Project Report: Optimizing Unfolding and Nesting for Material Utilization

Problem

Efficiently cutting materials (such as fabric or sheet metal) is a critical challenge in manufacturing. For three-dimensional objects like cubes, unfolding them into two-dimensional nets leads to multiple candidate layouts (cube nets). However, the way these nets are arranged can drastically affect material waste. The problem is to identify the unfolding (or packing) of a 3D shape that minimizes unused material when placed on a sheet.

Task

Our task is twofold:

1. **Generate Candidate Unfoldings:** Produce various candidate nets for a shape (e.g a cube has 11 known distinct nets) and represent them as SVG images.
2. **Evaluate and Optimize Nesting:** Use the Packaide library to pack these candidate nets onto a blank material sheet. Compute space utilization by comparing the area of the unfolded shapes with the area of the minimal bounding box covering them. Finally, select the candidate(s) that yield the highest utilization (i.e., minimal waste).

Methodology

- **Candidate Generation:** We hard-coded 11 candidate cube nets in SVG format. Each candidate represents a different way of unfolding the cube.
- **Nesting with Packaide:**
    - We utilized Packaide to “nest” the candidate nets onto a blank sheet. Packaide discretizes the SVG shapes into polygons (controlled by a tolerance parameter) and adds an offset (margin) around each shape to prevent overlaps.
    - We examined both the original candidate nets (using their own bounding boxes) and the version processed by Packaide’s packing algorithm.

High-Level Workflow Overview

1. **Candidate Definition:**

Generate unfolded nets of a shape in SVG format.

2. **Display Original Nets:**

For each candidate, compute and display its own bounding box and utilization ratio.

3. **Nesting Process:**

Use Packaide to pack each candidate onto a blank sheet.
Compute the union of the placed polygons and overlay its minimal bounding box.

4. **Evaluation:**

Compute the space utilization ratio for both the original and packed versions of each candidate.

5. **Selection:**

Compare all candidates and select the one(s) with the highest utilization ratio.
If two or more candidates achieve the same maximum ratio (and if their shapes differ in packing layout), all are reported as optimal.

6. **Visualization & Reporting:**

Render both versions for visual inspection and compile the evaluation metrics into the final report.

Summary / Conclusion

In this project, we developed a pipeline to optimize the unfolding of a 3D cube for minimal material waste. By generating candidate nets and applying the Packaide nesting algorithm, we computed space utilization ratios based on the bounding boxes of the placed parts. Our system not only compared the original and processed nets but also automatically selected the candidate(s) that maximize material usage.

Further report in Github