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Modeling and Virtual Prototyping of a Human Mannequin Equipped with a Multifunctional Solar Backpack

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***Abstract*: This paper aims to model a 3D mannequin wearing a novel multifunctional electronic-textile backpack. To achieve this goal, a human mannequin is initially created using MakeHuman software involving innovative anthropometric databases. Then, the multi-propose virtual 3D backpack is equipped a mini solar panel, a battery charging circuit, a battery, two microcontrollers (Arduino Uno and ESP32 WROOM-32), DC voltage regulator modules (XL6009 IC), geolocation devices, weight controller sensor, MPU6050 sensor, a testing Smartphone with software application developed via Thunkable. etc. Finally, the overall platform is implemented and well visualized under Blender software, as an innovative virtual 3D studio for multifunctional solar Backpack.**

***Keywords*: Modeling, Virtual Mannequin, MakeHuman, virtual Backpack Blender platform, 3D clothing studio for Solar Backpacks.**

1. Introduction

Virtual prototyping, also referred to as three-dimensional (3D) design, is a digital technology that enables the realistic representation of an object prior to its physical realization [1], [2]. In the clothing and textile sector, prototyping corresponds to the development of a virtual or physical sample of a garment or accessory before mass production [3]. This approach allows designers and manufacturers to visualize garments in three dimensions [4], refine design concepts [5], and evaluate fit, aesthetics, and functional performance [6] before proceeding to production [7].

Beyond the apparel industry, prototyping plays a significant role across various textile-related fields [8, [9]. In fashion design, it supports the transformation of creative concepts into feasible products while facilitating early detection of design limitations and market relevance [10], [11]. For textile engineers and manufacturers, virtual prototyping enables the analysis of fabric behavior, optimization of production processes, and improvement of overall garment quality, while reducing material waste and production costs [12], [13]. In the retail and investment sectors, prototyping assists in product presentation, consumer evaluation, and informed decision-making regarding product development and marketing strategies [14]–[16].

To support these objectives, numerous 3D modeling tools are employed in clothing and fashion prototyping, including MakeHuman, Blender, CLO, Marvelous Designer, Tuka3D, ZBrush, and other computer-aided design platforms [17]–[19]. In this study, the MakeHuman and Blender software packages are utilized to develop a virtual human mannequin equipped with a multifunctional solar backpack. Section 2 describes the materials and methods adopted, Section 3 presents and discusses the obtained results, and Section 4 concludes the paper.

2. Tools and Methods

In this section, we will present the conceptual diagram, and the various software and hardware tools that were used to create our virtual mannequin.

A. Conceptual Schema Electronic-Textile of the New Multifunctional Solar Backpack

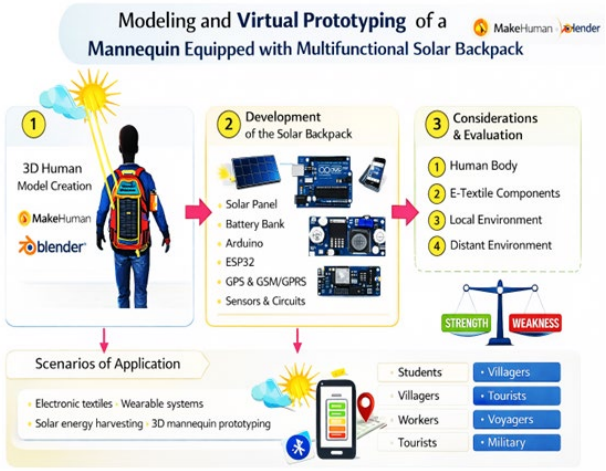

Fig. 1. Conceptual diagram of multifunctional electronic-textile backpack

B. Implementation Tools

1) Electronic Equipment

Table 1 describes the electronic equipment required to manufacture the multifunctional textile electronic backpack.

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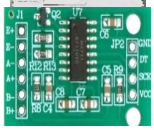
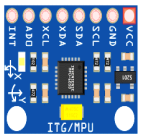
Table 1
Model variable used

Numbers	Illustrations	Features
(a) Solar panel [1], [2], [3]	 Solar panel	A mini panel 10 Watt, 6 V
(b) Charging circuit	Electronic circuit	Based on XL6009 IC
(c) Battery	 Power Bank	25000 mAh
(d) ESP 32 Micro-Chips ([4], [5], [6], [7], [8])	 ESP32	Vcc: 3.2: V-Bluetooth/BLE 4.0; CAN ports - Arduino IDE/C++ driver
(e) Arduino Uno Micro-Chip [9]	 Arduino Uno	- Supply voltage: 5V; - Intensity: 500 Ma. 2.5 Watts
(f) Voltage regulator ([10], [11], [12], [13], [14])	 DC-DCXL6009	Based on the XL6009/5V
(g) Connector and cable	Electric	For USB ports, 5V, 10W
(h) Current sensor	Electronic circuit	Based on the LM358N
(i) Smartphone		Galaxy S3
(j) Computer portable		Model: 15-ef1071wm; Storage capacity: 128 GB; 4 GB; AMD; Windows 10; 15.6 inches.
(k) HX711		Supply voltage: 2.6 V to 5.5 V;Number of channels: 2; ADC converter: 24-bit; Preamplifier: low noise 32 / 64 / 128; Updated frequency: 10 Hz / 80 Hz; Pins:openings for goldpin connectors - 2.54 mm(strap included); Operating temperature: -20 °C to 85 °C Module dimensions: 33 x 20 mm
(l) MPU6050		Power supply: 3-5 V; MPU-6050 chipset resolution: 16 bit I2C compatible output Very low consumption. Operating temperature -40 / +80º Selectable scales: +/- 2, 4, 8, 16 g Gyroscope ranges: +/- 250, 500, 1000, 2000 º / s. Compatible with Arduino libraries
(m) Weight sensor		Holder diameter: 10cm (tray diameter) Operating voltage: 3.3V5V (5V recommended). Maximum measurement force: 10 kg Appearance height: 3.5 cm (pillar included) AD Module: HX711 (High Precision 24-bit hx711 A/D Converter Chip) post-calibration accuracy: less than 1g Operating current: ETLT; 1.5 mA.

2) Software Tools

a) MakeHuman

MakeHuman software is a free and open source 3D virtual modeler dedicated to the rapid creation of realistic or imaginary human characters [15], [16], [17] . Its role is therefore: to edit human body data, such as: sex, size, morphology, positions, movement, body parts, etc.); To export the created character in OBJ, Wavefront or Collada format. Also to other modelers such as Blender [18] . MakeHuman has a simple interface to generate a human-like body based on general criteria such as sex, musculature, weight or age. It also allows you to refine each part of the body separately and to modify the pose of the model using a bone system. [19], [20], [21] Version -1.1.0-win32 gave us the opportunity to create our realistic-looking 3D virtual human character, focusing mainly on morphing details (gender, size, morphology, positions, movement, body parts, etc.) and then exporting it in OBJ format to the Blender modeler for dressing. Following the reveal of the MakeHuman software, we will then present the Blender software.

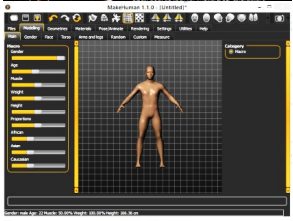
b) Blender

Blender software is a free and open-source 3D virtual modeler that promotes the rapid creation of arbitrary technical structure objects [22], [23], [24] . Its purpose is to create detailed 3D structures and objects; Animate characters or elements for films or video games; Simulate natural or physical environments such as water or smoke; Produce high-quality final images and videos from 3D creations; Import virtual characters from MakeHuman, or from other 3D modelers [25], [26] . We used version-2.90.0-windows 64 to model our backpack, also to import the virtual mannequin from MakeHuman for dressing.

c) GIMP

Gimp is a free, open-source, GNU/GPL-licensed image editing and processing software that competes directly with Adobe Photoshop. The image editor is powerful and offers all the essential features of a professional tool [27] . The

Table 2
Modeling of the bag in MakeHuman

No.	Operations	Images
1	Download and install MakeHuman-1.1.0-win32 software	
2	Set gender, weight, height and age	
3	Adjust the garment	
4	Adjust the shoes	

application supports RGB, CMYK, and HSV color spaces and offers an impressive number of filters and artistic effects. We used gimp -2.10.38 for our photo editing.

C. Virtual Mannequin Modeling Method Via MakeHuman

Bag modeling used MakeHuman to generate a realistic human model for ergonomic fit and posture evaluation.

D. Virtual Modeling Method of the Solar Backpack Via Blender

The virtual modeling of the solar backpack was carried out using Blender, a professional 3D modeling and rendering software widely used for product design visualization. The methodology began with polygonal modeling of the backpack structure based on real geometric dimensions to ensure accuracy and proportionality. Functional components such as the flexible solar panel, rechargeable battery, electronic control modules, and internal wiring channels were then integrated into the digital model. Specific materials and textures were applied to realistically simulate textile fabrics, polymer surfaces, and photovoltaic panels. Lighting, shading, and camera positioning were carefully adjusted to obtain high-quality and realistic renderings. This virtual modeling approach allowed the evaluation of the backpack's aesthetics, ergonomics, and component arrangement, as well as the identification of potential design constraints. Consequently, the method significantly reduced development time and cost by validating the design prior to physical prototyping.

E. Finalize the Formatting of Images Obtained on Imaging Software

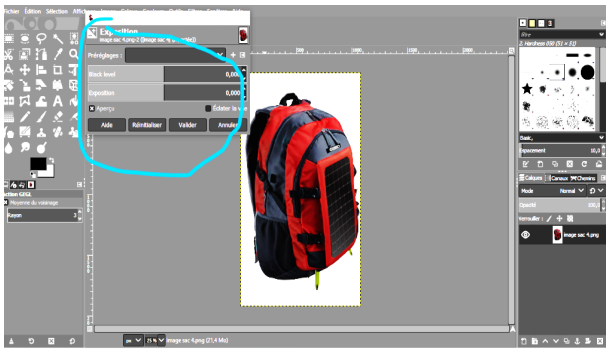


Fig. 2. End of formatting of images obtained on "GIMP" imaging software

3. Results and Discussions

A. Results of Virtual Mannequin Modeling in MakeHuman

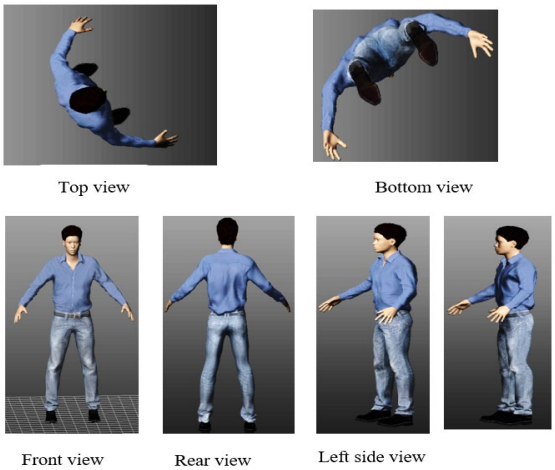
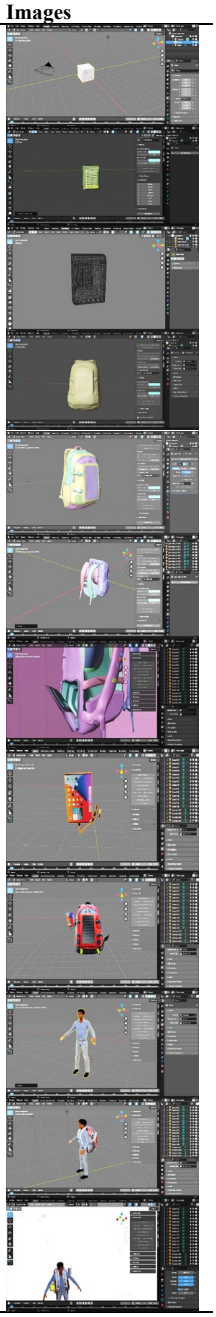


Fig. 3. Results from character modeling in MakeHuman

Table 3
Modeling the bag in blender

Operations	Images
Download and install Blender version 4.1 software then open the home interface	
Arrange the base of the sculpting bag	
Subdivide the object	
Sculpt the subdivided object	
Decompose the modeled object into sub-objects	
Complete the modeling of the bag with other objects	
Prepare the bag pocket	
Design the tablet and the bag cords using a modeling process	
Put the textures on the different parts of the bag	
Import the model into Blender	
Put the bag on the mannequin	
Prepare the lighting scene for shooting	

This software gives us exact precision on anthropometric data in a fraction of a second. We obtained our virtual male mannequin, aged 22 years, with a weight equal to 55 kg, a height of 1m, 664, or a body mass index equal to 20 corresponding to an ideal weight. It should be noted that the MakeHuman software has limits, particularly in terms of its very limited dressing palette. Figure 3 shows the results from the modeling of the character in MakeHuman in front, back, bottom, top, right and left profile views.

Fig. 4. Results from dressing the 3D character in blender

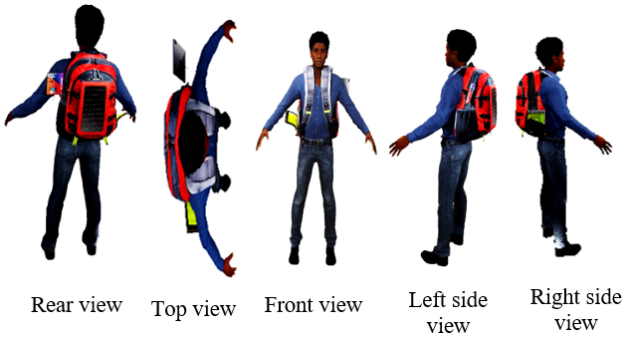


Fig. 5. Results from dressing the 3D character in Blender

B. Implementation of Electronic Devices on the Stylistic Design of the Bag

Fig. 6. Specifications for the installation of electronic devices on the stylistic drawing of the backpack

4. Conclusion

This article proposed a virtual mannequin, based on MakeHuman and Blender software, equipped with a multifunctional solar textile electronic bag. This virtual mannequin, created with 3D software, allowed us to assemble the model, test the fit, and display ultra-realistic images of the bag, including the appearance of the fabric ready for production.

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