A Design and Fabrication Workflow for Upcycling Leftover Fabrics as Mosaic Art

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Abstract

This study proposes a system to support the creation of mosaic art through upcycling fabric scraps, such as leftovers from garment manufacturing and disposed clothing. First, we apply filters to an input target image to achieve noise processing, pixelization, and color reduction. The processed target image is further subdivided into parts while considering fabricability constraints. Then, for each part, the most similar fabric from the source images of available scraps are selected and a part of the fabric is identified by template matching. Finally, the obtained fabric part is replaced with the part in the target image. This process is repeated for each part, resulting in a mosaic art that resembles the input image. This system allows users to create mosaic art that makes use of leftover fabrics. In addition, the system has potential to be applied to various other material scraps, such as wood, in the future.

Introduction

In today's mass production and consumption society, large amounts of leftover materials are produced, and we are not utilizing these materials in efficient ways (Davies 2021). Especially the fashion industry has a large impact on waste production. According to a survey, the amount of discarded clothing in 2020 was 66% of the amount given up by households after use, indicating the situation of clothing waste is an considerable problem. The fashion industry consumes large amount of water, being responsible for 20 % of global waste water, while clothing waste is a significant component of landfills, polluting soils and giving rise to other environmental issues (Igini 2023).

Upcycling is one possible approach to help reduce these problems. It is a reuse method where the materials of an original product are utilized as the are in a new product. This is different from *recycling* where materials are first returned to its raw state before being used for a new product. As an example of upcycling, there is an attempt to make effective use of materials instead of turning them into waste by using leftover fabrics from the production of bags (FUMIKODA 2024). In this way, it is possible to reduce the environmental burden of textile waste while also raising awareness of the issue, and ideally, reducing the need to produce new fabrics. However, a challenge is that leftover fabrics—whether it is production waste or disposed clothes—typically have various irregular shapes and sizes. Therefore, the design and arrangement of the leftover fabrics can be complex and difficult to handle manually.

In this paper, we address this challenge by proposing a design and fabrication workflow that support the creation of mosaic art using leftover fabrics. The workflow generates images by adjusting the size and shape of each part according to the pattern of the leftover fabrics, and aims to make the best use of unprocessed leftover fabrics at hand. For fabrication, in our workflow, we avoid cutting exact shape of fabrics because is tedious and causes frays around the edges. Instead, we adopt a tuck-in approach inspired by a Japanese craft technique called "Kimekomi-zaiku" (Ikidane 2018). This technique involves tucking fabric into precisely carved grooves on a wooden or styrofoam base to create detailed patterns. However, our process is less requiring than the traditional process because we use a laser cutter for automatic and precise cutting. Finally, we conducted a feasibility study of the proposed workflow by fabricating a mosaic artwork of "Girl with a Pearl Earring" by Johannes Vermeer.

In summary, our contributions are as follows.

- A workflow that takes a target image and source images of leftover fabrics as inputs, and output a mosaic art.
- A simplified tucking-in technique for fabricating mosaic art using a laser cutter.
- A feasibility study of the proposed workflow.

Related Work

Sewing Plan Support Systems

There is a large body of research that develop design tools for assisting users to create sewing patterns based on design intentions. The input for the target designs are various, including 3D models (Mori and Igarashi 2007), 3D point clouds (Korosteleva and Lee 2022) and sketches (Wang et al. 2018). They aim to create sewing patterns for 3D outputs, such as clothing and stuffed animals, while our output is limited to 2D outputs. However, they assume that the output will be made from new materials. In other words, unlike our system, these systems do not consider the shapes and colors of a limited set of available materials to which a design needs to be adapted.

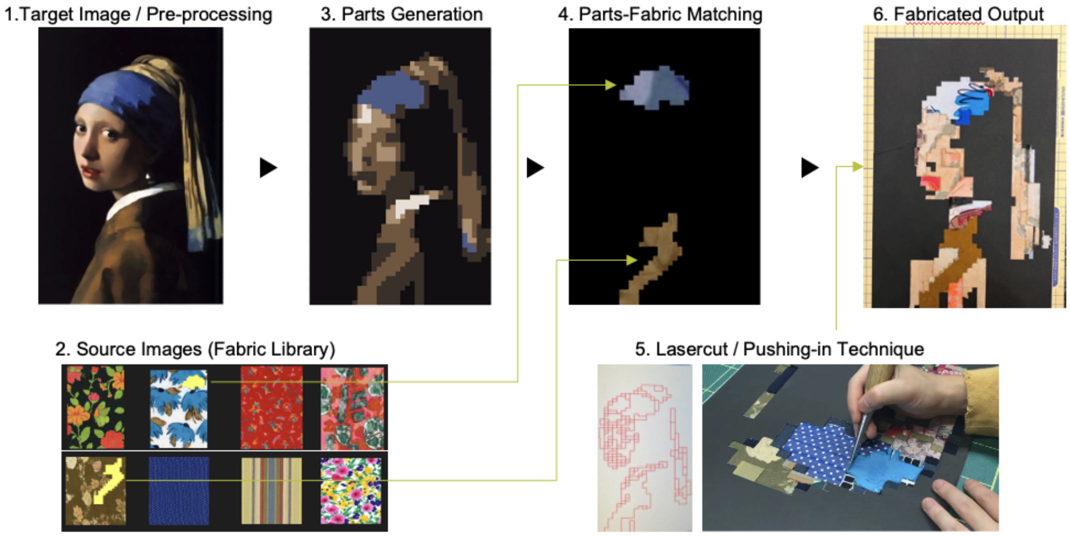

Figure 1: Workflow overview: Taking 1) input image and 2) 2D scanned fabric images, 3) parts are generated by reducing and clustering colors. 4) Each part is searched for through the fabric image library to find the best match. 5) The mosaic art is fabricated by laser cutting grooves combined with a manual tucking-in technique. 6) A fabricated output.

Patchwork Design Support Systems

There are several prior studies on computational fabrication supporting fabric craft including patchwork. Nozaki et al. developed a craft support system that allows beginners to easily engage in quilt making (Yuka Nozaki 2017). This system outputs quilt designs as image files, which can be printed on fabric. By sewing along the printed pattern boundaries, beginners can enjoy crafting with ease. The quilt designs are generated automatically by specifying colors and patterns for a base shape (triangle) and using periodic tiling to create geometric shapes.

In another study, Igarashi et al. developed an interactive system called Patchy that supports the design of original patchwork patterns (Yuki Igarashi 2015). Users start by drawing the silhouette of a patchwork pattern using a paint interface, then they design sketch strokes, draw stitch strokes, and finally sew the patchwork. This interface includes functions to deform the shape of stitch lines and to check the overall color balance from a distance, offering a high degree of design freedom. Moreover, Leake, et al. proposed an algorithm for generating paper-pieceable patchwork patterns based on line sketch inputs (Leake et al. 2021a). Paper-pieceable quilts, also known as foundation piecing, involve stitching fabric pieces onto a paper template to ensure precise shapes of intricate designs. In another work, Leake, et al. propose a system for improvisational designs of patchworks (Leake et al. 2021b).

Unlike these works, we focus on design and fabrication with leftover fabrics. Another difference is that our design process is mostly automated, while most related works provide design interfaces.

Sketch-Based Interface for Designing 2D Patterns

There are several prior studies on mosaics (Hausner 2001), (Abdrashitov et al. 2014), (Dobashi et al. 2002). Abdrashitov et al. developed Mosaic, a sketch-based application for easily and automatically creating digital decorative mosaics from scratch (Abdrashitov et al. 2014). By using a tile generation algorithm and stroke and brush-based tile duplication operations, users can create mosaic images with just a few simple strokes and shapes. This application is accessible to many users, allowing beginners to create artistic mosaics that reflect their own style.

Design and Fabrication Support System for Other Materials

There are several prior studies on wood inlay crafts. Ito et al. proposed a support system that allows even beginners to easily create original 2D wood inlay crafts (Kenyu Itoh 2018). This system has a paint tool for users to design and a script that automatically generates a 3D model of the mold based on the created design. Users can produce actual wood inlay crafts by printing the 3D model generated by this system with a 3D printer.

Workflow

In this section, we present the workflow (refer to Figure 1 for overview). First, an input target image is processed by a chain of basic image processing techniques—pixelization, color reduction, clustering cells, and connecting. Second, the available leftover fabrics are scanned. Third, we generate parts based on the pre-processed input image. Forth, we perform image matching on each target part with the material source images. After finding the best match of fabric and location for each part, we combine them to generate a final image consisting of parts of leftover fabrics. Finally,

Figure 2: Scanned leftover fabrics

the output is fabricated using laser cutter and a tuck-in technique.

Pre-processing Target Image

Based on a user-selected target image, we reduce noise by applying a Gaussian filter to the image. This is important because it affects the quality of the parts separation and their matching results with leftover fabrics. Another important process is pixelization which defines the impression of the final outcome as well as basic specifications such as size of an artwork, grid size, and so on. The size of an artwork defines the overall height and width of the artwork, and the grid size defines the number of cells as well as the height and width of each cell. These specs are conditioned by the size and numbers of available leftover fabrics. After the size of an artwork and the grid size are set, the target image is pixelized resulting in a collections of rectangular cells. We connect these cells to create parts in the parts generation step.

Leftover Fabrics Library as Source Images

Figure 2 shows a part of scanned leftover fabrics. The size of these images reflects actual size of fabrics, e.g., a image with size of 480×720 pixel is 48×72 mm. We expect that fabrics have various shapes as they are leftovers from production lines. After these fabrics are scanned, we made the background color white.

Parts Generation

In this step, we connect rectangular cells by evaluating colors of neighboring cells. Although our workflow could take free-form shapes for parts instead of collections of rectangular cells, we perform pixelization and use rectangular cells. One reason is that it simplified the fabrication process. Another reason is visual effects of a mosaic art. We intend for the art work's whole image to be perceived standing at a distance, and that the detail texture will be apparent when they get closer.

Clustering Cells. After the pixelization of the target image, we perform further image processing for generating parts that are suitable for the later fabrication process. First, we reduce the colors used in the target image by applying k-Means clustering (Lloyd 1982). Through this process we simplify the target image while largely maintaining the overall impression of the image. Moreover, we obtain a color palette (a number of colors used in the image). K-Means clustering automatically categorizes the colors in an image into the specified value of k. It is also controllable by users. By changing the number of clusters (the value of k), users can explore how many colors they use, balancing between visual effect and fabrication workload.

Creating and Adjusting Parts. After clustering, we create parts by connecting neighboring cells based on the assumption that similar color of cells are next each other in the original target image. After creating each part, we modify the details of the parts considering fabrication process. For example, after pixelization of the target image, we often find checkerboard patterns (Figure 4, top-left). In such cases, cells are visually connected but spatially separated, resulting in many isolated parts making fabrication process more tedious. Therefore, it is essential to connect these separated cells without losing the quality of the whole picture. A naive approach would be to scan through each cell and evenly dilate around it. However, this process often changes the whole image structure, especially in cases with a limited number of cells, as is often the case in mosaic art. Therefore, we selectively dilate cells to avoid changing the whole impression of the image.

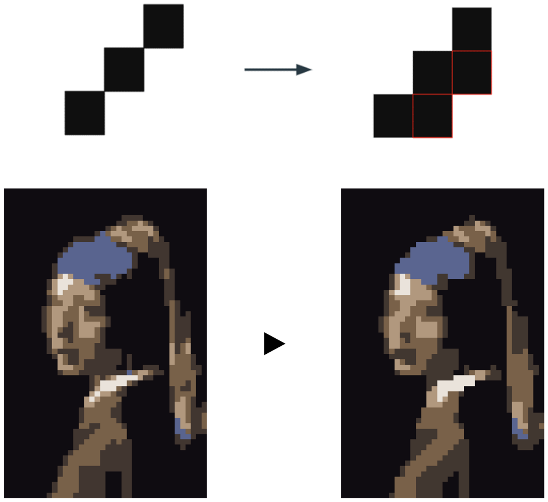

Figure 3: Top: dilation of parts, and bottom: results before and after dilation. As in the bottom left image which is before applying the process, k-means clustering already connected some neighboring cells due to the assumption of gradient color in the target image.

Our dilating process unfolds as follows. For each cell in an image, we count the colors of the eight neighborhood cells that are different from the color of the cell of interest, and find the most frequent color. Then, the cell of interest is replaced by the color. This operation is performed if the same color is found in the eight neighborhood but not in the four neighborhood cells that are top, bottom, left and right cells. The most frequent color in the four neighborhood cells is selected and the cell is filled with that color.

Matching Parts and Leftover Fabrics

The forth step in Figure 1 shows the template matching of combined cells (parts) with source (leftover fabric) images. First we prepare masks for each part. Then, we use them for scanning from top left to right bottom for all the source images. At each position, we calculate similarity score and after scanning all the source images, we obtain the best fabric and its position for each mask. Finally the masks are applied to the selected source images and combined these parts to render a completion image that is a mosaic art using leftover fabrics.

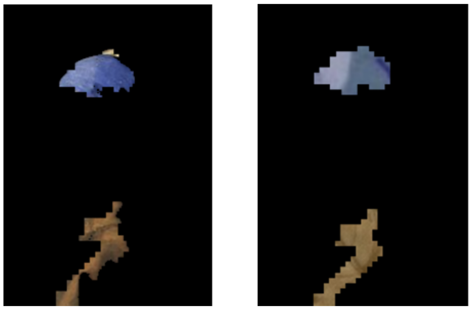

Figure 4: Left: two parts with textures from a target image. Right: parts with textures from source images.

Fabrication

In traditional Kimekomi-zaiku technique, a hard wooden board with surface notches is crafted for tucking fabrics in. As a result, we can achieve a patchwork of fabrics without sewing seams. Instead of wooden materials, we use a styrofoam board with notches by a laser cutter. For fabrics, we manually cut the corresponding areas of fabrics, and then tuck these rough-cut fabric part in notches.

Implementation Details

We used a EPSON GT-X980 scanner to scan the leftover fabrics. The leftover fabrics were provided by a clothing factory. For development, the programming language Python 3.11.5 and the laptop computer (MacBook Air 2021 with M1 chip) were used. The laser cutter used was a Universal Laser Systems Co., Ltd, model VLS6.75.

Results

We conducted a feasibility study of the proposed workflow by creating a mosaic art with the implemented workflow. The sixth step in Figure 1 shows a result of mosaic art works made using actual leftover fabrics. In this case, *Girl with a Pearl Earring* was selected as the target image. The artwork comprised 28 fabric parts cut selected from 71 scanned leftover fabric images. Each image size was 2550 by 3509 pixels. The final outcome image size was set with 200 by 300 mm. A generated vector image was used as cut lines on a styrofoam board with a laser cutter (red lines in the fifth step in Figure 1. We tested the workflow except fabrication step with another image as in Figure 5.

Figure 5: A result of the workflow picturing a swallow.

During cutting and tucking processes, we referred the rendered completion image generated by the workflow. This process did not involve any systematic assistance and was dependent on a user's skills and experiences. Since the proportion of colors varies greatly depending on the chosen area, it is necessary to consider a function to identify areas with a higher similarity. Especially when it came to adjusting detail positions, it was difficult to visually distinguish which leftover fabrics were used. For the other result in Figure 5, we found many small parts. That means the gradient color assumption was not suitable for this case, especially the head of the swallow with high frequency of different colors.

Conclusion

We proposed a computational fabrication workflow that utilizes leftover fabrics for making mosaic art, and created a physical artwork using the developed workflow. This workflow enables novice users to enjoy making mosaic art out of various leftover fabrics. We tested two target images (*Girl with a Pearl Earring* and an image of a swallow), and an actual artwork was fabricated using the first image. Going forward, there are several potential future works. First, it could be more effective use of material to apply semantic segmentation to a target image for parts creation step instead of separating the target image by color. This provides semantically meaningful parts such as head, arms, and hands and so forth, and if the system finds similar parts in leftover fabrics, we could avoid unnecessary cut of fabrics and maximize the original textures of them. Second, rotation of scanned fabric images would contribute to higher quality of matching. Finally, it would be helpful to guide users where to cut leftover fabrics. A simple but effective approach would be cutting fabrics by a laser cutter, however, it is mandatory to align the coordinates of a fabric and a cutting paths.

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