DEFECT DETECTION IN FIBERED MATERIAL USING METHODS OF MACHINE LEARNING

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Abstract: SILON s.r.o is manufacturer of polyester fibres which get used in wide range of applications, many of them requiring highest quality material. Due to manufacturing processes, some fibres are not drawn properly and stay in the fiber as bundles, or brittle, thick threads. Proposed lab station should automate process of quality check of each batch. It consists of linescan camera scanner and computer with software for detection and analysis of defects.

Keywords: EEICT, polyester fiber, fluorescence, Rhodamine B, scanner, linescan camera, quality check, defect detection, CNN, convolutional neural network, FCN, fully convolutional network

1 INTRODUCTION

SILON s.r.o has been manufacturing TESIL® polyester fibres for over 50 years and was creating them using exclusively PET bottle flakes since 2002 [1].

Quality control is essential part of every industrial process. TESIL® has been, until now, inspected by hand, using carding machines. The carded fiber is laid on lit surface and quality inspector checks for any thick and/or bundled threads. Final number is counted and then extrapolated to whole batch.

Proposed machine will automate this process using machine learning and Fully Convolutional Networks (FCN).

The machine consists of linescan camera, two lighting units, XY linear actuators and glass cover, creating a scanning unit as shown in figure 2. A prototype has been built, demonstrating scaning capabilities, resolution and field of view of camera.

2 APPLICATION

The company SILON s.r.o is making TESIL fibres in variety of colors, for building industry, automotive, and personal hygiene, but mainly in white shades.

It's possible to color fibres using chemical compound Rhodamine B. It sticks to thick, nondrawn fibres, and allows them to fluoresce under right lighting. This is considered in design of the scanner and lighting unit that is used to illuminate the sample. The absorption and fluorescence spectra are shown in figue 1.

3 CAMERA & LIGHTING

Linescan camera reads one line at a time. This makes it suitable to scan long strips of material, where one picture from conventional area scan cameras doesn't cover the whole object. It's especially advantageous for moving objects, for example endles webs of material that move underneath the camera.

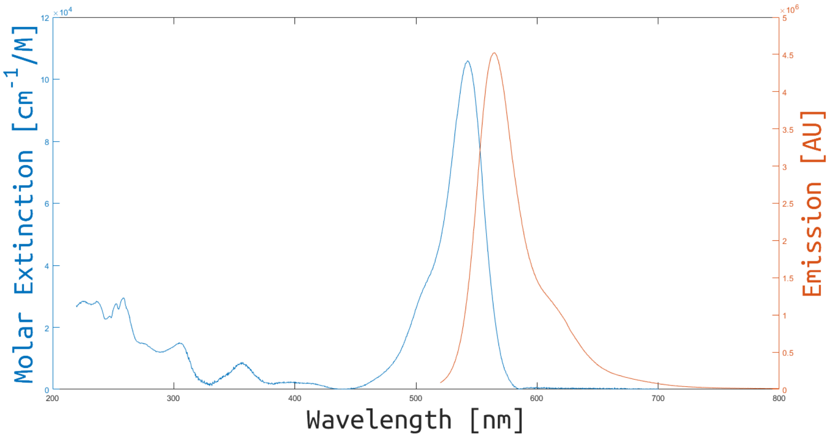

Figure 1: Absorption (blue) and fluorescence (orange) spectra of Rhodamine B. [4]

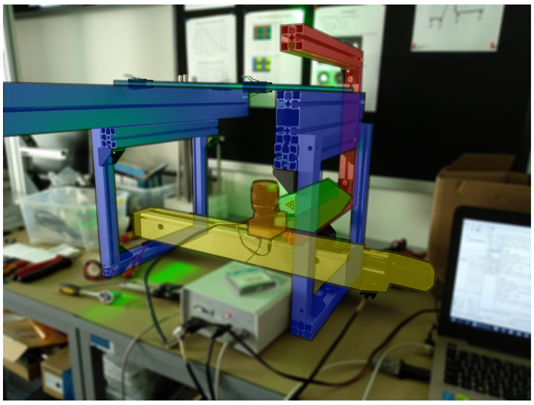

Figure 2: Scanner setup with camera (orange) and fluorescence light (green) highlighted. Transmission light is not present currently.

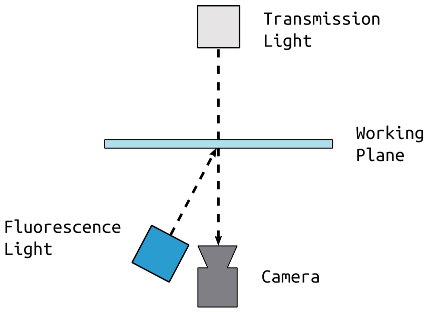

Figure 3: Placement of Transmission and Fluorescence lights. Side view.

The transmission light sits above the camera, on the other side of moving “C” profile from camera. It illuminates the working plane and shines straight into the lens. There is also frosted glass cover between the light and the working plane to ensure uniform distribution of light. That creates bright image in the camera, except for light blocking objects. They appear as black shadows on bright surface. This is especially helpful for detection of bundles of threads and thick standalone threads.

Second light is on the same side as camera. The light points towards the working plane, where the camera looks. Its wavelength is 520 *nm*, which makes it suitable to excite Rhodamine B. Fluoresced light then travels straight into the camera.

4 FILTER

Three diferent filters were tested. First is low pass filter blocking any wavelength shorter than 635 *nm*, second one is similar, only with threshold of 605 *nm*. Third one is band pass filter with thresholds 450 *nm* and 645 *nm*. 605 *nm* filter offered best results, which is confirmed by fluorescence light and Rhodamine excitation spectra. 635 *nm* is too far from emitted color, so the image is very dark. The band pass on the other hand covers both fluoresced light and exciting light. That creates light artifacts which make detection more difficult. The filters can be compared with spectra in figure 1.

5 FULLY CONVOLUTIONAL NETWORKS

Usual CNNs create feature vector that can be then classified into single or multiple classes. But where's the need for image segmentation instead of classification, the standard CNN falls short. That's where *fully connected network* (or FCN) comes.

Instead of having picture with classes associated to it forming the training dataset, there is now set of two pictures. First one is the original, the second one is a map of present objects. That allows for finding borders of distinct objects in the picture, but is also very difficult to get dataset large enough to train this type of network.

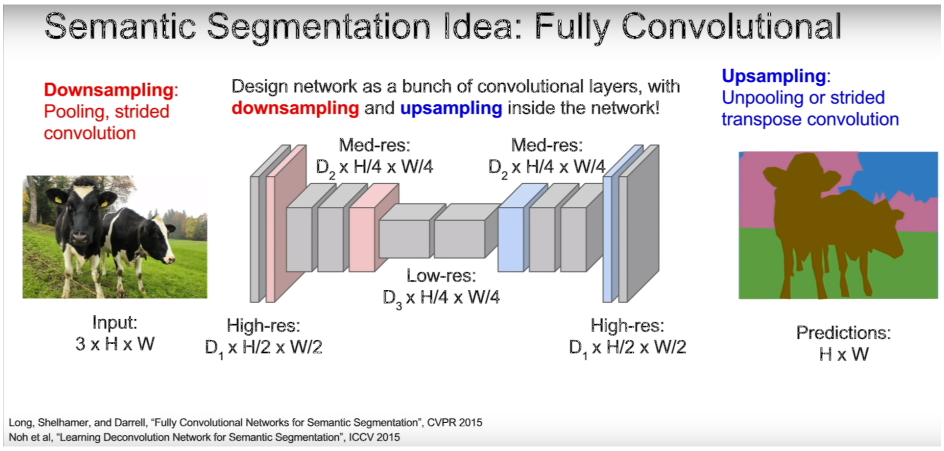

Figure 4: Example of fully connected network from Standford lectures [2].

This network consists of convolutional layers, pooling layers and new type of layer, that's called transpose convolution. The transpose convolution uses its filter to project single value to larger field.

Other types of upsampling include various versions of unpooling, also discussed in the Stanford lectures on machine learning [2]. The unpooling process can copy single value to 2×2 fields, or place a single value in one of the corners of this 2×2 field and fill the rest with zeros.

6 TESTS

Several preliminary tests were conducted on scanner prototype to demonstrate functionality and test different light constellation. Figures 5 and 6 show same spot under different lighting. Notice figure 6 especially, as there is no trace of defect under the transmission light.

Best results were achieved with combination of white transmission light and green light (520 *nm*) with 605 *nm* filter in the lens.

There is not enough test sample photos of the fibre, so the first test of neural network was done with substitute dataset of worms under microscope [3]. The results look promising and suggest, that using FCN is suitable option.

7 CONCLUSION

Newly developed scanner could be powerful tool for detection of defects in fibered material. The setup with two different types of light shows promising results and the linescan camera has good enough resolution. Fully convolutional network should be able to find majority of inconsistent and defect fibres.

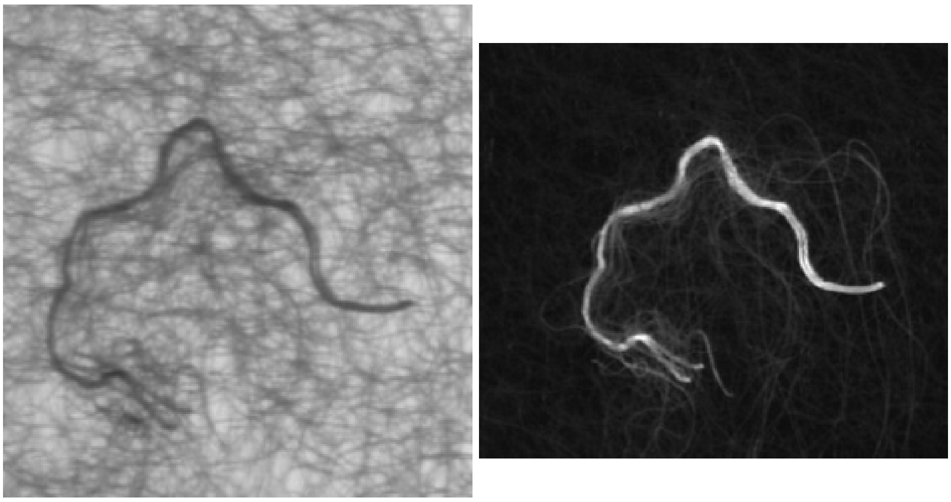

Figure 5: Image under transmission light(left) and fluorescence light (right).

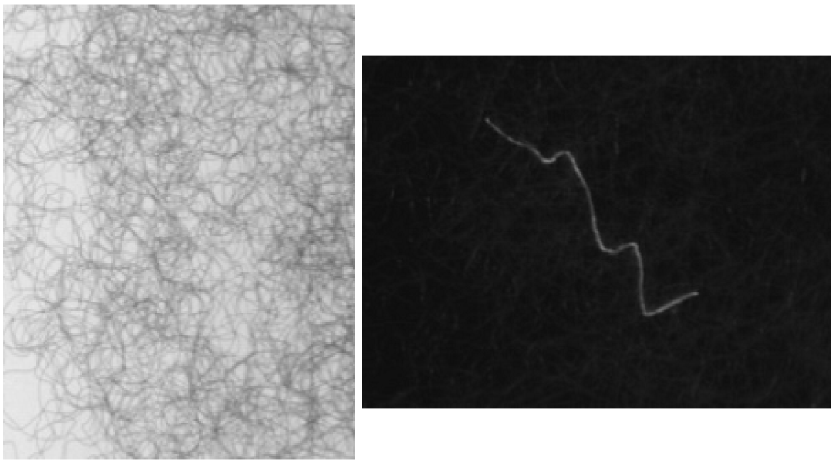

Figure 6: Image under transmission light(left) and fluorescence light (right). Here the thick fiber would be completely undetectable without rhodamine coloring.

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