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ADVANCING ADAPTIVE CLOTHING DESIGN FOR FEMALES WITH DOWN SYNDROME: THE ROLE OF BODY SCANNERS AND AI SOFTWARE

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Abstract

Females with Down syndrome (DS) have distinct clothing needs due to their unique body proportions, sensory sensitivities, and mobility constraints. Conventional garments often fail to meet these requirements, causing discomfort and limiting ease of movement. This study investigates how Netello 3D body scanning technology and CLO 3D AI-powered software can be utilized to develop adaptive clothing tailored for individuals with DS. Netello body scanning provides accurate anthropometric data, ensuring garments are designed for better fit and enhanced comfort. Meanwhile, CLO 3D software supports AI-assisted pattern creation, allowing customized clothing to accommodate medical, sensory, and motor challenges.

This research follows a mixed-methods methodology and incorporates a virtual case study to assess the real-world applicability of these innovations. The objective is to determine how AI-integrated design and advanced body scanning technology improve the accessibility, functionality, and overall wearability of adaptive clothing. Findings from this study will advance the field of inclusive fashion, helping individuals with DS achieve greater independence and comfort in their daily lives.

Keywords: *Adaptive fashion, Down syndrome clothing, 3D body scanning, AI-powered garment design, anthropometric measurement, assistive apparel, digital pattern-making, inclusive textile innovation.*

1. INTRODUCTION

Clothing plays a crucial role in ensuring comfort, functionality, and self-expression. However, individuals with Down syndrome (DS) often face significant challenges in finding well-fitting, comfortable, and adaptive clothing due to unique body structures, sensory sensitivities, and motor difficulties. Despite advancements in the fashion industry, there remains a lack of specialized clothing options for females with DS. According to estimates, approximately 23,000 to 29,000 children are born with Down syndrome each year in India. (Mapmygenome) Down syndrome occurs when an individual has an extra partial (or whole) copy of chromosome 21. It is not yet known why this syndrome occurs, but it has always been a part of the human condition. It exists in all regions across the globe and commonly results in variable effects on learning styles, physical characteristics, and health. (Organization) The total number of females with Down syndrome in India is significant, yet the availability of adaptive clothing remains limited. This research explores how emerging technologies such as 3D body scanning and AI-driven design software can bridge this gap.

The following distinction is made by the World Health Organization (WHO, 1980), in the context of health experience, between impairment, disability, and handicap: "Impairment. Any loss or abnormality of psychological, physiological, or anatomical structure or function. "Disability: Any restriction or lack of ability to perform an activity in a manner within the range considered normal for a human being. (R*).

Females with DS often struggle with traditional clothing due to shorter limbs, broader necks, and unique torso proportions, which make standard sizes uncomfortable and ill-fitting. Additionally, many individuals experience hypotonia (low muscle tone), sensory sensitivities, and difficulties with fine motor skills, making it challenging to wear clothing with small fasteners, stiff fabrics, or tight-fitting designs. These challenges highlight the necessity for adaptive clothing, which incorporates features such as adjustable fastenings, stretchable fabrics, seamless designs, and easy-to-wear closures to enhance comfort and independence.

There is a significant need to enhance the aesthetic appeal of clothing design to make it competitive and attractive in the fashion market. Everyone deserves to feel beautiful, including females with Down syndrome. Traditionally, adaptive clothing has leaned heavily towards functionality, often neglecting the aesthetic preferences of style-conscious individuals. This has resulted in a perceptible gap between the fashion-forward community and the limited available options in adaptive wear. (R*)

This study focuses on Netello 3D body scanning technology for accurate anthropometric measurements and CLO 3D AI-based pattern-making software to create adaptive garments tailored for females with DS. The research

employs a mixed-methods approach, including quantitative data from body scans and qualitative insights from a virtual case study, to analyze the impact of technology-driven design solutions on clothing accessibility.

2. LITERATURE REVIEW

The literature review explores existing studies on adaptive clothing for individuals with disabilities, the application of 3D body scanning technology, and the role of AI in garment design. Studies highlight that traditional clothing often fails to meet the needs of individuals with DS, leading to discomfort and limited independence in dressing. Furthermore, technological advancements in fashion, such as computer-aided design (CAD) software and machine learning for pattern development, offer promising solutions for creating more inclusive clothing.

At the International level, there are many organisations that are actively working with adaptive clothing. Big retail brands like Kozie Clothes, NBZ apparel, Target, and Tommy Hilfiger have dedicated clothing lines developed for people with specific disabilities. (Choudhury)

Adaptive clothing has a huge scope in the Indian market as there are very few brands catering to a few disabilities at present and adaptive wear is hardly available in physical stores. Even the existing brands are at a very nascent stage, often inspired by the disability of some family member or someone closely related. (Bhandari, Adaptive Clothing Brands in Mainstream Fashion)

In India, the adaptive clothing market is gradually evolving to cater to the unique needs of individuals with disabilities, including those with Down syndrome. One notable brand making strides in this area is Aaraam Se, founded by Kochi-based designer Ashima Bhan. Established in 2020, Aaraam Se focuses on creating comfortable and stylish clothing for people with limited mobility, such as the elderly and individuals with disabilities. The brand offers practical designs featuring elements like snap buttons, rear openings, and zippered legs on pants, all tailored to facilitate ease of dressing and undressing. Additionally, Aaraam Se provides customization options to address specific clothing needs, ensuring that each garment meets the unique requirements of its wearer (TextileValueChain.in, 2023).

While Aaraam Se is pioneering adaptive fashion in India, the overall availability of such specialized clothing remains limited.

Other brands contributing to adaptive fashion in India include:

Cocoon' by the 'Old is Gold Store'. However, apparels are no longer available in their store. Ekansh Trust, a Pune-based organization launched a competition in 2019 for designing adaptive clothing. They aimed to create a product catalog to promote adaptive clothing in India's mainstream industry, catering to senior citizens, PwDs, and individuals facing clothing challenges after surgery. Today, there are a couple of homegrown brands that are making adaptive clothing. 'Moveability Clothing' from Kottayam, 'Cur8abilty' from Mumbai, and 'Zyenika' from Kolkata are some of the brands. (Choudhury)

Suvastra Designs: Suvastra Designs, founded by Shalini Visakan, from Chennai, designs inclusive clothing for both persons with and without disabilities. She has designed shirts with magnetic buttons and pants with Velcro for wheelchair bound people, a one-piece saree for aging and wheelchair bound women ladies. It designs especially long crotches to accommodate adult diapers and attaches bigger loops to zippers for ease with fingers. She has used cotton and linen fabric for designing her Indo-Western collection. (Bhandari, Adaptive Clothing Brands in Mainstream Fashion)

While these brands are making important contributions to adaptive clothing in India, the overall availability of such specialized clothing remains limited. This underscores the importance of research and technological integration, as discussed in this study, to develop more inclusive and accessible clothing solutions for individuals with Down syndrome and other disabilities.

In order to reduce the stigma of adaptive clothing, while also enhancing the quality of life for people with disabilities, a change in the fashion industry must happen. Although the industry has made some developments towards designing for this segment of the population, most apparel designers have not been trained to design for alternative markets such as plus-sizes or the disabled. Future designers need to be prepared for a market that encompasses all body types, not just the "normal" body shape. (Kelsey Kosinski)

3. CHALLENGES IN CLOTHING FOR FEMALES WITH DOWN SYNDROME

3.1 Unique Body Proportions

Individuals with Down syndrome (DS) have distinct physical characteristics that influence clothing design. Research shows that adults with DS often have shorter heights, with legs being disproportionately shorter compared to their trunk length. Limb proportions also differ, with shorter arms and broader hands, which can affect sleeve length and ease of movement.

Craniofacial features commonly include a broader head shape, indicated by a higher cephalic index, and a tendency towards brachycephaly or hyperbrachycephaly, which results in a wide, short skull. Additionally, facial

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dimensions often exhibit reduced height and width, contributing to a distinctive round appearance. Individuals with DS may also have smaller ears and a flatter back of the head.

In terms of body shape, individuals with DS often exhibit variations such as the oval body shape, where the bust measurement is greater than the mid-waist, abdomen, and hip, or the Diamond body shape, where the bust measurement is smaller than the mid-waist, abdomen, and hip. Additionally, due to a considerable difference between the girth measurements of the bust and hip, the Spoon body shape has also been identified.

These unique body proportions necessitate specialized clothing designs that accommodate shorter limbs, broader necks, and specific craniofacial structures while considering the appropriate body shapes to ensure a proper fit and comfort.

Comparative Analysis of Body Measurements: Typical Adult Female vs. Adult Female with Down Syndrome

Measurement Category	Typical Adult Female (cm)	Adult Female with DS (cm)
Stature (Height)	160-170	135-150
Trunk Length	Proportional	Relatively Longer
Leg Length	Proportional	Shorter
Neck Circumference	30-35	35-40
Arm Length	50-55	40-45
Hip Width	90-100	100-110
Shoulder Width	38-42	32-36

This comparative data highlights the disparities in body proportions between a typical adult female and an adult female with DS, emphasizing the need for customized clothing patterns to ensure proper fit and functionality.

Creating clothing for individuals with disabilities is more complex, as these individuals require garments tailored to their measurements and movements

3.2 Sensory Sensitivities and Comfort Issues

Individuals with Down syndrome (DS) often experience sensory processing challenges that significantly impact their comfort, particularly concerning clothing choices. These sensory sensitivities can lead to discomfort and distress, making it essential to consider specific factors in clothing design.

Common Sensory Sensitivities:

- Tags and Labels: The presence of tags and labels in clothing can cause significant discomfort due to their scratchy texture and sharp edges, leading to constant irritation and distraction (Huynh)
- Seams and Stitching: Rough seams and stitching can be bothersome, causing irritation and even pain for individuals with sensory sensitivities (Huynh)
- Fabric Texture: The texture of fabric plays a crucial role in determining comfort. Rough or scratchy fabrics can feel abrasive against the skin, causing irritation and discomfort (Huynh)

Implications for Clothing Design:

To address these sensory sensitivities, clothing for females with DS should incorporate:

- Tag less Designs: Eliminating tags and labels can prevent unnecessary irritation.
- Seamless Construction: Utilizing seamless designs can reduce discomfort caused by rough seams and stitching.
- Soft, Breathable Fabrics: Selecting materials like cotton, bamboo, or modal can provide a soothing tactile experience, enhancing overall comfort.

By prioritizing these design elements, adaptive clothing can significantly improve comfort and reduce sensory-related distress for females with Down syndrome.

3.3 Limited Availability of Stylish Adaptive Clothing

3.4 Challenges in Dressing Independence

Individuals with Down syndrome often face challenges in achieving dressing independence due to factors such as limited dexterity, difficulties with traditional fasteners, and restricted range of motion. Designing suitable adaptive clothing can address these challenges and promote greater autonomy.

Challenges in Dressing Independence:

- Limited Dexterity: Fine motor skill difficulties can make manipulating small buttons, zippers, and hooks challenging.
- Traditional Fasteners: Standard closures may be difficult to manage, leading to frustration and dependence on assistance.
- Range of Motion Limitations: Reaching behind to fasten garments can be problematic for those with restricted movement.

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Adaptive Clothing Solutions:

- Alternative Fasteners: Replacing traditional buttons and zippers with magnetic closures or Velcro can simplify the dressing process. Brands like Lady Fines have eliminated buttons in favor of Velcro or magnets, aiding those with limited dexterity. (https://ladyfines.com/)
- Front-Opening Designs: Garments that open at the front, such as wraparound dresses or shirts with front closures, eliminate the need to reach behind, facilitating easier dressing.
- Elastic Waistbands: Pants and skirts with elastic waistbands remove the need for zippers or buttons, allowing individuals to dress more independently. This design accommodates those with fine motor challenges, providing comfort and ease

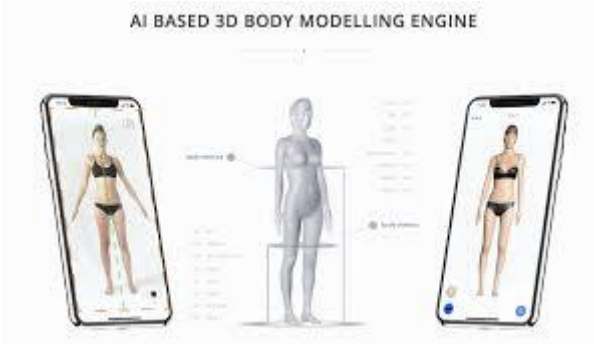
By incorporating these adaptive features, clothing can be made more accessible, enabling females with Down syndrome to dress with greater independence and confidence.

4. THE ROLE OF BODY SCANNERS IN ADAPTIVE CLOTHING DESIGN

Adaptive clothing design requires precise measurements to ensure a comfortable and functional fit for individuals with unique body proportions, such as those with Down syndrome (DS) or other special needs. Netello Body Scanners, a cutting-edge technology in anthropometric data collection, play a crucial role in enhancing adaptive clothing design by offering high-accuracy, non-invasive body measurement solutions.

4.1 Accurate 3D Body Measurement

Netello Body Scanners use 3D scanning technology to capture detailed body dimensions, including limb proportions, torso length, and girth measurements. For individuals with DS, who often have shorter limbs, broader necks, and varying body shapes (e.g., oval, diamond, spoon), these scanners provide essential data for designing well-fitted garments.



4.2 Customization and Fit Optimization

By generating a comprehensive digital body profile, Netello scanners help designers create clothing that accommodates specific needs, such as:

- Shorter sleeve and pant lengths
- Wider neck openings for comfort
- Adjustable waistbands for fluctuating abdominal girth
- Adaptive fastenings for ease of wear

4.3 Real-time Adjustments and Prototyping

Traditional measurement techniques can be time-consuming and prone to human error. Netello Body Scanners streamline the process, reducing fitting trials and fabric waste. This efficiency is particularly beneficial for mass customization in an adaptive fashion.

5. AI SOFTWARE IN ADAPTIVE CLOTHING DESIGN

CLO3D is an advanced software that leverages artificial intelligence to transform the fashion industry through realistic 3D garment simulation and virtual prototyping. This technology is particularly significant in the design of adaptive clothing, as it helps create inclusive and functional apparel for individuals with unique body proportions, including those with Down syndrome (DS) and other special needs.

5.1 AI-driven Pattern Making and Tailoring

CLO3D allows designers to create customized digital patterns tailored to individuals with specific body measurements. For adaptive clothing, this ensures:

- Accurate fit for diverse body shapes (e.g., oval, diamond, spoon body types)
- Adjusted sleeve and pant lengths for shorter limbs
- Wider neck openings and flexible fastenings for easy wearability

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5.2 Virtual Fitting Simulations

With CLO3D, designers can conduct virtual fittings on avatars with custom body measurements, eliminating the need for multiple physical prototypes. This is especially beneficial for adaptive clothing as it:

- Reduces fabric waste and production costs
- Speeds up the design process by identifying fit issues early
- Allows real-time adjustments for comfort and functionality
- CLO3D enables designers to visualize and test these modifications digitally before production, ensuring they meet the wearer's needs effectively.

5.3 Personalization Based on User Preferences

CLO3D can integrate with 3D body scanning tools such as Netello, enabling designers to import exact body measurements directly into the software. This ensures an accurate digital representation of the wearer, resulting in better-fitting adaptive garments. Additionally, CLO3D allows brands to enhance size inclusivity by generating digital patterns for various body types. Its AI-driven customization ensures that individuals with disabilities receive personalized clothing that is both functional and stylish.

6. METHODOLOGY

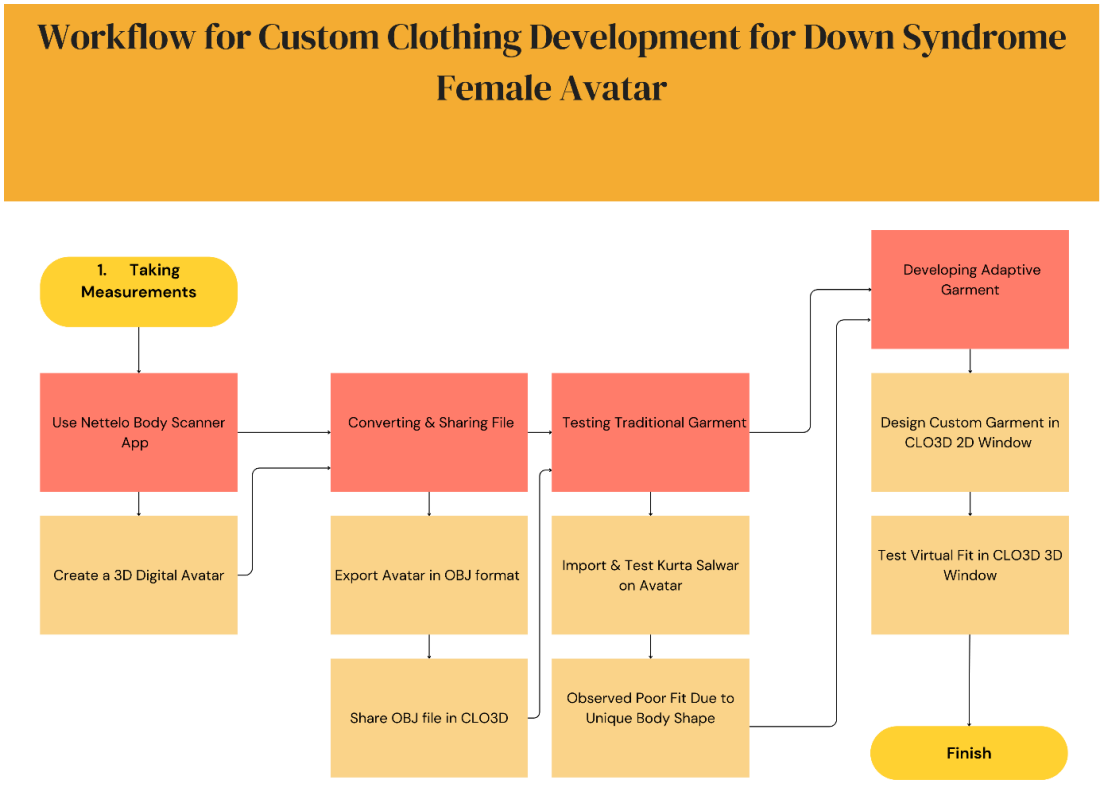
This research adopts a mixed-methods approach that integrates both quantitative and qualitative techniques.

- **Data Collection**: The study will use Netello 3D body scanning to capture body measurements of females with DS, generating accurate anthropometric data.
- **AI-Driven Design**: The CLO 3D AI software will be employed to create adaptive garment patterns based on the scanned data.
- **Virtual Case Study**: Participants will provide feedback on digital garment prototypes to assess fit, comfort, and functional aspects before physical production.

7. CASE STUDY: COMPARATIVE ANALYSIS OF BODY METRICS AND ADAPTIVE DESIGN

This case study explores the use of Netello 3D body scanning technology and CLO 3D AI-powered software in designing adaptive clothing for a female with Down syndrome. The process began with a full-body scan using Netello, capturing precise anthropometric measurements to understand unique body proportions and fit challenges. The scanned data was then converted into an OBJ format and imported into CLO 3D software, where adaptive garments were digitally designed and tested.

Process Overview:



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1. **Body Scanning with Netello**:
   - The subject underwent a full-body scan using Netello 3D scanning technology.
   - The scan captured detailed body measurements, including limb proportions, trunk length, and other critical anthropometric data.
   - This data was analyzed to identify specific fitting challenges unique to individuals with Down syndrome.

Measurement	Average Value (cm)	Notes
Height	135–145 cm	Shorter stature compared to the general population
Weight	55–70 kg	Higher body fat percentage observed in some studies
Head Circumference	51–55 cm	Higher cephalic index (broader and shorter skull)
Neck Circumference	35–38 cm	Generally broader neck
Shoulder Width	34–38 cm	Relatively narrow shoulders
Bust Circumference	80–95 cm	Varies based on individual body composition
Waist Circumference	85–100 cm	Abdominal girth tends to be larger
Hip Circumference	90–105 cm	Hip size varies; may be close to waist measurement
Arm Length	40–45 cm	Shorter arm length compared to height
Forearm Length	22–26 cm	Proportionally shorter forearm
Upper Arm Girth	28–32 cm	Slightly broader upper arms
Thigh Circumference	50–60 cm	Thighs may have higher fat distribution
Inseam Length	55–65 cm	Shorter leg length relative to trunk
Calf Circumference	30–38 cm	Calves may be proportionally larger

2. **Data Conversion and Import to CLO 3D**:
   - The scanned body model was exported in OBJ format.
   - The OBJ file was imported into CLO 3D, allowing designers to work with a precise digital replica of the subject's body.

3. **Comparing Traditional Clothing Fit**:
   - Initially, traditional dresses were tested on the digital body model, revealing significant fit issues such as tightness around the broader neck, excessive looseness in the midsection, and incorrect sleeve and pant lengths.

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- These issues highlighted the limitations of conventional sizing systems and the need for adaptive modifications.

4. **Adaptive Clothing Design in CLO 3D**:

- AI-driven pattern-making tools were used to create customized garments.
- Adaptive features like seamless construction and ergonomic fits were included, along with front zipper openings, darts for body shape adjustment, broad waistbands, and flared sleeves and pants for enhanced mobility and comfort.

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5. **Virtual Testing and Refinement**:

- The CLO 3D software provided an interactive virtual try-on experience.
- Compared to traditional clothing, the adaptive designs provided a significantly better fit, ensuring that the garment aligned with the unique proportions of the body scan.
- Iterative modifications were made based on mobility and sensory considerations.
- The finalized design was assessed for practicality before transitioning to physical production.

Key Findings:

- The integration of Netello 3D scanning and CLO 3D design significantly improved garment customization and fit accuracy.
- Traditional clothing designs failed to accommodate the unique proportions of individuals with Down syndrome, whereas adaptive clothing provided a better fit and improved ease of movement.
- Virtual testing reduced the need for multiple physical prototypes, enhancing efficiency in adaptive clothing design.
- The digital workflow enabled a more inclusive and personalized approach to garment development for individuals with Down syndrome.

This case study highlights the potential of technology-driven design solutions in an adaptive fashion, demonstrating how digital tools can enhance accessibility and customization for individuals with Down syndrome.

This case study explores the use of Netello 3D body scanning technology and CLO 3D AI-powered software in designing adaptive clothing for a female with Down syndrome. The process began with a full-body scan using Netello, capturing precise anthropometric measurements to understand unique body proportions and fit challenges. The scanned data was then converted into an OBJ format and imported into CLO 3D software, where adaptive garments were digitally designed and tested.

Key adaptations included a wide neckline, flared pants, and bell sleeves, creating an A-line silhouette that accommodates a diamond body shape and enhances limited dexterity for ease of movement. To address sensory sensitivities, tags and labels were avoided, and soft, stretchable cotton jersey fabric was utilized. The design featured full front zipper openings in both the kurta and pant crotch to facilitate easy wearing, tailored specifically to individual needs. The virtual fitting process using CLO 3D allowed for iterative adjustments, ensuring that the clothing met functional and sensory comfort requirements before physical production. This integration of digital tools highlights the potential of technology-driven design in improving accessibility and customization for individuals with Down syndrome.

7.1 Comparative Market Analysis of Adaptive vs. Traditional Clothing in India with integration of advanced technologies:

The data suggests that adaptive clothing constitutes a minimal percentage of the overall fashion industry, emphasizing the need for further investment and development in this sector to ensure accessibility and inclusivity.

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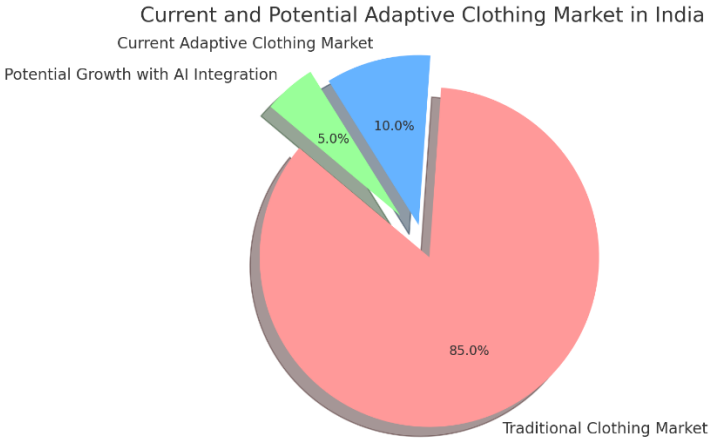

7.2 Cost Analysis and Economic Viability of AI-Driven Adaptive Clothing

To support the Indian fashion business, the cost sheet below presents an analysis of the financial implications of integrating AI and body scanning technologies in adaptive clothing design:

Cost Component	Traditional Clothing (INR)	AI-Driven Adaptive Clothing (INR)
Fabric Cost	500	700
Manufacturing	1000	1200
AI Technology Integration	0	1500
Body Scanning & Customization	0	1000
Total Cost	1500	4400

The cost analysis demonstrates that while initial investment in AI and 3D body scanning technology may be higher, long-term benefits include reduced material wastage, precise fittings, minimized return rates, and streamlined production. These factors collectively enhance the efficiency and profitability of the adaptive clothing sector, offering a viable growth opportunity for the Indian fashion industry.

8. LIMITATIONS AND FUTURE SCOPE

While this study highlights the advantages of using 3D body scanning and AI-driven design for adaptive clothing, several limitations remain. Firstly, access to high-precision body scanning technology like Netello is limited in many regions, especially in developing countries, making widespread adoption challenging. Secondly, AI-powered design tools such as CLO 3D require technical expertise, which may not be readily available among traditional fashion designers. Additionally, the cost of implementing these advanced technologies can be prohibitive for small-scale manufacturers and independent designers.

Future research should explore the scalability of AI-driven adaptive clothing design, ensuring affordability and accessibility for a broader population. Further studies could also investigate the long-term wearability and user satisfaction of AI-designed garments through real-world testing. Integrating sustainable materials and production methods into adaptive clothing design could be another area for future exploration, ensuring both functional and environmentally friendly solutions. Moreover, collaboration with healthcare professionals and occupational therapists can refine design features to better meet the needs of individuals with Down syndrome and other disabilities. Lastly, developing AI models that learn from real-world user feedback could further enhance the precision and effectiveness of adaptive clothing solutions.

9. CONCLUSION

This study demonstrates the significant advantages of using Netello 3D body scanning and CLO 3D AI-powered software in designing adaptive clothing for females with Down syndrome. The research highlights that traditional clothing often fails to accommodate the unique body proportions of individuals with Down syndrome, leading to poor fit, discomfort, and restricted movement. Conventional garments tend to be too tight around the neck, excessively loose around the midsection, and improperly proportioned in sleeve and pant lengths, making them unsuitable for individuals with Down syndrome.

By leveraging advanced technology, this study successfully created adaptive clothing tailored to individual body measurements. The integration of Netello 3D body scanning enabled precise anthropometric data collection, while CLO 3D software allowed real-time digital fitting and design refinement. The comparative study revealed

that adaptive clothing designed using this technology provided a significantly better fit, enhanced mobility, and improved overall comfort compared to traditionally designed garments.

Moreover, the use of virtual fitting simulations in CLO 3D reduced the time and resources required for multiple physical prototypes, streamlining the design and production process. This approach not only makes adaptive clothing more accessible but also paves the way for a more inclusive fashion industry. Future advancements in AI-driven clothing design could further enhance customization, ensuring that individuals with Down syndrome and other disabilities have access to well-fitted, comfortable, and stylish clothing options.

Hardware Requirements

1. **3D Body Scanner**: A 3D body scanner app uses a device equipped with depth sensors (e.g., structured light, time-of-flight, or stereo vision) to capture the person's body shape and measurements.
2. **Smartphone or Tablet**: A mobile device with a high-resolution camera and sufficient processing power.

Software Requirements

1. **Body Scanner App**: A specialized app (e.g., Nutella Body Scanner) that utilizes the device's depth sensors and camera to capture 3D body data.
2. **3D Modeling Software**: Integrated software that processes the captured data to create a 3D avatar.

Development Process

1. **Preparation**: Ensure the adult Indian female with Down syndrome is comfortable and willing to participate. Explain the process and obtain the necessary consent.
2. **Scanning**: Use the 3D body scanner app to capture the person's body data. This typically involves:
   - Standing in front of the device
   - Holding still for a few seconds
   - Rotating slowly to capture data from multiple angles
3. **Data Processing**: The app processes the captured data to create a 3D point cloud, which represents the person's body shape and measurements.
4. **3D Modelling**: The integrated 3D modeling software uses point cloud data to generate a 3D avatar. This involves:
   - Creating a digital mesh
   - Adding texture and color
   - Refining the model's shape and proportions
5. **Customization**: The app may allow for customization, such as:
   - Adjusting body proportions
   - Changing clothing or accessories
   - Adding facial features or expressions
6. **Final Avatar**: The resulting 3D avatar can be exported in various formats (e.g., OBJ, STL, or FBX) for use in applications like CLO 3D.

CONSIDERATIONS

1. **Consent and Privacy**: Ensure individuals with Down syndrome provide informed consent and understand how their data will be used.
2. **Accessibility**: During the scanning and modelling process, consider the accessibility needs of the individual with Down syndrome.
3. **Accuracy and Representation**: Strive to create an accurate and respectful representation of the individual with Down syndrome.

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