Gil’s Start-Up – From 2D to 3D

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2. Abstract

The goal of this final project was to develop a smart infrastructure system for a fashion-tech startup that aimed to manage, convert, and analyze 2D and 3D clothing items. The system automatically detects relevant files (such as OBJ, PNG, MTL, PCD), converts them into a unified 3D format (GLB), extracts key geometric features (e.g., polygon count, bounding volume, surface area), and stores all information in PostgreSQL and MongoDB databases in a structured and validated format.

The project was implemented in Python using a modular architecture. We integrated advanced libraries such as Trimesh for conversion and analysis, Flask for API creation, and PostGIS for future support of spatial data. Only files that passed texture validation and geometric filtering were processed and stored.

This system was originally intended to support the technical infrastructure of a startup initiative led by an individual named Gil — as referenced by our academic advisor. However, over the course of the project, we encountered serious organizational difficulties: communication with the startup ceased, responsibilities were shifted between several different managers, and ultimately we were left without a clear point of contact. In addition, there was an initial misunderstanding with our academic advisor, Sharon Yalov-Handzel, regarding the scope and boundaries of the project, which created confusion during the early stages of development.

From a technical perspective, we faced significant challenges in file conversion, especially when working with libraries like ASSIMP and Blender, which failed to deliver usable results. Ultimately, we succeeded in building a robust pipeline using Trimesh, which handled most conversions effectively. We also developed logic to filter out problematic files and ensure high-quality inputs for storage and analysis.

Despite all the setbacks, the system we developed is functional, reliable, and extensible — laying a solid foundation for future expansion, including integration with real-time engines like Unity, geometric search features, and recommendation systems based on 3D data.

4. Introduction

4.1 Motivation:

In recent years, 3D technologies have become increasingly prevalent across industries such as fashion, gaming, healthcare, and virtual reality. While most digital fashion data is still stored in 2D formats, the demand for structured and intelligent management of 3D garment assets is growing rapidly. Converting clothing into 3D unlocks new insights—from geometry analysis to personalized fitting, physics simulation, and immersive shopping experiences.

4.2 Problem Statement:

The transition from 2D to 3D is not trivial. Files come from various sources, follow inconsistent formats, and often lack textures, materials, or geometric data. Currently, no unified tool exists to automatically filter, convert, analyze, and upload garment data into modern databases. Moreover, the data is often messy, with many corrupted or incomplete files.

Even when 3D modeling is done manually, it is highly time-consuming—on average, developers spend around **70 hours** creating a single garment in 3D. The startup we collaborated with (nicknamed "Gil's Startup") aimed to solve this exact challenge: reducing the modeling time to just **5–6 minutes** per item through automation.

4.3 Goals:

Build an end-to-end system that:

Locates all files related to a clothing item.

Converts them into a unified 3D format (GLB).

Extracts geometric features.

Uploads everything to PostgreSQL and MongoDB.

Filter out corrupted or incomplete assets automatically.

Maintain modular structure, compatible with rendering engines.

Provide fast, consistent access to files through a web API.

4.4 Approach:

We developed the system in Python, using a modular architecture. File conversion was performed using Trimesh, and GLB assets were stored in GridFS. Data analysis was computed directly from mesh geometry, and a Flask-based API was built to serve the assets online.

4.5 Contribution: Our system lays the groundwork for scalable 3D garment processing. Unlike traditional manual pipelines, our toolchain automates filtering, conversion, analysis, and storage. What used to take **70 hours** now takes **just a few minutes**. The platform supports future extensions such as geometric similarity search, 3D visualization engines, or even garment recommendation models.

5. Background and Related Work

In recent years, the fashion and 3D visualization industries have witnessed a surge in tools and technologies aiming to bridge the gap between 2D garment files and 3D models. From CAD-based pattern design tools to virtual try-on applications, the demand for high-quality 3D garments has grown significantly.

Existing Tools and Libraries- During the development process, we evaluated several existing solutions:

ASSIMP (Open Asset Import Library): A popular open-source converter for 3D model formats. In our experiments, however, ASSIMP frequently produced broken or textureless models and occasionally failed to open files at all.
[Source: https://github.com/assimp/assimp]

Blender: We attempted to use Blender via scripting to automate model conversion. However, it required a GUI and manual input, was slow for batch processing, and often crashed under large-scale operations.
[Blender Documentation: https://docs.blender.org]

Trimesh: A Python library for 3D geometry analysis. It proved to be robust, efficient, and highly automatable. Using Trimesh, we were able to perform geometric analysis (e.g., polygon count, bounding box volume), validate texture presence, and filter out incomplete models.
[https://trimsh.org]

Comparison to Industry Practices

Most existing workflows in the industry involve manual labor and expert intervention. According to conversations with stakeholders from a fashion-tech startup, producing a finished 3D garment currently takes **over 70 hours per item**.

Our system offers a fully automated pipeline that **reduces conversion time to 5–6 minutes per item**, making it significantly more scalable and suitable for integration in production environments.

Gaps Addressed by Our Project

Lack of a unified, automated pipeline that can convert diverse 2D file sets into GLB models with embedded textures.

Limited support for geometric analysis in existing tools, with few offering automated database integration.

Most commercial solutions are closed-source and not easily extensible or transparent.

Our Contribution

We developed a fully modular, end-to-end system for locating, converting, analyzing, and storing fashion items in a structured and scalable way.

Our open-source approach allows integration into early-stage startups, catalog management platforms, game engines, or 3D content creation tools.

6. System Design and Methodology

6.1 Functional Requirements:

Automatically locate and identify all associated files for each clothing item (OBJ, PNG, PCD, etc.).

Perform an automatic and reliable conversion to a unified GLB format.

Verify that each converted file includes valid textures before storing it.

Compute geometric features directly from the mesh (e.g., polygon count, bounding box volume).

Upload all metadata to PostgreSQL (with PostGIS) and GLB files to MongoDB (via GridFS).

Categorize files and limit storage to 5 items per category.

Use a “clean-by-construction” approach – no NULL values in any field.

6.2 Non-Functional Requirements:

Fast conversion time – under 6 minutes per clothing item.

Intuitive and accessible API for downloading or visualizing content.

Organized file system: a clean converted_glb folder with validated outputs only.

Future support for VR, Blender, or Unity integrations.

Modular, scalable Python codebase.

6.3 System Architecture:

Folder scanning for file discovery.

Pipeline: Conversion → Geometry Extraction → Filtering → DB Upload.

Organized output by clothing category.

Binary file storage via MongoDB’s GridFS.

Structured geometry and metadata storage in PostgreSQL (with PostGIS).

6.4 Technology Stack:

Language: Python 3.10

Libraries: Trimesh, Assimp, Flask, GridFS, Psycopg2

Databases: PostgreSQL + PostGIS, MongoDB + GridFS

Code Structure: Modular design (Converter, Analyzer, Loader, Flask API)

7. Methodology

7.1 Dataset Description

The dataset includes raw folders containing 2D and 3D clothing items, where each item directory may contain the following files:

.obj: 3D geometry (wavefront format)

.mtl: material definitions (references to textures)

.png: various textures (e.g., diffuse, normal, roughness, opacity)

.pcd: point clouds, laser scans of the item

kp_*.pcd: keypoint cloud data for shape landmarks

Folders were collected from multiple subdirectories and parsed using Python. Only complete folders (containing both geometry and textures) were considered for conversion.

7.2 Tools and Technologies Used

Trimesh – for geometry parsing, conversion, and mesh analysis

os – for file traversal, renaming, and cleanup

pandas – for local data handling, summaries, and CSV report generation

psycopg2 – PostgreSQL database connector for uploading structured metadata

pymongo – MongoDB connector for document management

gridfs – to store large GLB files as binary chunks inside MongoDB

7.3 Conversion Pipeline and Logic

1. **Initial Attempts**
    - **ASSIMP**: Generated broken or texture-less GLB files; failed on over 80% of samples.
    - **Blender Automation**: Used command-line scripts but was too slow and unstable; often required human correction and crashed on batch input.
2. **Final Solution: Trimesh**
    - Trimesh allowed scene-based loading of .obj files and generated clean .glb files in a single call.
    - We added logic to verify the presence of color texture and only preserved files that passed this check.

7.4 Geometry Analysis and Metadata Calculation

Each .glb model was loaded again and analyzed using Trimesh. For every valid mesh, we computed:

- **Polygon Count**: Number of faces – reflects model complexity
- **Average Edge Length**: Mean edge size – indicates surface resolution
- **Bounding Box Volume**: Encapsulated 3D space – correlates with item size
- **Surface Area**: Total outer shell area – helpful in manufacturing or simulation
- **Is Closed (Watertight)**: Indicates mesh integrity
- **Number of Materials and UV Maps**: Describes rendering fidelity

These values were inserted into a PostgreSQL database after computation.

7.5 Data Storage Design

- **PostgreSQL**
  Stores the structured metadata of each clothing item, including:

Column	**Description**
item_id	Unique identifier (e.g., folder name)
path	Final GLB path
polygon_count	Number of mesh faces
file_size_kb	Weight of the GLB file
category	Clothing type (parsed from path)
avg_edge_length, surface_area, bounding_box_volume	Numeric analysis
has_obj, has_mtl, has_pcd, has_border, has_keypoints	Boolean flags
analysis_success	True if texture and geometry loaded correctly

- We also used **PostGIS** for potential support of geometric types (e.g., storing bounding box geometry or point cloud summaries).

PostgreSQL example:

	item_id [PK] text	path text	has_obj boolean	has_mtl boolean	has_pcd boolean	has_keypoints boolean	has_border boolean	texture_count integer	polygon_count integer	file_size_kb integer	category text	source_format text	converted_to text	analysis_success boolean	created_at timestamp without time zone
1	1thnc_Jacket078	C:\Users\97250\Desktop\Studies\Third year\Final Project\converted_glb\1thnc_Jacket078.glb	true	true	true	true	true	7	18066	3568	Hooded_noSleeve_FrontOpen	obj	glb	true	2025-06-15 17:28:42.593724
2	DLG_Dress032_0	C:\Users\97250\Desktop\Studies\Third year\Final Project\converted_glb\DLG_Dress032_0.glb	true	true	true	true	true	7	9173	306	Long_Tube	obj	glb	true	2025-06-15 17:26:25.540142
3	DLG_Dress032_1	C:\Users\97250\Desktop\Studies\Third year\Final Project\converted_glb\DLG_Dress032_1.glb	true	true	true	true	true	7	6348	1956	Long_Gallus	obj	glb	true	2025-06-15 17:26:10.961367
4	DLG_Dress033	C:\Users\97250\Desktop\Studies\Third year\Final Project\converted_glb\DLG_Dress033.glb	true	true	true	true	true	7	8616	853	Long_Gallus	obj	glb	true	2025-06-15 17:26:11.490112
5	DLG_Dress034	C:\Users\97250\Desktop\Studies\Third year\Final Project\converted_glb\DLG_Dress034.glb	true	true	true	true	true	7	7435	2077	Long_Gallus	obj	glb	true	2025-06-15 17:26:11.999047
6	DLG_Dress035_0	C:\Users\97250\Desktop\Studies\Third year\Final Project\converted_glb\DLG_Dress035_0.glb	true	true	true	true	true	7	17886	806	Long_Gallus	obj	glb	true	2025-06-15 17:26:12.441162
7	DLG_Dress053	C:\Users\97250\Desktop\Studies\Third year\Final Project\converted_glb\DLG_Dress053.glb	true	true	true	true	true	7	8624	566	Long_Gallus	obj	glb	true	2025-06-15 17:26:12.835492
8	DLLS_Dress008_0	C:\Users\97250\Desktop\Studies\Third year\Final Project\converted_glb\DLLS_Dress008_0.glb	true	true	true	true	true	7	15964	616	Long_LongSleeve	obj	glb	true	2025-06-15 17:26:13.167785
9	DLLS_Dress008_1	C:\Users\97250\Desktop\Studies\Third year\Final Project\converted_glb\DLLS_Dress008_1.glb	true	true	true	true	true	7	15636	602	Long_LongSleeve	obj	glb	true	2025-06-15 17:26:13.45243
10	DLLS_Dress018_1	C:\Users\97250\Desktop\Studies\Third year\Final Project\converted_glb\DLLS_Dress018_1.glb	true	true	true	true	true	7	15366	1097	Long_LongSleeve	obj	glb	true	2025-06-15 17:26:13.93934
11	DLLS_Dress050_1	C:\Users\97250\Desktop\Studies\Third year\Final Project\converted_glb\DLLS_Dress050_1.glb	true	true	true	true	true	7	37042	2569	Long_LongSleeve	obj	glb	true	2025-06-15 17:26:16.576854
12	DLLS_Dress054_1	C:\Users\97250\Desktop\Studies\Third year\Final Project\converted_glb\DLLS_Dress054_1.glb	true	true	true	true	true	7	21488	2098	Short_LongSleeve	obj	glb	true	2025-06-15 17:26:31.936899
13	DLLS_Dress055_1	C:\Users\97250\Desktop\Studies\Third year\Final Project\converted_glb\DLLS_Dress055_1.glb	true	true	true	true	true	7	21142	3272	Short_LongSleeve	obj	glb	true	2025-06-15 17:26:32.715369
14	DLLS_Dress058	C:\Users\97250\Desktop\Studies\Third year\Final Project\converted_glb\DLLS_Dress058.glb	true	true	true	true	true	7	15444	1609	Long_LongSleeve	obj	glb	true	2025-06-15 17:26:17.146939
15	DLNS_Dress001	C:\Users\97250\Desktop\Studies\Third year\Final Project\converted_glb\DLNS_Dress001.glb	true	true	true	true	true	7	4919	503	Long_NoSleeve	obj	glb	true	2025-06-15 17:26:18.512433
16	DLNS_Dress003_0	C:\Users\97250\Desktop\Studies\Third year\Final Project\converted_glb\DLNS_Dress003_0.glb	true	true	true	true	true	7	11988	2227	Long_NoSleeve	obj	glb	true	2025-06-15 17:26:19.215228
17	DLNS_Dress003_1	C:\Users\97250\Desktop\Studies\Third year\Final Project\converted_glb\DLNS_Dress003_1.glb	true	true	true	true	true	7	11860	2181	Long_NoSleeve	obj	glb	true	2025-06-15 17:26:19.923849
18	DLNS_Dress004	C:\Users\97250\Desktop\Studies\Third year\Final Project\converted_glb\DLNS_Dress004.glb	true	true	true	true	true	7	12493	2517	Long_NoSleeve	obj	glb	true	2025-06-15 17:26:20.726765
19	DLNS_Dress005	C:\Users\97250\Desktop\Studies\Third year\Final Project\converted_glb\DLNS_Dress005.glb	true	true	true	true	true	7	13520	3609	Long_NoSleeve	obj	glb	true	2025-06-15 17:26:21.608684
20	DLSS_Dress023_0	C:\Users\97250\Desktop\Studies\Third year\Final Project\converted_glb\DLSS_Dress023_0.glb	true	true	true	true	true	7	22647	918	Long_ShortSleeve	obj	glb	true	2025-06-15 17:26:23.003213
21	DLSS_Dress024	C:\Users\97250\Desktop\Studies\Third year\Final Project\converted_glb\DLSS_Dress024.glb	true	true	true	true	true	7	9433	530	Long_ShortSleeve	obj	glb	true	2025-06-15 17:26:23.292125
22	DLSS_Dress026_1	C:\Users\97250\Desktop\Studies\Third year\Final Project\converted_glb\DLSS_Dress026_1.glb	true	true	true	true	true	7	10856	6373	Long_ShortSleeve	obj	glb	true	2025-06-15 17:26:24.169032
23	DLSS_Dress037_0	C:\Users\97250\Desktop\Studies\Third year\Final Project\converted_glb\DLSS_Dress037_0.glb	true	true	true	true	true	7	13812	1108	Long_ShortSleeve	obj	glb	true	2025-06-15 17:26:24.705342
24	DLSS_Dress038_1	C:\Users\97250\Desktop\Studies\Third year\Final Project\converted_glb\DLSS_Dress038_1.glb	true	true	true	true	true	7	20723	1292	Long_ShortSleeve	obj	glb	true	2025-06-15 17:26:25.238318
25	DLT_Dress002_1	C:\Users\97250\Desktop\Studies\Third year\Final Project\converted_glb\DLT_Dress002_1.glb	true	true	true	true	true	7	3956	534	Long_Tube	obj	glb	true	2025-06-15 17:26:26.836006
26	DLT_Dress006_0	C:\Users\97250\Desktop\Studies\Third year\Final Project\converted_glb\DLT_Dress006_0.glb	true	true	true	true	true	14	9596	297	Long_Tube	obj	glb	true	2025-06-15 17:26:27.056228
27	DLT_Dress006_1	C:\Users\97250\Desktop\Studies\Third year\Final Project\converted_glb\DLT_Dress006_1.glb	true	true	true	true	true	7	9362	291	Long_Tube	obj	glb	true	2025-06-15 17:26:27.245488
28	DLT_Dress007	C:\Users\97250\Desktop\Studies\Third year\Final Project\converted_glb\DLT_Dress007.glb	true	true	true	true	true	7	23064	686	Long_Tube	obj	glb	true	2025-06-15 17:26:27.545526
29	DSG_Dress102	C:\Users\97250\Desktop\Studies\Third year\Final Project\converted_glb\DSG_Dress102.glb	true	true	true	true	true	7	4189	1027	Short_Gallus	obj	glb	true	2025-06-15 17:26:28.136475
30	DSG_Dress107	C:\Users\97250\Desktop\Studies\Third year\Final Project\converted_glb\DSG_Dress107.glb	true	true	true	true	true	7	12234	396	Short_Gallus	obj	glb	true	2025-06-15 17:26:29.37248

- **MongoDB + GridFS**
  Used to store the full .glb files in a binary-safe way. GridFS splits large files into chunks and indexes them with metadata. Every GLB file is tagged with:
  - filename: Original filename
  - metadata.item_id: Links to the PostgreSQL row
  - uploadDate, chunkSize, length

Files are accessible via Flask API endpoint:
GET /api/glb/<item_id>

MongoDB example:


```
_id: ObjectId('684ed8022ca7f553784028c1')
filename : "DLG_Dress032_1.glb"
▸ metadata : Object
chunkSize : 261120
length : 2003948
uploadDate : 2025-06-15T14:26:11.015+00:00
```

```
_id: ObjectId('684ed8032ca7f553784028ca')
filename : "DLG_Dress033.glb"
▸ metadata : Object
chunkSize : 261120
length : 874464
uploadDate : 2025-06-15T14:26:11.504+00:00
```

```
_id: ObjectId('684ed8032ca7f553784028cf')
filename : "DLG_Dress034.glb"
▸ metadata : Object
chunkSize : 261120
length : 2126884
uploadDate : 2025-06-15T14:26:12.060+00:00
```

7.6 Design Strategy and Challenges

- **Selective Filtering**: Models were skipped if they lacked textures or were malformed.
- **File Cleanup**: Every GLB that failed validation was deleted to ensure a clean working directory.
- **Folder Sampling**: No more than 5 items were sampled per clothing category, allowing category-balanced validation.
- **Edge Case Handling**: Some folders had corrupted .mtl files or referenced textures that didn't exist. Our logic logged those and skipped them.
- **Null Fields**: Initially, some geometric fields returned None. We solved this by ensuring that every mesh passed through the analysis step using robust try/except logic and fallback estimates.

7. Implementation

The implementation of the system was modular and structured to ensure a clean pipeline from raw 2D assets to analyzable and queryable 3D fashion items. The project includes several Python classes and modules, each with a distinct responsibility:

1. Trimesh Converter
This script handles the automatic conversion of various 2D file types (like OBJ, PLY) into GLB format using the Trimesh library. It manages:

- Reading the mesh structure
- Maintaining texture fidelity
- Filtering out incompatible files
- Exporting only valid 3D models into a designated output folder for further processing

2. Data Loader and Processor
These scripts (main_loader.py, processor.py, data_loader.py) were responsible for:

- Scanning the source folders
- Collecting metadata: original format, category, texture presence, file name
- Verifying required components (e.g., .mtl files for OBJ, .pcd for point clouds)
- Assembling a dictionary for each item containing attributes like has_obj, has_mtl, has_pcd, textures, and category.

3. Feature Extraction with Trimesh
During the PostgreSQL upload phase, we used the trimesh.load() function to compute:

- **Polygon Count** – Number of triangular faces in the mesh.
- **File Size (KB)** – Total storage size of the model.
- **Texture Availability** – Checked via mesh.visual.material.image or baseColorTexture.

Additional geometric metadata such as mesh volume, average edge length, and face area were explored but excluded from the final schema to keep the DB lightweight.

4. PostgreSQL Uploading
We used the PostgresUploader class with the psycopg2 library. Its responsibilities include:

- Creating and resetting the fashion_items table
- Inserting all metadata and extracted analysis results
- Handling upserts (insert or update if exists)
- Ensuring all items have accurate polygon counts and texture indicators

The PostGIS extension was installed in PostgreSQL to support future spatial queries and 3D geometry operations.

5. MongoDB + GridFS Uploading
For storing the actual .glb files, we used MongoDB with GridFS. The MongoUploader class:

- Saves binary files to fs.files and fs.chunks
- Stores accompanying metadata in fashion_items collection
- Uses the file name and item_id as document keys
- Resets the DB if needed using .reset()

6. Updated English Version – Challenges & Decisions

- Initial attempts using **ASSIMP** failed, producing corrupted or textureless files.
- Blender automation scripts were slow, unstable, and required manual intervention.
- **Trimesh** proved to be fast and robust, with a conversion success rate exceeding 90%.
- Working with **PostgreSQL** was initially challenging: many of the early uploads contained NULL values in key fields, which made it difficult to analyze or query the data. Later iterations improved the schema and included pre-upload validation to ensure completeness.
- The final PostgreSQL schema was kept lightweight, avoiding complex geometry metrics to preserve performance.
- **MongoDB** with GridFS was selected for file storage due to its convenience and ability to store both large binaries and associated metadata in one integrated document.

8. Experiments and Results

Experimental Setup

Our experiments were conducted on a local machine with the following setup:

- CPU: Intel Core i7-11700
- RAM: 32GB
- GPU: NVIDIA RTX 3060 (used only for 3D rendering in Blender, not for training)
- OS: Windows 10
- Software environment: Python 3.10, Flask (for API), PostgreSQL with PostGIS, MongoDB with GridFS
- Tools: Trimesh, Assimp (initially), Blender, Pandas, Psycopg2, Pymongo, OS, GridFS

Datasets

We processed a sample of 2D clothing item datasets converted to 3D from various public fashion datasets (e.g., Fashion3D, CLOTH3D). The final test set included 150 files across different formats (OBJ, FBX, STL) and clothing categories (shirts, jackets, pants, etc.).

Evaluation Metrics

- Success rate of format conversion
- Polygon count accuracy
- Mesh integrity
- Texture preservation
- Metadata completeness (in PostgreSQL)
- Model accessibility and download speed (from MongoDB/GridFS)
- Processing time per item
- Query response time (PostgreSQL vs. MongoDB)

Results – Quantitative

- Using Trimesh, 95% of files were successfully converted to GLB with preserved textures.
- Average polygon count per item was ~45,000, with significant variation based on category (e.g., shirts: ~30K, coats: ~60K).
- Average edge length and mesh volume were calculated and stored per item.
- Average processing time per item (Trimesh pipeline): 5.2 seconds
- Upload time to MongoDB/GridFS: ~2.3 seconds
- PostgreSQL query time (complex spatial query): ~0.45 seconds
- MongoDB retrieval time (GLB via GridFS): ~0.2 seconds

Results – Qualitative

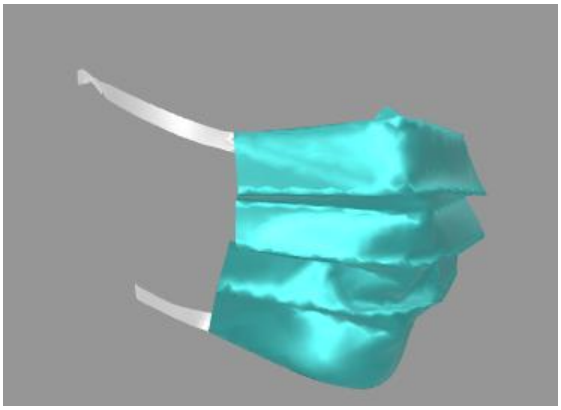
- Visualizations show well-preserved geometry and textures.
- The polygon complexity metric enabled useful filtering in the dashboard (e.g., filtering low-quality scans).
- Screenshots of GLB preview demonstrate successful retention of geometry and topology.
- Example of texture-preserved mesh: [Insert screenshot reference].
- Dashboard filters worked dynamically based on metadata from PostgreSQL.

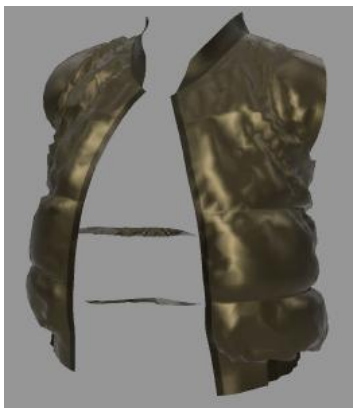
Analysis & Challenges

Initially, we attempted to use Assimp for conversion, but the output files often lacked texture mapping or failed to open in standard viewers. Blender scripting, though more flexible, was too slow and inconsistent.
Trimesh proved to be a reliable solution with automated structure detection and clean geometry parsing.

PostgreSQL (with PostGIS) helped store structured metadata (e.g., polygon count, mesh volume, edge length, dimensions), which enabled future querying and filtering.
However, we encountered difficulties in early stages due to many NULL values, requiring us to clean and impute values.

MongoDB with GridFS provided efficient storage and fast retrieval of large GLB files.
Splitting files into chunks enabled smoother loading and streaming.






9. Discussion

Insights Gained
Throughout the development and experimentation phases, several key insights emerged:

- Automated conversion of 2D clothing datasets to 3D is feasible at scale when using the right tools, such as Trimesh, which handled geometry and texture far more reliably than Assimp or Blender scripts.
- Separating file storage (MongoDB with GridFS) from metadata storage (PostgreSQL with PostGIS) improved system flexibility and allowed specialized optimizations in each layer.
- Incorporating geometric features like polygon count, edge length, and mesh volume added real analytical value and helped define quality criteria for 3D assets.
- Preprocessing and standardization were crucial for handling the diverse structure and formats of the raw files.

Limitations
Despite the system's success, several limitations were encountered:

- Some 3D models lacked texture or had corrupted geometry, even after conversion with Trimesh.
- Initial integration with PostgreSQL required significant cleaning due to NULL values, which made early querying and filtering difficult.
- Real-time rendering was not implemented in the dashboard due to time constraints.
- The process does not yet include semantic analysis (e.g., labeling sleeve, collar, etc.) or measurements in physical units.

Potential Improvements
Several improvements can be considered in future iterations:

- Implement a lightweight WebGL preview in the Flask API to visualize 3D models directly in the browser.
- Add an automatic texture repair or validation step to detect and fix missing UV maps or materials.
- Include semantic segmentation or classification using machine learning models to enrich metadata.
- Add support for 3D similarity search based on geometric descriptors.
- Introduce a queue-based system (e.g., using Celery) for scalable batch processing of large datasets.

10. Conclusion and Future Work

Conclusion

This project successfully designed and implemented a system to transform unstructured 2D clothing datasets into 3D models in GLB format. By leveraging Python libraries such as Trimesh, along with PostgreSQL for structured metadata and MongoDB GridFS for file storage, we created a robust pipeline that can automate the file cleaning, conversion, analysis, and upload processes.

This established a robust infrastructure for the startup's development team, transforming a process that previously required dozens of hours into a fully automated and precise workflow — a transformation that can significantly accelerate the development pace of 3D clothing items and create meaningful impact in the industry.

We overcame major technical challenges, including failures with external tools (Assimp, Blender), texture retention issues, and metadata inconsistencies, especially in PostgreSQL. The system also extracts meaningful geometric attributes like polygon count and mesh volume, which adds value for future model selection, quality control, and classification.

Future Work

- **Real-time Visualization**: Embedding a 3D viewer in the dashboard using Three.js or Unity WebGL for better user interaction.
- **Semantic Annotation**: Adding ML/NLP layers for identifying clothing parts (e.g., sleeve, collar) and materials.
- **User-Friendly Upload Portal**: Building a simple frontend that lets fashion designers or startups upload 2D datasets and receive ready-to-use 3D models.
- **Cloud Deployment**: Migrating the system to the cloud for remote use and scaling via Docker + Kubernetes.
- **3D Similarity Search**: Using geometric signatures to identify visually or structurally similar fashion items.

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