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Establishing a Demerit Count Reference Standard for the Classification and Grading of Leather Hides

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Leather hide, as a natural material, may have many types of undesirable surface defects. No analytical method has been devised for classifying and grading wet blue hide surface defects. A high return rate and disputes between the customer and manufacturing company usually cause additional costs. This paper proposes a semi-automatic machine vision method to measure the unusable surface defect areas in wet blue hides and a clear reference standard for the demerit count for graders to classify and grade wet blue hides. A statistical comparative evaluation of the grade deviation rate and a practical demerit count method for tannery performance are given to show the usefulness of the proposed approach.

Keywords: Demerit count; Image processing; Leather surface defects; Machine vision; Wet blue hide

1. Introduction

Leather hides are one of the major raw materials used in shoemaking and other branches of the leather industry. Defects such as scars, pinholes, putrid spots, parasitic damage, brand marks and growth marks may appear in different locations and sizes on the surface of a hide. These defects affect the aesthetic appearance, and amount of usable area, and hence reduce the value of a hide.

There is no universal agreement among different industries on the definition and classification of leather surface defects. There are no common standards observed within the industry. The standards used to grade wet blue hides are usually worked out using a rough percentage of the unusable defect area over the leather hide area observed by a grader. Table 1 shows the definition of four classes of leather hides and the categories of leather products from most tanneries in Taiwan and China [1]. This fuzzy definition is not sufficient for defining the commonly used grade levels of finished leather. The lack of a clear evaluation standard for leather surface quality usually causes much argument between the tanneries and the leather goods manufacturers.

A return rate of 15% is common, and the subsequent disruption of production schedules at leather goods manufacturers is severe [2]. For the tannery, the costs of regrading, resorting, replacing and redelivering are substantial.

In order to integrate the leather product categories in the leather supply chain and to reduce the return rate for leather surface defects, a clear reference standard for the classification and grading of wet blue hides for the tannery industry is required and is given in this paper.

The remainder of this paper is organised as follows. In Section 2, some machine vision systems for leather defects detection, classification and grading are surveyed. In Section 3, seven types of surface defects in wet blue hides are classified and discussed according to the defect shapes. In Section 4, we present the methods for wet blue hide defect extraction, unusable region defect grouping and physical unusable area calculation. Section 5 describes how the demerit count is established for each type of defect. In Section 6, some comparative, experimental results concerning the proposed method are presented. Section 7 gives summaries and the future direction of this research.

2. Literature Review

Detection is the process of determining if an object deviates from a given set of specifications. Some machine vision systems have been devised to detect leather hide surface defects. The LeaVis system [3] was a prototype industrial machine vision system aimed at processing and segmenting hide images marked by lines and other symbols that show defects and areas of different quality. The goal of the LeaVis system was to provide a visual input for a CAD system that sets trajectories for the knife to cut the hides.

Leather surface defects often look like various kinds of textures. They are composed of random features immersed within a random environment. António [4,5] used multiresolution pyramids to construct an image model of leather surface tex-

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Table 1. Wet blue hide-grading definition and leather product categories.

Class of hide	Percentage of unusable defect area	Fitness of leather products
1	$\frac{\text{Unusable defect areas}}{\text{Area of the piece of hide area}} < 10\%$	Upholstery leather, attaché case leather, belt leather
2	$10\% \leq \frac{\text{Unusable defect areas}}{\text{Area of the piece of hide}} < 20\%$	Nubuck, look calfskin leather, burnished leather, aniline leather, oil leather
3	$20\% \leq \frac{\text{Unusable defect areas}}{\text{Area of the piece of hide}} < 35\%$	Shoe upper leather, nappa, embossing leather, waterproof leather
4	$35\% \leq \frac{\text{Unusable defect areas}}{\text{Area of the piece of hide}}$	Embossing leather, shoe upper leather, waterproof leather

ture. This methodology was implemented and applied for segmenting the small vein and scar defects in calf leather.

Lovergine et al. [6] used a leather patch as a unit to classify the input leather surface types based on gradient orientation and local coherence. Leather defects such as scars and folds can be detected by segmenting the oriented texture map of the leather surface.

Branca et al. [7,8] found leather surface defects according to an oriented structure using human inspection. The patterns of the leather surface defects were analysed and represented by appropriate parameters. A neural network approach was used in analysing the oriented texture. Finally, a filter process was used to detect and classify the leather surface defects. The resulting system is flexible and does not depend upon dimensions, structure, or the colour of the defects.

In industry, because the physical dimension of a leather hide is quite large, it is difficult to detect all the defects in a leather hide in a short time. The size of a cow leather hide could be as large as $2\text{ m} \times 3\text{ m}$; but, a defective area could be as small as $150\ \mu\text{m} \times 150\ \mu\text{m}$. Defects are generally hidden behind the irregular textured background of the leather surface. These leather defects cannot be detected completely by a human grader.

Pölzleitner and Niel [9] proceeded in a hierarchical manner and detected seven features in wet blue hides using a local image description of the texture elements and final defect segmentation and grading.

Traditionally, leather hides are graded according to the quarter rule. A transparent template of 10×10 square-units with each unit equal to $\sqrt{10} \times \sqrt{10}\text{ cm}^2$, is used in measuring the defects [2]. The inspector counts the number of square-units covered by the leather defects. Based on this approach, Hoang et al. [10] proposed a machine vision system for defect classification. There are four types of defect ranging from *A* (the least serious) to *D* (the most serious), as shown in Table 2.

Table 2. Defect definitions used in this investigation [10].

Defect type	Defect definition
A	No depth (surface feels flat and even, no dents)
B	The depth (dents in the leather) must not be greater than 0.1 mm
C	Any defect area that is smaller than 4 mm^2
D	Any defect that is greater than 100 mm long; any defect more than 1.5 mm wide

3. Wet Blue Hide Manufacturing Process and Surface Defects Classification

3.1 Leather Hide Manufacturing Process

In the leather hide manufacturing process, a two-stage procedure is generally used. The pre-finished stage concerns wet-end operations. The function of the wet-end operation is hide tanning, which generates usable wet blue hides. The tanning process affects the characteristics of the leather. The finished stage contains dry-end operations, which controls the flexibility, scuffing, waterproof, folding endurance, abrasion resistance and solvent resistance properties [11].

3.2 Wet Blue Hide Surface Defect Classification

There can be numerous defects in raw hides, which may reduce the value of the hide, and hence reduce the value of the consequent product made from the leather. These defects may be caused by disease or external damage before the animal is slaughtered, or they may arise during flaying after slaughtering, or they may be the result of inadequate preservation during transport and storage of the raw hides. The defects due to natural causes often lack a well-defined classification standard and description method in terms of visual cues. No formal approaches have been found that could be applied to the classification of wet blue hide surface defects.

In this work, defects were classified according to their shapes detected easily by the inspector on each piece of hide. We started by collecting and analysing samples of 178 pieces of defective hide and by discussing the appearances and types of the leather surface defects with experienced experts. These defects were then categorised into seven types, i.e. thin spots, circular spots, thin lines, strips, holes, patterns, and irregulars, as summarised in Table 3.

Table 3. Seven types of wet blue hide defect classified by their shapes.

Type of defect	Defect appearance and definition	Mark or scar of hide defect
1. Thin spots	Spots like scars with a diameter ≤ 1 mm	Hair root, pinhole, putrid spot, dermatitis
2. Circular spots	Spots like scars with a diameter >1 mm	Thorn scratch, nail mark, chrome stain, salt stain, cure stain, putrefied
3. Thin lines	A line type scar with a width ≤ 1 mm	Vein, healed of scratch, wring felt mark
4. Strips	A line type scar with a width >1 mm	Score knife, neck wrinkle
5. Holes	Hole damage	Did damage, grub hole, bullet mark
6. Patterns	Animal breeding mark	Brand mark
7. Irregulars	No regular appearance in any of the above types or several mixed defect types	Wart, contamination, pipe grain, flay mark, putrefied, scratch, chafe mark, hook mark, gear mark, parasitic speckled (tick, mange, insufficient), dung stain

From the scanned images of the collected wet blue hide samples, the largest mean diameter for all thin spots is equal to 0.98 mm. The smallest mean circular spot diameter is equal to 1.20 mm. In Table 3, scar-like spots with a diameter less than or equal to 1 mm are defined as thin spot defects and spots with a diameter larger than 1 mm are defined as circular spot defects. The largest mean width for all thin line type scars is equal to 0.96 mm. The smallest mean width for strip type defects is equal to 1.07 mm. In Table 3, a line type scar narrower than or equal to 1 mm is defined as a thin line type defect. Line type scars wider than 1 mm are defined as strip type defects. Mark or scar examples corresponding to different types of hide defect are also given in Table 3. Though Table 3 is a good guideline for an experienced inspector to determine the types of defect on a piece of wet blue hide, for most inspectors, it is not so easy to distinguish the trial differences among these defects. So, we further recategorise the seven types of defect into four cases, as shown in Table 4. Case *A* treats all defects as only one type of defect. Case *B* divides all the defects into three types. The thin spot defect is combined with the circular spot defect to be a spot defect; a thin line and strip defect are combined to be a line defect; hole and pattern defects are combined into an irregular defect. In case *C*, the spot defect and line defect are determined as in case *B*. Case *D* remains as the same seven types of defects.

Table 4. Four wet blue hide classification cases.

Case	Type of defect
A: one type of defect	Defects
B: three types of defect	Spots, lines, irregulars
C: five types of defect	Spots, lines, holes, patterns, irregulars
D: seven types of defect	Thin spots, circular spots, thin lines, strips, holes, patterns, irregulars

The tannery industry can decide which case in Table 4 is to be used as a guideline for the classification of wet blue hide surface defects. If the smaller type of defect case is selected, it will be easier for an inspector to determine the types of defect and to count the total number of demerits on a piece of leather hide. If the larger type of defect case is selected, it will be more valid for grading the hide.

4. Measurement of Unusable Area of Hide Defects

We used digital image processing techniques to identify the wet blue hide defects. The unusable region caused by the defects was then measured. The number of demerits per type of defect, classified by shape, was then established, and a clearly defined wet blue hide surface defect classification was produced. The flowchart for this is shown in Fig. 1.

After acquiring the defect image, the software package Adobe Photoshop 4.0 [12] was used to develop four methods to extract the defects from a wet blue hide. The defects can then be grouped to form a larger unusable region and the number of pixels in each unusable region can be calculated. Hence, the unusable area for all of the defects in a wet blue hide can be obtained.

4.1 Four Methods for Wet Blue Hide Defects Extraction

Adobe Photoshop 4.0 was used to highlight the principal discrepancies in the brightness and grey levels between defective and flawless wet blue hides. Four semi-automatic methods, based on Adobe Photoshop 4.0, are described below [12]:

1. *Contrast method.* The grey level of the pixels in the defective region image was checked. If some of the pixels are different from the average grey level, these pixels can be categorised as a defect. The defective hide surface regions are often darker than the normal background pixels in a

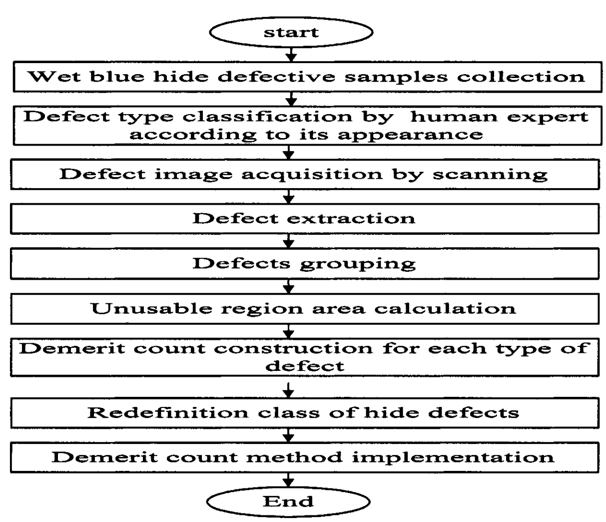

Fig. 1. The flowchart for classification and grading of hide defects.

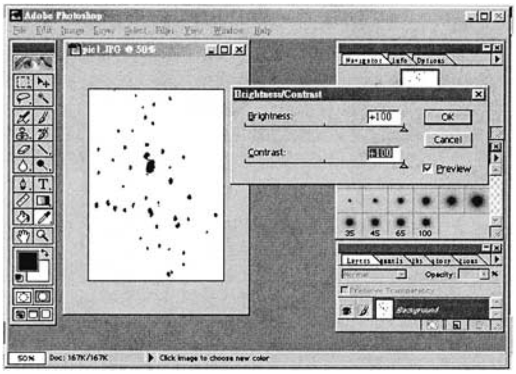

Fig. 2. Defective image extracted by adjusting the brightness and contrast of circular spots.

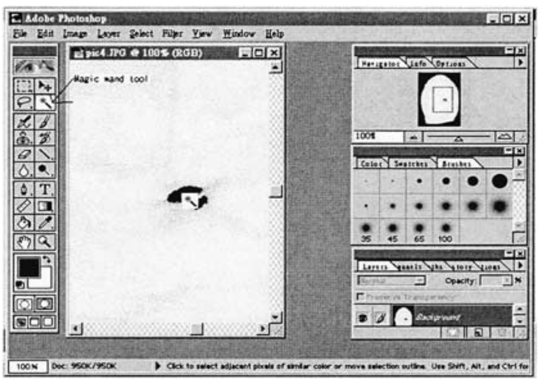

Fig. 3. Hole type defect selected by using a magic wand tool.

leather hide. From the histogram of the entire image, we can choose a threshold and use it to set the pixels with a darker grey level as defective hide and the pixels with a lighter grey level as flawless hide. A binary operation is then applied. The hide defect is extracted. This method can detect spot defects such as bullet marks or hole defects. Figure 2 shows the result of adjusting the brightness and contrast of a bullet mark defective image.

2. *Internal colour level method*. In a defective region, according to the colour level to be processed, the same colour level in all of the defects can be shown from the non-processed region using the Adobe Photoshop 4.0 magic wand function. This method can detect general defects that have a clear profile such as nail stains, bullet stains, and holes. Figure 3 shows a hole type defective image.
3. *External colour level method*. This method is the opposite of the above internal colour level method. This method can detect very small defects or unclear profiles such as contamination, putrid spots, hair roots, dung stains, and flay marks. Figure 4 shows a contamination defective image.
4. *Fuzzy method*. The defective region to be processed in an image has a fuzzy colour level range. Selecting the magic wand (fuzzy function), we can adjust the defects within the same colour level range into a black or white image. This

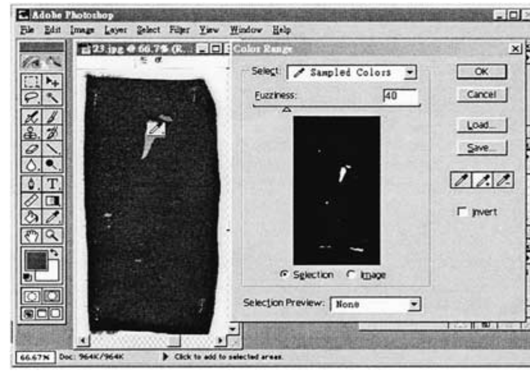

Fig. 5. Pipe grain defective image within the same colour level range extracted by fuzzy method.

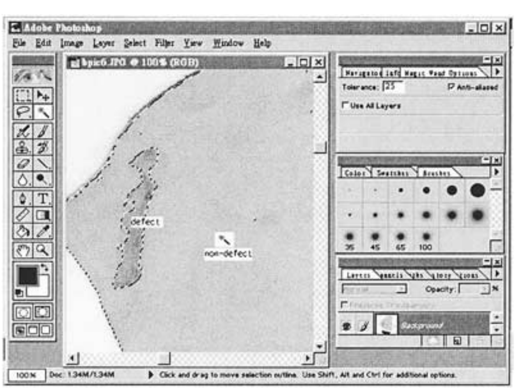

Fig. 4. Contamination image extraction by using a magic wand tool.

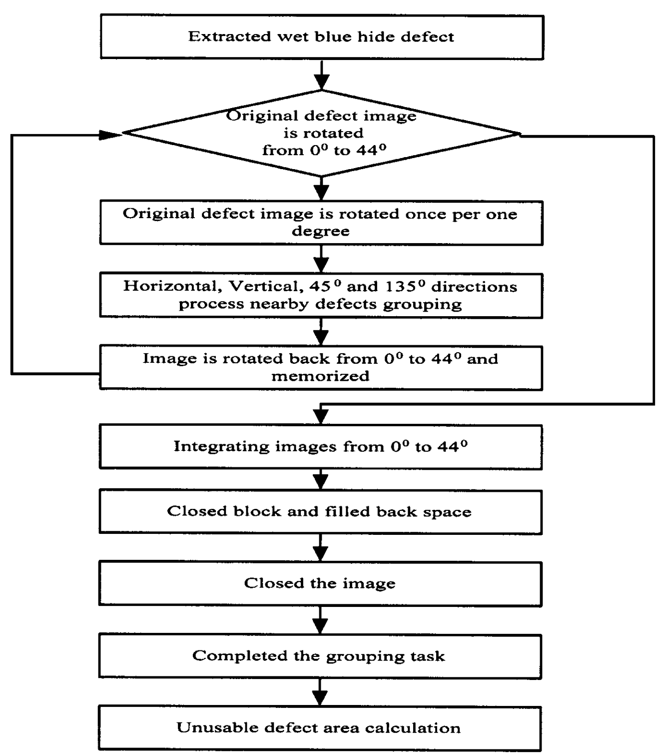

Fig. 6. A flowchart for nearby defects automatic grouping algorithm.

method can detect defect types such as dig damage, pipe grain, gear marks, rust specks, bullet stains, and split damage scattered on the hide surface. Figure 5 shows a fuzzy pipe grain defective image.

Each of these methods can be used to detect leather hide defects using the grey level attribute on defective and flawless background leather.

However, there is still no stable method that can be used to detect the same type of defect in any background leather. All four methods have to be tried before deciding which method is suitable for wet blue hide defect detection and extraction.

4.2 Nearby Defects Grouping and Unusable Area Calculation

When defects are detected using the methods described in Section 4.1, from the viewpoint of leather footwear or handbag manufacturers who use leather as their main raw material, some regions between two nearby defects might be too small to use. If the distance between two nearby defects is less than $\sqrt{10}$ cm [13], then the two defects are grouped into a larger unusable region. A flowchart for a nearby defects automatic grouping algorithm is shown in Fig. 6.

Figure 7 is an example of the procedures for grouping bullet mark defects into a larger unusable region. Figure 8 is the result of neck wrinkle mark defects grouped into an unusable region. After analysing the defect data extracted from the 178 collected defective samples, the unusable area of a hide can be defined by the number of pixels in the unusable region, multiplied by a constant 0.00029 cm^2 $pixel^{-1}$ at a resolution of 150 dpi. Based on the unusable areas, we can thus construct a demerit count for each type of wet blue hide surface defect.

5. Establishing a Demerit Count for Each Type of Defect

We can construct a demerit count for each type of wet blue hide defect using the average value of the areas in the unusable region.

Table 5 lists the demerit count for each type of wet blue hide defect in the four classification cases. The demerit count for each type of defect is the sum of all of the unusable areas for each type of defect divided by the sample number for that type with the resultant value rounded to its nearest integer. The calculating unit area for a demerit count is 1 cm^2. The demerit count for each type of defect can be used for wet blue hide grading.

According to the demerit count of the unusable defect area, we can redefine the wet blue hide grading level, which is given in Table 1, as shown in Table 6.

In Table 6, the number of demerits:

$$D = 25\,000\ \text{cm}^2 \text{ (the average area of a piece of side wet blue hide)} \times \text{the percentage of unusable defect areas listed in Table 1} \div 1\ \text{cm}^2 \quad (1)$$

For example, $8750 = 25\,000\ \text{cm}^2 \times 35\% \div 1\ \text{cm}^2$

The wet blue hide class is defined more clearly in Table 6 than in Table 1. When the hide is spread out over a table manually during the wet blue hide-grading procedure, the grader need only count the total number of demerits for the different types of defects. This hide can be categorised easily into an appropriate class by referring to Table 6.

6. Demerit Count Method Implementation

To evaluate the performance of the demerit count method for wet blue hide grading, the grading results are compared with the results from the automatic machine vision inspection method [14] and the traditional manual grading method. Let P_v, P_c, and P_m be the grading result for pieces of wet blue hide assigned by a grader using the automatic machine vision inspection, demerit count, and traditional manual methods, respectively. The deviation between the grading result by the automatic machine vision inspection method and the demerit count method can be computed using:

$$G_d = |P_v - P_c| \quad (2)$$

Similarly, the grading deviation between the grading results from the vision inspection method and the traditional manual method can be computed using:

$$G_d = |P_v - P_m| \quad (3)$$

The deviation rate can be written as:

$$\text{Deviation rate} = G_d\, /\, \text{Total pieces of wet blue hides} \quad (4)$$

A large tannery in Taiwan used the proposed demerit count method. Six containers of 5048 pieces of wet-salted hide were used as samples. After the tanning stage, each of the original 5048 pieces of hide was cut into two wet blue side leather hides. A total of 10 096 pieces of wet blue side leather hide (WBH) were available. An experienced grader was asked to grade the 10 096 WBHs five times. Each time the grader used the traditional manual method and each of the four demerit-count methods. Prior to this experimental procedure, the experienced grader was trained using the defect appearance and definition references given in Table 3. The comparative grading results are given in Table 7.

Using the automatic machine vision inspection method as a comparative reference, we can see from Table 7 that the deviation rate for the demerit count method is better than the traditional manual method. The deviation rate for the demerit count method in case D is equal to 0.12%, which is also more accurate than the other three cases. In order to show the practical effect of the demerit count methods on the tanneries, the demerit count method case D was applied in a suggested tannery for six months. The leather surface defect return rate was reduced monthly from 15.41% to 11.62%, 12.08%, 11.32%, 10.23%, 10.04%, and 10.43% [15]. The mean return rate was reduced to 10.95%. There was an obvious improvement in wet blue hide grading with the demerit count method. The demerit count method shows its usefulness for matching the order and reducing the return rate for leather surface defects in outgoing leather hides.

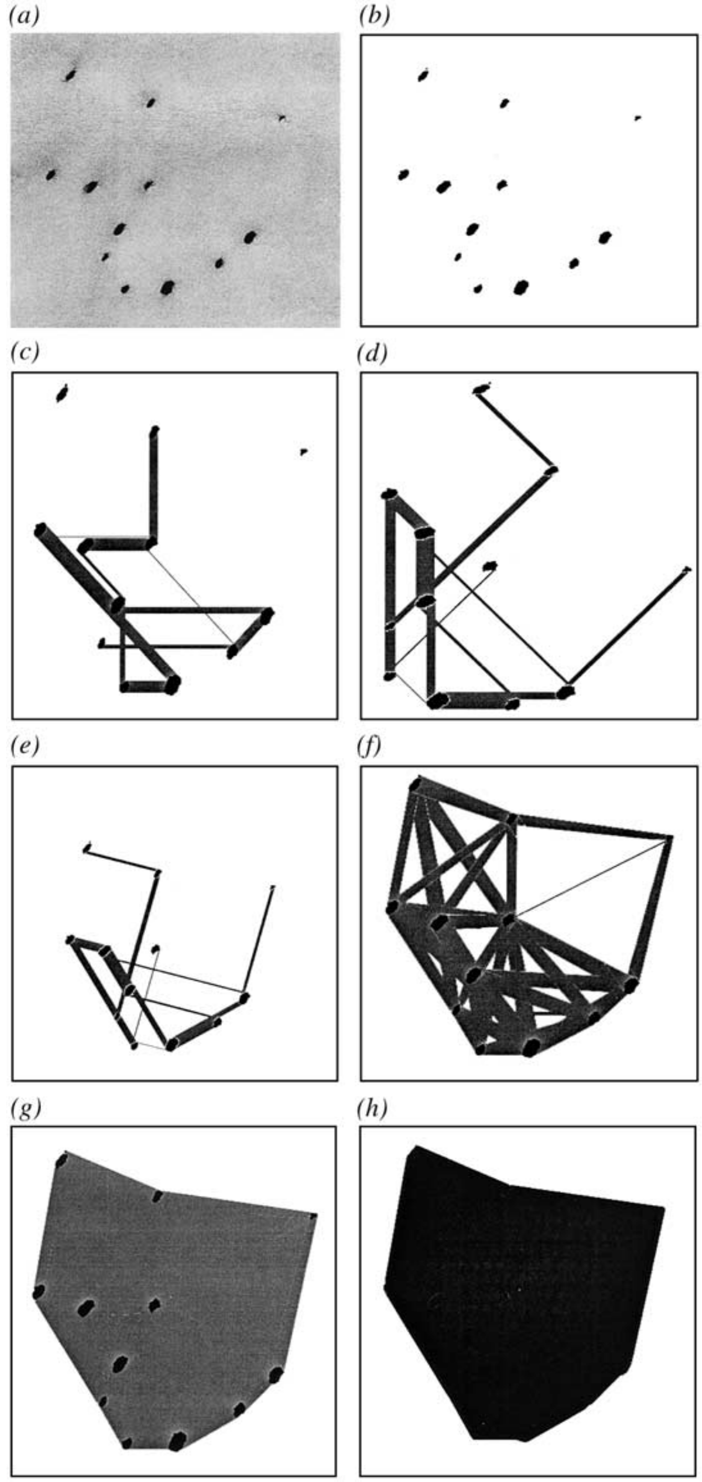

Fig. 7. The procedures for grouping the bullet mark defects into a larger unusable region (*a*) Original image. (*b*) Defect map. (*c*) All side's defective images connected to each other at 0°. (*d*) All side's defective images connected to each other after 30° rotation. (*e*) All side's defective images rotated back to 30° connected to each other. (*f*) All side's defective images connected and integrated to each other from 0° to 44°. (*g*) Closed block and filled black space. (*h*) The grouping task completed.

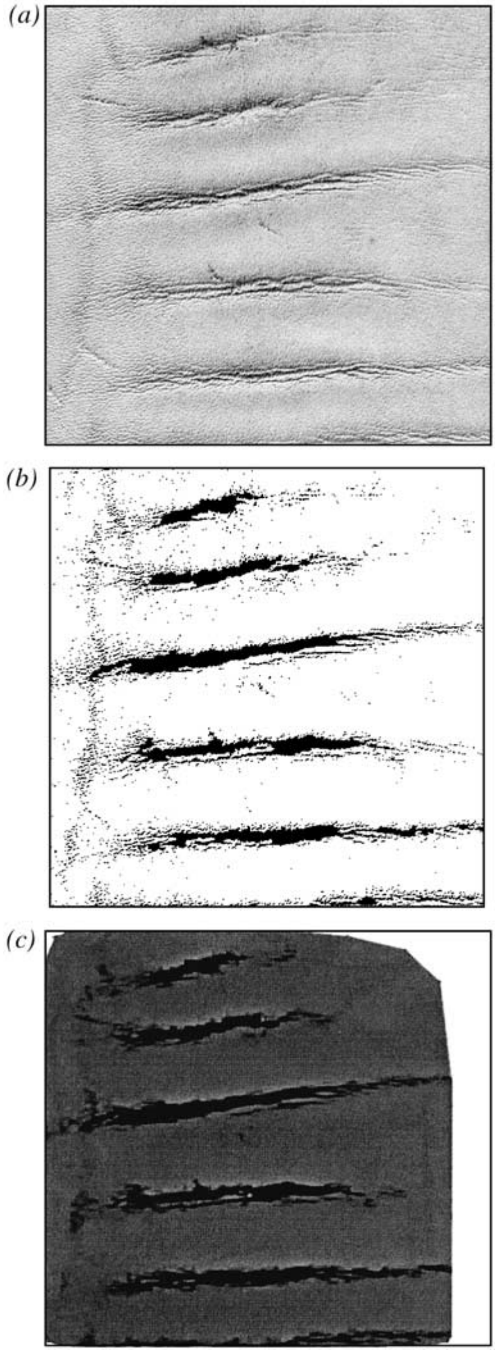

Fig. 8. The neck wrinkle mark defects grouped into an unusable region. (*a*) Original image. (*b*) Defect map. (*c*) Nearby defects grouped image.

7. Conclusions

In this paper, demerit count methods for detecting and classifying wet blue hide surface defects were proposed. After applying a demerit count method in a large tannery for six months, this method was shown to be reliable and effective through statistical performance evaluation results.

The demerit count method has the following benefits:

Table 5. Demerit count for each type of wet blue hide defect.

Case	Type of defect	Sample number	Sum of unusable area (cm^2)	Demerit count
A: one type of defect	Defects	178	24 856.3	140
B: three types of defect	Spots	42	6314.2	150
	Lines	50	7600.4	152
	Irregulars	86	10 941.7	127
C: five types of defect	Spots	42	6314.2	150
	Lines	50	7600.4	152
	Holes	13	681.6	52
	Patterns	15	1541.6	103
	Irregulars	58	8718.5	150
D: seven types of defect	Thin spots	26	4418.7	170
	Circular spots	16	1895.5	118
	Thin lines	18	3284.6	182
	Strips	32	4315.8	135
	Holes	13	681.6	52
	Patterns	15	1541.6	103
	Irregulars	58	8718.5	150

Table 6. Wet blue hide grading according to the demerit count.

Class of wet blue hide	Demerit count (*D*)	Fitness of leather products
1	$D < 2500$	Upholstery leather, attaché case leather, belt leather
2	$2500 < D < 5000$	Nubuck, look calfskin leather, burnished leather, aniline leather, oil leather
3	$5000 \leq D < 8750$	Shoe upper leather, nappa, embossing leather, waterproof leather
4	$D \geq 8750$	Embossing leather, shoe upper leather, waterproof leather

1. It provides a concise and reliable procedure to determine unusable defect areas on a piece of leather hide surface.
2. It can be used to reduce the effort for training a leather hide grading expert.
3. It can be easily implemented to reduce the return rate for leather surface defects.

Although, different types of hide defect can be detected by this method, a human grader must count the total number of demerits on a wet blue hide. Future research work will concentrate on counting the total number of demerits and grading the leather hide by machine vision automatically.

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Table 7. Comparative WBH grading results using the automatic machine vision inspection, demerit count and traditional manual methods.

Class of hide	Automatic machine vision inspection method	Demerit count methods								Traditional manual method	
		Case A One type of defect		Case *B* Three types of defect		Case *C* Five types of defect		Case *D* Seven types of defect			
	WBH (1)	WBH (2)	Deviation |(1)–(2)|	WBH (3)	Deviation |(1)–(3)|	WBH (4)	Deviation |(1)–(4)|	WBH (5)	Deviation |(1)–(5)|	WBH (6)	Deviation |(1)–(6)|
1	3818	3869	51	3838	20	3824	6	3816	2	3897	79
2	2105	2089	16	2091	14	2099	6	2101	4	2131	26
3	2250	2238	12	2254	4	2255	5	2254	4	2180	70
4	1923	1900	23	1913	10	1918	5	1925	2	1888	35
Summary	10 096	10 096	102	10 096	48	10 096	22	10 096	12	10 096	210
Deviation rate (%)	0	1.01		0.48		0.22		0.12		2.08	

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