(REFEREED RESEARCH)

DIGITIZING AND CLASSIFYING WOVEN FABRIC DEFECTS

DOKUMA KUMAŞ HATALARININ SINIFLANDIRILMASI VE SAYISALLAŞTIRILMASI

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ABSTRACT

The aim of this research is to digitize certain woven fabric defects from images of woven fabrics, taken by a CCD line scan camera. %100 cotton, plain and twill woven raw fabrics were used in the experiments. Using a lighted fabric quality control board, 2048*4096 pixels BMP format images of the fabrics were generated by a CCD line scan camera. Defected areas of the images were selected and classified by referring the fabrics. Average gray scale values and dimensions of the defected areas (missing pick, irregular pick density, starting mark, double pick, broken pick, broken end, hole-tear, oily spot, oily end, wrong drawing) were measured with the help of Photoshop CS3 program and results were compared with the regular image areas. Results showed that classification of fabric defects requires much more complicated algorithms than simple thresholding for industrial application of automated fabric quality control.

Key Words: Digitizing, Woven fabric defect, Gray scale value, Quality, Classification.

ÖZET

Bu çalışmanın amacı, CCD çizgisel kamera ile kaydedilen dokuma kumaş görüntülerindeki belirli dokuma hatalarının tespit edilerek, hata tanımlarının sayısallaştırılmasıdır. Deneylerde, %100 pamuklu, bezayağı ve dimi dokuma ham bez kumaşlar kullanılmıştır.. Işıklı kalite kontrol panosu kullanılarak, CCD çizgisel kamera ile 2048*4096 piksel boyutlarında, BMP formatında görüntüler alınmıştır. Hatalı kumaş görüntüleri seçilerek, dokuma kumaş hata tanımlarına uygun olarak sınıflandırılmıştır. Hatalı bölgelerdeki (atkı kaçığı, seyrek atkı, duruş izi, çift atkı, yarım atkı, çözgü kopuğu, delik-yırtık, yağ lekesi, yağlı çözgü teli, tahar hatası) ortalama gri renk değerleri ve hata boyutları Photoshop CS3 programı ile ölçülmüş ve sonuçlar hatasız kısımlardaki değerlerle kıyaslanmıştır.

Anahtar Kelimeler: Sayısallaştırma, Dokuma kumaş hatası, Gri renk değeri, Kalite, Sınıflandırma.

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1. INTRODUCTION

For years widely used method for detecting fabric defects is inspection of moving fabric on a lighted control board. Inspection process is performed by an experienced and specially trained expert for this action. Expert detects the defects during the control, on the basis of instructions given at his training and experiences of his own. Hereafter the expert fixes the defects if possible or marks to be fixed. During the control, expert also notes defect types and quantity of defects on a quality control chart. The decision of overall fabric quality is given by comparison of defect quantity detected on unit fabric area with the limits determined by customers or standard upper limits determined by experiences.

The control is so important because the price of second quality fabric is only 45%–65% of that of first-quality fabric (1). A typical web material is 1–3 m wide and is driven with speeds ranging from 20 to 200 m/min. Even in the best cases, experts can detect no more than 60% of the real defects, and they can not deal with fabric wider than 2 m and moving faster than 30 m/min (2,3). Therefore, to supply the reliability and international acceptability of woven fabric defect control, use of systems which are objective, fast and economic and assurance providing between fabric manufacturers and customers has become necessity.

Visual inspection systems can be used in a wide range of textile materials for purpose of control (4). Defects can produce a wide range of visible effects on the finished fabric (5). If the digital images of a fabric have differences with the digital images of the same fabric that has no defect, it should determine that there is a defect (4). When different types of fabric defects analyzed, there should be differences in terms of dimensions and gray color values of them (6). But wide range of patterns, colors on fabric and different types of fabric defects makes this operation difficult. By using automated inspection systems it is provided to take objective and repeatable decisions and modify the causes of defects rapidly and reduce caution times (4).

Automated inspection systems have attracted a lot of attention lately and defect detection methods developed by using morphological filters (7), gabor filters (3), local contrast deviations (8), artificial neural networks (9) and others. Morphological filters detected 88% of the defects but not classified them and created 3,3% false alarm on defect-free areas (7). Gabor filters detected 75% of the 32 different types of defects and classified them with only 3,8% false alarm (3). Local contrast deviation method is a type of thresholding and works with maximum 7,84 detection errors rate for certain types of defects (8). It was also reported that 90% of the defects in a plain fabric could be detected simply by thresholding (3, 7).

In this paper, considering that the dimensions and gray color values of different fabric defects are not similar, we tried to address how easy to classify of certain defects by simple methods like thresholding. These certain defects were chosen by analyzing the most occurred defects on fabrics and generated more than 90% of the total number of defects (4). Defects on the fabrics were original defects as it was. Machine run in slow speeds that created high resolution images to distinguish differences more accurately.

2. MATERIAL AND METHOD

2.1. Material

In this research % 100 cotton, plain and twill woven raw fabrics with defected parts were selected and some of them sewn together to create enough length to run the machine. For detecting fabric images, a custom-made fabric quality control board was used (Figure 1). CCS LND-600H-DF red LED line light was selected since red light has the most sensitive wavelength to the CCD cameras and mounted on board creating backlighting. Images were taken by ATMEL AViiVA SM2 1x4096 monocolor CCD line scan camera mounted on board with adjustable distance.

2.2. Method

On board shown in Fig. 1, “start”, “stop”, “rewind”, “light”, “control light” and “speed control” buttons were placed. System was controlled by one motor which allowed speed control. Camera system was connected to a computer for transferring data. Camera speed could be set to proper frequency through computer. Focus and light settings of camera were adjusted manually with the objective of camera. The most important parameters concerned with the system were pixel resolution, fabric running speed, camera speed, lighting and software. Each pixel covered about 4,54 (lengthwise) x 12,21 (crosswise) μ, or each 2048*4096 pixels image covered 9,3x41,0 cm^2 fabric area. Fabrics were run less than 1 m/s (calculated about 0,65 m/s) and camera speed was kept 14 kHz maximum line rate with backlighting.

A line scan camera is suitable for the inspection systems working at constant speeds. Although it was a line scan camera, the data were collected in a buffer and created 2D images on the monitor. Dimensions and average gray color values of classified defects were evaluated with Photoshop CS3 program as shown in Fig. 2.

Fig 1. Custom made fabric quality control board

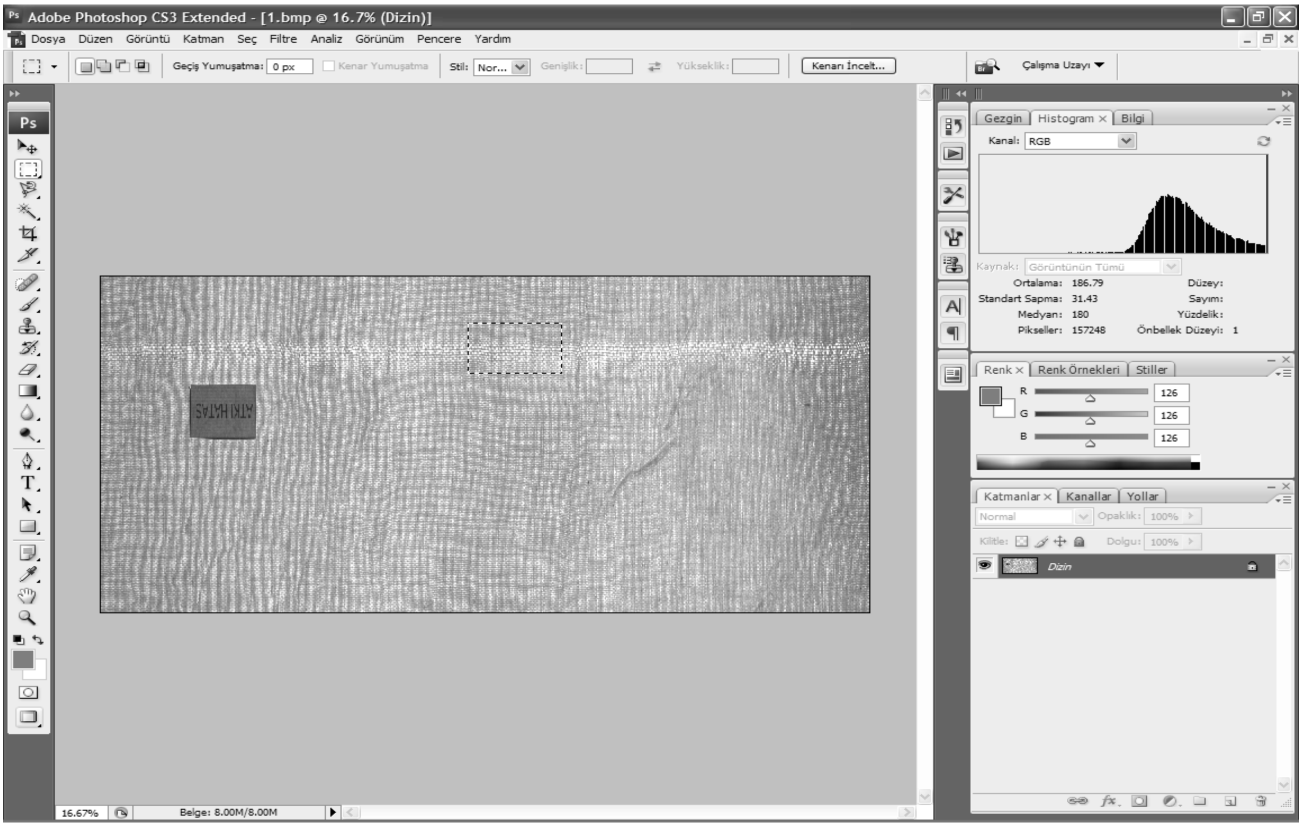

Fig 2. Evaluation of a classified defect with Photoshop CS3

3. RESULTS AND DISCUSSION

10 different defect types, missing pick (mispick), irregular pick density (filling bar), starting mark (stop mark), double pick, broken pick (weft crack), broken end, hole-tear, oily spot (stain), oily end and wrong drawing (misdraw) were analyzed on images of plain and twill fabrics. Defected areas of images were selected and measured by pixels on X and Y axis, and defects were classified by referring the fabrics. Average gray color values of regular and defected areas were found and compared to see the differences. In tables, P refers plain fabrics and T refers twill fabrics.

3.1. Evaluation of Missing Pick

Missing pick is defined as “a place where the weave design is broken by the absence of a pick” (10). Images of 15 missing picks were analyzed and numerical values were given in Table 1. Missing pick dimensions were measured between 36 and 220 pixels, equal to between 0,163 and 0,998 mm distance on fabric, in lengthwise and whole width in crosswise. Average gray color values of defected areas were changed between %14,6 and %22,1. The results were higher than the average gray color values of regular images as expected. Depending on structure of missing pick, fabric density decreases at the defected area, therefore more light pass through fabric.

3.2. Evaluation of Irregular Pick Density

“A visual defect across the width which contains a limited number of picks of different appearance than normal” is the definition of irregular pick density (11). Images of 16 irregular pick density were analyzed and numerical values were given in Table 2. As presented, irregular pick density defect dimensions were measured between 63 and 550 pixels in lengthwise and whole width in crosswise. The average gray color values of defected area were changed between %6,3 and %22. The results were higher than the average gray color values of regular images. Depending on structure of irregular pick density, all defected image areas had lower density than regular areas

3.3. Evaluation of Starting Mark

“A visible change in the density of the weave across the width of the fabric caused by the tension on the warp not being adjusted properly after the loom has been stopped.” is the definition of starting mark (11). Table 3 shows that starting mark defect dimensions were measured between 17 and 68 pixels in lengthwise and whole width in crosswise. The average gray color values of defected area were changed between %5,2 and %26,3. The results were higher than the average gray color values of regular images.

Analyzing the data in Table 1, Table 2 and Table 3, missing pick, irregular pick density and starting mark defects were existed throughout whole width. All three defects, depending on structure, had higher average gray level values than regular image areas because of lower density in defected area. Some of these images numerical values overlapped making classification impossible only with thresholding. However, irregular pick density is distinguishable with either higher pixels in lengthwise or overlapped number of pixels but repeated regularly in certain distance.

Table 1. Numerical values of missing pick

Fabric Number	Fabric Type End/cm Pick/cm	Dimensions of Defect on X Axis (Pixels)	Dimensions of Defect on Y Axis (Pixels)	Average Gray Color Values of Images	Average Gray Color Values of Defected Areas	Percentage Difference of Gray Color Values
1	P/26/22	4096	108	175	205	+17,3
2	P/27/23	4096	148	175	203	+15,9
3	P/30/30	4096	160	180	216	+20,0
4	T/32/23	4096	36	154	179	+16,4
5	P/34/25	4096	220	201	237	+17,6
6	P/32/30	4096	108	179	207	+16,0
7	T/33/24	4096	80	156	179	+14,6
8	P/32/24	4096	104	202	237	+17,4
9	P/28/21	4096	72	175	213	+21,8
10	P/24/16	4096	104	159	190	+19,6
11	P/24/16	4096	148	169	202	+19,7
12	P/32/26	4096	116	194	227	+16,9
13	T/33/16	4096	116	165	197	+19,5
14	T/33/16	4096	152	161	196	+22,1
15	P/28/24	4096	148	186	221	+19,1

Table 2. Numerical values of irregular pick density

Fabric Number	Fabric Type End/cm Pick/cm	Dimensions of Defect on X Axis (Pixels)	Dimensions of Defect on Y Axis (Pixels)	Average Gray Color Values of Images	Average Gray Color Values of Defected Areas	Percentage Difference of Gray Color Values
1	P/17/15	4096	156	141	158	+12,1
2	P/16/16	4096	156	136	166	+22,0
3	P/28/23	4096	550	175	197	+12,6
4	P/28/20	4096	109	199	213	+7,0
5	P/26/19	4096	63	202	216	+6,9
6	P/25/16	4096	100	133	160	+19,9
7	P/28/23	4096	85	199	211	+6,3
8	P/28/22	4096	232	172	190	+10,0
9	P/28/22	4096	533	175	195	+11,3
10	P/28/22	4096	161	175	192	+9,4
11	P/26/14	4096	205	180	194	+7,7
12	P/28/21	4096	95	172	188	+9,3
13	P/28/22	4096	67	173	194	+12,3
14	P/34/32	4096	402	179	200	+11,3
15	P/32/30	4096	333	174	197	+13,1
16	P/30/30	4096	162	174	195	+12,0

Table 3. Numerical values of starting mark

Fabric Number	Fabric Type End/cm Pick/cm	Dimensions of Defect on X Axis (Pixels)	Dimensions of Defect on Y Axis (Pixels)	Average Gray Color Values of Images	Average Gray Color Values of Defected Areas	Percentage Difference of Gray Color Values
1	T/33/15	4096	68	155	181	+17,0
2	P/28/20	4096	55	172	187	+8,7
3	P/28/23	4096	34	175	191	+9,4
4	P/16/15	4096	38	165	209	+26,3
5	T/33/15	4096	64	155	183	+17,8
6	T/34/17	4096	24	159	174	+9,1
7	P/26/23	4096	34	189	202	+7,1
8	P/26/18	4096	57	203	213	+5,2
9	P/28/22	4096	24	169	182	+7,1
10	P/28/20	4096	53	199	212	+6,5
11	P/28/20	4096	49	202	215	+6,2
12	P/32/30	4096	17	174	199	+14,2
13	T/32/17	4096	63	163	184	+13,0
14	P/28/19	4096	48	197	213	+7,9

3.4. Evaluation of Double Pick

Double pick is one of the most common defects, in which instead of taking a single yarn in the weft direction, the machine mistakenly take two yarns (12). According to data given in Table 4, double pick dimensions were measured between 9 and 18 pixels, equal to between 0,041 and 0,082 mm distance on fabric, in lengthwise and whole width in crosswise. Average gray color values of defected areas were changed between %8,8 and %21,3. The results were lower than the average gray color values of regular images. Depending on structure of double pick, fabric density increases at the defected area therefore less light pass through fabric.

3.5. Evaluation of Broken Pick

Broken pick is one among the common defect, where the yarns in the weft direction are cut or broken (12). Table 5 shows that broken pick dimensions measured between 1106 and 3430 pixels along the X axis and between 9 and 12 pixels along the Y axis. The average gray color values of defected area were changed between %4,0 and %22,6. The results were lower than the average gray color values of regular images. Higher fabric density generally creates lower percentage difference of gray color values as expected.

3.6. Evaluation of Broken End

Broken end is described as “a void in warp direction due to yarn breakage” (11).Images of 8 broken ends were analyzed and numerical values were given in Table 6. As presented, broken end dimensions measured between 15 and 82 pixels, equal to between 0,183 and 1,001 mm distance on fabric, in crosswise and between 16 and 94 pixels, equal to 0,072 and 0,426 mm distance on fabric, in lengthwise. The average gray color values of defected area were changed between %8,6 and %26,3. The results were lower than the average gray color values of regular images.

3.7. Evaluation of Hole-Tear

“An imperfection where one or more yarns are sufficiently damaged to create an aperture” is the definition of hole (11). Tear normally has longer dimensions than hole. Table 7 shows that hole-tear dimensions measured between 14 and 282 pixels along the X axis and between 94 and 875 pixels along the Y axis. The average gray color values of defected area were changed between %10,1 and %34,6. The results were higher than the average gray color values of regular images.

Table 4. Numerical values of double pick

Fabric Number	Fabric Type End/cm Pick/cm	Dimensions of Defect on X Axis (Pixels)	Dimensions of Defect on Y Axis (Pixels)	Average Gray Color Values of Images	Average Gray Color Values of Defected Areas	Percentage Difference of Gray Color Values
1	P/30/23	4096	11	175	148	-15,1
2	P/28/23	4096	11	176	153	-13,2
3	P/28/24	4096	17	179	142	-20,3
4	P/28/22	4096	12	183	144	-21,3
5	P/26/23	4096	11	175	155	-11,5
6	P/34/26	4096	10	199	163	-17,7
7	P/34/26	4096	9	192	156	-18,7
8	P/30/26	4096	9	193	162	-16,2
9	P/28/22	4096	9	172	155	-10,0
10	P/28/22	4096	11	174	142	-18,0
11	P/30/30	4096	12	179	156	-13,2
12	P/28/26	4096	9	174	153	-12,0
13	P/30/30	4096	9	174	147	-15,1
14	P/32/26	4096	9	196	159	-18,4
15	P/30/22	4096	11	186	165	-11,4
16	P/30/23	4096	18	188	159	-15,5
17	P/26/23	4096	9	188	172	-8,8
18	P/28/23	4096	9	191	166	-13,1

Table 5. Numerical values of broken pick

Fabric Number	Fabric Type End/cm Pick/cm	Dimensions of Defect on X Axis (Pixels)	Dimensions of Defect on Y Axis (Pixels)	Average Gray Color Values of Images	Average Gray Color Values of Defected Areas	Percentage Difference of Gray Color Values
1	P/30/30	3394	12	172	165	-4,0
2	P/34/32	3430	10	172	156	-9,1
3	P/28/23	1106	9	176	136	-22,6
4	P/28/25	3218	11	179	153	-14,5
5	P/30/22	2602	11	178	146	-17,5
6	P/28/23	2385	10	182	159	-12,8
7	P/32/30	2727	9	172	152	-11,4
8	P/28/24	2625	11	180	155	-13,8

Table 6. Numerical values of broken end

Fabric Number	Fabric Type End/cm Pick/cm	Dimensions of Defect on X Axis (Pixels)	Dimensions of Defect on Y Axis (Pixels)	Average Gray Color Values of Images	Average Gray Color Values of Defected Areas	Percentage Difference of Gray Color Values
1	P/30/30	22	27	172	135	-21,8
2	P/30/30	15	16	172	157	-8,6
3	P/34/27	45	16	199	156	-21,8
4	P/28/25	36	77	173	127	-26,3
5	P/24/16	21	35	138	109	-20,7
6	T/33/17	15	31	160	126	-21,4
7	P/30/23	82	39	179	135	-24,7
8	P/30/22	48	94	176	155	-11,5

Table 7. Numerical values of hole-tear

Fabric Number	Fabric Type End/cm Pick/cm	Dimensions of Defect on X Axis (Pixels)	Dimensions of Defect on Y Axis (Pixels)	Average Gray Color Values of Images	Average Gray Color Values of Defected Areas	Percentage Difference of Gray Color Values
1	T/34/22	108	298	150	178	+18,4
2	P/24/22	234	739	148	173	+16,5
3	P/28/24	20	164	171	189	+10,1
4	T/36/22	14	94	150	202	+34,6
5	P/24/23	282	717	148	178	+20,4
6	P/28/24	51	309	144	192	+33,2
7	P/24/18	255	875	145	180	+24,4

3.8. Evaluation of Oily Spot

Oily spot is defined as "an area of discoloration that penetrates the fabric surface" (11). Images of 15 oily spot were analyzed and numerical values were given in Table 8. According to the data, oily spot dimensions measured between 37 and 843 pixels along the X axis and between 82 and 1971 pixels along the Y axis. The average gray color values of defected area were changed between %9,7 and %27,3. It was noted that images of oily spot and hole-tear were had more complex shapes than the other defects. Dimensions of two defects were recorded as the longest line in both ways. Although measured dimensions of the two defects were very similar, their percentage difference of gray color values had different signs.

3.9. Evaluation of Oily End

It is defect that occurs by weaving oily or dirty warps. Images of 17 oily ends were analyzed and numerical values were given in Table 9. Oily end dimensions measured between 5 and 44 pixels, equal to between 0,061 and 0,537 mm distance on fabric, in crosswise and between 375 and 1637 pixels, equal to 1.702 and 7,431 mm distance on fabric, in lengthwise as shown in Table 9. The average gray color values of defected area were changed between %9,4 and %30,2. The results were lower than the average gray color values of regular images. Analyzing the data in Table 8 and Table 9, images of oily spot and oily end had similar gray color values. Also the dimensions of both defects on Y axis were comparable. But oily end existed on one or a few warp yarns therefore the measured dimensions of oily end on X axis were significantly less than oily spot.

3.10. Evaluation of Wrong Drawing

"One or more incorrectly drawn warp ends in the harness or reed" is the definiton of wrong drawing (11). From Table 10, it is seen that dimensions of defect on X axis are only between 4 and 8 pixels, however on Y axis are between 670 and 2048 pixels, equal to 3,410 and 9,297 mm distance on fabric. Indeed, 2048 pixels dimension on Y axis show that the defect dimension is longer than the image dimension and not fit into the image. The average gray color values of defected areas were changed between %6,8 and %17. The results were lower than the average gray color values of images.

Table 8. Numerical values of oily spot

Fabric Number	Fabric Type End/cm Pick/cm	Dimensions of Defect on X Axis (Pixels)	Dimensions of Defect on Y Axis (Pixels)	Average Gray Color Values of Images	Average Gray Color Values of Defected Areas	Percentage Difference of Gray Color Values
1	P/28/22	315	179	185	157	-14,9
2	P/28/23	170	828	183	151	-17,2
3	P/28/25	37	86	181	152	-16,1
4	P/32/30	138	267	169	150	-11,2
5	P/30/23	297	327	172	135	-21,3
6	T/36/23	76	157	150	109	-27,3
7	P/28/22	315	588	189	149	-21,2
8	P/34/26	43	82	195	160	-18,2
9	T/34/17	184	612	158	142	-9,7
10	P/34/27	84	223	191	156	-18,4
11	T/34/17	843	1971	150	120	-19,9
12	P/28/24	88	372	168	133	-21,2
13	P/36/33	351	517	173	135	-21,6
14	P/28/21	500	706	179	143	-20,0
15	P/32/24	85	1095	172	130	-24,2

Table 9. Numerical values of oily end

Fabric Number	Fabric Type End/cm Pick/cm	Dimensions of Defect on X Axis (Pixels)	Dimensions of Defect on Y Axis (Pixels)	Average Gray Color Values of Images	Average Gray Color Values of Defected Areas	Percentage Difference of Gray Color Values
1	P/34/27	15	437	204	143	-30,2
2	P/34/27	44	1373	197	172	-12,8
3	P/32/31	6	658	172	134	-22,2
4	P/28/21	13	706	179	153	-14,3
5	P/28/21	18	528	185	168	-9,4
6	P/28/23	29	798	179	142	-20,8
7	P/34/31	9	567	172	141	-18,3
8	P/30/27	5	382	173	146	-15,5
9	P/30/25	9	553	176	149	-15,6
10	T/33/18	8	399	163	139	-15,1
11	T/33/18	8	375	166	124	-25,2
12	P/32/26	10	768	205	172	-16,0
13	P/32/26	18	1200	206	176	-14,7
14	P/32/28	20	435	199	169	-14,9
15	P/34/27	35	1637	195	158	-19,1
16	P/33/25	13	701	194	145	-25,3
17	P/28/24	10	757	176	135	-23,2

Table 10. Numerical values of wrong drawing

Fabric Number	Fabric Type End/cm Pick/cm	Dimensions of Defect on X Axis (Pixels)	Dimensions of Defect on Y Axis (Pixels)	Average Gray Color Values of Images	Average Gray Color Values of Defected Areas	Percentage Difference of Gray Color Values
1	P/28/23	8	1335	167	155	-6,8
2	P/32/26	5	2048	203	184	-9,4
3	P/34/28	6	1219	197	164	-16,7
4	P/33/31	5	1069	172	154	-10,6
5	P/34/26	4	2048	192	160	-17,0
6	P/32/30	5	682	172	157	-8,6
7	P/28/26	4	670	198	168	-15,3

4. CONCLUSION

Table 11 summarizes the obtained results. It was observed that there were differences between the images of a fabric having no defect and the images of the same fabric having defect. The gray color values changed at the defected areas, either increased or decreased depending on defect type. At the defected area, if fabric density increased, less light passed through the fabric, hence the measured degrees of average gray color values were decreased or vice versa.

Some of these images numerical values overlapped making classification impossible only with thresholding. However, many of them have significant differences to conclude. For example oily spot has distinctive shape than the rest. Four defect types occur in the whole width, however only one, double pick, creates negative sign in percentage difference of gray color values. Hole-tear generates positive sign in percentage difference of gray color values but differentiate from others by dimensions on X axis not occurring in all width. Irregular pick density is distinguishable from missing pick and starting mark with either higher pixels in lengthwise or overlapped number of pixels but repeated regularly in certain distance. On the other hand, oily end and wrong drawing numerical values are insignificant making classification.

It should be known that higher number of observation will create more overlapped numerical values. Also considering many type of defect not mentioned in this paper and many type of structure, classification of fabric defects requires much more complicated algorithms than simple thresholding for industrial application of automated fabric quality control. Thresholding could be very good method to detect the defects, however to classify the defects it needs further analysis.

Table 11. Summary of fabric defects

Defect Type	Dimensions of Defect on X Axis (Pixel)	Dimensions of Defect on Y Axis (Pixel)	Average Gray Color Values of Images	Average Gray Color Values of Defected Areas	Percentage Difference of Gray Color Values
Missing Pick	4096	36-220	154-202	179-237	+14,6/+22,1
Irregular Pick Density	4096	63-550	133-202	158-216	+6,3/+22,0
Starting Mark	4096	17-68	155-203	174-215	+5,2/+26,3
Double Pick	4096	9-18	172-199	142-172	-8,8/-21,3
Broken Pick	1106-3430	9-12	172-182	136-165	-4,0/-22,6
Broken End	15-82	16-94	138-199	109-157	-8,6/-26,3
Hole-Tear	14-282	94-875	144-171	173-202	+10,1/+34,6
Oily Spot	37-843	82-1971	150-195	109-160	-9,7/-27,3
Oily End	5-44	375-1637	163-206	124-176	-9,4/-30,2
Wrong Drawing	4-8	670-2048	167-203	154-184	-6,8/-17,0

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