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Development of an Algorithm for Textile Waste Arrangement

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Abstract: With the constant availability of new designs at extremely low prices, the production and disposal of clothing have increased significantly, leading to the need for the sustainable management of processes. The implementation of established craft practices in modern sustainable mass production requires the development and application of software and hardware computer tools as well as production machinery. Although the management of textile waste for interior design articles is addressed in the scientific literature by various techniques, there is still limited data and strategies based on the use of specific algorithms. Therefore, in this research, an algorithm is proposed, with the help of which textile waste resulting from upholstery production can be reused in the creation of interior decoration parts. The algorithm is implemented in the GNU Octave 6.4 programming environment, which makes it easily redistributable and accessible. The algorithm consists of a total of six stages, offering an option for arranging the textile elements and analyzing their color characteristics. The arrangement is performed with a Voronoi diagram, and the colors are represented by a four-color circle. Moreover, data on waste textile fabrics are presented, as well as their application in the conception of interior design elements. The proposed algorithm allows designers to focus on the visual design rather than compatibility checks and constraints. The present paper provides an algorithm for reusing textile wastes, which come in a variety of shapes and colors and are produced throughout the fabric cutting phase of upholstery manufacturing, in order to identify the most optimal combinations in matching irregular waste shapes and combinations of colors, create a suitable pattern for new interior design items, and contribute to improving the sustainable management of textile waste that is produced in considerable amounts.

Keywords: design tools; craft; fabrication; sustainability; circular economy; algorithm; textile waste

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1. Introduction

Accelerated population growth, increasingly fast-paced and consumption-based lifestyles, exponential advances in technology, and the development of industry and agriculture to meet the growing needs of mankind have the unfortunate consequence, first and foremost, of generating waste in huge quantities. In the past few decades, global waste production has increased substantially, and currently there are no indications of a decline. Moreover, less than 20% of waste is recycled annually, with enormous amounts still improperly managed [1].

Among the most numerous and hazardous industrial wastes are chemicals from many industrial fields, with some of the most relevant being the medical sector [2,3] and textile industry [4]. The resulting toxic products of these industries [5–7] pollute the environment and reach the human body through food, breathing, direct contact, etc., generating or aggravating numerous diseases [8].

The textile industry, with its many stages of manufacturing and the large quantities of items produced, contributes to the overconsumption of natural resources. In 2020, the average EU textile consumption per individual required 400 square meters of land, 9 square meters of water, and 391 kg of raw materials, resulting in a carbon footprint of approximately 270 kg. It has been determined that the global apparel and textile sector worldwide consumed 79 billion cubic meters of water in 2015, while the EU's entire economy required 266 billion cubic meters in 2017 [4].

From agricultural and petrochemical production (i.e., fiber generation) to manufacturing, distribution, and the retail sector, the textile and fashion industries have a lengthy and intricate supply chain. Every single manufacturing process has a direct effect on the environment due to the use of water, materials, chemicals, and energy. Pre-consumer waste in the garment sector, also known as production waste, is generated throughout the production of textiles and apparel and consists of yarn, fiber, and fabric waste. Fabric waste is generated throughout the cutting stage of garment making and is affected by the conceptualization of the flat patterns and the overall garment design. Furthermore, garment assembly errors may result in substantial garment waste [9].

In the textile industry, the largest amount of waste is created in the cutting process [10]. Cut waste occurs because of gaps in the marking plan between pattern components [11]. These wastes are called raw material wastes and are determined by the characteristics of the product (i.e., shape and size of the patterns), the properties of the textile materials (i.e., width, design, dimensional changes, etc.) and the structure of the order (i.e., the number of pieces in the order). In recent years, the concept of circular economy and associated policies have widely addressed resource use, production, consumption, and waste [12].

Textile waste is used in the production of wadding for car doors and household accessories such as pillows, napkins, tablecloths, carpets, etc. [13]. The study of Sai et al. [14] aimed at designing and producing artifacts for interior decoration from waste fabrics. Governmental decision makers, entrepreneurs, and manufacturing industries are putting a greater emphasis on devising sustainable strategies to minimize textile waste generated during the production process [15,16].

Several strategies are available to address waste in order to reduce it. Textile reuse encompasses a variety of methods for extending the lifespan of textile products by shifting them to new owners, with or without adjustment. In contrast, textile recycling typically refers to the reuse of pre- or post-consumer textile waste in the production of novel textile or non-textile items [17]. Because preventing an issue is preferable to solving it, this assertion is congruent with waste management strategies. Considering the numerous advantages that waste generation prevention provides over the treatment of waste, waste source reduction and waste minimization can be viewed as a more suitable and sustainable waste-decreasing strategy. The concept involves preventing waste from being created before it is produced. This system-wide approach to waste management prevents waste rather than merely administering it. Integrated waste management is a relatively new concept in the realm of waste management that incorporates new dimensions into methods for dealing with waste and improves numerous traditional procedures for handling it. Integrated waste management incorporates technical as well as non-technical elements of waste administration [18].

From the review of available literature sources, it can be summarized that in recent years, from the point of view of sustainable development and the circular economy, more and more authors are directing our attention to the use of waste materials from clothing production in the design of modern fashion accessories, household elements, and works of art. There is also a trend towards the introduction of well-established craft practices in modern serial production. Botsman and Rogers [19] suggested that designers strike a balance between the needs of consumers and the common interests of society, prioritizing the ecological effects of the products.

Different algorithms [20,21] and procedures have been proposed to facilitate modern designs using craft techniques. These algorithms do not fully cover the possibilities of applying waste materials from clothing production to create new and original products.

For this reason, the aim of the present work is to propose such an algorithm by which waste textile fabrics can be used in the contemporary design of products for interior decoration. The research proposes such models by reusing the textile waste resulting from the process of cutting tapestries, leading to new solutions to finding the best combinations of textile waste, considering that many approaches do not involve algorithms. These are the result of matching irregular shapes of waste and color combinations to achieve a suitable pattern for new interior design items (i.e., tablecloths, pillow covers, chair covers). The novelty of this research lies in the development of an algorithm that enables the reuse of textile waste, provides visual modeling capabilities, integrates into designers' workflows, and allows a focus on visual design rather than compatibility checks and constraints. It addresses key aspects of sustainable design practices and provides valuable insights for researchers, practitioners, and industry professionals striving for more sustainable and efficient design processes in fashion and interior design.

2. Literature Methodology

The present paper's design was based on a literature search methodology that assessed the correlation between textile waste from cutting processes and the sustainable management of their reuse. The search methodology involved two approaches: an advanced search in three databases (ScienceDirect, SpringerLink, and Web of Science) with wide scientific coverage involving the use of the Boolean operator AND for the numerical evaluation of articles involved in the above-mentioned correlation (Figure 1), and a more detailed search in the SpringerLink, providing detailed information on research areas and subdisciplines (Figure 2) [22].

Even though the number of articles evaluating textile waste, textile waste from cutting processes, and the sustainable management of textile reuse per se is relatively large, the number of publications that have evaluated certain aspects resulting from their correlation is very small, opening research directions and facilitating areas where there are still unmet needs due to not having sufficient studies.

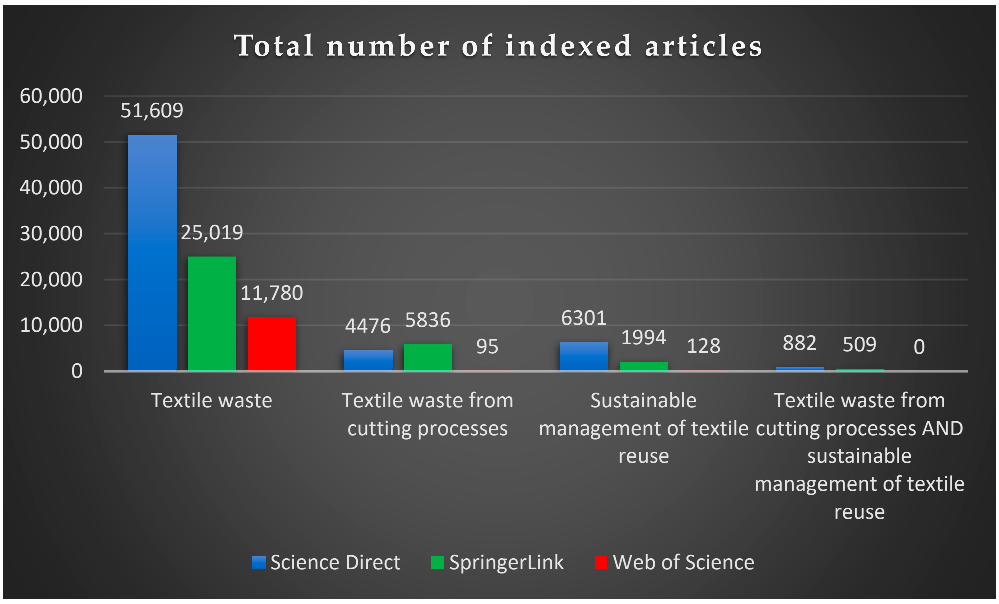

Figure 1. Total number of publications displayed for specific search terms in specific scientific databases.

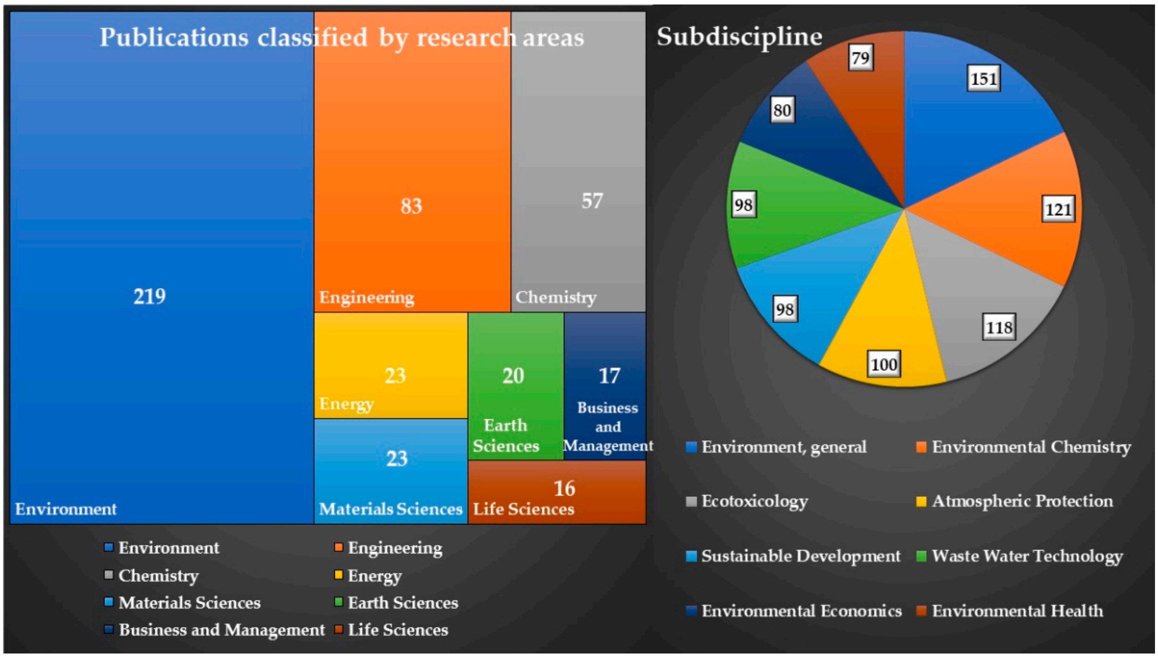

Figure 2. Publications in the field included in different research areas and subdisciplines provided by SpringerLink for the searching algorithm "textile waste from cutting processes AND sustainable management of textile reuse".

3. Material and Methods

The waste textile fabrics were procured from the Westbridge Manufacturing SRL company from Oradea, Romania, specializing in cutting and sewing fabric upholstery for sofas. The objective of this article was to analyze ways of reutilizing waste fabrics of various shapes and colors, which are presented in a general form in Figure 3.

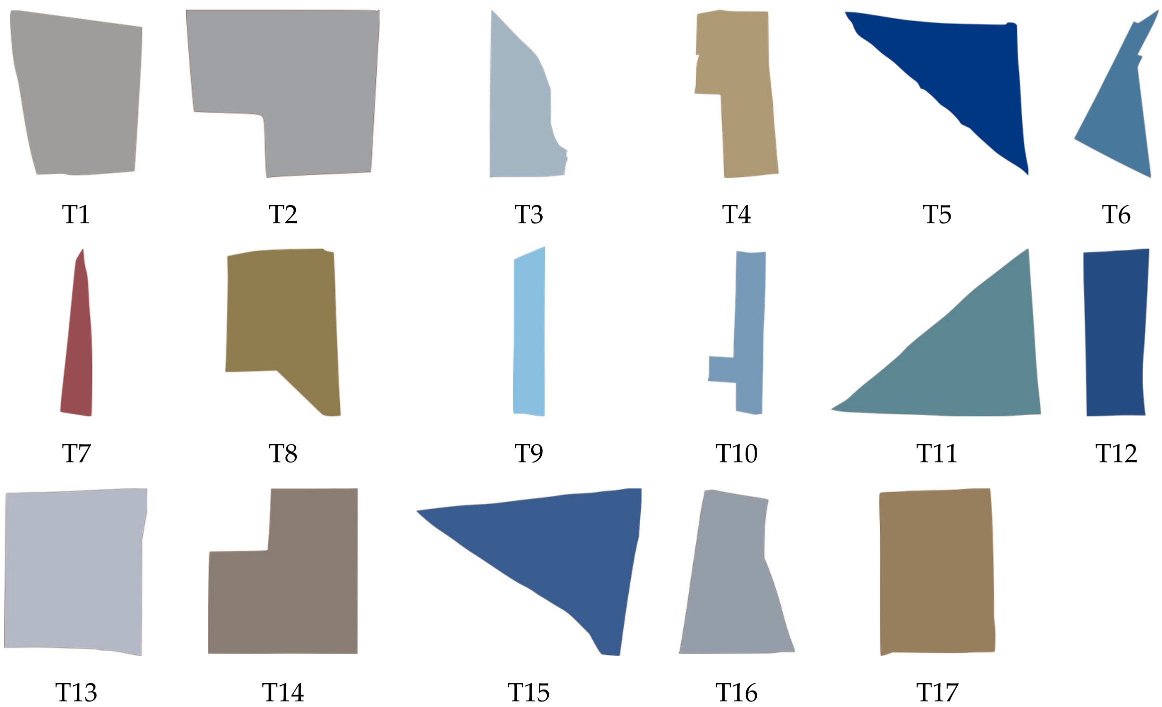

Figure 3. Textile waste of different shapes and colors, as the subject of this study, to be reused as interior design pieces.

The implementation of image processing algorithms and procedures was carried out in the GNU Octave 6.4 programming environment (GNU Octave, https://octave.org/, accessed on 10 February 2023). It is a free analog of the popular Matlab environment, version 2017b (The Mathworks Inc., Natick, MA, USA) and offers most of the features of Matlab, with some minor differences.

In the algorithm proposed in this article, the images of the textile fabrics are represented as a matrix, with the dimensions nxm. The number of rows and columns in this matrix is determined as follows:

$$n = \sqrt{N} \begin{cases} if\ n = int(n),\ m = n \\ if\ n \neq int(n),\ m = n + 1 \end{cases} \tag{1}$$

where N is the number of images; n is the number of rows; m is the number of columns of the image matrix. If n is an integer, then $n = m$ and the matrix is square.

A Voronoi diagram is used in the image processing algorithm. In general, obtaining this diagram can be described by the distance $d(x,\mathrm{A}) = \inf\{d(x,\mathrm{a}) \mid \mathrm{aEA}\}$, which defines that between the variable x and the subsample variable A,

$$R_k = \{x \in X | d(x, P_k \leq d(x, P_j),\ for\ all\ j \neq k\} \tag{2}$$

where X is a metric space with distance function d; K is a set of indices; $(P_k)k_E K$ is a sequence of complete subsamples in the space X. R_k is the Voronoi domain; P_k is the set of all points in the given space; P_j are the remaining points; j is an index that is different from k.

The conversion from the RGB color model to the Lab color model is carried out with function "*rgb2lab*" in Octave. In this programming environment, the conversion between the two-color models is performed under a luminance level setting of D65 and observer 2 degree.

4. Results and Discussion

The result of the research was an algorithm that was developed for the image processing of waste textile fabrics coming from upholstery production. The algorithm proposes ways of reutilizing the waste fabrics (which come in various shapes and colors) generated during the fabric cutting stage of the upholstery production to find the best combinations in matching irregular shapes of waste and color combinations and to achieve a suitable pattern for new items of interior design. The algorithm consists of a total of six stages (Figure 4) and offers an option for arranging the textile elements and analyzing their color characteristics. The created pattern design was used to simulate several elements of interior design, such as a pillow and an armchair. The arrangement was carried out using a Voronoi diagram, and the colors are represented by a four-color circle.

Stage 1. Images of waste materials are located in a common folder, as files with the extension *.PNG. These are loaded by the main program and arranged in an nxn1 matrix, which can be square or rectangular, depending on the number of images. The "*subplot*" command from the Octave programming environment is used. The resulting figure is saved in the folder with the extension *.JPG. This image is again loaded by the algorithm for further processing.

Stage 2. The loaded image is converted to black and white, with an appropriate binarization threshold. Using the "*regionprops*" function, the centers of gravity for each element are obtained.

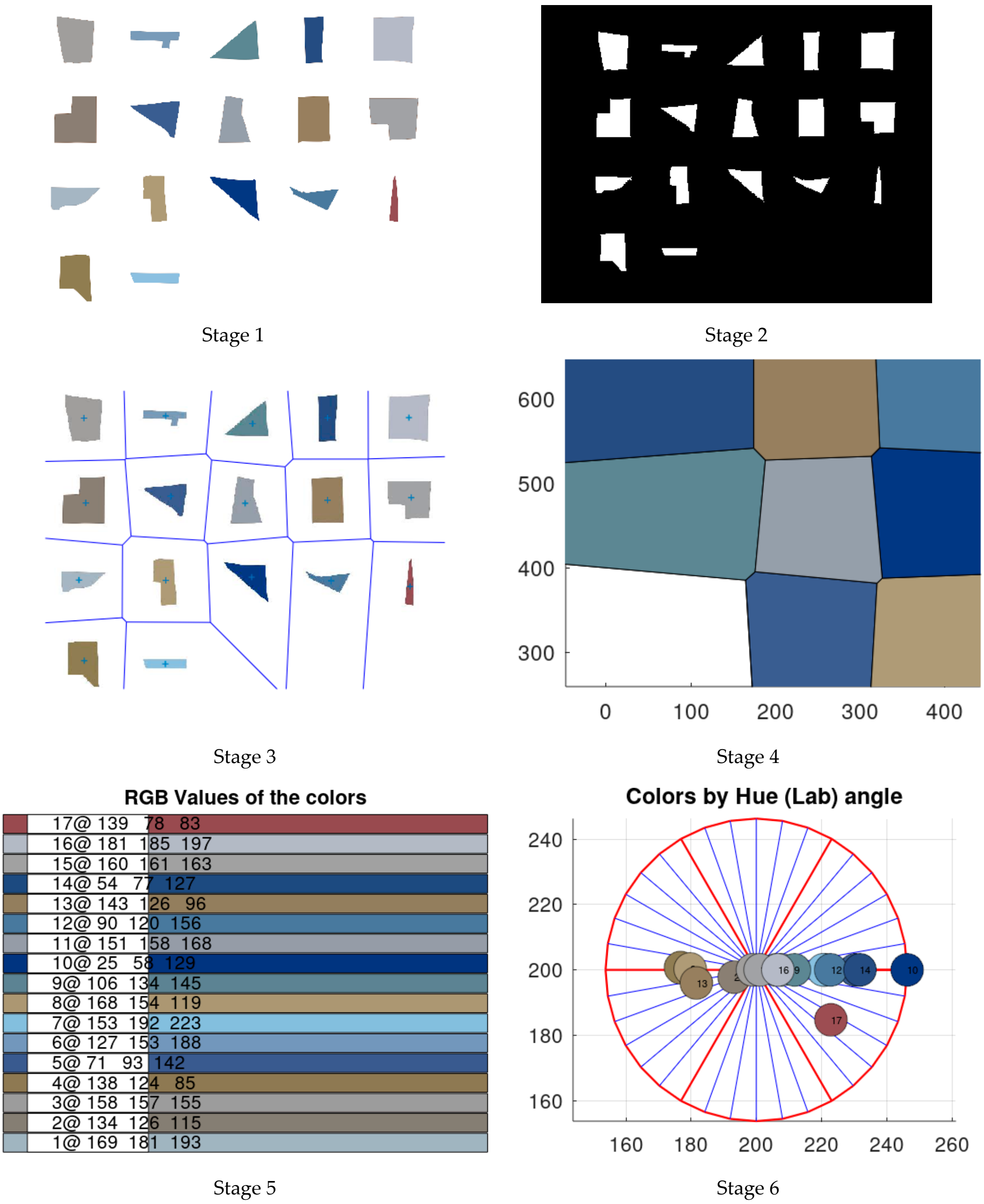

Figure 4. The algorithm for image processing of textile waste carried out in 6 specific steps.

Stage 3. The command “*[v1,c1] = voronoin ([x,y],{“Qbb”});*” is used to obtain a Voronoi diagram. This diagram is calculated according to the points representing the centers of gravity for each textile element. The items themselves are plotted in the diagram. This is done to guide the user on the appropriate placement of elements when creating designs with them.

Stage 4. Using the command *“patch(v1(c1{d},1),v1(c1{d},2),col1(d,:))”*, the Voronoi diagram is recreated, but with areas filled with the colors of the elements.

Stage 5. The colors of the elements with their RGB values are visualized. These values can be used in the analysis and visualization of the developed designs from the textile items.

Stage 6. The colors of the pieces are applied to the Lab four-color circle. The function of this visualization helps the designer to easily judge whether the colors are contrasting or related. Thus, s/he can judge how the combinations between them will look when creating designs with the textile articles.

The algorithm is presented as a GNU Octave code in Appendix A. The workability of the proposed algorithm in processing images of waste materials from textile fabrics used in upholstery production has been verified. Fabric waste comes in various shapes and colors; the resulting colors of textile waste products are related, related–contrasting, or completely contrasting.

Table 1 shows data on the color components of textile waste fabrics. The values of the color components vary considerably, as follows: from dark and light blue, light and dark red, gray, brown, and various shades of green.

Table 1. Values of RGB and Lab color components of waste textile fabrics.

CC TW	R	G	B	L	a	b	CC TW	R	G	B	L	a	b
T1	169	181	193	73.11	−1.73	−7.50	**T10**	25	58	129	26.21	15.76	−43.48
T2	134	126	115	53.20	1.03	7.08	**T11**	151	158	168	64.85	−0.46	−6.05
T3	158	157	155	64.76	−0.02	1.17	**T12**	90	120	156	49.50	−1.01	−22.79
T4	138	124	85	52.37	−0.67	23.27	**T13**	143	126	96	53.61	1.76	18.75
T5	71	93	142	39.78	6.09	−29.68	**T14**	54	77	127	33.19	7.15	−30.97
T6	127	153	188	62.44	−0.67	−21.08	**T15**	160	161	163	66.22	0.03	−1.16
T7	153	192	223	75.95	−5.75	−19.67	**T16**	181	185	197	75.17	0.94	−6.53
T8	168	154	119	63.97	−0.41	20.28	**T17**	139	78	83	40.51	26.21	8.34
T9	106	134	145	54.19	−7.27	−9.15	-	-	-	-	-	-	-

CC—color component; TW—textile waste with corresponding number; R, G, and B—color components from RGB color model; L, a, b—color components from Lab color model.

Examples of interior design applications of the sorted textile waste were offered. For this purpose, the online applications Art of Where (https://artofwhere.com, accessed on 23 February 2023) and Bags of Love (https://www.bagsoflove.co.uk, accessed on 27 February 2023) were used to simulate several interior design elements, which include a pillow and an occasional armchair (Figure 5), based on the pattern obtained from the algorithm design.

The pattern was based on a square shape, and the fabric's joints worked together to create a mixture of joints and patterns that mixed nicely with the fabric's many colors. The occasional armchair is suitable to decorate a living room. The proposed model is a new version of this type of armchair using pieces of fabric from textile waste. In this way, they can be used sustainably for many years. The various colors of the pillow can help improve the physical and emotional state of the user and should be chosen to provide the maximum comfort.

Via computational imaging and color analysis, the present article provides an investigation into the reuse of textile waste resulting from upholstery production. A six-stage algorithm was developed for the visual processing of textile waste. The algorithm uses image segmentation approaches, Voronoi diagrams, and color analysis to arrange and assess the color properties of textile elements. A pattern based on a square shape was used to simulate a few elements of interior design, such as pillows and armchairs.

The successful application of the algorithm was proven by analyzing the color components of waste textile fabrics. With the proposed algorithm, the recommendations of Zhang [23], regarding the implementation of craft production techniques in the modern sustainable design of interior design accessories, can be fulfilled. The authors presented a table with RGB and Lab color component values, demonstrating the vast array of colors present in the waste fabrics, such as various hues of blue, red, gray, brown, and green. By converting the RGB color model to the Lab color model, the algorithm enabled a more thorough analysis of the color characteristics, enabling designers to readily evaluate color combinations and contrasts.

(**a**) (**b**)

Figure 5. Home décor designs based on the pattern obtained from the algorithm. (**a**). Occasional armchair; (**b**). Pillow 18 × 18.

The results of the study demonstrate the viability of using waste textiles in sustainable design implementations. By repurposing these elements, designers can contribute to waste reduction and the preservation of the environment, while designing visually enticing products with a distinct identity. The algorithm's application to interior design elements such as pillows and armchairs demonstrates its applicability and relevance in actual design scenarios.

In addition, the authors highlight the potential advantages of using textile waste products to enhance consumers' physical and psychological health. While offering optimum comfort, the various hues of the patterns may improve the aesthetic appeal of interior spaces. This aspect is consistent with current studies on the psychological effects of colors [24,25], which demonstrate that color choices can affect mood, well-being, and the overall user experience.

Contemporary commercial reasoning in the textile industry is founded on expanding production and sales, rapid manufacturing, poor product quality, and a short lifespan of products, which all result in unsustainable consumption, rapid material turnover, considerable waste, and extensive ecological effects. Consequently, manufacturing processes and patterns of consumption need to be modified. In order to obtain certain improvements, the participation of all stakeholders is essential: textile manufacturers need to invest in clean technology, clothing companies must develop new business patterns, consumers must modify their purchasing habits, and lawmakers must adjust regulations and global business standards. The emphasis is on key strategies for establishing an entirely novel model for sustainable industries, such as limiting growth, reducing waste, and supporting a circular economy. Good management of post-consumer textile waste is mandatory for attaining a zero-waste target [26].

The implications of technology transfer may additionally play a role in the management of textile waste. By transferring novel algorithms and strategies and integrating software tools, creators are able to effectively repurpose textile waste and create novel and distinctive products. Moreover, the transfer of technology may enable creators to improve their design procedures, increase their efficiency, and concentrate on visual aesthetics, as opposed to being limited by compatibility checks and constraints. In addition, it supports sustainable manufacturing practices, assists the circular economy, and addresses the industry's critical textile waste challenge [27,28].

By reusing garment production waste in the creation of interior design elements, the algorithm helps reduce waste in the fashion industry, contributing to sustainability. The algorithm allows designers to utilize scraps effectively, maximizing the use of available resources and minimizing the need for additional materials. By repurposing textile waste, designers can potentially reduce the costs associated with purchasing new materials. This is particularly beneficial for designers working on a limited budget or for businesses aiming to optimize their production expenses.

By using textile waste resulting from the main production process to create interior design elements, the costs related to the purchase of raw material are completely eliminated. In addition, companies can considerably reduce the total amount of waste generated, which will be reflected in a reduction in costs related to the collection and storage of textile waste in landfills. For a company that only makes interior design elements from the waste from another company, the main advantage is that these materials will be attained for free; the company only bears the costs of managing and sorting them, which are much lower than having to purchase the necessary materials.

The algorithm is implemented in the GNU Octave programming environment, which is redistributable and easily accessible. Designers can utilize the algorithm without significant barriers, promoting its widespread adoption and potential for collaboration. The algorithm offers designers the option to arrange textile elements using the Voronoi diagram, a mathematical tool for partitioning space that enables creative freedom and flexibility in designing interior elements and clothing accessories. The algorithm includes the analysis of color characteristics, representing them with a four-color circle, providing designers with insights into color combinations and assisting them in creating visually appealing designs.

By automating compatibility checks and constraints, the algorithm allows designers to focus on the visual design aspect rather than spending time on manual checks. This streamlines the design process and improves overall efficiency. The proposed tool seamlessly integrates into designers' workflow, making it user-friendly and easily adaptable, facilitating the design of basic combinations of textile pieces, and enhancing the overall productivity and output of designers. This presents certain advantages and limitations (Figure 6).

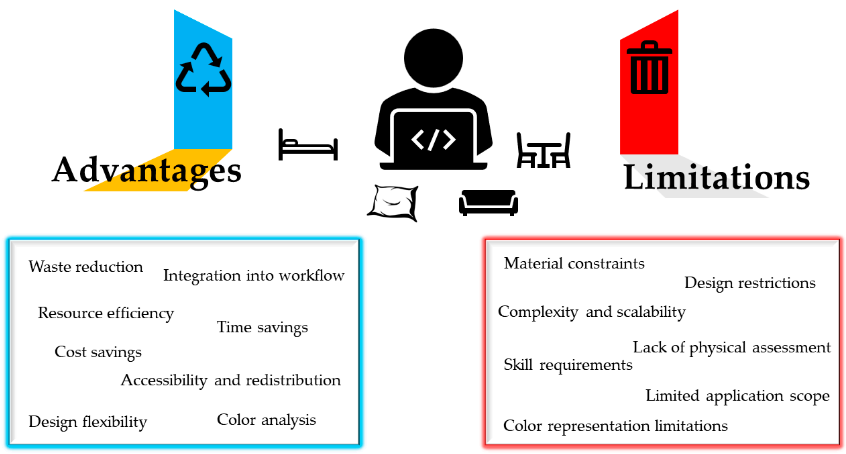

Figure 6. Strengths (blue) and limitations (red) of the algorithm.

The algorithm relies on the availability of waste textile fabrics from garment production. If there is a limited supply or if the quality of the waste fabric is insufficient, it may restrict the options for designers and limit the feasibility of the algorithm. The algorithm imposes restrictions on the geometry of the fabric elements used and the order in which they are arranged. This may limit the design possibilities and creative freedom for designers who prefer more unconventional or complex designs. The algorithm requires designers to have a certain level of technical skills and familiarity with the GNU Octave programming environment. Hence, designers who are not comfortable with programming or software tools may face challenges in utilizing the algorithm effectively.

The algorithm is specifically designed for the creation of interior design elements using garment production waste, so it may not be directly applicable to other design domains or industries, which limits its versatility and broader adoption. While the algorithm includes color analysis using a four-color circle representation, this may not capture the full complexity and nuances of color in interior design. Designers who require more precise color matching or intricate color schemes may find the algorithm's color representation inadequate. The algorithm focuses primarily on the visual design aspect, allowing designers to focus on aesthetics rather than compatibility checks and constraints. However, it does not account for physical factors such as fabric durability, texture, or performance, which may be important considerations for interior design and clothing accessories. The algorithm consists of six stages, which may introduce complexity and potentially slow down the design process as well as present limitations regarding the scalability of the algorithm in dealing with larger quantities of waste fabric or more intricate design requirements.

The main strength of this research is its novelty, considering that the new algorithm facilitates and allows textile waste recovery. As a kind of limitation, the proposed algorithm can be further improved in order to achieve a higher level of successful automation as part of the patchwork techniques. This will further refine the methods proposed by Yuan et al. [29] and Minda [30] as solutions for using waste textile fabrics.

The presented algorithm's application to the repurposing of waste textile fabrics indicates a promising strategy for sustainable design practices. This study offers valuable insights into image processing techniques, color analysis, and interior design applications, demonstrating possible applications for waste reduction and innovative textile waste utilization. Additional research and investigation in this field could lead to the development of innovative solutions that support a more sustainable and aesthetically appealing design industry.

The limitations of this work can be solved in further research by the following means:

- While this research focuses on upholstery production waste, efforts can be made to adapt the algorithm for other aspects of textile waste management. This could involve exploring additional waste streams, such as garment manufacturing, textile recycling, or consumer textile waste, and developing specific modules or adaptations to address the unique challenges in these areas.
- To enhance the algorithm's effectiveness and applicability, it can be integrated with emerging technologies. For example, artificial intelligence techniques can be leveraged to improve the accuracy and efficiency of waste classification or prediction. Virtual reality or simulation tools can be used to create immersive experiences or virtual environments for waste management planning and decision making. Collaborating with experts in these fields can help identify specific opportunities and facilitate the incorporation of elements that can enhance the algorithm's capabilities.
- The algorithm can be designed to be flexible and customizable, allowing users to adapt it to their specific contexts. This could involve developing a modular architecture that can be easily modified or extended to accommodate different waste management scenarios. Providing a user-friendly interface or API (Application Programming Interface) that allows users to configure parameters, select relevant features, or incorporate domain-specific knowledge could increase the algorithm's adaptability and usefulness across different applications.
- The algorithm can be regularly updated and improved based on feedback and real-world validation. Discussions with industry stakeholders, waste management professionals, and researchers could be useful to gather insights, validate the algorithm's performance, and incorporate lessons learned into future iterations. This iterative approach would ensure that the algorithm remains relevant and effective as new challenges and technologies emerge in the field of textile waste management.

The algorithm presents both advantages which give it the potential for increased applicability and limitations in the form of unmet needs that will have to be addressed in future research directions. Advanced algorithms for optimization, such as hybrid heuristics [31], metaheuristics [32], adaptive algorithms, self-adaptive algorithms, and island algorithms, may play a crucial role in resolving difficult decision-making issues in a variety of domains, including the textile industry. These algorithms provide successful strategies for solving complex real-world issues while offering optimal or near-optimal solutions [33,34].

In fields such as medicine [35,36], online education, scheduling, multi-objective optimization, transportation, and data classification, complex algorithms for optimization enhance the use and distribution of resources, adapt to unpredictable circumstances, minimize costs, improve decision-making processes, and increase overall efficiency [37]. Furthermore, the algorithms can simultaneously consider multiple objectives, limitations, and factors, enabling more thorough and effective decision making [38]. As a future scientific direction, the performance and scalability of our method could be evaluated by comparing the proposed method to the most advanced algorithms. This comparison would shed light on the efficacy of sophisticated optimization algorithms in resolving textile waste management issues and provide a direction for future developments in the field.

5. Conclusions

To address uncontrollable fabric waste issues, the upholstery sector and fashion industry need a new perspective that eliminates wasteful fabric practices. In the present work, an algorithm is proposed with which patterns and designs can be calculated using scraps of fabric produced from cutting textile fabrics from upholstery production. Through the proposed tool, a visual model of the used textile waste and a few combinations were offered. Fabric elements are arranged into a finished pattern of the final product. Thus, it is anticipated that this study will bridge the gap between academic research and efforts by the upholstery sector to reduce cut waste.

The presented tool fits into designers' workflow and greatly facilitates the design of basic combinations of textile pieces. The algorithm allows designers to focus on the visual design rather than compatibility checks and constraints.

The results of this research can be practically applied in interior design, fashion design, production planning, consumer decision making, design education, and sustainability initiatives within the fashion and interior design industries.

The algorithm's effectiveness and applicability could be further enhanced by incorporating innovative technologies such as artificial intelligence, virtual reality, or advanced simulation tools. Continuing this work through collaboration with industry stakeholders and integration with emerging technologies could advance the algorithm's effectiveness, broaden its applicability, and contribute to sustainable design practices in the fashion and interior design industries.

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Conflicts of Interest: The authors declare no conflict of interest.

Appendix A

List of the software in GNU Octave

1	2	3

tic
clc, clear all, close all
pkg load image
 	
d1=dir(‘*.png’); a=numel(d1)
 	
a1=(1:a).’;
n=sqrt(size(a1,1))
if n==round(n)
n = round(sqrt(size(a1,1)))
n1=n
else
n=round(sqrt(size(a1,1)))
n1=n+1
endif
 	
figure
hold on
for b=1:a
subplot(n,n1,b)
imshow(d1(b).name)
end
print -djpg figure1.jpg
hold off
 	
i=imread(‘figure1.jpg’)
i1=im2bw(i,0.95)
i2=imcomplement(i1)
i2=bwareaopen (i2, 100)
figure
imshow(i2)
 	
ss=regionprops(i2)
 	
for j=1:a
c(j,1:2)=ss(j).Centroid
end
 	
x=c(:,2); y=c(:,1)
 	
figure
hold on
imshow(i)
voronoi(y,x)
axis equal
hold off
 	
figure
hold on
x1=round(x);y1=round(y)
 	
col=impixel (i, y1, x1)
col1=(col/255)
 	
$v1, c1$
=voronoin ([x,y],{“Qbb”});
 	
for d = 1:a
patch(v1(c1{d},1),v1(c1{d},2),
col1(d,:))
end
hold off
axis equal
	%Creating Lab Wheel
	
	rgb=col
	numcolors=a
	num_rects=numcolors
	
	rect_colors = rgb/255
	rgb1=rgb
	
	j=0
	for l=1:length(rgb(:,1))
	j=j+1
	mn=min(rgb(j,1),rgb(j,2))
	Iw(j)=min(mn,rgb(j,3))
	mn1=min(1-rgb(j,1),1-rgb(j,2))
	Ib(j)=min(mn1,1-rgb(j,3))
	end
	Iw=transpose(Iw);Ib=transpose(Ib)
	Iw=[Iw, Iw, Iw]
	Ib=[Ib, Ib, Ib]
	
	rgb2=rgb1; map1=rgb1/255
	lab=rgb2lab(map1)
	
	figure
	title(‘RGB Values of the colors’)
	m=0
	for i=1:num_rects
	rectangle(‘Position’,
	[0,i+m,10,num_rects], ‘FaceColor’,
	rect_colors(i,:));
	rectangle(‘Position’,
	[.5,i+m,2.5,num_rects],
	‘FaceColor’, ‘w’);
	ylim([0 num_rects^2+num_rects])
	axis off
	str1=num2str(rgb1(i,:))
	str2=num2str(i)
	text(1,i+m+num_rects/2,[str2 ‘@ ’
	str1])
	m=m+num_rects
	end
	
	figure
	title(‘Colors by Hue (Lab) angle’)
	hold on
	
	t=360/pi
	nn=0
	for bn=1:length(map1(:,1))
	nn=nn+1
	if lab(nn,1)<0&&lab(nn,3)<0
	degr(nn)=atan(lab(nn,3)/lab(nn,2))*t
	end
	if lab(nn,1)==0
	degr(nn)=(pi/4)*t
	end
	if lab(nn,1)>0&&lab(nn,3)>0
	degr(nn)=(pi/2)-
	atan(lab(nn,3)/lab(nn,2))*t
	end
	end
		degr=transpose(degr)
		r=rgb2(:,1); g=rgb2(:,2);
		b=rgb2(:,3)
		rx=sqrt(lab(:,2).^2+lab(:,3).^2)
		
		ri=rgb2(:,1)
		gi=rgb2(:,2)
		bi=rgb2(:,3)
		delta=sqrt(ri.^2+gi.^2+bi.^2)
		
		a=200;b=200;r=max(rx);t=pi/180
		
		fi3=0:10:360
		x3=a+r*cos(fi3*t)
		y3=b+r*sin(fi3*t)
		plot(x3,y3,‘r’,‘linewidth’,2)
		x3=transpose(x3)
		y3=transpose(y3)
		a1=repmat(a,length(x3),1)
		
		for i=1:length(a1)
		x4(i,:)=[a1(i),x3(i)]
		y4(i,:)=[a1(i),y3(i)]
		end
		plot(x4’,y4’,‘b’)
		
		fi3=0:60:360
		x3=a+r*cos(fi3*t)
		y3=b+r*sin(fi3*t)
		x3=transpose(x3)
		y3=transpose(y3)
		a1=repmat(a,length(x3),1)
		for i=1:length(a1)
		x5(i,:)=[a1(i),x3(i)]
		y5(i,:)=[a1(i),y3(i)]
		end
		plot(x5’,y5’,‘r’,‘linewidth’,2)
		
		r=rx
		fi=transpose(degr)
		
		for i=1:num_rects
		
		x(i)=a+r(i)*cos(fi(i)*t)
		y(i)=b+r(i)*sin(fi(i)*t)
		x=transpose(x)
		y=transpose(y)
		
		fi4=0:360
		r1=5
		x6=x(i)+r1*cos(fi4*t)
		y6=y(i)+r1*sin(fi4*t)
		fill(x6,y6,map1(i,:))
		%circles(x(i),y(i),wh,‘facecolor’,
		map1(i,:))
		str2=num2str(i)
		text(x(i),y(i),str2)
		
		axis equal
		grid on
		end
		toc

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