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ICT-Based Framework for Virtual Rendering of Digital Cloth on 3D Models

Ashish Dochania

Abstract: ***The proposed framework provides opportunities, knowledge, and the potential to use information and communication technology (ICT) to create 3D models of woven fabrics. Here, we propose the open-source Computer Aided Textile Design—DigiBunai™ — and the Microsoft 3D viewer to visualise fabric renderings on pre-built models designed in Autodesk Maya. Indian handloom weavers have excellent skills and knowledge to create complex patterns in woven textiles. Still, due to a lack of digital literacy, they cannot use digital tools. They rely on their experience, knowledge, and sample-taking to ascertain the actual appearance of their fabrics. The objective of this framework is to provide a cost-effective solution for visualizing simulated CAD fabric on 3D models. It also allows the hand-weaving artists to predict their products before they are made on the looms. It can save time, reduce material waste during sample-taking, and improve the aesthetics of the woven fabric. It can also align the production of handwoven fabrics with demand and market trends.***

Keywords: DigiBunai™ Computer-Aided Textile Design (CATD), Fabric Rendering, 3D Models, Weaving, Information & Communication Tool (ICT)

Nomenclature:
ICT: Information and Communication Technology
CATD: Computer-Aided Textile Design
BRDF: Bidirectional Reflectance Distribution Function
CAD: Computer-Aided Design
SF: Sustainable Fashion

I. INTRODUCTION

India is a land of diverse languages, traditions, attire, and beliefs. A strong influence of regional customs can be seen in the lives of people in various regions. Here, people's traditional clothing plays a significant role in capturing beautiful, memorable moments at festivals. These festivals infuse people's lives with colour through diverse clothing & art. People who possess the skills to produce crafts and clothing using conventional apparatus & traditional, labour-intensive production methods. Their skills are passed down from one generation to the next, preserving the craft's originality. Here, a strong connection has developed between people, traditions, clothing, regional art, colours, materials & the production process.

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*Correspondence Author(s)
Ashish Dochania*, Manager Product Development & Training, DIC, Ministry of Electronics & Information Technology, Delhi, India. Email ID: aseem.dochania@gmail.com, ORCID ID: 0009-0001-0786-2952

Clothing may be produced by hand or by machine. The level of human intervention in production depends on the type of machinery used. In the modern era, Information and Communication Technology (ICT) solutions enable the visualisation of clothing before it is produced, helping manufacturers and buyers alike see what the final product will look like. In support of handmade clothing manufacturers, the Digital India Corporation, under the Ministry of Electronics & Information Technology, has developed free CAD software for weaving. This software allows manufacturers to create two-dimensional models of finished products, such as shirts, pants, coats, and curtains, helping them in the design and production process without the burden of licensing fees.

Realistic cloth is essential for graphics applications, from entertainment and apparel rendering to textile design. By enabling predictive preview of fabric designs before they are woven, we can minimise the need for test weaving, saving considerable time, raw materials, and costs. Many

Small-scale manufacturers who produce clothing by hand are not aware of how to effectively visualise their products to meet market and buyer needs. Here, two aspects come into play: first, technology, which supports manufacturing & second, the need to generate marketing opportunities. This paper covered freely available technologies & their working methodologies for designing digital fabrics and rendering on 3D models without creating physical samples.

II. LITERATURE REVIEW

India is a land of diverse languages, traditions, attire, and beliefs. A strong influence of regional customs can be seen in the lives of people in various regions. Here, people's traditional clothing plays a significant role in capturing beautiful, memorable moments at festivals. These festivals infuse people's lives with colour through diverse clothing and art. People who possess the skills to produce crafts and clothing using conventional apparatus and traditional laborious methods of production. Their skills are passed down from one generation to the next, preserving the craft's originality. Here, a strong connection has developed among people, traditions, clothing, regional art, colours, materials, and the production process. Clothing may be produced by hand or by machine. The level of human intervention in production depends on the type of machinery used. In the modern era, Information and Communication Technology (ICT) solutions enable the visualisation of clothing before it is produced, helping manufacturers and buyers alike see how the final product will look. In support of handmade clothing manufacturers, the Digital India Corporation, under the Ministry of Electronics & Information Technology, has developed free CAD software for weaving. This

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Realistic cloth is essential for graphics applications, from entertainment and apparel rendering to textile design. By enabling predictive preview of fabric designs before they are woven, we can minimise the need for test weaving, saving considerable time, raw materials, and costs [1]. Many small-scale handcrafted clothing manufacturers are unaware of how to visualise their products to effectively meet market and buyer needs. Here, two aspects come into play: first, technology that supports manufacturing, and second, generating marketing opportunities. This paper covers freely available technologies and their methodologies for designing digital fabrics and rendering on 3D models without creating physical samples. Digital cloth rendering encompasses various stages of development for creating realistic digital cloth based on physical parameters & abstract visualization of cloth on the physical objects. It enables the manufacturer to understand their products without developing physical cloth/fabric. Many studies have been conducted to simulate fabric based on yarn-level information, while altering yarn & fabric parameters such as yarn density, yarn count, yarn hairiness, number of twists, twisting direction, bending rigidity, drape, weave, lustre, etc. The system creates a simulated image of the fabric based on the input information, then renders it onto the created 3D models/objects.

Many fashion industries are working on sustainable fashion (SF) to minimise the industry's adverse environmental and social impacts. The classical garment design and manufacturing processes need to be optimised to better meet the SF's requirements. Hence, cutting-edge digital

Technologies (e.g., 3D human body scanning and virtual reality) have been widely adopted to reshape the entire garment customisation process in a more sustainable way. Here, SF can provide more accurate & personalized products based on consumer needs & satisfaction [1].

The design tools have had a significant impact on garment visualization over the past few years. Many computer-aided design (CAD) & digital media applications, such as Photoshop, Illustrator, and After Effects, help transform static 2D designs into dynamic 3D visualisations of clothing. It introduces a new digital aesthetic by accurately simulating the garment's surface, texture & motions. In this regard, 3D platforms provide extended capabilities & offer real-time interaction between 2D patterns and 3D simulations as material properties are changed [2].

In computer graphics, a cloth is defined as an infinitely thin polygonal surface. Due to this abstraction, the original nature of the textile, which is either woven or knitted, has been neglected during the rendering. The Bidirectional Reflectance Distribution Functions (BRDFs) are used to model fabric appearance, but they model only surface reflectance and do not capture the details of the yarns used [3].

Here, the research is broadly categorized into two categories: one is curve-based and surface-based. The curved-based models use the mathematical formulations that specify the structural analysis of the fabric (fibre & yarn level) rather than reflectance data. It offers high-level detail but incurs substantial computational and storage costs when handling curves explicitly. These methods have a complex geometry and are not suitable for rendering large-scale fabric. Due to storage requirements for 3D details and the complexity of multiple bounces in modelling curves, rendering is challenging. On the other hand, Surface-based models use the mesh geometry to handle the weaver pattern but overlook parallax effects. In this method, cloth is defined as 2D thin sheets applied to a 3D mesh. This method can represent the appearance of the cloth using BRDFs. The surface-based models are pretty fast for cloth rendering due to the lack of fibre or yarn-level details (compensated by texture mapping) and shadowing and masking (either missing or homogeneous regardless of local structures) [4].

Here, one generates fabric based on yarn & fabric properties, then renders it realistically on 3D objects. We should know the material definition of fabric in terms of appearance, physical & data attributes. Colour, texture, and lustre are significant factors, along with physical properties such as elasticity & bending rigidity, in rendering 3D models realistically. To render the clothing alongside a moving 3D character, SMPL models & multipose datasets are used to construct a suitable human body. The simulation of the fabric and the model's physical movement was achieved using spring-particle models. There are hierarchical bounding boxes and a hierarchical space decomposition

method used to improve the detection speed of collision and efficiency between the model & fabric. Sometimes this methodology creates a few issues in rendering, like a heavy workload of design & simulation, involving AI problems. Rendering of clothing takes a long time, considering the training of multiple algorithms [5].

The fibre-based models have achieved high-quality, close-up detail at the fibre level but suffer from high computational cost, limiting their practicality. Few studies have examined the novel hierarchical model that analytically aggregates light simulation at the fibre level by building on dual-scattering theory [6].

Designing realistic shading models and capturing real fabric are both challenging tasks. In a few studies, yarns are treated as bent and twisted cylinders, which are then shaded using a microflake-based bidirectional reflectance distribution function (BRDF) model. This inverse rendering approach used a neural network to estimate initial fabric parameters.

And an optimization based on differentiable rendering to refine the results [7].

Apart from the above methodologies, a few production environments rely on Handcrafted Texture Maps coupled with shaders to approximate the appearance of actual fabric. It produces excellent fabric visuals but depends on resources and artistic expertise, and is frequently inadequate at capturing light interactions between yarns [8].

On the other hand, it is possible to generate 3D textured cloths from real and synthetic images using the defined prompts. After that, the diffusion method has been used to transform the cloth images into 3D garment geometries. Sometimes, generated geometry cannot be utilized

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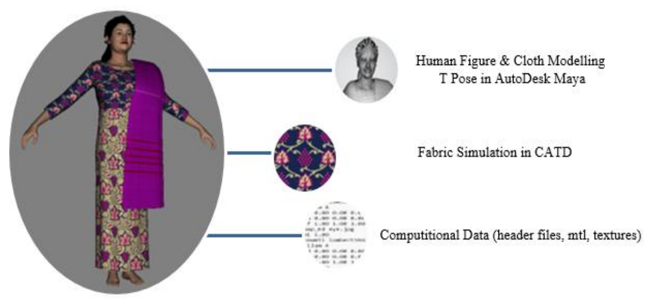
directly on the targeted 3d objects; the optimization mesh deformation technique matches the base template to the generated 3D target. The deformation of the base template mesh to the desired 3D geometry is a careful procedure that preserves mesh quality & topology during simulation [9].

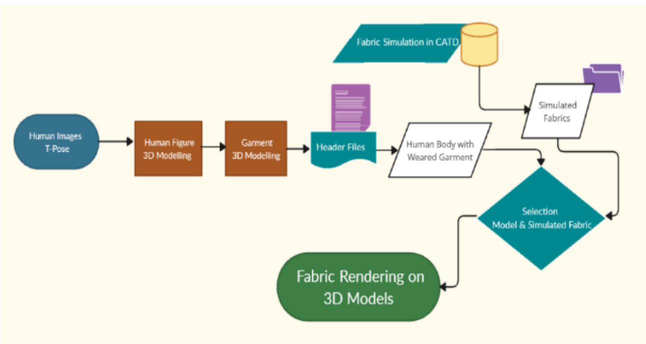
III. METHODOLOGY

To design the human figures & clothing mesh structures, we are using Autodesk Maya CAD, a high-end 3D graphics software, & we will use the "OBJ" format, a widely used file format for representing 3D geometry. Wavefront Technologies initially developed it for its Advanced Visualizer software. OBJ files store information about a 3D model's vertices, faces, texture coordinates, normals, and material properties. First, we need to create the fabrics digitally using the software. Simultaneously, we will scan the object with a 3D scanner or use Autodesk Maya to develop a mesh structure for the human figure and clothing. The designer will then unwrap the clothing and separate it from the object's body. For a saree, we will use a full image of the saree and overlay it onto the generated clothing mesh. Once the cloth-structured model is finalised, we can apply any cloth design to it.

For other fabrics that aren't a complete garment at the weaving stage, such as shirts, pants, salwar suits, kurtas, or skirts, we will use an image of the fabric, whether digital or physical. The fabric image will be applied to the clothing's 3D structure as a repeated pattern.



[Fig.1: Simulated Fabric Rendering on 3D Models]



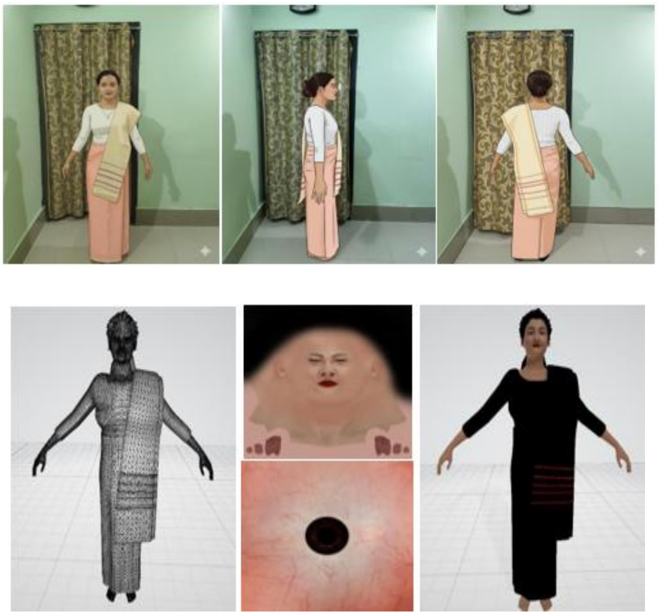
[Fig.2: Work Flow]

Here, we are using image-based modelling to create 3D models & cloth over them.

A. Image-based Modelling

To create a model, we will need type images (front, back & side) of the object. Additionally, unwrapped images of the imposed clothing with specific dimensions are required. The designer will first create a model with the clothing structure.

If different fabric swatches need to be applied to various parts of the garment, the designer will break down the mesh into the necessary units for precise placement. However, if a single image of the garment is being imposed, there's no need to break down the mesh structure. The designer only needs to define the model's starting and ending positions.



[Fig.3: 3D Modelling of Human Figure with Cloth/Garment]

B. Files/Assets Present in each 3D Mannequin/Model Folder

Each 3D Mannequin/Model must have the following Files/Assets present inside its directory for proper loading, rendering, and functioning inside the 3D Viewer module:

C. Metadata File

Here, we have created a header file to connect the model to render the various fabric swatches in a Java-based 3D viewer. It should be placed in the same directory as the OBJ file and the other assets. This header file contains the following details used for 3D Visuals, as shown below.

Table I: Header File

Entry	Description
NAME	Name of Mannequin/Model
DESC	Model Description
HEIGHT	Height of model in inches
Component Name (e.g. Body, Border 01 etc.)	All Garment Component names shown as bullet points
W_Component (e.g. W_Body)	Width of mesh present inside UV texture map image of selected Component.
H_Component (e.g. H_Body)	Height of mesh present inside UV texture map image of selected Component.
R_Component (e.g. R_Border_02)	Repeat direction for this component {"b", "h" "v"} b: bidirectional repeats h: only horizontal repeats v: only vertical repeats

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Table II: Data Description

Object File (.OBJ)	3D Mannequin/Model object file containing 3D spatial information (vertices, faces, vertex textures etc.).
Material File (.MTL)	Material properties and reference to various UV texture images.
Metadata File (without any file extension)	Contains information used by 3D Viewer for functioning. i.e. various garment components, repeat direction, height/width of mesh etc.
UV Texture for each garment component (.PNG)	UV texture images (2048 x 2048) for each garment component. It must be in PNG format (transparent image except mesh portion).
Any other assets for model eyes, face, hair etc.	JPG Image assets

Our digital rendering process utilises DigiBunai™, an open-source Computer-Aided Textile Design (CATD) software. This platform was developed by the Ministry of Electronics & Information Technology (MeitY), which also oversees the development of the 3D structures themselves.

Table III: Sample Data: Header File

```
NAME=Cotton_Phi_Matek_Phanek_Manipur
DESC=Phanek Manipur
HEIGHT=70
Body
W_Body=2048
H_Body=2048
R_Body=b
Shawl
W_Shawl=2048
H_Shawl=2048
R_Shawl=b
Blouse
W_Blouse=2048
H_Blouse=2048
R_Blouse=b
Shawl_Strips
W_Shawl_Strips=2048
H_Shawl_Strips=2048
R_Shawl_Strips=b
```

D. Seamless Integration and Automated Rendering

The DigiBunai™ system is designed for efficiency and ease of use: The viewer link connects to the existing DigiBunai™ fabric library, providing access to created fabric swatches. When the user selects a particular fabric swatch to render on the 3D cloth, it takes instructions from the header file to repeat the swatch before rendering on the model. The data inherent in the header file that defines the vertical & horizontal pixel dimensions as well as the direction of repeats. The header file reference should match the OBJ file to ensure the information is sourced correctly.

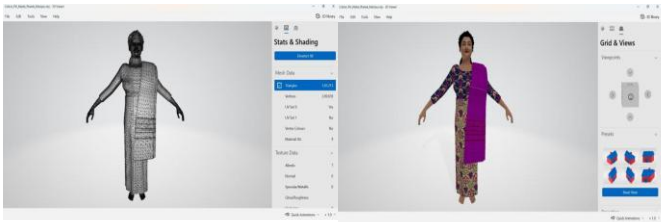
For every place in the code where the user wants to render the fabric design, the design must be defined clearly in the header file.

[Fig.4: Facility to Change the Clothing]

The rendering of fabric to create a complete garment on a 3D platform is based on the defined sizes of each garment part and the mesh to distribute the design uniformly or achieve a realistic look. Here, 3D models are static & the mesh density is predefined, but the user can adjust the properties of the simulated fabric to achieve a realistic garment appearance.

[Fig.5: Facility to Change the Clothing]

If a user has created a 3D model along with material and related texture files, it can be easily rendered in Microsoft 3D Viewer. Any repeat of the design to generate an actual 3D look of the fabric can be customised manually using any paint software. The repeated design texture will be applied to 3D models using the same reference defined in the Material Template Library (mtl) file.



[Fig.6: Facility to Change the Clothing]

IV. DISCUSSION & CONCLUSION

The research has successfully defined two methodologies for rendering digital fabrics onto three-dimensional models. It enables the user to see the look of their end products, such as garments, home furnishings, or other woven products. Inclusion of three software programs, Autodesk Maya, DigiBunai™ CATD & Microsoft 3D Viewer, provides capabilities to render the woven fabrics. Many online platforms sell 3D models along with clothing, which can be used to render the simulated fabric of the open-source DigiBunai™ CATD. Microsoft 3D Viewer provides functionality to analyse mesh density, adjust light angles, and rotate and zoom objects to render the model effectively. The pipeline for cloth rendering is significant for small-scale manufacturers of woven goods who cannot afford the high cost of CAD licensing. The system can help them learn about their products through 3D visuals, and also support institutional students who are willing to undertake a project in Textile Designing or Weaving. The robust DigiBunai™ platform plays a significant role in simulating fabric based on yarn or fabric parameters such as count, colours, type, density, weave, etc. The appearance of the rendered fabric on 3D models is based on the simulated fabric in DigiBunai™ CATD.

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DECLARATION STATEMENT

I must verify the accuracy of the following information as the article's author.

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AUTHOR'S PROFILE

Ashish Dochania was born in Rajasthan, India, on 2 September 1984. He earned his Bachelor of Engineering (BE) and Master of Technology (M. Tech) in Textile Technology. With more than 14 years of professional experience in India's textile industry, Ashish has developed expertise across yarn spinning, weaving, and textile CAD/Textile Design. He currently serves as a Project Manager (Product Development & Training) at Digital India Corporation, under the Ministry of Electronics & Information Technology. In this role, he leads the development of ICT-based solutions tailored to the needs of weavers and designers. His responsibilities include application development, functional testing, benchmarking, deployment, training of trainers (TOT), training of assessors (TOA), and stakeholder outreach to promote adoption. Ashish also spearheads efforts to enhance existing functionality and design new features driven by grassroots-level requirements. His work bridges traditional textile craftsmanship with digital innovation, aiming to empower artisans through accessible technology and sustainable digital tools.

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