Abstract—this paper gives a short overview of using imaging spectrograph for identifying different waste paper grades from waste paper stream. After reference research it occurred that most of the high-end systems use spectroscopy to identify different paper types. To estimate the usability of this approach the test measurements were ordered, software for analyzing the results were developed and distinguishability of some materials were tested with positive results.

I. INTRODUCTION

Estonian company Infokaitse OÜ collects the waste paper directly from offices for recycling. The company wishes to increase the throughput of sorting lines by implementing automatic sorting system mainly for separating white office paper from waste paper flow. Other materials, considered in this paper that should be separated are newspapers, carton, checks, sticky notes and copying papers. In some cases the white office paper can be covered with sticky notes or can be inside film-pockets and therefore should be separated for additional manual sorting.

II. WASTE PAPER SORTING METHODS

Reference [1] describes the multisensory system consisting of lignin sensor (measures the intensity of fluorescence), stiffness sensor (for estimating the material stiffness) and RGB camera (color) is described. The classification process of this kind of method is quite sophisticated. Reference [2] gives and overview of using the NIR (near infrared) spectroscopy to effectively classify polymers and cellulose based materials. In Reference [3] the Bright-White sensor which senses the fluorescence paper and combined system using RGB camera, gloss sensor and near infrared sensor to sense additional paper “signatures” are described. The resulting system can identify several materials with high speed. In Reference [4] the advantages of using spectrometer instead of RGB camera and design of high speed spectroscope are represented. Therefore it can be stated that using spectroscopic methods instead of RGB or monochrome cameras or additional sensor systems give more convenient results, are more flexible and can be cheaper to implement though the hardware of single unit is more expensive.

Imaging spectrograph References [2, 5] can be used for acquiring hyperspectral image from the moving transportation line. The device measures single “line” of the object on the production line at a time. Incoming light is split into wide amount of spectrums which are projected on common industrial vision camera sensor. The acquired image consists of spatial and spectral information and by acquiring images continuously the second dimension is measured. Using some simple techniques it is possible to obtain corresponding spectrum of measured object that can be used for material identification.

III. MEASUREMENTS

To preliminarily test the usability of spectrograph in current application the measurements of sample materials were ordered from the manufacturer of spectrographs [5]. Measurements in two spectrum ranges were made with 2 different system setups: Inspector V10 (VNIR 400 – 1000 nm) and Inspector N17E (NIR 900 – 1700 nm). In both cases appropriate cameras and lenses were used. The test setup consisted of test rig with adjustable camera mount, movable table (maximum line speed 65 mm/s), wide spectrum halogen light unit and measurement system.

With VNIR the measurement line speed was 2.25 mm/s, frame rate 14 fps, spectral response 400 - 1000 nm, spectral resolution 6.8 nm and resolution 0.19 x 0.16 mm (width x length). NIR spectrograph the line speed was 60 mm/s, frame rate 80 fps, spectral response 900 - 1700 nm, spectral resolution 5 nm and resolution 0.83 x 0.75 mm (width x length).

The ENVI file format Reference [6] is used for data storage. It uses a generalized raster data format consisting of a simple flat binary file and small associated ASCII header file. BIL (band interleaved by line format) is used where the first line of the first band is followed by first line of second band etc.

The sample materials were composed by using materials sorted by Infokaitse OÜ. The samples were attached on the carrier sheets to simplify the measuring process. Spectrums of 5 sheets in total containing over 100 samples of different materials were acquired. In this paper the simple analysis of separating only white office paper, newspaper, carton, check, copying paper, yellow sticky note and white office paper in film pocket is described. Since sample materials contained much more materials the future analysis are possible.

IV. ANALYSIS

The measurement process is a multistage process starting with acquisition of one dark (represents sensor noise) and one bright image (measuring standard white material which spectral reflection values over the full measurement range are known). To compare different measurements the reflectance should be presented in absolute units, to obtain this the measured data needs to be normalized Reference [2]. After normalization the effect of dark current and light unit spectral response is eliminated from measurement results (although the noise in the beginning and end of measurement spectrum is increased due to lower response).

For measurement data analysis the software was developed by using National Instruments LabView system design software. Software loads measurement files and it is possible to compose simplified database of spectrums of different materials by manually selecting pixels on spatial image. Software calculates mean spectrum and standard deviation of
the selected spectrums. Standard deviation gives an estimation of differences between selected spectrums helping to prevent the selection of spectrums which are highly differing from mean spectrum.

Since measurement data is quite noisy in the end and in the beginning of measurement range, the easiest way to eliminate the effect of that noise is to remove the certain amount of samples in the beginning and in the end of dataset. After that the data is smoothed by using simple moving average with width of 5. On the same figure the mean of ten spectrums is shown. This approach is not the best since there is data loss, in the future something more effective should be used.

The mean value of 20 randomly selected spectrums from area which belongs to one material acquired with V10 was calculated. Same process was repeated on each material sample. After that the graph containing all the mean spectrums of samples were plotted where it is easy to distinguish all the mentioned materials (Fig. 1.). The main differences lay in visible spectrum; for most of the materials the plots are quite flat in range from 750 nm to 1000 nm.

In the next step some random pixels were selected on the spatial image, correlation coefficient r was calculated between mean of selected spectrums and all the mean spectrums in database and sorted decreasingly. Correlation coefficient r gives and estimation of how much the two datasets are correlated; in this case the linear correlation coefficient is used. The highest r value shows the closest match from the database.

With each material at first one random pixel and after that five random pixels were selected. With V10 all the results were positive, matching the highest r correctly with material in both cases (one and mean of five). In most of the cases the matching r was above 0.99. In a case of white office paper the difference between the first (correct) and second match was around 0.1. With yellow sticky notes and copying paper it was around 0.08. With other materials this number was around 0.5. When selecting mean of five spectrums the difference between true match and the following one is greater.

In a N17E case the newspaper, carton and office paper in film pocket have difference with next r value above 0.01 and are somewhat distinguishable. When using mean of five spectrums the results always stand out, when selecting one spectrum it is sometimes distinguishable. Other described materials are not distinguishable with N17E using described approach.

V. CONCLUSIONS

Hyperspectral imaging can be used for sorting white office paper from waste paper flow. The simplified approach described in this paper is manual and is used for rough estimation of usability in sorting waste paper. It is known that using hyperspectral imaging enables to acquire more information and therefore gives more precise results. In the future automatic classification should be implemented with some more advanced data preparation and classification methods. Further research is needed to estimate which spectral range (VNIR or NIR) is more effective.

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Fig. 1. Spectrums acquired with Imspector V10.

Similar database were manually constructed using N17E measurement data (Fig. 2.). Here the differences between the spectrums are smaller. Newspaper, office paper in film pocket and carton are more distinguishable, spectrums of rest of materials are quite similar.

Fig. 2. Spectrums acquired with Imspector N17E.