Recyclable Waste Paper Sorting Using Template Matching

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Abstract. This paper explores the application of image processing techniques in recyclable waste paper sorting. In recycling, waste papers are segregated into various grades as they are subjected to different recycling processes. Highly sorted paper streams will facilitate high quality end products, and save processing chemicals and energy. Since 1932 to 2009, different mechanical and optical paper sorting methods have been developed to fill the demand of paper sorting. Still, in many countries including Malaysia, waste papers are sorted into different grades using manual sorting system. Due to inadequate throughput and some major drawbacks of mechanical paper sorting systems, the popularity of optical paper sorting systems is increased. Automated paper sorting systems offer significant advantages over human inspection in terms of fatigue, throughput, speed, and accuracy. This research attempts to develop a smart vision sensing system that able to separate the different grades of paper using Template Matching. For constructing template database, the RGB components of the pixel values are used to construct RGBString for template images. Finally, paper object grade is identified based on the maximum occurrence of a specific template image in the search image. The outcomes from the experiment in classification for White Paper, Old Newsprint Paper and Old Corrugated Cardboard are 96%, 92% and 96%, respectively. The remarkable achievement obtained with the method is the accurate identification and dynamic sorting of all grades of papers using simple image processing techniques.

Keywords: Waste Paper Sorting, Grades of Paper, and Template matching.

1 Introduction

The primary challenge in the recycling of paper is to obtain raw material with the highest purity. In recycling, waste papers are segregated into various grades as they are subjected to different recycling processes. Highly sorted paper streams will facilitate high quality end product, and save processing chemicals and energy. Grade refers to the quality of a paper or pulp [1]. Since 1932 to 2009, different mechanical and optical paper sorting methods have been developed to fill the demand of paper sorting. Still, in many countries including Malaysia, waste papers are sorted into different grades using manual sorting system. Due to inadequate throughput and some major

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drawbacks of mechanical paper sorting systems, the popularity of optical paper sorting systems is increased. The waste paper sorting systems are classified into Manual and Automated Systems. Automated paper sorting systems offer significant advantages over manual paper sorting systems in terms of fatigue, throughput, speed, and accuracy.

Faibish et al. [2] proposed an automated paper recycling system where ultrasounds are used to separate different grades of papers. However, due to contact manipulation and sensing, the system is too slow (80 ms/sub-frame) for industrial applications.Ramasubramanian et al. [3] developed lignin sensor that works well for separating newsprint samples from others. But the lignin sensors are influenced by sensor distance from the sample and color. Hottenstein et al. [4] proposed a sensor-based sorting approach in which a brightness sensor (reflected light intensity at 457 nm) is used to sort papers primarily into three categories, namely, white papers containing optical brighteners, white papers without optical brighteners, and other types of paper. Venditti et al. [5] developed a stiffness sensor that is used to sort recovered paper into paperboard and others. However, it cannot distinguish between a stack of newsprint versus a single paperboard. Sandberg [6] patented a sorting device to separate paper objects from contaminants. The sensor-based sorting method by Bialski et al [7] and Grubbs et al. [8] have not been successful mainly due to the absence of reliable sensing systems to distinguish between grades. In 2002, Khalfan et al. [9] introduced an optical paper sorting method using diffuse reflectance to identify a sheet of paper as either white or non-white. Their proposed paper sorting system segregated papers into white and ground wood paper according to the amount of lignin content. Eixelberger et al. [10] proposed optical paper sorting method to separate waste paper into two classes based on the radiation reflected from the surface of the papers. Bruner et al [11] proposed one optical paper sorting method to separate waste papers into bright white paper and others based on amount the fluorescence present on the surface of paper objects. Doak et al. [12] proposed an optical paper sorting method to separate different grades of paper based upon at least one characteristics of color, glossiness and the presence of printed matter. Gschweitl et al. [13] developed paper sorting method using visible light, ultraviolet light, x-rays and / or infrared light to illuminate the paper for sorting. They utilized mechanical pickers thus indicating that the system would operate at relatively low speeds.

The implementation of the previous methods, while being a step forward in the large-volume automated sorting technology, is still complex, expensive and sometimes offers limited reliability. All the systems segregate only two types of papers at one time. Moreover, no image processing or intelligence techniques are used to extract features or characteistics from the paper objects.

MO Rahman et al [14] developed an electronic image based waste paper sorting technique. The technique focused on the four points in the periphery of the paper object and then features are extracted surrounding those four points. Since the method didn't consider texture information of the entire paper objects, it may provide misleading information regarding paper grade. Thus, the main goal of this study is the development of a smart vision sensing system that will be able to separate the different grades of paper using template matching [15]. In this proposed system, RGB color components of the entire paper object are considered to create RGBString for N-cells of search image, which leads to overcome the major drawback of the previous electronic image based waste paper sorting technique. Moreover, the algorithm provides robust result because of filtering the unexpected and misleading color regions of the paper object during feature extraction process.

The remainder of this paper is organized as follows: Section 2 briefly describes the proposed Template Matching Based Waste Paper Grade Identification System. Section 3 discuses the experimental results and section 4 draws the concluding remarks.

2 Template Matching Based Waste Paper Grade Identification System

Figure 1 illustrates the basic block diagram of the recyclable waste paper grade identification system using Template Matching. The proposed system operates in two phases, i.e. enrollment and identification. Both phases have some common components. The enrollment phase consists of image acquisition, preprocessing, feature extraction, RGBString construction for template images and creation of the reference database. The identification phase consists of image acquisition, preprocessing, feature extraction, RGBString construction for N-cells, matching, and decision. In the subsection 2.1 to 2.4, it will be discussed all the processes of both enrollment and identification phases.

2.1 Image Acquisition

In this proposed system, 320×240 RGB images are taken from inspection zone on the conveyor belt using a commercially available Webcam. In webcam properties setting, the brightness, contrast and saturation are adjusted at 50%, 50% and 100% of their respective scales. In the experiment, it is observed that the performance of the vision system is extremely influenced by the lighting arrangement. After necessary calibration, front lighting-directional-darkfield illumination [15] is selected for this experiment. The conveyor belt speed is 14 feet per minute. The real time scanning process produces two types of signals namely presence of object (PObj) and absence of object (AObj). The system always performs scanning operation to detect the presence of object. The system captures the images from the inspection zone based on two signals. If AObj signal is detected after the signal PObj, then the system captures the image of paper object from the inspection zone. This technique separates individual paper object from the sequence of paper objects.

2.2 Preprocessing

The first step in the preprocessing block is to take the image from inspection zone after trimming unnecessary boundary portion of the image. After that, the background noise is eliminated from the image using combined operation of threshold and morphological operation erosion [15] with 3×3 minimum convolution filter.

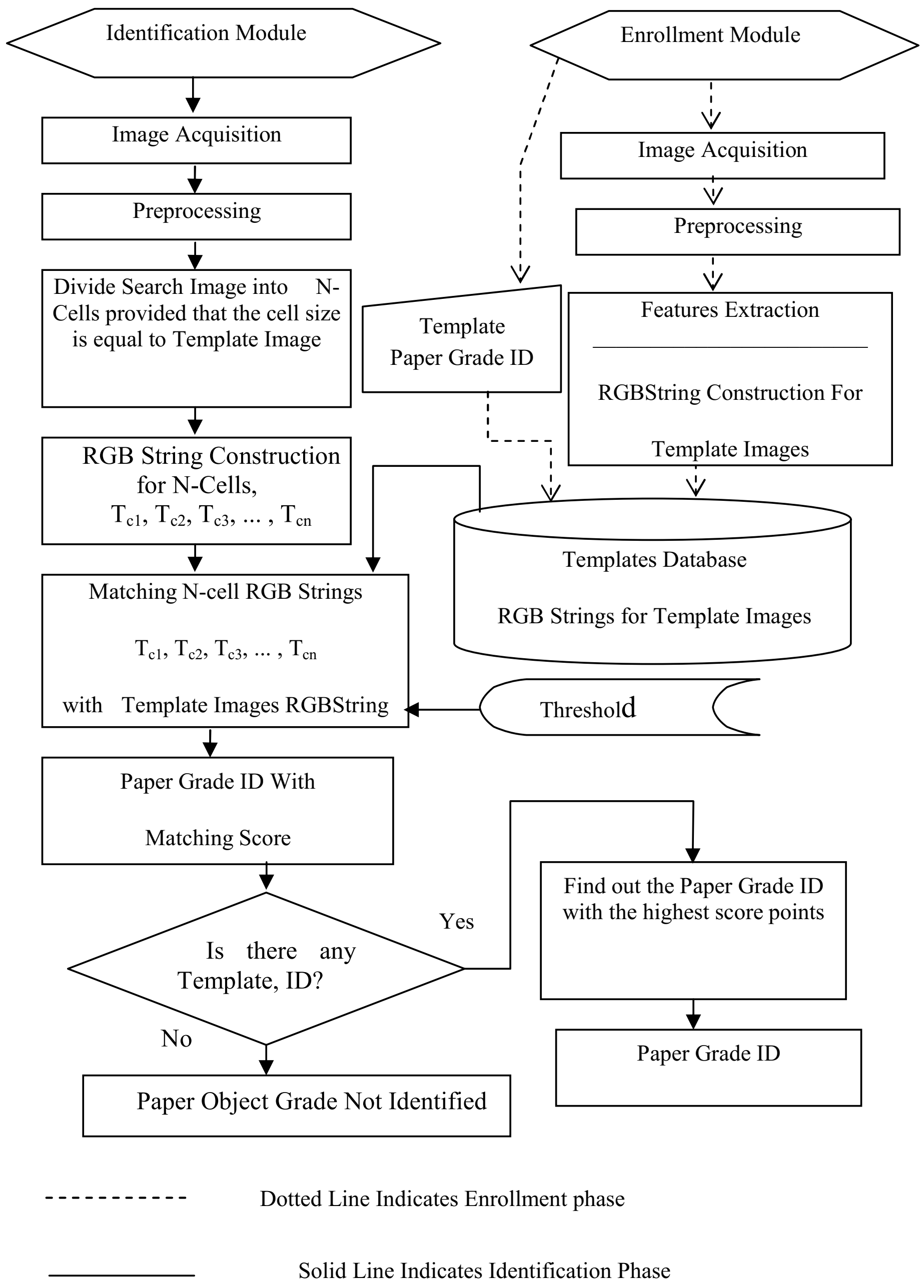


Fig. 1. Block Diagram of the Paper Grade Identification System Using Template Matching

2.3 RGB String for Template and Search Image

The paper object image consists of three components red, green and blue. For gray scale value, standard grayscale transformation is obtained from the original RGB image components. The four components 'R' (red), 'G' (green), 'B' (blue) and 'Y' (gray) are considered for the paper images. 'Y' is taken for gray component to avoid the conflict with green 'G'. The basic strategies followed in the construction of RGB string is that the color component take first place in the RGBString, which component value is the maximum out of red, green and blue component values, then second and third. Finally fourth color position is reserved gray component. The repetition of the color component depends on the value of the color component since the ranges of the color component values are different for various types of paper grades shown in [14].

For template construction, the system generated RGBString for template image after getting the value of template width, TW and template height, TH for template image and information regarding the interested region of the preprocessed image. The Search image is divided into N-cells shown in Figure 2. The cell size must be equal to the template image. The RGB strings for N-cells are obtained using the RGBString-ForSearchImage, RGBString and ColorRepeat procedures. The unnecessary cells are filtered during calculating RGB string.

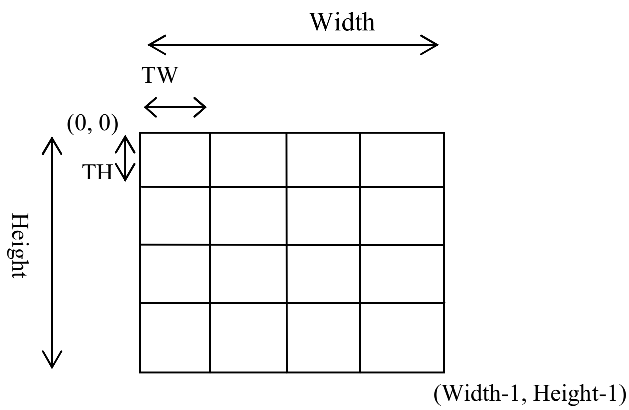


Fig. 2. Template Image and Search Image

Procedure: RGBStringForSearch Image

MCOL = Width/ TW ' MCOL stands for Number of Columns
NROW = Height / TH 'NROW stands for Number of Rows
NCELL = MCOL × NROW ' NCELL stands for number of Cells in Search Image
For I = 1 To MCOL
  For J= 1 To NROW
    StartCellWidth = (I-1) × TW
    EndCellWidth = (I × TW)-1

```
            StartCellHeight = (J-1) × TH
            EndCellHeight = (I × TH) –1
            Call RGBString (StartCellWidth, EndCellWidth, StartCellHeight,
EndCellHeight)
            Save the RGBString
        Next J
   Next I
```

Procedure: RGBString

```
    For  m  = StartCellWidth    To      EndCellWidth
       For        n= StartCellHeight      To       EndCellHeight
            pointRGB = ImagePoint(m, n)
            RedColor = pointRGB Mod 256
            GreenColor = ((pointRGB And &HFF00FF00) / 256&)
            BlueColor = (pointRGB And &HFF0000) / (256& * 256&)
            GrayColor = (RedColor + GreenColor + BlueColor) / 3

           If RedColor <> 0 And GreenColor <> 0 And BlueColor <> 0 Then
                              //Filter the unnecessary pixels
               SortingDescendingOrder(RGBComponents)
              Call ColorRepeat() procedure for Red, Green, Blue and Gray
Color Values
               RGBString = RGBString + FirstColor + SecondColor +
ThirdColor +
                              FourthColor + "."
                              // "." Indicates the number of pixels in RGB-Strings
            End If
         Next n
    Next m
```

Procedure: ColorRepeat (ColorValue As Integer)

ColorRepeat procedure take the Color Values of Red, Green, Blue, and Gray level value and return the integer number for repeating the "R", "G", "B" and "Y" in the RGB string for each pixel value.

```
   If  ColorValue <=63 Then
            ColorRepeat = 1
   Else
            If   ColorValue >=64 and ColorValue  <=184 Then
                  ColorRepeat = 2
           Else
                  If   ColorValue >=185 and ColorValue  <=229 Then
                    ColorRepeat = 3
```

```
            Else
0                           ColorRepeat = 4
            End If
        End If
  End If
```

2.4 Matching and Decision

The matching process is implemented by string matching algorithm. In this process, RGB strings of N-cells are compared with all the template RGB strings. For each Template RGBString, after matching with RGBString of one cell of the search image, the matching score between template RGBString and Cell RGBString compared with threshold value; if the matching score crosses the threshold level then the respective template gets one point. The matching scores value 92% is considered as the threshold value. In this way, the maximum occurrence of a specific template in the search image will achieve the highest points. Finally, the template ID with the highest points is identified as the candidate paper object grade ID. The variable cn stands for the maximum number of cells in search image and c1 stands for 1. The variable tm stands for the maximum number of templates and t1 is for the starting value of template and t1 value is 1.

Pseudocode: Matching Process

```
  For I = t1  to tm                    // I stands for Template Image
      For  J = c1  To cn       //J stands for Cell Images of Search Image
        Compare    RGBString of Template T[I] with RGBString of Cell Image T[J]
        If   the matching score >= threshold Then
                 OccurrenceOfTemplateImage    [I]    =    OccurrenceOfTemplateImage [I] +1
           End IF
        Next J
  Next I
```

Pseudocode: Decision Process

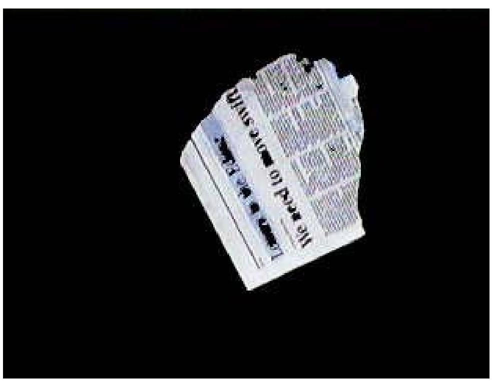
```
  Max = OccurrenceOfTemplateImage [1]  // Max temporary variable
  PaperGrade = 1     //Paper grade for  the candidate paper objects
   t2= 2                  // t2 stands for 2nd Template Image
  tm = Number  of  Template  Images
  For I = t2 to tm               // I stands for Template Image
       IF OccurrenceOfTemplateImage [I] > Max Then
           Max = OccurrenceOfTemplateImage [I]
           PaperGrade = I
        End If
```

Next I
Print PaperGrade //PaperGrade finally return the Paper grade ID of the Search Image

3 Experimental Results and Discussion

In this section a relative comparison is made based on the outcomes of this proposed method for Old Corrugated Cardboard (OCC), Old News Paper (ONP) and White Paper (WP). The three types of waste papers- WP, ONP and OCC had taken in this experiment because of their dominating role in waste papers. One hundred paper samples per grade are considered in this experiment. Figure 3 illustrated the ONP images in both original and preprocessed forms. The Figure 3(a) is represented the original ONP image with background noises and Figure 3(b) is represented the preprocessed ONP image without background noise.

(a)



(b)

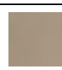
Fig. 3. Original and Preprocessed Paper Image: (a) Old Newsprint Paper With Background Noise, and (b) Preprocessed ONP image after removing background noise

Table 1. Some Example of RGB-String Units For Single Pixel

Sl. No.	RGBString for Single Pixel
1.	RGBY
2.	RRGGBBYY
3.	RRRGGGBBBYYY
4.	RRRRGGGGBBBBYYYY
5.	RBGY
6.	RRBBGGYY
7.	RRRBBBGGGYYY
8.	RRRRBBBBGGGGYYYY
9.	BRGY
10.	BBRRGGYY
11.	BBBRRRGGGYYY
12.	BBBBRRRRGGGGYYYY
13.	BGRY
14.	BBGGRRYY
15.	BBBGGGRRRYYY
16.	BBBBGGGGRRRRYYYY
17.	GRBY
18.	GGRRBBYY
19.	GGGRRRBBBYYY
20.	GGGGRRRRBBBBYYYY
21.	GBRY
22.	GGBBRRYY
23.	GGGBBBRRRYYY
24	GGGGBBBBRRRRYYYY

The paper object image consists of collection of pixels and the pixels color consists of red, green and blue components. The hybridization of red, green and blue components produces millions of colors (24 bits (3 bytes) yields 16,777,216 colors). From the experimental and industrial observations, the basic colors of WP, ONP and OCC are fully distinctive. But in printing subtractive colors- cyan, magenta, yellow, and

Table 2. Identification success rate for Different Template size

Method	Template Size Width × Height	Template Image	Name of the Paper Grade	Correct Identification Rate
Template Matching	5 × 5		WP	96%
			ONP	92%
			OCC	96%
	10 × 10		WP	86%
			ONP	82%
			OCC	84%
	20 × 20		WP	78%
			ONP	72%
			OCC	76%

black are used, which are based on reflective light. As a result of different combination of printed colors, the recyclable waste papers have diversity in color configurations. Due to different color combination, it is difficult to segregate different types of paper objects. In this experiment, different template images are created for different grade of papers. Even different template images are created for same paper grade with different template sizes. The performance of this experiment is greatly influenced by template size. If the template size is decreased then the success rate of paper grade recognition is increased. But the computational time is increased due to the number of cells in search image. The template image data is the multiple or polymer of any one of the RGBString units from table 1. The repetition of the RGBString units in template RGBString is depended on the number of pixels (or size) of the template image.

In experiment, it has been found that the WP template consists of multiple of BBBBRRRRGGGGYYYY RGBString unit (serial no 12) or BBBBGGGGRRRRYYYY (serial no 16), the ONP template consists of multiple of RRRGGGBBBYYY RGBString unit (serial no 3) or RRRBBBGGGYYY (serial no 7) and the OCC template consists of multiple of RRGGBBYY RGBString unit (serial no 2) or RRBBGGYY (serial no 6). Moreover, the repetition of “R”, “G”, “B” and “Y’ color components in the RGBString for the pixel value is significantly influenced by the lighting arrangement. Thus, in order to achieve the best performance from this method, it should to maintain the lighting consistency in both enrollment and identification phases of this system. The success rates of the paper grade identification process for different template sizes are shown in Table 2. The correct identification rate is calculated based on the percentage of the number of paper objects are classified into their respective paper grades. When the template size is 5 × 5 then the achieved classification rates for WP, ONP, and OCC are 96%, 92% and 96%, respectively.

4 Conclusion

The main emphasis of this work is on the development of a new method for automated paper sorting system. In the experiment, it is observed that the performance of the vision system is extremely influenced by the lighting arrangement and template size. The method described here mainly transforms the pixels value to RGB strings, comparison of RGB-strings among template images and N-cells of search image, apply matching score and threshold value to identify the grade of the paper object. From the review, it was noted that five sensors namely ultrasonic, lignin, gloss, stiffness and color sensors are used in paper sorting systems. Ultrasonic sensors are slow, which make them unsuitable for industry use. Lignin sensor can only be used to separate the newsprint papers from others and its performance is strictly color dependent. Stiffness sensor is typically used for separating cardboard from others paper grades where as gloss sensor is used for the separation of glossy paper from others. Color sensor, on the other hand, measures the radiation of the paper surface and commonly used to identify white papers. Thus, the most important point addressed in the proposed method is that the method, which uses computer vision, can be easily implement for sorting multiple grades of papers. The remarkable achievement obtained from the proposed method is the result of identification for three major paper grades -WP, ONP and OCC just using simple image processing techniques. The further works can be carried out for all grades of papers and the work may also be extended to other solid wastes sorting like plastic, metal, glass and so on.

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