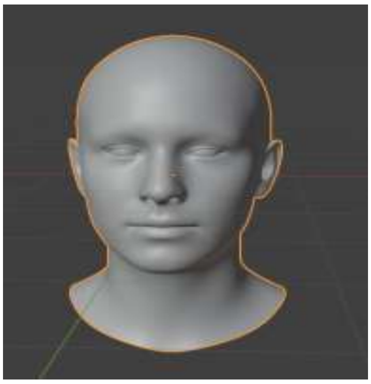

Figure 4 : Refinement of the 3D facial model from base mesh to detailed geometry

3.6 Step 6: Exporting into Bambu Studio Software

Model STL file was imported to Bambu Studio where it was sliced and prepared for printing. The positioning of the model was done in order to reduce support structure while ensuring that the face remains accurate. The tree-like automatic support structures were created to help with overhang areas like the nose and lips. The orientation and support structure setup of the model can be illustrated in Figure 5.

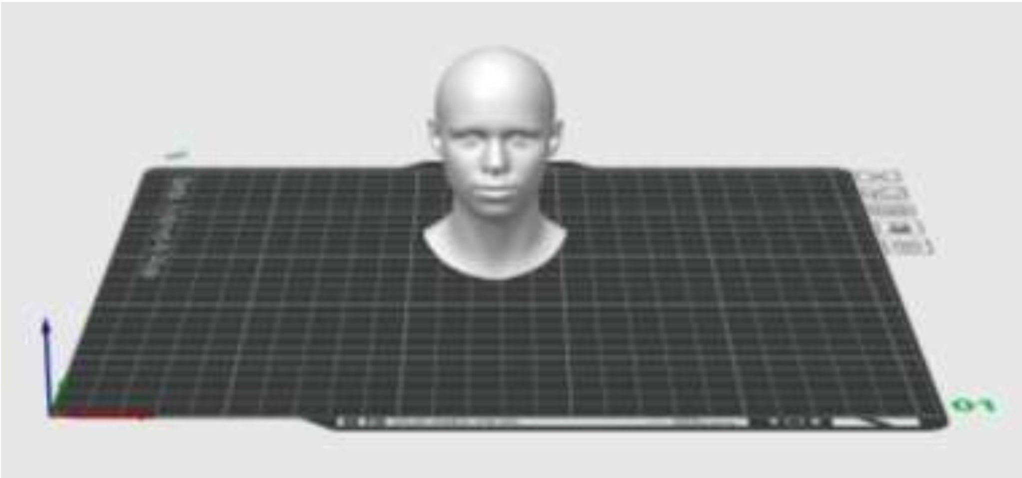

Figure 5 : Orientation and support generation in Bambu Studio for FDM printing

3.7 Step 7: Slicing and G-Code Generation

Settings for printing such as layer thickness, infill percentage, print speed, nozzle temperature, and support percentage were chosen. The slicer translated the three-dimensional model to G-code commands that will guide the printer.

3.8 Step 8: Printing via FDM Methodology

The produced G-code file was loaded to the Bambu Lab A1 FDM 3D printer. The filament type utilized for this step was PLA filament. The printing was done layer by layer in accordance with the preset tool path.

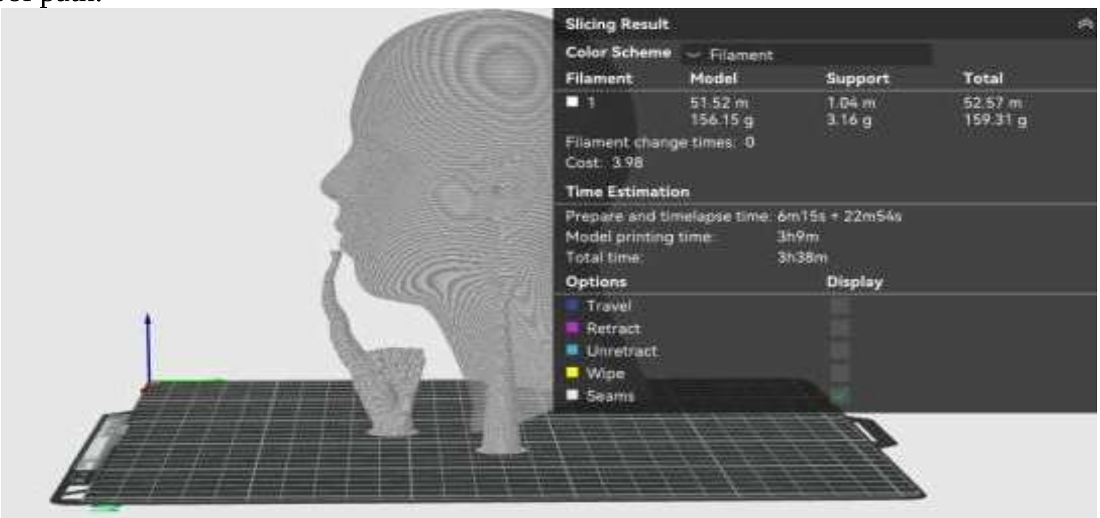

Figure 6 : Selection of printing parameters and G-code generation for FDM fabrication

3.9 Step 9: Post Processing

In this stage, the produced support structures were removed. The final touch was applied to the printed face model with the help of sanding and finishing work. The post-processed facial model is presented in Figure 7.

Figure 7 : Physical model fabricated in FDM

IV. Conclusion

In this paper, an optimized process of building a three-dimensional model of a human face through fused deposition modelling was discussed. By applying the correct methods of modelling, optimizing and printing, the complex geometry of the human face was accurately modelled.

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