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The Application of an Intelligent System in Digital Weave Design: Optimising Light Intensity and Font Selection for Enhanced Fabric Creation

Uporaba inteligentnega sistema pri digitalnem oblikovanju tkanine: optimizacija osvetljenosti in izbira pisave

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Abstract

The increasing demand for creative and aesthetically pleasing fabric designs has been facilitated significantly by advances in software engineering, enabling textile designers to meet these challenges more effectively. Complex designs that were once difficult or nearly impossible to produce are now readily available with the aid of specialized software. However, the use of such software necessitates a high level of skill and experience, and there is limited literature on its performance under varying environmental conditions. This research focuses on the application of digital weaving software to identify best practices for font selection and considers the impact of light intensity on image capture. The statistical analysis reveals a strong linear correlation between light intensity and variation in unbroken floats. The study's findings recommend specific font styles for writing text on fabric selvedge and suggest an optimal light intensity range for camera-based image capture, which is crucial for subsequent software processing. These insights are expected to assist textile technologists in creating fabric selvedge with woven text more efficiently.
Keywords: digital weaving, optimization, intricate designs, Jacquard, intelligent systems

Izvleček

Zadovoljevanje naraščajočega povpraševanja po kreativnih in estetsko privlačnih vzorcih tkanin je znatno olajšano z napredkom v razvoju programske opreme, ki tekstilnim oblikovalcem in tehnologom omogoča učinkovito spopadanje s temi izzivi. Zapleteni vzorci, ki jih je bilo nekoč težko ali skoraj nemogoče izdelati, so sedaj z uporabo specializirane programske opreme zlahka izvedljivi. Uporaba tovrstne programske opreme zahteva visoko raven znanja in izkušenj, literature o njenem delovanju v različnih okoljskih razmerah pa je malo. Ta

raziskava se osredinja na uporabo programske opreme za digitalno tkanje, za prepoznavanje najboljših praks pri izbiri pisave, in upošteva tudi vpliv intenzivnosti svetlobe na zajem slike. Statistična analiza razkriva visoko linearno korelacijo med intenzivnostjo svetlobe in variacijo flotirajočih niti. Rezultati raziskave so priporočila za izbor določenih slogov pisav za vstavljanje besedila na rob tkanine in predlogi optimalnega razpona intenzivnosti osvetlitve za zajem slike s kamero, kar je ključnega pomena za nadaljnjo obdelavo s programsko opremo. Pričakovati je, da bodo ti vpogledi pomagali tekstilnim oblikovalcem in tehnologom pri učinkovitejšem ustvarjanju robov tkanine s tkanim besedilom.
Ključne besede: digitalno tkanje, optimizacija, zapleteni dizajni, žakard, inteligentni sistemi

1 Introduction

A Jacquard loom is a type of weaving machine capable of producing intricate and artistic fabric designs. Jacquard weaving has a long-standing tradition and historical significance. Before 1804, Jacquard fabrics were made by hand. It was in that year that Joseph Jacquard introduced punch cards to automate the Jacquard loom. The early versions of the loom were referred to as "treadle looms," later evolving into "pattern looms," and eventually becoming known as "draw looms" [1]. Modern electronic Jacquard weaving machines are widely used in the textile industry. These machines have electronic selection systems that allow them to harness control to generate specified designs [2, 3]. Significant advances in Jacquard technology have occurred over the past few decades [4]. Modern Jacquard machines have transitioned to electronic forms with computer controls, and Jacquard weaving now widely utilizes network communication [5, 6]. Additionally, the hook count in computerized Jacquard machines has increased to 20,000, significantly expanding patterning capabilities [7]. The latest approach in computer art design is digital picture design, with Jacquard fabric now regarded as a "high-grade" material featuring intricate colours and textures. The design and techniques for digital Jacquard fabrics are inspired by computer-generated images and colour modes, allowing the creation of advanced Jacquard fabric designs that surpass traditional free-hand patterns [8]. In contemporary Jacquard weaving, the variability of the colour of the yarn is limited to electronic Jacquard technology, making it challenging to achieve a wide range of weave colours. To reproduce pictorial images with minimal yarn variation, a CMYK (cyan, magenta, yellow and black) colour system is used to define artwork colours, with primary colour data applied to weave structures. These weave colours display a wide spectrum of brightness, hue, ad chroma variations, closely mimicking the effect of pigment mixing [9].

Currently, there is limited literature on the performance of widely used Jacquard software. While the potential for design creation is great, translating these designs into woven fabric presents several challenges. These challenges include managing the number of colours in a design, selecting the appropriate design to achieve the desired appearance and configuring machine settings for computer-aided manufacturing. An essential technical parameter in Jacquard weaving is the control of unbroken floats. In textile terminology, a float refers to the length of yarn on the surface of a woven fabric between two consecutive intersections of yarns woven at right angles, and it is a critical factor in determining a fabric's weave-ability. This research specifically examines the process of floatation editing, emphasizing the importance of managing float length, particularly at the edges and borders of design motifs. Proper floatation control is critical for maintaining the sharpness and aesthetic quality of woven text and intricate patterns. At the borders of these motifs, where float length control becomes particularly challenging, the precision of floatation directly impacts the visibility and readability of the woven fabric. This study, therefore, addresses the intricate process of floatation editing to ensure that the design remains visually intact, even in its most detailed parts. This research focuses on selecting font styles to print text for Jacquard weave patterns on the fabric selvedge, and examines the impact of sunlight on the designs through image processing techniques for colour reduction and weave assignment. The findings of this research will assist Jacquard designers in effectively incorporating text into designs and developing new patterns using camera-based methods. Future research should explore the integration of advanced AI algorithms to further enhance design precision and automation in Jacquard weaving.

2 Methodology

Research results were analysed using both subjective and objective methods. The subjective evaluation involved visual inspection during the float-breaking process, along with feedback from respondents gathered through a survey. The objective analysis focused on quantifying the number of broken and unbroken floats. This study did not involve the physical production of woven fabric. Instead, the weaving process was simulated using digital images to evaluate the occurrence of unbroken floats under varying light intensities and times of day. Table 2 provides details of the unbroken floats for the selected fonts of the 225 font styles studied. To determine the most visible font for digital weaving, the pre-installed Microsoft Paint application, available on all Microsoft operating systems, was used. A total of 225 different font styles from the Microsoft Word application were selected for evaluation. Fonts were categorised as "Good" if they retained clarity, "Satisfactory" if they showed slight degradation and "Compromised" if they became hard to read due to excessive float breaking. The "The quick brown fox jumps over the lazy dog" was used for all font styles. The image size was set to 744 pixels in width and 120 pixels in height before copying the text from Word to Paint, as illustrated in Figure 1. The images were then saved in Portable Network Graphic (PNG) files. ScotWeave, software developed by ScotCad Textiles Ltd., UK, was used to convert these image files into a format readable by the Bonas Jacquard machine. The image files were opened in the artwork module of ScotWeave, where the colours were reduced to grayscale and then further limited to only two colours. The processed artwork was then opened in the Jacquard designer module, where yarns were defined, and 5-end satin and sateen weaves were added to the colour Jacquard module.

The float length was set to six (6) in the float breaking tool within the Jacquard designer module. The number of floats was measured on both sides (face and back) of the fabric and in both weaving directions (warp and weft). This process was repeated four times to minimize the number of floats as much as possible. Finally, the output from the Jacquard designer module was exported in Bitmap format for fabric weaving. The Bitmap format was chosen as an intermediate step due to its compatibility with image processing tools and lossless quality, enabling precise design adjustments. After optimizing the design, it was converted to the Jacquard-specific format required for the loom, ensuring compatibility while maintaining design integrity.

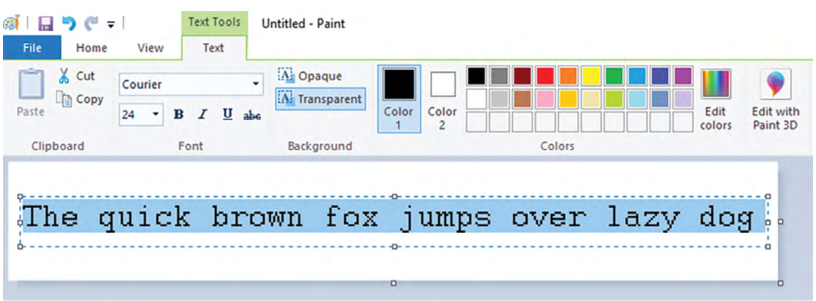


Figure 1: Microsoft paint with copied font style from Microsoft Word

2.1 Optimization of light conditions for Jacquard weaving

Referring to Figures 2 and 3, images were captured from two locations at the National Textile University (NTU), Pakistan: the main entrance (UME) and the medical centre (UMC), during morning and evening hours. The images were taken using an Android smartphone equipped with a 48MP AI quad-camera. Sunlight intensity, measured in lux, was recorded using the Lux Light Meter application developed by Micro Inc., available in the Google Play Store. To optimise light conditions for Jacquard weaving, the Jacquard inscription "The quick brown fox jumps over the lazy dog" was simulated using the collected lighting data. The images captured under varying light intensities were processed to assess their effect on the clarity and readability of the text in the simulated Jacquard weave. The impact of light intensity on the unbroken floats and overall fabric design was observed. The float-breaking process followed a specific sequence: first breaking the warp float on the face side of the fabric, followed by the weft float on the face side, then the warp float on the backside and finally the weft float on the backside. The results were used to determine the optimal lighting conditions for accurate image capture, which is crucial for subsequent software processing in Jacquard weaving. To analyse the impact of lighting on fabric quality, images were captured at various times of the day, starting from the morning, with light intensity measured using the Lux Light Meter application. The time of day was recorded to assess how varying light conditions influenced the occurrence of unbroken floats. While camera angles were considered during image capture, their impact on the results was minimal and did not significantly affect the fabric quality. The primary focus was on how light intensity changes throughout the day correlated with the visual clarity of the woven fabric. Twelve images were taken at one-hour intervals, starting at 5 am (Pakistan Standard Time). Detailed timings and corresponding light intensities are provided in Table 1. The camera angles were set at 76.0 (x, y), 77.0 (x, v) and 83.0 (x, y) for image capture.

The process of converting these images for computer-aided design followed the same procedure as described in the methodology section, except that the number of colours was reasonably reduced to preserve image quality. Additionally, the intelligent system known as "The PictureJaq Feature" within ScotWeave was used to apply weaves to the colours, ensuring a smooth integration of the design with the weaving process while maintaining optimal visual detail. The reduction of colours and application of weaves were necessary to maintain image clarity and achieve a high-quality woven output suitable for manufacturing.

Table 1: Time and light intensity measurements at two locations of the NTU

Ser. no.	University main hall		University medical center	
	Time (24 h)	Intensity (lux)	Time (24 h)	Intensity (lux)
1	6:15	7	6:22	61
2	7:15	1750	7:22	1840
3	8:15	4500	8:22	5439
4	9:15	7421	9:22	7621
5	10:18	35500	10:23	27621
6	11:18	45335	11:23	35200
7	12:18	34300	12:25	27220
8	13:20	21520	13:25	23500
9	15:15	16070	15:25	13528
10	16:15	2100	16:25	2200
11	17:15	105	17:12	200
12	17:43	2	17.45	0

3 Results and discussion

3.1 Results

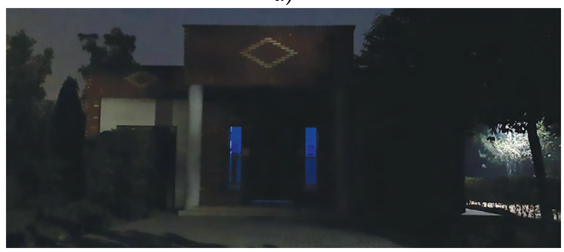
The results of the study were analysed to evaluate the impact of different font styles and light intensity conditions on the number of unbroken floats in the Jacquard weave patterns. Both subjective and objective analyses were performed to assess the visual quality and quantification of floatation across

a)

b)

Figure 2: Images taken in the early morning of (a) UME and (b) UMC

a)



b)

Figure 3: Images taken in the late evening of (a) UME and (b) UMC

different fonts and lighting scenarios. Additionally, a supplementary Excel file (.xlsx) is available, which contains comprehensive data for all 225 fonts. When the float-breaking function was applied in the software, new floats emerged from newly formed interlacement points from the breaking of previous floats. This process was repeated for four iterations, with the first ten fonts, arranged alphabetically, selected for further analysis. The results are summarized in Table 3. In this table, green cells indicate that the font style's visual appearance remains clear as the floats are broken, yellow cells denote satisfactory visibility, and red cells indicate that visibility and readability fall below acceptable levels for the human eye.

Although the camera angle parameter was considered during image capture, its direct impact on the number of unbroken floats was minimal, and therefore, it is not included in the results presented in Tables 4 and 5. It was observed that breaking floats over four iterations had minimal impact on the visual quality of most font styles, except for Bancroft Condensed, whose quality degraded from "good" to "satisfactory". Figure 4 represents examples of font styles with an increased difficulty level of readability. The subjective survey identified the five top font styles with the most visually appealing appearance. Arial Black, Berlin Sans FB Demi, Cambria, Franklin Gothic Demi and Segoe UI Black.

Figure 4: Examples of font styles with an increased difficulty in level of readability: (a) Blackader ITC, (b) Edwardian script ITC, (c) Freestyle script, (d) French script MT, (e) Kunstler script, (f) Palace script MT and (g) Parchment

Table 2: Details of number of unbroken floats of selected fonts

Ser. no.	Font name	No. of unbroken floats			
		Face of fabric		Back of fabric	
		Warp	Weft	Warp	Weft
1	Courier	0	0	0	0
2	Fixedly	0	0	0	0
3	MS Outlook	0	0	0	0
4	MS serif	0	0	0	0
5	Small fonts	0	24	0	0
6	System	0	0	0	0
7	Terminal	0	0	0	0

Table 3: No. of unbroken floats from the first ten (10) font styles after four iterations

Ser. no.	Font style	No. of unbroken floats															
		Face of fabric								Back of fabric							
		Warp				Weft				Warp				Weft			
		1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
1	Agency	6	0	*	*	0	*	*	*	5	0	*	*	10	0	*	*
2	Algerian	14	1	0	*	29	1	0	*	50	2	0	*	39	2	0	*
3	Arial black	14	3	*	*	11	*	*	*	6	*	*	*	27	1	*	*
4	Arial Narrow	4	0	*	*	9	*	9	0	2	0	*	*	13	0	*	*
5	Arial rounded MT Bold	13	1	0	*	10	0	*	*	3	1	0	*	40	0	*	*
6	Baskerville Old face	5	0	*	*	21	0	*	*	45	5	0	*	6	0	*	*
7	Arial Unicode MS	5	0	*	*	18	0	*	*	3	0	*	*	13	1	0	*
8	Bancroft	3	0	*	*	31	0	*	*	1	0	*	*	12	0	*	*
9	Bancroft condensed	3	0	*	*	5	0	*	*	1	0	*	*	9	0	*	*
10	Bancroft light	2	0	*	*	17	0	*	*	1	0	*	*	8	0	*	*

* Not affected

To explore the relationship between camera angles, light intensity and the visual appearance of woven fabric, the results related to the number of unbroken floats at the university's main entrance (UME) and the University Medical Center (UMC) are presented in Tables 4 and 5. These tables provide information regarding how different lighting conditions and their corresponding effects on fabric quality are influenced by the time of day. Figures 5 and 6 illustrate the initial (morning) time data, specifically from the first attempt to weave the warp on the face side of the fabric. These figures highlight the correlation between the time of day and light intensity, showcasing how these variables influence the occurrence of unbroken floats and, ultimately, the visual clarity of the woven fabric. This information is crucial for understanding how environmental factors, such as lighting and positioning, impact the quality of textile designs.

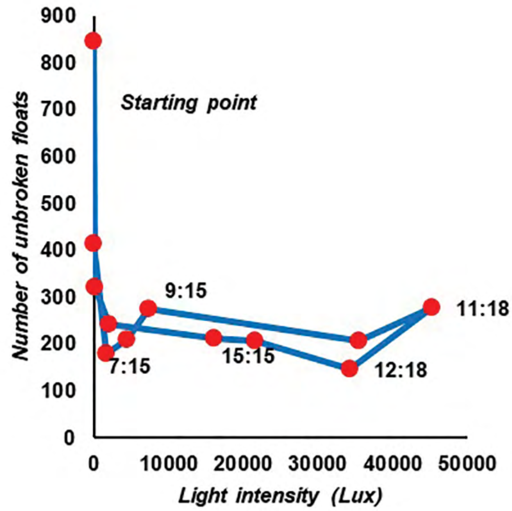


Figure 5: Graphical representation showing how many continuous floats there are at the university's main entrance (UME) as the sun rises and sets

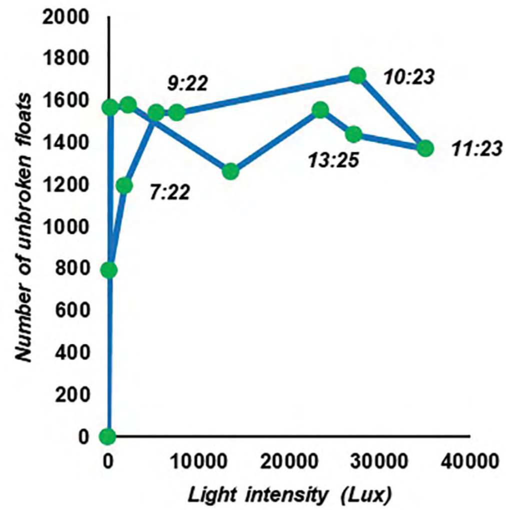


Figure 6: Graphical representation showing how many continuous floats there are at the University's Medical Center (UMC) as the sun rises and sets

Table 4: No. of unbroken floats at the University Main Entrance (UME) after four iterations

Ser. no.	Main entrance		No. of unbroken floats															
			Face of fabric								Back of fabric							
			Warp				Weft				Weft				Weft			
	Time (24 h)	Intensity (lux)	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
1	6:15	7	416	1	*	*	0	*	*	*	0	*	*	*	783	22	*	*
2	7:15	1750	180	1	*	*	0	*	*	*	405	*	*	*	285	5	*	*
3	8:15	4500	209	0	*	*	26	*	*	*	0	*	*	*	199	6	1	*
4	9:15	7421	275	1	*	*	5	*	*	*	917	*	*	*	287	13	1	*
5	10:18	35500	206	1	*	*	0	*	*	*	38	*	*	*	269	9	1	*
6	11:18	45335	278	0	*	*	225	*	*	*	0	*	*	*	314	8	*	*
7	12:18	34300	148	0	*	*	81	1	*	*	223	*	*	*	251	10	0	*
8	13:20	21520	206	1	*	*	329	*	*	*	0	*	*	*	313	8	*	*
9	15:15	16070	214	0	*	*	380	1	*	*	424	*	*	*	399	13	*	*
10	16:15	2100	242	0	*	*	0	*	*	*	349	*	*	*	297	9	0	*
11	17:15	105	322	0	*	*	49	*	*	*	0	*	*	*	436	13	1	*
12	17:43	2	847	5	*	*	0	*	*	*	0	*	*	*	1127	12	*	*

*Not affected

Table 5: Number of unbroken floats on the University Medical Center (UMC) picture after four iterations

Ser. no.	Medical center		No. of unbroken floats															
			Face of fabric								Back of fabric							
			Warp				Weft				Warp				Weft			
	Time (24 h)	Intensity (lux)	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
1	6:22	61	790	3	*	*	0	*	*	*	6	*	*	*	694	27	0	*
2	7:22	1840	1196	4	*	*	0	*	*	*	239	*	*	*	1120	48	0	*
3	8:22	5439	1542	14	*	*	0	*	*	*	0	*	*	*	1556	54	2	*
4	9:22	7621	1542	10	*	*	0	*	*	*	87	*	*	*	1948	50	2	*
5	10:23	27621	1717	10	*	*	0	*	*	*	8	*	*	*	1782	98	4	0
6	11:23	35200	1374	4	*	*	0	*	*	*	650	*	*	*	1733	90	3	0
7	12:25	27220	1439	7	*	*	27	*	*	*	94	*	*	*	2152	99	5	*
8	13:25	23500	1553	3	*	*	11	1	*	*	322	*	*	*	2220	96	6	*
9	15:25	13528	1262	6	*	*	0	*	*	*	480	1	*	*	1790	87	4	*
10	16:25	2200	1581	9	*	*	9	*	*	*	737	*	*	*	2165	98	3	*
11	17:12	200	1567	7	*	*	4	*	*	*	257	*	*	*	1411	38	*	*
12	17.45	0	0	*	*	*	0	*	*	*	0	*	*	*	0	*	*	*

*Not affected

3.2 Discussion

The objective evaluations in Table 2 indicate that seven font styles had zero unbroken floats from the outset, and thus did not require any float-breaking process. These fonts included Courier, Fixedly, MS Outlook, MS Serif, Small Fonts, System and Terminal. Although the number of unbroken floats for most font styles remained within acceptable limits, several were difficult to read. One contributing factor to poor visibility was their relatively small text size. Furthermore, many of these fonts were thin or italic, increasing the complexity of the interlacements during weaving. Examples of such challenging fonts are shown in Figure 4. As a result, these font styles were excluded from the first phase of the study. It was observed that after breaking the warp float on the fabric's face side, the floats on the warp of the backside and the weft floats on the face side became less significant. The primary focus for breaking floats was the weft direction on the backside of the fabric, largely due to the directional choice when applying the float breaking function. If the function was applied in the weft direction first, the results could be reversed.

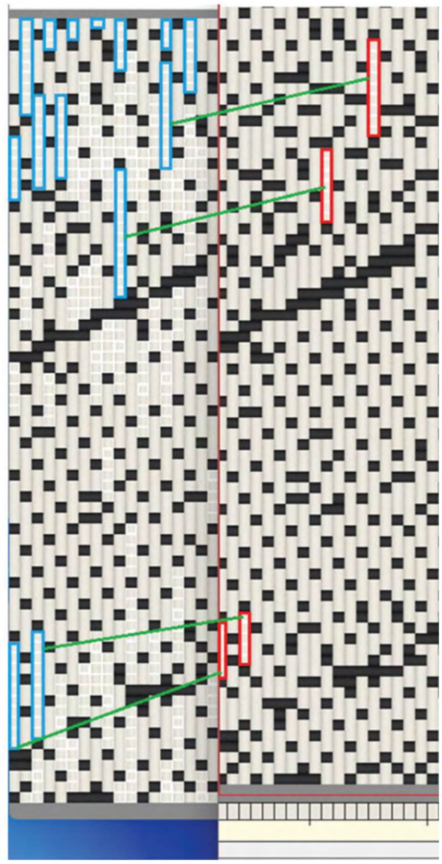
During the initial phases of float breaking, it was relatively easy to reduce a significant number of unbroken floats because many remained unbroken, as seen in Figure 7. However, after several iterations (in this case four), the number of unbroken floats began to increase. This is due to the emergence of new floats at newly created intersection points, which occurs because the original floats were broken. This indicates that float breaking becomes progressively more complex as fewer unbroken floats remain, requiring more strategic intervention. The blue rectangle in the Figure 7(a) is intended to illustrate the warp floats on the 14th warp, and while it currently encloses 10 weave points, this does not impact the interpretation of the results or the methodology applied. The focus of the figure is to visually convey the float-breaking process rather than the exact count of weave points in the rectangle.

The red rectangle of size five (5) drawn on the third warp in Figure 7(b) represents a scenario where the float-breaking algorithm identifies floats just below the defined threshold of six (6). This is due to the algorithm's inherent flexibility, which prioritizes the structural integrity and aesthetic consistency of the design. While the floating point is set to six (6), the software dynamically adjusts to handle cases where shorter floats need to be highlighted for improved weave stability.

As shown in Figures 5 and 6, it was observed that the number of unbroken floats was at its lowest in the early morning (7:15 am) and gradually increased as the sun rose, reaching its peak around noon (11:18 am). The maximum light intensity recorded during the day was 45,335 lux. As the sun began to set, the number of unbroken floats decreased along with the light intensity, continuing until afternoon (3:15 pm). A similar pattern of increasing unbroken floats with rising sunlight, followed by a decrease as the sun set, was also observed at the University Medical Center. These results are consistent with previous studies [10–15], indicating that light intensity and camera angle significantly affect image quality, leading to variations in results when using the same software and processing methods. The ongoing research aims to find solutions to minimize the impact of environmental factors, such as light and camera angle, to optimize the performance of digital image processing software. At this stage, a survey was conducted to assess which lighting conditions produced the most visually appealing fabric appearance. Forty percent of the respondents preferred a light intensity range of 2000–5000 lux, suggesting that this range offers optimal conditions for visual clarity and readability in woven fabric designs. This preference highlights the importance of controlled lighting in achieving consistent results in digital weaving processes.

3.3 Statistical analysis of the data

Statistical analysis performed based on the results using the light intensity and unbroken floats data for the UME and UMC are given in Figure 8. Analysis



a) b)

Figure 7: Float breaking: a) unbroken floats are shown by the blue rectangle and white-bordered blocks; b) the red rectangles remaining unbroken floats are shown after the float-breaking function is applied

was performed against each result and outcomes were recorded. During the analysis, a Pearson correlation coefficient (r) between light intensity and the number of unbroken floats in the warp and weft directions was calculated using the formula below to determine how strongly the light intensity influence the fabric quality.

$$r = \frac{n(\Sigma xy)-(\Sigma x)(\Sigma y)}{\sqrt{(n\Sigma\ ^{2}-(\Sigma x)^{2}][n\Sigma\ ^{2}-(\Sigma y)^{2}]}} \quad (1)$$

where x represents the light intensity, y represents the number of unbroken floats and n represents the number of data pairs.

A linear regression analysis was performed to model the relationship between the light intensity and unbroken floats, which helps in predicting how the changes in light intensity could affect the unbroken floats. High intensity light seems to reduce unbroken floats until noon, after which the trend might reverse as the light intensity decreases.

Figure 8 presents a linear regression analysis of unbroken floats against light intensity for UME warp, UME weft, UMC warp and UMC weft. The R^2 values indicate how well the linear models fit the data. UME warp (a) has an R^2 of 0.6931, showing a moderate negative correlation, meaning light intensity explains about 69% of the variation in unbroken floats. UME weft (b) has a stronger negative correlation with an R^2 of 0.8771. UMC warp (c) has an even stronger negative correlation, with an R^2 of 0.9771, while UMC weft (d) has the strongest positive correlation, with an R^2 of 0.9877, suggesting that light intensity has a major impact on UMC weft performance. These results indicate that UMC fabrics, particularly weft, are more significantly affected by light intensity than UME fabrics, with the positive relationship for UMC weft contrasting with the negative trends observed in the other cases.

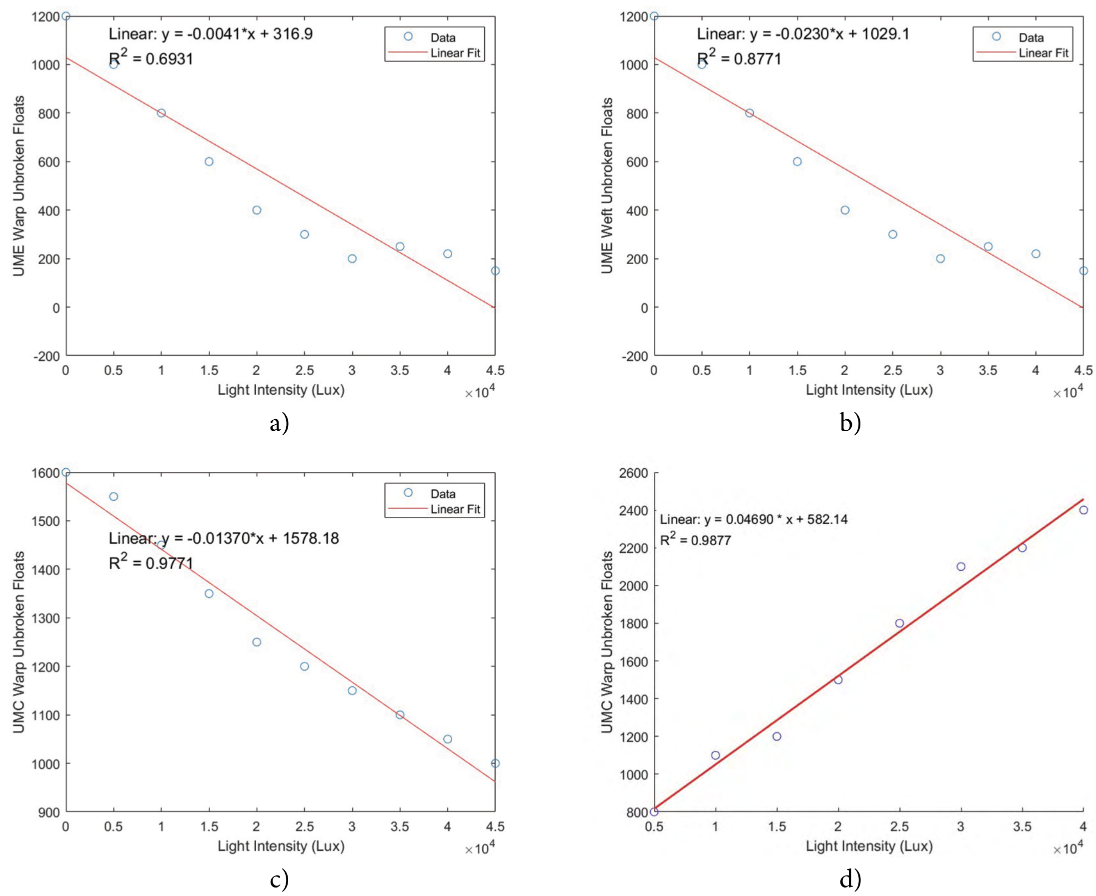


Figure 8: Linear regression of unbroken floats against light intensity for (a) UME warp, (b) UME weft, (c) UMC warp and (d) UMC weft

4 Conclusion

This study highlights the delicate balance between technical weaving requirements and aesthetic preferences in fabric design, particularly in the context of woven text on fabric selvedges. Careful consideration of light intensity and image processing techniques is essential for achieving high-quality and visually appealing results. The recommended light intensity range of 2,200 lux to 55,000 lux provides an optimal setting for capturing images for digital weaving, contributing to more effective colour reduction and fabric design optimization. The variation in unbroken floats is strongly influenced by light intensity, meaning that environmental factors such as light intensity play a significant role in the optimisation of woven fabric design. These insights are valuable for textile designers and manufacturers aiming to enhance the clarity and aesthetic appeal of woven designs. Future research should focus on refining digital weaving processes by further exploring the impact of environmental factors, such as light intensity and camera angles, to enhance the precision and consistency of woven fabric designs.

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