HYPERSPECTRAL IMAGING FOR TEXTILE SORTING AND RECYCLING IN INDUSTRY

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ABSTRACT

Recycling of textile materials is becoming very relevant due to the increasing textile waste and its large environmental impact. The Resyntex project aims at dealing with this textile waste by enabling its chemical recycling. To do so textile pure materials and blends need to be sorted first. In this paper we evaluate the suitability of hyperspectral imaging for pure and blend textile sorting. For this purpose we use the Imec line-scan sensor in the 450-950nm range, since its cost, compactness and speed characteristics make it suitable for industrial deployment. To deal with the strong color interference a hierarchical classification approach is proposed. The results on the available sample set show promising discrimination potential.

***Index Terms*—** VIS-NIR spectral response, textile material, color classification.

1. INTRODUCTION

The textile sector uses a huge quantity of raw materials and produces a substantial amount of waste. This is partly due to the fact that only a small amount of wearable textiles is recycled. Most of these textiles are landfilled or incinerated, with a high environmental impact. The European project RESYNTEX aims at designing, developing an industrial symbiosis between the unwearable blends (wool, cotton, synthetic polymers – representing 93% of all components) of textile waste and the chemical industry. To enable chemical recycling, sorting of textile material according to material/blend is required first. In this respect Hyperspectral Imaging has a great potential for material discrimination.

However, the adoption of hyperspectral imaging by the industry has so far been limited due to the lack of fast, compact and cost-effective hyperspectral cameras with adequate specifications. To bridge the gap between research and industry Imec has developed a unique hyperspectral sensor concept in which the spectral unit is monolithically integrated on top of a standard CMOS sensor at wafer level. This heavily reduces the cost and improves the compactness and speed of the hyperspectral camera, enabling the adoption of hyperspectral technology by industry. Therefore we use the Imec line-scan 150 sensor [1] providing us with 150 bands in the 450-950nm range for the purpose of textile discrimination. Most of state-of-the-art work on textile discrimination has focused on textile sorting in the SWIR range (1000-2500nm) [2],[3]. We have explored instead the feasibility for textile discrimination in the VIS-NIR range covered by Imec sensors.

2. ANALYSIS AND RESULTS

The imaging system used in this study is shown in Figure 1, with an Adimec hyperspectral camera and a translation stage where the textile pieces are placed. The Imec line scan sensor acquires 150 bands in the 450-950nm range. Its spectral unit is integrated in the standard CMOS sensor at wafer level, which reduces its cost and increases the acquisition speed. This way, for standard illumination (325W) the system can reach a speed of 1080 lines per second. Our ongoing implementation on a conveyor belt setup works at around 0.5m/s, enough for processing 1 cloth item/s. The initial pilot system in the Resyntex project expects to reach speeds of 100kg/h of processed textiles. This is equivalent to 500 tons/year or 1 cloth item every 10 seconds (assuming a 300gr item on average). In the system under preparation each textile item will be processed separately and, according to the acquired spectra, sorted in a corresponding basket by an air-separator system.

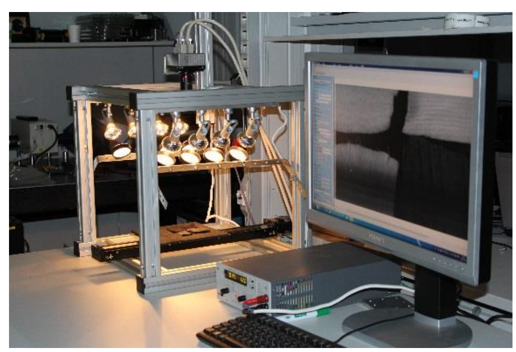

Figure 1: Imec hyperspectral system

While in the SWIR range the impact of the color tint on the textile spectra is very low, in the VIS-NIR range the color impact is very high. This highly increases the intra-class variability per material type and increases the difficulty for material classification. We deal with this color influence by implementing hierarchical classification, in which color classification is followed by material classification per color category. Color classification is performed by means of L,a,b parameter computation [4] and selection of L,a,b value with closest Euclidean distance from the colors available in the library, as shown in Table 1.

Table 1: Color classification based on Lab values

Wool 'Real color' (L,a,b)	Classifier label (L,a,b)
Black (29.0 -8.0 -7.4)	Black (34.5-12.2 -12.8)
Red (58.2 14.3 -17.2)	Red (54.2 16.9 -12.9)
Light Green(60.4 -6.0 -2.2)	*Beige* (69.5 -5.9 -4.1)
Beige (63.0 -0.7 -4.2)	Beige (69.5 -5.9 -4.1)
Blue (40.9 -8.1 -10.8)	Dark blue (43.1 -7 -10.2)

Material classification is then performed per color category. Both Quadratic Discriminant Classifier [5] or SVM [7] have produced good results, indicating so far good potential for discrimination of pure materials and blends within this spectral range. Figure 2 shows the material classification results for a 'red' set of materials. While at pixel level there are few miss-classifications at object level the classification is 100% accurate. Similar results are obtained for other color categories tested and summarized in Table 2 where the classification accuracy per material and color set is indicated.

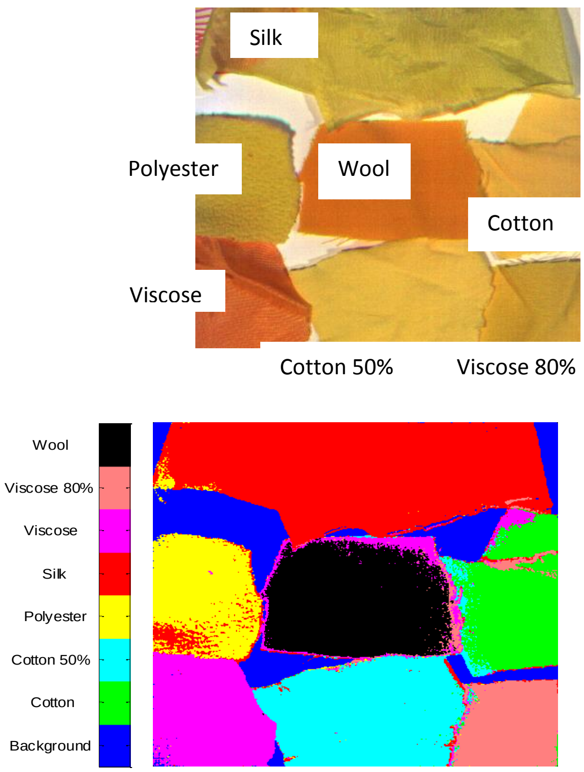

Figure 2: False color image of red textiles (above) and corresponding classified image (below).

Table 2: Material classification accuracy per color set

Color set	Black	White	Blue	Red
100% Cotton	100%	93%	92.5%	91.5%
100% PET	100%	95%	100%	95%
100% Wool	100%	100%	90%	95%
100% Viscose	97.5%	100%	-	92.5%
100% Polyamide	100%	100%	75%	100%
100% Silk	100%	100%	90%	100%
100% Acrylic	-	90%	100%	100%
80% Cotton	-	60%	88%	70%
70% Cotton	97.5%	80%	-	75%
60% Cotton	100%	90%	-	85%
50% Cotton	-	-	95%	-

3. CONCLUSIONS

The feasibility study performed over a variety of pure textile materials (cotton, viscose, polyester, wool, silk and polyamides) and blends (cotton and polyester, viscose and polyester) is promising and seems to indicate that material discrimination can be performed by means of hyperspectral imaging in the VIS-NIR range. The textile samples available for the study were limited in terms of colors, materials and available blend types. In order to guarantee a robust sorting system for all textiles varieties we need to include a more extensive sample set in the training phase. In the same spectral range we also want to evaluate the material discrimination possibilities of the Imec Mosaic sensor (25 bands in the 600-1000nm range) [6] since this would enable fast portable on-site inspection of textiles.

ACKNOWLEDGMENTs

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4. REFERENCES

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