PatchUp: Interactive Patchwork Design for Scrap Fabric Upcycling

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Figure 1: We propose PatchUp, an interactive design tool for upcycling fabric scraps by packing them in an aesthetic way guided by traditional quilt block designs. The newly made fabrics from the scraps can be used for other crafting projects. Here we show three examples made from patchwork fabrics designed using our system. From left to right: tote bag; box T-shirt (toddler size); skirt (adult size). Each example uses a different quilt block to guide the patchwork design. Rectangular boundaries were overlaid on top of the design to delineate the individual strips or the start fabric scrap in the center.

Abstract

Garment making, quilting, and other textile making often involve cutting shapes from fabric sheets, resulting in leftover fabric pieces of various sizes and colors. Typically, fabric scraps are reused for both cost and environmental reasons: downcycled into filler materials or recycled fibers, or upcycled into new creations by crafters and artists. However, optimizing reuse and imagining new possibilities for these varied scraps can be difficult due to the large space of possible layouts and uses. We present an interactive design tool, PatchUp, which helps users create patchwork designs while considering available fabric scraps and reuse efficiency. Rather than solely maximizing reuse through automated packing, which can lead to visually incoherent designs, we introduce novel heuristics inspired by traditional quilt blocks. Our user study shows PatchUp effectively helps users maximize scrap usage while saving them significant manual effort, empowering them to explore new ways to repurpose their scraps and create visually pleasing designs.

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CCS Concepts

• **Human-centered computing** → *Interaction design*; • **Computing methodologies** → *Graphics systems and interfaces.*

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1 Introduction

The process of making textile objects creates fabric leftovers of various colors, sizes, and quality. Since fabric production is a resource- and chemical-intensive process, it can be helpful to consider ways to reuse these materials before sending them to landfill. In factory settings, smaller pieces are typically downcycled into filler materials or recycled into fibers for yarns, while larger, higher-quality scraps can be upcycled into new products [Khairul Akter et al. 2022]. Some fabric recyclers [FABCYCLE 2025; FABSCRAP 2024; Weaver 2025] also directly work with designers, apparel manufacturers, and local maker communities to collect any scraps, such as off-cuts and deadstock fabrics, and sell any reusable scraps to give them a second life.

Among the many ways to upcycle these fabric scraps, *patchwork* is a popular option. The word itself can refer to the technique of assembling pieces of fabrics with stitching, or the objects produced with that technique [Legrand 2023]. These scrappy-looking textile designs have a long history and are created around the world. Patchwork was once common when materials like cotton were more rare and valuable so every little piece was treasured. Today, patchwork has become sought after for its aesthetic appeal, and many individual crafters and artists enjoy using scraps (their own or bought from fabric recyclers) to achieve such a visual style while being environmentally friendly [Carson 2023; O'Flaherty 2023].

Creating a visually attractive and well-constructed patchwork design with fabric scraps is challenging. Fabric scraps often have very different shapes, sizes, and colors, which makes it difficult to manually explore a large space of design possibilities. It is even more challenging if one wants to maximize their scrap material usage and ensure the final patchwork piece is large enough for an upcycling project. Existing patchwork design tools [Igarashi and Mitani 2015; Leake and Daly 2024] focus on visual aesthetics and design freedom, so the created designs may not be using scraps as effectively or sustainably as possible. In this work, we present PatchUp, the first material-centric patchwork design tool for creating upcycled fabric sheets efficiently. PatchUp starts from the users' scraps and helps them create visually pleasing designs that efficiently reuse the available materials.

Given the available scraps, putting them together to cover the largest possible 2D region can be seen as a form of 2D bin packing problem, which is well-studied [Iori et al. 2021; Jylänki 2010]. However, solely focusing on maximizing the final packed area and the scrap material usage through an automatic method could lead to visually incoherent designs because existing automatic methods do not consider fabric colors or other visual properties. Thus, we need a way to bridge user control over the aesthetics of the design and packing optimization.

To address this challenge, we take inspiration from patchwork quilting. Our main insight is that some quilt blocks lend themselves well to efficient and aesthetically pleasing packing due to their sequential strip structures. First, traditional quilt blocks often follow visual design principles, such as balance and harmony. Second, the strip structures serve as intermediate design steps, breaking down the patchwork design choices into sequentially added strips that could be laid out in visually meaningful ways. This allows us to expose to users the high-level design decisions of selecting strips while still allowing efficient optimization through mixed integer programming to maximize scrap reuse in each strip. Specifically in this work, we use three pieced block patterns made of strips [Brackman 2021]: log cabin, courthouse steps, and rail fence (shown in Figures 1 and 5). In addition, the strip structure enables relatively straightforward sewing, and PatchUp automatically generates fabrication instructions.

We showcase PatchUp's design capabilities with three upcycling projects created with patchwork fabrics designed using our tool (Figure 1). To further evaluate our quilt-block-inspired packing algorithm and the design tool, we conducted technical evaluations of the algorithm (Section 6) and a user study with our interactive packing interface (Section 7). Participants generally found PatchUp helpful in using scrap material efficiently and reducing manual effort needed to create the patchwork design and felt inspired to create more upcycled textiles from their scraps.

2 Background and Related Work

In this section, we present a brief overview of quilting, the craft from which our design tool takes inspiration. Next, we survey topics relevant to our work in design tools for patchwork, collage design, and minimizing material waste.

Quilting. Quilting is a process that involves designing a layered textile object. Often, three layers are involved: the decorative top layer where design elements are placed, the batting middle layer, which creates warmth and volume, and the plainer backing layer [Legrand 2023]. The top layer usually involves the main visual design created through patchwork (piecing multiple fabrics together with sewing) or appliqué (fixing fabrics of desired shapes on top of others).

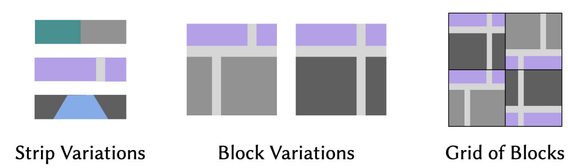


Figure 2: Quilt design can be broken down into a hierarchical structure, starting from deciding on fabrics, then individual strips and blocks, and finally the layout of the blocks.

Many quilts are block-based, meaning that a single geometric pattern is repeated in a grid layout (Figure 2 right). Common geometric shapes can be found in the block patterns, including rectangles, squares, diamonds, and triangles (Figure 2 middle). In this work, we focus on block patterns that mainly consist of rectangles as shown in Figures 1 and 5. Combinations of these rectangles produce "strips" (Figure 2 left). We center the design variations around the strips since they correspond to how quilters typically construct blocks and ultimately larger patchwork quilt tops.

Design Tools for Quilting and Patchwork. Prior work has focused on different aspects of the quilt-making process. Some have developed algorithms for generating free-motion quilting (also called stitching or thread painting) paths to display certain imagery on the quilt top [Carlson et al. 2015; Li et al. 2019; Liu et al. 2017] when joining multiple layers into a quilt. Most other works look at the quilt top design, or patchwork design, including interactive tools for visualizing patchwork designs [Igarashi and Mitani 2015], and for designing paper pieceable quilt tops [Leake et al. 2022, 2021a], bargello quilts [Coahran and Fiume 2005], and improvisational quilts [Leake et al. 2021b]. Recent work has also explored ways to support patchwork design using fabric scraps. ScrapMap [2024] supports generating traditional scrappy quilt patterns, optimizing to satisfy color constraints assuming that users work with a few large scraps of different colors from which pattern elements can be cut. However, it only checks fabrication feasibility afterward and does not prioritize scrap reuse efficiency. In this work, we focus on optimizing scrap material reuse; our goal is to allow users to upcycle many smaller scraps into a larger piece of patchwork for other sewing projects, while balancing reuse efficiency and aesthetics via quilt-block-inspired layouts.

Collage Design. Closely related to patchwork is the craft domain of collage. Collage is a form of visual arts that involves gluing elements together [Leland 2011]. The concept of collage has been widely employed and evolved in domains such as visual arts (paintings, sculptures, etc.), architectural design, and landscape design [Adibi 2021]. Patchwork or quilt top designs can also be thought of as collages of fabrics; in fact, there are glue-based techniques for creating quilt tops such as fusible appliqué.

Paper collages and photo/picture collages are the most similar to fabric collages. Several computational methods [Battiato et al. 2007; Goferman et al. 2010; Huang et al. 2011; Rother et al. 2006; Wang et al. 2006] have been developed for photo collage, and the focus is to figure out an optimal placement and transform (scaling and rotation) of images so that the collage looks like some other input imagery or shape. Fabric collages also need to consider visual features when placing elements, but creating collages using scrap materials is constrained by the actual sizes of scrap pieces. Shinjo et al. [2024] created a workflow that takes in an image and converts it to a mosaic art pattern that can be recreated using scraps by tucking scraps onto a laser-cut board. Our work focuses on helping users maximize scrap reuse while still having some level of artistic control over the fabric collage design. We also provide sewing assembly instructions so that the outputs can be used as material sheets for new objects.

Minimizing Waste through Packing. Bin packing and cutting problems have been widely studied in industries like furniture, fashion, logistics, and manufacturing where it is desirable to have zero/minimal-waste designs and packaging to save space and materials [ElShishtawy et al. 2022; Fırat and Alpaslan 2020; Koo et al. 2017; Zhang et al. 2024]. Computational design systems have also been proposed to support the goal of reducing waste [Saakes et al. 2013; Sethapakdi et al. 2021] and reusing materials [Qi et al. 2025] via packing. In rare cases, packing considers aesthetic goals for creative applications, such as photo layouts [Reinert et al. 2013].

The traditional bin packing problem involves packing rectangles into a fixed-size rectangular bin, and is known to be NP-Hard. Variations of the problem explore different parameters for (1) the dimensionality (usually 2D, but there are 1D and higher dimensional variants); (2) the kinds of shapes to pack (orthogonal, irregular but polygonal, or any general shapes); (3) the optimization goal (e.g., minimize number of bins required, minimize material/space waste); and (4) the constraints (e.g., the guillotine constraint which means only edge-to-edge cuts are allowed [Pietrobuoni 2015]).

Usually, bin packing problems are solved by heuristic-based optimization methods (for a thorough review of recent exact methods and relaxations, please see [Iori et al. 2021]). Our packing approach differs from typical bin packing problems in several key ways. First, we do not pack towards a fixed-size bin. Second, we require the packing to have no holes while classical bin packing/cutting does not enforce that there are no gaps between the shapes. Third, we want to maximize the amount of scrap fabrics used. Lastly, we allow scraps to be cut during packing and keep track of the cut-off shapes if their dimensions are larger than 1 inch.

A related problem to bin packing is the polygon covering problem, where the goal is to cover a polygonal region, often with constraints such as rectilinearity, using the minimum number of simple geometric shapes like rectangles [Hanauer et al. 2023]. This problem allows arbitrary shape overlap and produces a no-gap covering. However, the shapes can take any size needed to cover the input shape, and thus cannot reflect the physical size constraints of using actual fabric scraps.

Given these special constraints imposed by working with fabric scraps intended to be sewn into sheets for reuse, in this work, we present a novel packing algorithm where the structure and visual appearance of the packing result is inspired by three traditional quilt blocks.

3 System Overview

PatchUp allows users to interactively design a "new" fabric from their fabric scraps (Figure 3). Our system design was informed by a formative study to understand how crafters work with fabric scraps. We interviewed five quilters who regularly work with scraps about their processes, and reviewed books [Brackett 2013; Cier 2011; Ebben 2008; Harrison 2023; Tarr 2022; Vandenbosch 2015] and online blogs [Amy 2023; Holt 2013; janomeman 2020; Knight 2023; Nelson 2018] on topics including reusing scraps and scrappy patchwork. From the study, we learned that scraps are usually sorted by fabric properties such as color or print, size or shape, and material. Then makers create strips and patchwork from these sorted and organized fabric bins. Many makers also trim their scraps into rectangular pieces or pieces with straight edges, which are easier to sew than oddly shaped or curved pieces.

Therefore, our design tool uses a two-phase aproach that first sorts fabric scraps into bins (*binning*) and then packs rectangular strips made from scraps (*packing*) (Figure 4).

3.1 Design Tool Walkthrough

We now walk through how to use PatchUp with an example design guided by the Rail Fence packing strategy (Figure 8a, rightmost).

The user starts by uploading photos of fabric scraps, and PatchUp provides a semi-automatic pipeline to extract individual fabric images (Section 4.1). In our example, the user uploaded photos of linen and woven fabric scraps bought from an Etsy shop.

Next, the user groups fabrics into bins based on different criteria, such as color tone, color brightness, or patterns. Our tool provides automatic sorting based on color properties and also allows manual drag and drop to sort the fabrics (Section 4.2). For the Rail Fence design, the user groups the fabrics into three bins by "Color Tone + Brightness" and manually adjusts the bins to get the three bins as shown in Figure 4a: darker fabrics, the earthy color tones, and the floral patterns. For easier reference, the user renames the bins to "Dark", "Earthy", and "Floral".

The user then selects a packing strategy inspired by different quilt blocks (see Figure 5) and enters the packing stage. During packing, the user chooses strip options to pack. They can preview their current design and its estimated size, and stop when it reaches a desired size or an overall pattern they like. When generating the next set of options to choose from, users can optionally select which one or more fabric bins they would like to use for generating the strip options, or express preferences through ranking criteria or aesthetic control constraints (Section 4.3). For any generated strip option, the user can click to open a reorder panel that allows

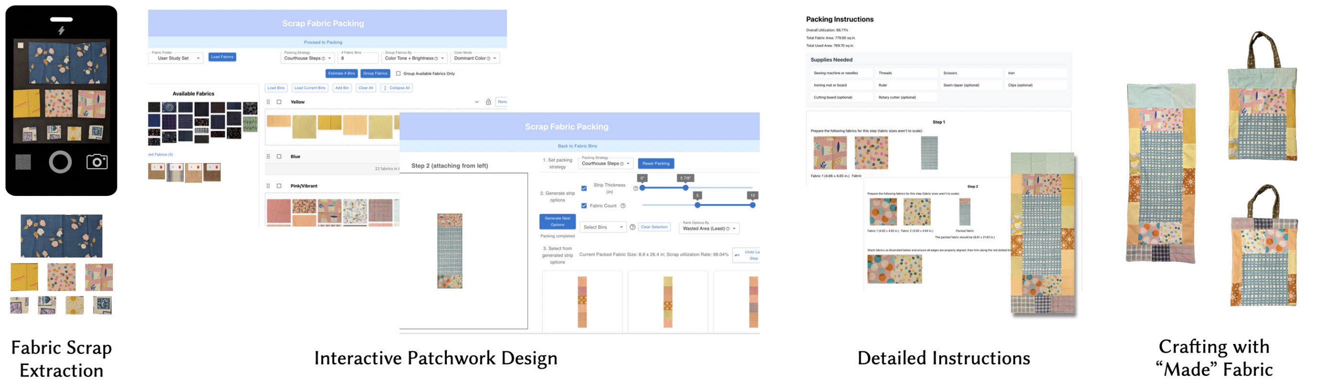


Figure 3: PatchUp's workflow. The user begins by uploading photos of their scraps. Our tool automatically extracts the scrap boundaries and sizes. They then use the UI to sort their fabrics into bins and select strip options. The tool automatically generates detailed instructions, and then the user can sew the resulting patchwork sheet and create any item they wish with it, such as a tote bag.

(a) Binning UI. B1: loading fabric scrap sets. B2: the area displaying available scraps to be binned (empty means all are sorted into the bins). B3: available controls for automatic binning. B4: the area displaying fabric bins.

(b) Packing UI. P1: packing strategy selection and additional parameters if any. P2: controls that influence strip option generation. P3: generated strip options and information about current packing. P4: the patchwork design in progress. P5: the area displaying instructions.

Figure 4: PatchUp's UI screenshots. The example design here is discussed in more detail in Section 3.1.

them to drag-and-drop to reorder fabrics and obtain their preferred permutation. For the example design (Figure 4b), since Rail Fence is chosen as the packing strategy, an additional parameter, the start length of the first sub-block, needs to be specified. Here the user specifies 10 inches. For each sub-block, the user selects one strip from each bin (Dark, Earthy, then Floral), ensuring roughly similar sizes (in this case close to squares) using the Strip Thickness slider. The user also chooses to sort based on low color tone contrast within each strip for crafting their material sheet.

Finally, the user generates detailed instructions for how to construct the design (Section 4.4). Our system takes into account seam allowances so that the design can be successfully pieced using a user-selected standard seam allowance. After constructing this patchwork fabric, the user can use this new fabric for a wide range of applications, such as home accessories or garments.

4 Methods and Implementation

PatchUp is implemented as a web app that uses ReactJS for the frontend and Flask in Python for the backend. The software is available at https://github.com/merlinyx/patchup. Next, we explain in detail the methods in each step of the system workflow.

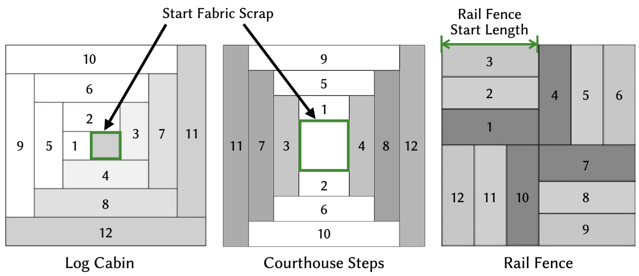
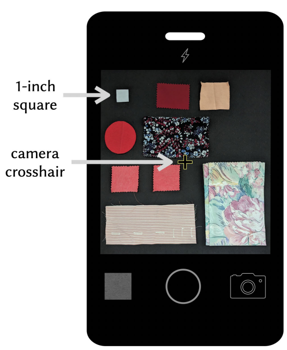


Figure 5: Three quilt blocks we take inspiration from and their corresponding strip packing sequences. Based on which quilt block to use as a guide, the strip options generated will be matched to a different target length (see Target Length Constraint 2). The Log Cabin design will first match to the left side of the start fabric, the top side, the right side, and the bottom side, and then repeat the sequence. The Courthouse Steps design will match to the top, bottom, left, and right sides and then repeat. The Rail Fence design requires a start length parameter L_S as the target for the first strip and does not continue beyond the 12-strip pattern.

4.1 Scrap Fabric Image Extraction



To input scrap fabrics into the system, the user takes a photo of the scrap pieces placed on a flat surface, ideally with the pieces ironed flat. The background surface should contrast with the scrap pieces to make the boundaries of each piece visible, and the camera should be level and right on top of the surface. A 1-inch-square piece of paper needs to be placed in the top left corner of each photo for calibration purposes. The recommended photo setup is illustrated in the inset figure.

We then use a semi-automatic method to segment the fabric images from the photos. Our algorithm uses opencv [OpenCV 2025] to automatically traces the boundaries of each piece; we apply erosion with kernel size 5 for three times on the Gaussian-blurred input photo, and extract the contours with area above a certain threshold, keeping only the top n contours where n is the number of items (including the calibration square) in the photo that the user provides. The user can manually adjust any errors or missed boundaries in the UI. Our system estimates the dimensions of each scrap fabric based on comparisons with the 1-inch calibration square.

Although the fabric scrap pieces might not always be perfectly flat or rectangular, we choose to extract the largest rectangular region from each fabric image and only consider the maximum inscribed rectangle of each scrap for simplicity. In our examples, including those from the purchased scrap bags, this assumption only led to an average of 3% material waste the scraps at this phase. However, this waste could be greater for scrap sets with highly irregular boundaries.

4.2 Fabric Binning

PatchUp enables users to easily sort fabric scraps by color tone (or hue), color brightness (or value), and color (LAB space color). In addition, the users can select whether they want to use the dominant color (the most common color in the scrap image) or the average color. Users can decide on the number of bins or let the tool suggest a number of bins. We compute the distances of the colors of fabric scrap images following the CIE 1994 textile color difference formula [Lindbloom 2017], and apply hierarchical clustering with the computed color distances.

Fabric bins provide a way to filter the fabrics being used for strip option generation. As the design progresses and strip pieces are added to the textile sheet, fabrics can be used up or trimmed further. PatchUp keeps track of these changes for the users, logging which fabrics have usable scraps remaining. If a bin runs low on fabrics or the user does not like how the generated options look, they can modify the fabric bins throughout the packing process.

4.3 Strip Option Generation

A strip option can be thought of as a combination of different fabrics, or more precisely, fabric image edges (see Figure 6). We treat each scrap fabric as having two edges, one for the width and one for the height. The problem we need to solve is essentially coming up with sets of edges that sum up to a specific target length. The target length at each step of the packing process is automatically determined based on the user-selected quilt block and the start fabric scrap (plus the start length parameter if the quilt block selected is Rail Fence), as illustrated in Figure 5. In addition, in order to leave no holes in the packing, we need edge sets with sums no less than the target length, and we also need to consider the user's visual preferences. We formulate this edge selection problem as a constrained mixed-integer programming problem and use Gurobi [Gurobi Optimization, LLC 2024] to solve for solutions.

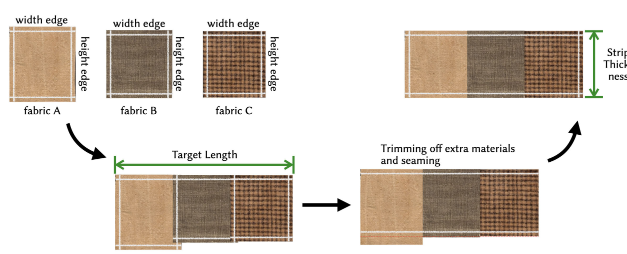


Figure 6: An example strip option and its strip thickness illustrated. Three fabrics A, B, C are selected to form this option because their edge lengths sum up to the target length ($w_A + w_B + w_C \geq L_T$). In this case, the strip thickness is the height edge length of fabric C because $h_C = \min(h_A, h_B, h_C)$.

For each fabric f in the input fabric collection $\mathcal{F}$, we introduce two binary variables e_f^w and e_f^h, indicating whether the width or height edge is selected (variable equal to 1 means selected). Selecting the height edge implies that the fabric is rotated by 90 degrees before being attached to the strip.

The edge selection formulation includes the following types of constraints:

Validity Constraints. These constraints ensure that the generated strip option is valid:

(1) Same Fabric Constraint: each fabric can only contribute one edge to a strip;
(2) Target Length Constraint: the total length of selected edges must meet or slightly exceed the target length.

Aesthetic Control Constraints. These constraints are imposed on two properties of strip options:

(1) Strip Thickness: computed as the minimum length of the unselected edges within a strip, determines how thick the strip to attach will be;
(2) Fabric Count: computed as the number of fabrics within a strip, determines how scrappy this strip will look like and how many seams need to be sewn.

Depending on what style the user prefers, they may adjust a slider to indicate that they want thicker strips or thinner ones, or they want to use more or fewer scraps in the strips.

Because we want to make sure the packing is as efficient as possible, we define the optimization objective to be minimizing wasted fabric area. Wasted area is computed by considering (1) fabric portions that extend beyond the strip thickness and (2) any excess length beyond the target length.

After generating multiple valid strip options, users can rank them according to the following ranking criteria:

- Wasted Area (Ascending): the same as the optimization objective; it prioritizes reuse efficiency;
- Color Contrast (Ascending or Descending): the contrast of fabric colors within a strip option; it prioritizes either consistent or differing colors;
- Color Tone Contrast (Ascending or Descending): the contrast of fabric color tones (or hue) within a strip option; it prioritizes either consistent or differing tones;
- Color Brightness Contrast (Ascending or Descending): the contrast of fabric color brightness (or value) within a strip option; it prioritizes either consistent or differing brightness.

All the above constraints, objective functions, and ranking criteria can be expressed as functions of the edge selection variables e_f^w and e_f^h. Details about the problem formulation can be found in Appendix A.

4.3.1 Solver Implementation Details. Since MIP solvers like Gurobi find only one solution at a time, we used a custom solution callback to store any solution found. To ensure that the solutions are different, in the callback function we add new constraints ensuring the next solution found is different from the existing solutions. To keep the UI responsive, we set a time limit for the solver. In general, the solver quickly finds a variety of options, ranging from 0 to 90+, depending on the available fabrics to use and the user-set constraints. For reference, the average API response time in a typical user session is 0.25 seconds when working with 40+ fabric scraps , and 0.6 seconds when working with 80+ scraps.

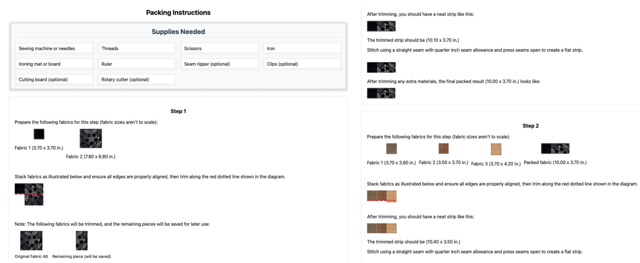


Figure 7: Screenshot of the instructions for the Rail Fence design in Figure 8a, rightmost, discussed in the tool walkthrough (Section 3.1).

4.4 Assembly and Instructions

When the user finishes the design, detailed instructions for fabricating the design will be generated and can be exported as a PDF. During the design process, the tool keeps track of each step's selected options and the side it will be attached to, and it puts together the instructions using the saved information. PatchUp takes into account one-quarter-inch seam allowances for seaming together fabric scraps to ensure the design can be physically assembled. Figure 7 shows the first two steps of the instructions for fabricating the Rail Fence design (Figure 8a, rightmost).

5 Results

To explore the design capabilities of PatchUp, we ran experiments with both physical and digital inputs. Our physical inputs included three fabric scrap bags (one from FABSCRAP [FABSCRAP 2024] and two from Etsy). The scrap bags were random collections provided by online sellers with no pre-determined sizes. We photographed and digitized these scraps using the process described in Section 4.1. For our purely digital inputs, we compiled a test set of fabric images using Creative Commons Adobe Stock images and tilable fabric textures [Váncsa 2025]. In the rest of this paper, we refer to these different input scrap sets as FABSCRAP, Etsy Cotton, Etsy Linen, and Stock Image Textured. Statistics about the scrap size and shape distribution can be found in Table 1.

With PatchUp, we can easily create design variations through different packing strategies (Figure 8a).

Without changing the packing strategy, we can also achieve significantly different designs through the various constraints and option ranking methods available to control the final design. The left and middle columns in Figure 8b illustrate the impact of the strip thickness filtering, where the left design uses a 3-5 in. constraint on all the strip options and the middle design uses 1-3 in. Figure 8c shows the control provided by one of the option ranking methods, where we sort the options by contrast of color tone within a strip. The left prioritizes high contrast while the right prioritizes low contrast, and we can see that the right tends to have more uniform-looking strips while the left looks a bit more scrappy and chaotic.

Fabric bins have a significant impact on the design as well. In Figure 8b, the middle and right designs show that given the same packing strategy and thickness filtering, the designs can still look different due to how the fabrics were binned. More specifically, the middle design grouped the scraps into two bins with roughly a warm color tone and a cool color tone, then creating a divide of

Table 1: We compute some statistics about the size and shape distributions about the scrap sets. The Max Aspect Ratio measures whether the set has extreme width/height ratios for the shapes, and Square % measures how many of them are close to squares (aspect ratio≤1.1:1). The Size Range computes the minimum and maximum of all widths and heights of the scrap pieces.

Dataset	# Scraps	Square %	Max Aspect Ratio	Size Range	Characteristics
Etsy Cotton	98	40.8	3.2:1	2.40−17.56in	Mixed sizes, elongated rectangles, more rectangles
Etsy Linen	46	60.9	1.4:1	1.70−8.85in	Mixed sizes, more squares
FABSCRAP	31	41.9	2.5:1	0.94−14.08in	Highly variable sizes, more rectangles
Stock Image Textured	80	61.3	4.7:1	2.06−9.91in	Mixed sizes, some elongated rectangles

warm and cool tones across the diagonal, while the right design used more granular binning, with four bins corresponding roughly to yellows, pinks, blues, and mixed colors and each covering one side of the square.

Lastly, we validate our tool's instruction generation by fabricating patchwork designs created with the tool and using them for upcycling projects (see Figure 1). We did not encounter any erroneous instructions as we followed the generated instructions to build these designs, each with 6 to 12 strips to put together.

6 Technical Evaluation

We evaluate our proposed packing algorithm by testing it with different distributions of fabric scrap shapes, as well as comparing it with existing bin packing algorithms with open-source implementations. Since no user would be present for this evaluation, we make our method automatic by (1) automatic binning based on fabric edge lengths; (2) not specifying any aesthetic control constraints; (3) always selecting the least wasted area strip option to pack in each step until no more options are available. We also evaluate the physical accuracy of our image extraction method.

6.1 Testing with Different Distributions of Fabric Scraps

To understand the differences between the packing strategies and how well they might work with different distributions of fabric scraps, we tested them with the three fabric scrap sets bought from online sellers (discussed in Section 5), and additionally eight generated sets of more extreme size distributions to probe edge case performance. The generated sets are single-color images and by default, each has a 20% probability of being a square. For each test set, we vary the distribution of fabric scrap sizes, and in some cases, also the square probability.

We use the following metrics when evaluating the algorithm efficiency: (1) reused: the total area of scrap pieces that get reused in the patchwork design; (2) wasted: the total area of cut-off pieces that are too small to be reused again; (3) unused: scrap pieces that are not used in the current design but can be used in a different design. The breakdown of percentages of reused, wasted, and unused scraps for each test case using each quilt-block-inspired packing strategy is shown in Figure 9.

Our packing algorithm wastes little material: on average, the wasted percentage is 3.63%, with the three fabric sets' average being 0.75% and the generated test sets' average being 4.71%. The Log Cabin and Courthouse Steps strategies have reuse efficiency range in 70-95% and Rail-Fence ranges 8-52%. The Rail Fence strategy is expected to have a lower reuse efficiency because we consider it as a strategy that only packs 12 strips as shown in Figure 5, as opposed to Log Cabin and Courthouse Steps, which can continue to pack infinitely as long as there is enough material.

We observe that among the generated sets, the set with similar-sized scraps appears to have the highest reuse efficiency using all three strategies. When there are imbalances between sizes of scraps, both Log Cabin and Courthouse Steps produce relatively higher waste. This could suggest that a collection of similar-sized scraps could get reused more efficiently through our packing method (comparing Similar Sized with Power Law and Bimodal in Figure 9). All three packing strategies produce relatively higher waste if 80% of the shapes are squares (Figure 9 Square Heavy). This means that to reuse scraps more effectively through PatchUp, it would be good to have a more balanced ratio between rectangular pieces and square pieces.

6.2 Comparing with Automatic Bin Packing

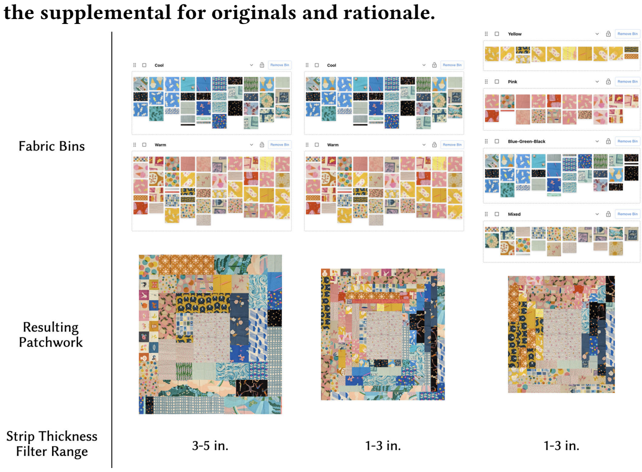
The three open-source implementations we compared against were Strip Packing [Mxbonn 2025] (based on [Zhang et al. 2016]), Guillotine Packer [Schroeder 2024] (based on [Jylänki 2010]), and RectPack [secnot 2025] (based on [Huang and Korf 2013; Jylänki 2010]).

Comparison Setup. We used the following setup to be able to compare our methods with the automatic bin packing methods:

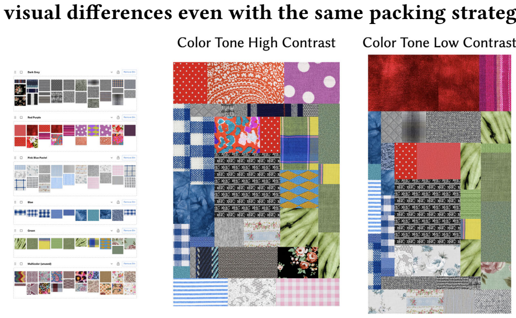
(1) Because bin packing methods require a bin size to start with, we applied a grid search for the best width and height parameters so that all fabric scraps could be packed into a single bin. Our method does not require additional parameters like bin size but when the Rail Fence packing strategy is selected, a start length parameter is required (the width of the first sub-block) so we applied a grid search for this parameter in a similar fashion.
(2) Since bin packing methods do not consider seam allowances, we set the seam allowance to zero in our method.
(3) Our algorithm always generates hole-free packing. Since bin packing does not guarantee that the result has no holes, we compute the largest gap-free area within the packed bin (dark red rectangle in Figure 10b).

We used the fabric scrap sets FABSCRAP, Etsy Linen, and Etsy Cotton for the comparison and here we discuss the results of FABSCRAP in more detail; the other sets' results are similar and can be found in Appendix D. For FABSCRAP, our proposed packing algorithm reuses fabric scraps efficiently, generating very little waste (<1%, see Figure 9 first three bars). Log Cabin and Courthouse Steps

(a) Using the Etsy Linen fabrics to create designs with all three packing strategies. Notice that the designs still resemble their quilt block guides and look distinct even when the same set of scraps and the same bins (see Figure 4a) are used. Note: floral fabrics were recolored here to improve contrast and avoid unintended visual patterns; see the supplemental for originals and rationale.



(b) Using the Etsy Cotton fabrics to create designs with Log Cabin. Binning variation: the first two columns use the same bins where the fabrics are grouped into a bin of Cool colors and a bin of Warm colors. The third columns use a 4-bin grouping where fabrics are grouped into "Yellow", "Pink", "Blue-Green-Black" and "Mixed". Constraint variation: the first column filtered the strip thickness to be within 3-5 in. while the last two columns used 1-3 in. Both variations bring about visual differences even with the same packing strategy.



(c) Using the Stock Image Textured fabrics to create designs with Courthouse Steps. Ranking variation: by changing how we sort the generated options and prioritizing high contrast or low contrast within the strip, even when the bins are the same, the visual results are conspicuously different.

Figure 8: Possible design variations using PatchUp.

make use of 86.5% and 83.6% scraps, respectively. Rail Fence makes use of fewer scraps and produces a smaller patchwork because it stops after completing the 12-strip pattern.

Compared to our approach, where not all fabrics are used, bin packing methods can always use all of the fabrics when packing towards the right bin size. However, the resulting packing results have gaps and thus are not suitable to be used as a plan to make a sheet of fabric from scraps. If we look at the dark red rectangles showing the gap-free regions, their sizes are similar to that of the Rail Fence result and moderately smaller than that of the Log Cabin or Courthouse Steps result. In addition, the visual styles of the results of our method and the bin packing methods are distinct because our packing is guided by quilt blocks with specific strip structures and layouts. Due to the inherent visual properties like symmetry from the quilt blocks, our method generates more aesthetically pleasing results.

6.3 Dimensional Accuracy

To evaluate the accuracy of the calibration method used in image extraction and the packing algorithm, we measured the dimensions of fabricated designs and compared them with the computed dimensions. As shown in Table 2, the relative error is less than 5%. This suggests that our tool provides a good estimate of how large the final design would be, which is important when the user intends to use the final design for a pattern that calls for a specific size.

7 User Evaluation

To understand how PatchUp can support users in efficiently reusing scraps while providing sufficient control over the final patchwork design, we conducted a user evaluation with crafters.

7.1 Participants

We recruited 10 participants with varying levels of experience making textile crafts and using scrap fabrics. As shown in Table 3, textile crafting experience ranged from a few months to 50 years, and eight participants have used scraps in projects before. Among the 10 participants, 3 are members of a local quilt guild (P6, P7, P9), and the other 7 participants are part of local crafting interest groups.

7.2 Study Procedure

The study sessions were conducted one-on-one, and each lasted 60-75 minutes. The experimenter started by obtaining consent to record the participant's screen actions and the conversations during the session. In the first 15-25 minutes, the experimenter first demonstrated the tool with a test set of images. The participant then freely interacted with the tool and asked any questions during the process to familiarize themselves with the tool. Next, the participant was asked to complete two design tasks.

Task 1: [Playing with Contrast] Imagine you're designing a pillowcase for a living room. Create a design that makes use of contrasting colors.

Task 2: [Scrappy Fabric for Tote Bag] Imagine you are working with a stash of fabric scraps that you accumulated over the years. Now you want to create a new piece of fabric from these fabric scraps that can be used to make a tote bag (assuming that for a simple tote bag design, this new piece of fabric will

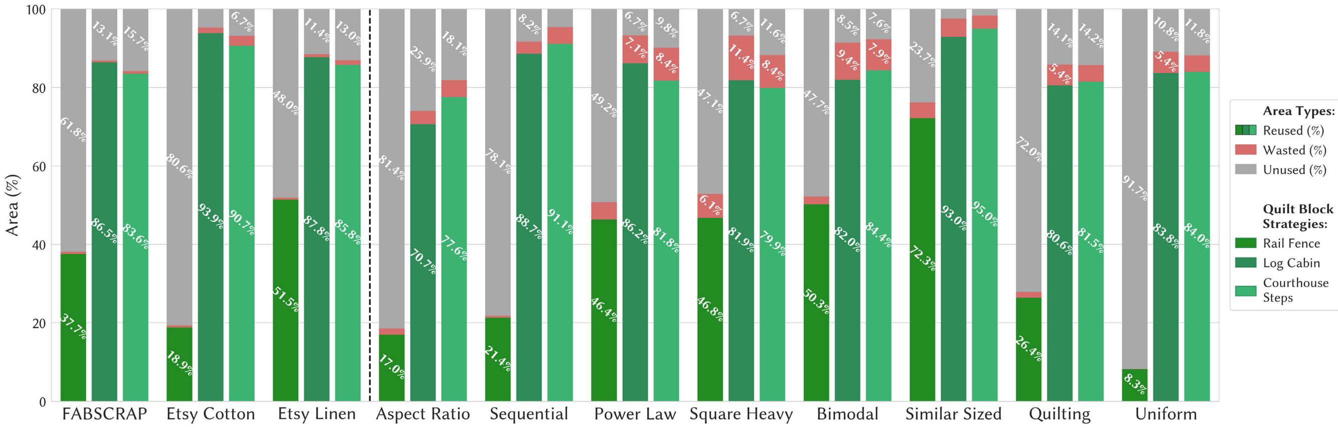


Figure 9: We plot the reused, wasted, and unused percentages of a given test case for each quilt-block-inspired packing strategy. The first three test cases are sets of actual fabric scraps and the other eight are generated test sets of different shape distributions. Aspect ratio: 70% are high-aspect-ratio rectangles (between 5:1 and 10:1); Bimodal: 60% near min size, 40% near max size; Power Law: 60% small sizes, 30% medium sizes, 10% large sizes; Sequential: uniformly increasing sizes; Similar Sized: the sizes are within 10% to 20% of each other; Square Heavy: 80% are squares of different sizes; Quilting: 80% are standard quilting fabric sizes such as Jelly Rolls (2.5 in. strips), Charm Packs (5 in. squares), Cake Layers (10 in. squares), Coins (6.5 in. squares); Uniform: all random sizes. The size ranges (unitless for the generated sets) are 50-500 except for Square Heavy, Bimodal, and Similar Sized, which is 50-200. More detailed settings about these generated sets can be found in Table 4.

(a) Our method with three packing strategies. The packing results' areas are as follows: Rail Fence - 343.55 in^2; Log Cabin - 789.02 in^2; Courthouse Steps - 762.17 in^2.

(b) Three automatic bin packing methods. The packing results' largest gap-free areas out of total bin areas are as follows: Strip Packing - 325.21 / 1051.49 in^2; Guillotine Packer - 323.13 / 968.83 in^2; RectPack - 485.41 / 946.00 in^2.

Figure 10: Packing results comparison between PatchUp strategies and three bin packing methods. The dark red rectangles indicate the largest gap-free rectangles within the bin packing results.

Table 2: Comparison of computed and measured dimensions with error percentages. Fabricated examples were close to the tool's predicted dimensions. Some amount of error or ease is often present in sewing, and these error values are consistent with typical patterns and sewing errors.

Fabricated Item	Computed (W×H)	Measured (W×H)	Width Error (%)	Height Error (%)
Tote Bag Design (Figure 1 left)	13.50 × 34.14 in.	13.88 × 35.25 in.	-2.74%	-3.15%
Box T-shirt Design (Figure 1 middle)	27.10 × 24.00 in.	27.88 × 24.50 in.	-2.80%	-2.04%
Skirt Design (Figure 1 right)	25.50 × 50.20 in.	26.42 × 52.75 in.	-3.71%	-4.83%
P5's Design (Figure 13b)	19.04 × 19.48 in.	19.20 × 19.75 in.	-0.83%	-1.37%

be folded in half and sewn together on two sides, leaving one opening, to form the bag body, and then the bag handles will be attached later).

Following each task, the experimenter asked open-ended questions specific to each task, focusing on how the participants approached the task and how they thought about the experience using the tool.

After the tasks, participants were asked to fill out a post-study questionnaire on the tool's usability, what they liked or disliked

Table 3: Summary of user study participants. Participants had been sewing for 1-50 years, and all but P2 and P3 had experience working with scrap fabrics, reflecting a range of experience levels with patchwork.

ID	Gender	Age	Years of Sewing Experience	Used Scraps Before?
P1	F	25–34	15	Yes
P2	F	25–34	~2	No
P3	F	25–34	2	No
P4	M	25–34	~5	Yes
P5	NB	25–34	2	Yes
P6	F	35–44	2	Yes
P7	F	25–34	5	Yes
P8	F	55–64	~50	Yes
P9	F	35–44	11	Yes
P10	F	25–34	~1	Yes

about the tool, and how it could be improved. The experimenter also asked some general questions about the tool and the participants' experiences with using scraps.

At the end of the sessions, the experimenter followed up with the participants asking if they would like to try to use PatchUp with their own scraps. Four participants showed interest, and we were able to schedule in-person sessions with P4 and P5. Prior to the follow-up sessions, participants brought their scraps to the experimenter, who helped with digitizing the fabrics. During the follow-up sessions, the participants designed using their own scraps and fabricated their own designs (see Figure 13).

7.3 Results

Participants said that they generally felt positive about PatchUp, finding it helpful for maximizing scrap usage and allowing them to create visually pleasing designs (Figure 11).

7.3.1 Tradeoffs between scrap reuse efficiency and the visual design. Participants generally agreed that PatchUp effectively helped them maximize scrap fabric usage (Figure 11 No.4). However, interestingly, when asked about whether they prioritized saving materials during the design tasks, most of them said they did not consider the wasted area of each strip option and the reuse efficiency of the current design. This indicates they valued this material savings and trusted the tool to help them use scraps efficiently but they did not necessarily focus closely on this throughout the design process. Several participants said that they felt the tool did a good job of keeping track of the remaining scraps and the scrap reuse efficiency for them. P6 noted, "I did not think so much about the scrap utilization ... I knew I could see that it was keeping track of it." P8 said, "This puts a number to [reuse efficiency], which is kind of nice ... I can focus on the creativity and what my eye sees." Similarly, P10 highlighted that the tool "eases the cognitive load of trying to save the material." Some participants (P4, P9) said they were just happy to be using *any* scraps from their pile.

Participants also appreciated that the tool would save any cut-off portions that are still large enough for later use. P1 said "I didn't really think about the scrap material saving. I think the fact that there are so many scraps made me feel like ... I could just pick and choose anything I wanted ... I like the idea that when you cut off the scraps, you're going to have more." She found the experience "empowering" because it changed her mindset from thinking how she could "simply utilize all the scraps as much as possible" to thinking how she could actually design something she wants with the scraps. P2 thought the tool helped "lower the mental load of keeping track of all of the different scraps and what they might look like when half-way used." P5 also really liked that "the tool was actually keeping track of that for me by virtually cutting it and reincorporating it." P8 noted though that aiming to reuse the leftovers put additional pressure on cutting the pieces correctly.

7.3.2 Supporting design exploration and providing user control. When asked about what they liked most about the tool, participants highlighted the automatic binning (8 of 10) and strip option generation (7 of 10) features. They valued the abundance of variations and the ability to rearrange, sort, and personalize options.

Participants said that they liked the variation in the design suggestions. For example, P2 said "I like that it inspired me on how different bins could look or what was missing" when describing the automatic binning. P2, P9, and P10 liked the novelty of seeing subsequent generated strip options. P2 reflected in the post-study conversations that during Task 2 (see Figure 12 left) she was at one point not sure what would be good to add to the design next, but when she scrolled through the available options and saw a strip option with yellows, she found it effectively counterbalanced the blues and immediately knew that it was what she wanted. P9 had a similar experience: after Task 1 (see Figure 12 right), she said "I liked ... whatever came up ... that little tiny stripe of blue plaid is kind of delightful there." And she found the abundant options available helpful in creating the chaotic look she wanted in her design. P10 found the Wasted Area ranking (Ranking Criterion 1) especially helpful: "The available options ... actually could go together well in ways that I did not consider ... Sort[ing] by wasted area pushed me to try combinations that I'd not do otherwise."

Overall, the strip-level generation offered both structure and design freedom, as can be seen in the variety of designs created by participants during the user study (Appendix A). Participants said they generally felt they had enough agency to intervene and modify generated strips. They enjoyed the ability to rearrange fabrics within a strip option, though several requested even more design flexibility (see Section 7.3.6).

7.3.3 Value of digitally laying out scraps. Participants consistently found that designing digitally with the tool saved time and effort (Figure 11 No.3). P2 liked "being able to plan out the entire patchwork before getting started," and P9 thought "being able to visualize the end product without cutting into my fabric and making a mistake is a really nice feature." P4 echoed that this tool would help them avoid mistakes: "if I was doing this by myself there would be a lot more times where I'd have to pull out the seam and realize things don't as much as I thought it would, or the strip is just a little too short because I didn't consider the seam allowances."

The alternative of designing this type of scrap sheet manually was considered overwhelming and time-consuming. P3 said, "If I were to [design manually], it would be very difficult ... I'd probably have to do it on the floor, too." P4 echoed that the tool would save "hours and hours of just like sitting on the floor shuffling things

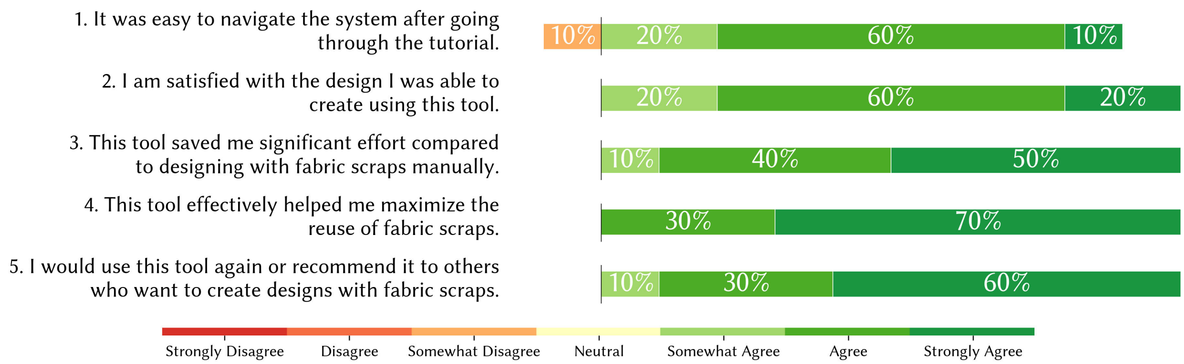


Figure 11: Summary of Likert-scale usability questions. Participants found PatchUp supported them in maximizing scrap usage and allowing them to create satisfying designs. Most participants found the tool easy to navigate. P10, who found the tool the most difficult, wanted to swap out fabrics in the generated options, which required additional effort to modify the automatically suggested bins in the binning stage.

P2, Task 2 (Partial) P9, Task 1

Figure 12: Highlighting two participant designs. P2's Task 2 design: the left yellow-ish strip (in red rectangle) surprised P2 and she liked how it counterbalanced the blues well and without seeing it, she thought she would not think yellow was what she wanted. P9's Task 1 design: the strip towards the bottom (in red rectangle) had a small piece of blue plaid which P9 found unexpected and liked how it looked.

around." P8 also thought that "I would get really overwhelmed with all the fabrics just on my own."

7.3.4 Fabrication instructions. All participants found the instructions helpful and felt confident that they could put together their design with the instructions. P2 said "I really liked how it went into usable instructions." P4 agreed that "The explicit instructions are really helpful." P4 and P5 both successfully constructed their designs from the tool's outputs during follow-up sessions. Some participants chose to improvise with the instructions. For example, P4 swapped in a larger piece of frog fabric to enlarge the final result, illustrating how the instructions could serve as a good starting point rather than a rigid plan.

7.3.5 Project ideas with the tool. Participants envisioned a wide range of potential uses for patchwork sheets created with the tool, including household items (pot holders, bags, cases, book covers, blankets, napkins, tablecloths, pillow cases, tea cozies), clothing

P4, Rail Fence

(7.95 x 6.99 in.)

(a) Since P4 did not trim the fabricated result, we did not include it in Table 2. P4 also decided to swap in a larger piece of the frog fabrics in the last strip (there were many frog fabric scraps) so that he did not need to trim off the design and could get the final result to be bigger. P4 intended to use this for his dog's jacket.

P5, Log Cabin

(19.04 x 19.48 in.)

(b) P5 followed the instructions closely, except in the last round on the leftmost vertical strip, where they reordered the fabrics to avoid two similar-looking scraps being next to each other (where the red box is). P5 intended to make this into a wall hanging or a bag for their portable loom.

Figure 13: Designs created by P4 and P5 with their own scrap fabrics and fabricated.

items (quilt jackets, hats), and quilts (lap quilts, scrappy quilts, baby quilts). P4 said their friends would love to use this tool to design scrappy jackets. P8 felt motivated to start working on a scrappy quilt. P10 was inspired by the designs they created with the tool and would like to upcycle their wardrobe through patchwork designs.

7.3.6 Feature suggestions. Participants had various suggestions for improving the tool, mainly centered around better visualization and more flexible user control. These include (1) enhancing binning functionalities (allowing meta-bins for cross-bin strip option generation and automatic sorting into equal-sized bins); (2) easier strip option filtering (marking favorite options or fabrics, specifying strip thickness ranges based on prior strips, contrasting the strip with the current design instead of within the strip); (3) more flexible customization of generated strip options (rotating directional fabrics, swapping individual fabrics in a strip option); (4) better conveying the sense of scale of the design and the strip options through improved dimension visualization and previewing the selected strip; (5) incorporating design guides such as bin templates for specific packing strategies (e.g., automatically alternate between bins for the three-strip groups in Rail Fence), sewing pattern templates for common upcycling projects to guide the design process (e.g., overlaying a tote bag pattern on the canvas and visualizing the 3D shape), and the capability to create multiple patchworks in a multi-block layout. These feature requests offer valuable directions for future tool development.

8 Discussion and Future Work

This work proposed PatchUp that uses domain-specific heuristics in packing algorithms to enable efficient material reuse and control over designs. As discussed in Section 7.3, participants found the tool helped them create satisfying patchwork designs using scraps efficiently and liked the variety of options generated. However, the system has several limitations and opportunities for future work.

Digitizing fabric scraps. Although our current semi-automatic method for fabric image extraction (Section 4.1) was sufficient for relatively small projects, there are opportunities for further streamlining this process for larger sets of fabric scraps. P7 suggested that it could be nice to allow users to describe what fabrics they have available and generate some palette matching the description for getting an initial idea. P4 suggested making a mobile app that a user could use to keep track of all the scraps produced every time they work on a new sewing/crafting project. Future work could improve the current extraction method to be fully automatic using state-of-the-art image segmentation methods like SAM2 [Ravi et al. 2024] and incorporate the ideas suggested by the participants.

Handling irregular scraps and packing targets. We only considered packing rectangular fabric scraps in this work (although photos of scrap pieces can be non-rectangular, we extracted rectangles from them). This simplification can lead to a small amount of error in our efficiency calculation, depending on these input shapes. However, scraps from certain projects, such as garment making (as mentioned by P1 and P3), could have very irregular or curved shapes in practice. Irregular shape packing, like 2D bin packing, is also an extensively studied problem [Guo et al. 2022; Leao et al. 2020]. Considering more irregular shapes and curved edges would be a challenging and interesting future direction. We could start with incorporating non-rectangular shapes like triangles, since triangles are also very common in quilt blocks. This would allow the tool to support more quilt blocks, providing more visual variety in patchwork designs.

We could also consider packing toward irregular shapes to support custom sheets for projects. For example, many clothing panels, such as a top with armholes, have non-rectangular shapes. Being able to pack towards a non-rectangular target shape could allow users to place their scraps with respect to the placement on the final garment, instead of packing a sheet to be cut later.

Balancing between design freedom and scrap reuse efficiency. Our technical evaluation (Section 6) and user study results (Section 7) suggest that breaking down a patchwork design into strips is an effective way to allow both user control and material waste minimization. This approach is informed by our understanding of how crafters use their scraps but will not yield globally optimal solutions in terms of reuse efficiency. Future work could explore more global optimization strategies or problem formulations (e.g., [Minarčík et al. 2024]) that consider the overall design, including desired material sheet dimensions and visual layout.

The tool can already support users in creating a diverse set of designs with the three quilt blocks, and the Log Cabin and Courthouse Steps achieve relatively high reuse efficiency (>80% in typical cases). To further improve the design variations while maintaining material efficiency, it would be useful to understand what makes a quilt block (i.e., a 2D space partitioning) suitable for achieving a high scrap reuse efficiency. The current three blocks supported are categorized as *strip quilt blocks* [Brackman 2021], and we could investigate how other blocks in this family would perform, including the Roman Square, Roman Stripe, and variations of Rail Fence (4 or 5 strips in a sub-block).

Lastly, we considered wasting less area of fabric scraps and creating larger "new" fabric pieces as higher reuse efficiency. But there are other meaningful indicators, such as the fabric count (which we treated as a secondary aesthetic control variable). Exploring alternative measures of reuse efficiency could accommodate how different users define efficient reuse in their own practice.

Domain-aware heuristic for packing. Although this work focuses on fabric patchwork as an application of the quilt-block-inspired packing algorithm, we believe that the same idea applies in other domains that care about both visual aesthetics and material efficiency. For example, applications like leather working, wood flooring, tile mosaics, and upholstery covering could benefit from the strip-based design approach, while potentially having other considerations specific to the domain, such as minimizing the lengths of cuts. In addition, studying designs from these domains could lead to new packing strategies involving trapezoids and non-rectangular pieces. Another area of future work is exploring if there are more suitable intermediate design abstractions for different application domains.

9 Conclusion

Upcycling fabric scraps can be challenging due to the variety of colors, sizes, and numbers of scrap pieces. In this work, we propose a design tool called PatchUp that uses novel heuristics inspired by quilt blocks to guide patchwork design from scraps. We evaluated the tool with a user study that indicated users found it effective at helping them optimize scrap material usage while providing creative control over their design. This highlights an important opportunity for considering other creative applications of domain-specific packing and incorporating visual objectives into packing problems.

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A MIP Formulation Details

Given a list of n fabrics $\mathcal{F}$, we introduce $2n$ binary variables:

$$\mathcal{E} = \bigcup_{f \in \mathcal{F}} \{e_f^w, e_f^h\}, \quad \text{where } e_f^w, e_f^h \in \{0, 1\}$$

Here, $e_f^w = 1$ indicates that the width edge of fabric f is used to construct the strip, while $e_f^h = 1$ indicates that the height edge is used instead. Selecting the height edge implies that the fabric is rotated by 90 degrees before being attached to the strip. Each fabric can contribute at most one edge, and the selected edge contributes its corresponding length to the total: we denote the width and height of fabric f as w_f and h_f, respectively.

Validity Constraints. We add two kinds of constraints to ensure that the generated strip option is valid:

(1) Same Fabric Constraint ($\mathbf{C_{SF}}$):

$$\forall f \in \mathcal{F}, e_f^w + e_f^h \leq 1$$

which means either width or height edge of the same fabric can be selected but not both;

(2) Target Length Constraint ($\mathbf{C_{TL}}$):

$$L_T \leq \sum_{f \in \mathcal{F}} \left(e_f^w w_f + e_f^h h_f \right) \leq L_T + THRESH$$

where $THRESH$ is a small threshold[1] that allows the generated option to have a bit extra length (in this work we used 1 inch) if the option does not meet the exact target length.

Aesthetic Control Constraints. Two kinds of constraints for filtering the generated options are available: (1) Strip thickness which determines how thick the strip to attach will be. (2) Fabric count which determines how scrappy this strip will look like.

(1) Strip Thickness ($\mathbf{C_{ST}}$): for each strip option, we consider its thickness to be the minimum length of the unselected edges of the selected fabrics (see definition illustrated in Figure 6). We first define a precomputed matrix for all $2n$ edges where

$$W_{ij} = \begin{cases} 1, & \text{if } Length(i) \leq Length(j), \\ 0, & \text{otherwise.} \end{cases}$$

With this matrix, it is obvious that if an edge i_0 has the smallest length among the selected edges, all $W_{i_0 j}$ entries should be 1. To facilitate the computation of the minimum length, we add additional binary variables m_f^w, m_f^h for each edge indicating whether its unselected sibling edge is the minimum-length edge. First, only selected edges can be considered for the minimum: $\forall f \in \mathcal{F}, m_f^w \leq e_f^w, m_f^h \leq e_f^h$. Second, there is only one minimum edge: $\sum_f m_f^w + m_f^h = 1$. Third, the minimum edge should satisfy the precomputed results in the W matrix:

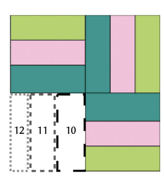
$$\begin{aligned} \forall f, f' \in \mathcal{F},\ f \neq f', W_{f^w f'^w} &\geq m_f^h + e_{f'}^h - 1 \\ W_{f^h f'^h} &\geq m_f^w + e_{f'}^w - 1 \end{aligned}$$

Lastly, we can define the following constraints to ensure the strip thickness is the minimum length of selected fabrics' unselected edges:

$$\begin{aligned} \forall f \in \mathcal{F}, w_f + (1 - m_f^h)M \geq \mathbf{C_{ST}} &\geq w_f - (1 - m_f^h)M \\ h_f + (1 - m_f^w)M \geq \mathbf{C_{ST}} &\geq h_f - (1 - m_f^w)M \end{aligned}$$

where M is a large number (we used $M = 1e6$) so that for example, when the width edge of fabric f is the minimum edge (i.e., $m_f^w = 1, m_f^h = 0$), the second inequality will essentially become $h_f \geq \mathbf{C_{ST}} \geq h_f$ (limiting the $\mathbf{C_{ST}}$ to take on the minimum unselected edge length), while the first inequality is easily satisfiable.

(2) Fabric Count ($\mathbf{C_{FC}}$): $\sum_{f \in \mathcal{F}} e_f^w + e_f^h$ computes the number of fabric scraps used in an option.



Additional Constraints for Rail Fence. Specifically for the Rail Fence block, in the last sub-block, the three strips are more constrained on the Strip Thickness (see inset figure). Therefore, for the last three packing steps, we encode additional

[1] The upper bound here is not strictly necessary given that we are already optimizing for minimum wasted area, which included a term that accounts for matching the target length. Removing this upper bound does not affect the validity of our approach, but it is helpful to ensure the solutions we display to the users are of roughly similar lengths and all close to the target length.

constraints on C_{ST}:

Step 10: $C_{ST} \leq L_S$

Step 11: $C_{ST} \leq L_S - C_{ST,step10}$

Step 12: $C_{ST} \leq L_S - C_{ST,step10} - C_{ST,step11}$

Optimization Objective. We choose to use the wasted area as the objective and minimize it when generating strip options because less wasted area generally means larger consolidated sheet of fabric for later use, which is directly related to reuse efficiency.

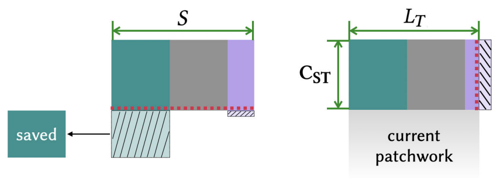


Figure 14: Wasted area objective. The left corresponds to the first summation term (portion of fabric scraps that goes beyond the strip thickness), and the right corresponds to the second term (the entire strip's extra portion beyond the target length). This overestimates the wasted area because the cut-off portions that are large enough (> THRESH) will get saved instead of being wasted, like the teal piece.

We can approximate the wasted area of a strip option by computing the sum of fabrics beyond the strip thickness as follows:

$$\sum_{f\in\mathcal{F}} \left(e_f^w w_f (h_f - \mathrm{C_{ST}}) + e_f^h h_f (w_f - \mathrm{C_{ST}}) \right) + (S - L_T)\mathrm{C_{ST}}$$

where $S = \sum_{f\in\mathcal{F}} \left(e_f^w w_f + e_f^h h_f \right)$. The first summation term calculates the portion of fabrics that goes beyond the strip thickness, and the second term calculates the portion of the entire strip that goes beyond the target length. This is an overestimation because sometimes the extra fabric beyond the strip thickness may be large enough to be reused and thus would not be considered part of the wasted area (see Figure 14).

Ranking Criteria. In the four ranking criteria (Wasted Area, Color Contrast, Color Tone Contrast, Color Brightness Contrast), the Wasted Area criterion is defined the same as the optimization objective. The remaining criteria are computed after the strip options are generated. We encode each ranking criterion as a function of the option's fabrics. Without loss of generality, we only describe the criterion that ranks a certain property in *ascending* order (the descending order is the opposite of how that is defined).

(1) Wasted Area ($\mathbf{R_{WA}}$): This is the true wasted area computed after the strip option is known. For a given strip option O, the wasted area is computed as

$$\left(\sum_{f\in O} e_f^w w_f \Delta_f^h + e_f^h h_f \Delta_f^w \right) + (S - L_T)\mathrm{C_{ST}}$$

where

$$S = \sum_{f\in O} \left(e_f^w w_f + e_f^h h_f \right),$$

$$\Delta_f^w = \begin{cases} 0, & \text{if } h_f - \mathrm{C_{ST}} > \text{THRESH} \\ h_f - \mathrm{C_{ST}}, & \text{otherwise} \end{cases},$$

$$\Delta_f^h = \begin{cases} 0, & \text{if } w_f - \mathrm{C_{ST}} > \text{THRESH} \\ w_f - \mathrm{C_{ST}}, & \text{otherwise} \end{cases}.$$

(2) Color Contrast ($\mathbf{R_{CC}}$): We precompute the pair-wise color differences between each fabric so that

$$CD_{ff'} = \begin{cases} color\_difference(f, f'), & f \neq f', \\ 0, & \text{otherwise.} \end{cases}$$

The `color_difference` function is implemented with the `python-colormath` library and computes differences between the two fabric images' dominant color in the LAB color space. For each pair of fabrics within an option O, we compute the sum of the corresponding entries in matrix CD: $\sum_{f\in O} \sum_{f'\in O} CD_{ff'}$.

(3) Color Tone Contrast ($\mathbf{R_{CTC}}$): Similar to Color Contrast (Criterion 2), we precompute the color tone (or hue) difference matrix TD and for each pair of fabrics within an option O, this rank is defined as $\sum_{f\in O} \sum_{f'\in O} TD_{ff'}$.

(4) Color Brightness Contrast ($\mathbf{R_{CBC}}$): Similar to Color Contrast (Criterion 2), we precompute the color brightness (or value) difference matrix BD and for each pair of fabrics within an option O, this rank is defined as $\sum_{f\in O} \sum_{f'\in O} BD_{ff'}$.

B Image Recoloring

We recolored the Etsy Linen fabrics in the designs shown in Figure 8a to avoid unintended visual associations. In the original set, the Floral bin fabrics were quite dark, and when arranged in the Rail Fence pattern, they produced a layout with an unfortunate and offensive visual similarity. To address this, we adjusted the highlight levels and shifted the color tone of the Floral fabrics to a lighter, sepia palette. Figure 15 shows the original and recolored versions of these fabrics.

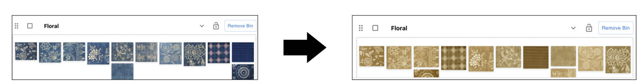


Figure 15: The original and recolored versions of the Floral bin fabrics.

C Generated Test Sets Distribution

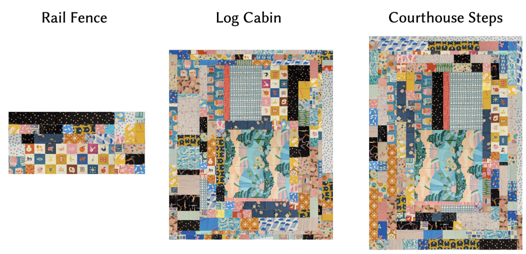
We describe in detail the settings used to generate the test sets for probing the packing algorithm in Table 4.

D Comparing with Automatic Bin Packing Using Other Fabric Scrap Sets

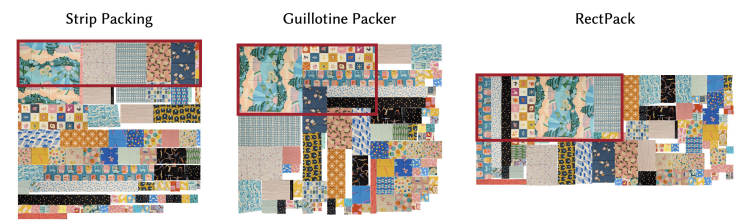
Figures 16, 17 show additional visual comparisons between packing results generated via our method and those generated with automatic bin packing methods. The two fabric scrap sets here are Etsy Cotton and Etsy Linen.

Table 4: Details on the generated test image sets. These parameters are passed to a test image set generator we implemented.

Dataset	Scenarios	# Scraps	Size Range	Square %	Additional Parameters
Aspect Ratio	Extreme aspect ratios	50	50 – 500	10%	70% narrow rectangles with aspect ratio range 5:1-10:1
Sequential	Decreasing size sequence	50	50 – 500	20%	-
Power Law	Many small, few large	50	50 – 500	20%	power law exponent 1.5
Mixed Quilting	Standard quilting sizes	100	50 – 500	-	80% standard quilting sizes, rest with 10% size variations
Square Heavy	High proportion of squares	50	50 – 200	80%	-
Bimodal	Two size clusters	50	50 – 200	50%	-
Similar Sized	Sizes within small range	50	50 – 200	20%	15% size variations from each other
Uniform	Random uniform distribution	200	50 – 500	20%	-



(a) Our method with three packing strategies. The packing results' areas are as follows: Rail Fence - 481.15 in^2; Log Cabin - 2393.20 in^2; Courthouse Steps - 2311.16 in^2.



(b) Three automatic bin packing methods. The packing results' largest gap-free areas out of total bin areas are as follows: Strip Packing - 635.30 / 2809.52 in^2; Guillotine Packer - 785.25 / 2763.26 in^2; RectPack - 891.92 / 2670.20 in^2.

Figure 16: Packing results comparison between PatchUp strategies and three bin packing methods using Etsy Cotton set. The dark red rectangles indicate the largest gap-free rectangles within the bin packing results.

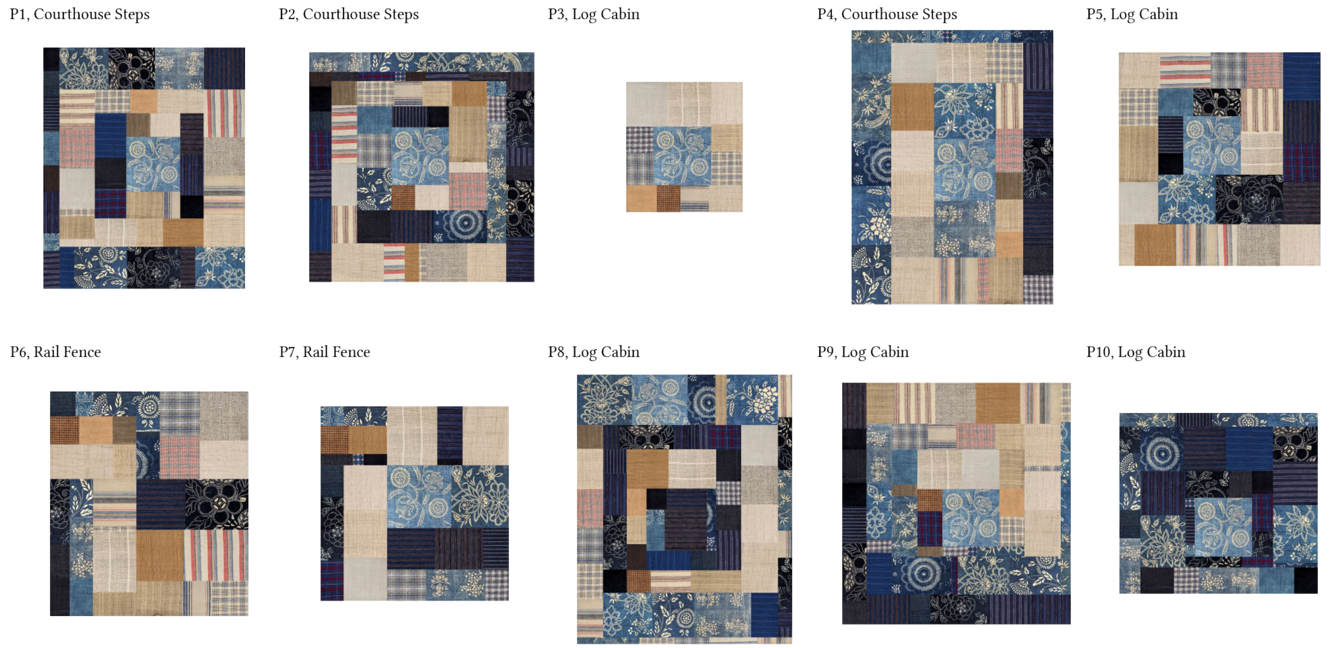
(a) Our method with three packing strategies. The packing results' areas are as follows: Rail Fence - 803.30 in^2; Log Cabin - 1369.71 in^2; Courthouse Steps - 1339.51 in^2.

(b) Three automatic bin packing methods. The packing results' largest gap-free areas out of total bin areas are as follows: Strip Packing - 294.67 / 1746.21 in^2; Guillotine Packer - 345.46 / 1691.63 in^2; RectPack - 365.62 / 1651.11 in^2.

Figure 17: Packing results comparison between PatchUp strategies and three bin packing methods using Etsy Linen set. The dark red rectangles indicate the largest gap-free rectangles within the bin packing results.

E User Designs

Figure 18 shows the designs created by participants during the user evaluation.



(a) Task 1 designs. To create contrast, most participants chose to bin their fabrics into a lighter bin and a darker bin. P3 preferred lighter fabrics while P10 preferred darker fabrics and focused on making sure the prints and solids patterns were in contrast. Several others tried to create spiraling structures of contrasting colors, or added darker strips as "boundaries" for the design. Most participants tried to make sure no two similar fabrics were next to each other.

(b) Task 2 designs. Compared to Task 1, participants all went for a different quilt block strategy. When designing the fabric for tote bag, participants all thought about how the fabric would look like made into a tote bag, and they tended to create more rectangular designs. Interestingly, P6 and P9 had in mind a bag pattern with a rectangular bottom that would be touching the ground, while P3 and P8 wanted to only create one side of the tote bag. P1 was the most cognizant of the finished size and tried to make it a size good for making a typical tote bag.

Figure 18: Designs created by participants in Task 1 and Task 2.