Hyperspectral Imaging for Analysis and Classification of Plastic Waste

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Why is it needed?

- Environmental issues
  - Plastics and its laminates as one of the most common packaging materials
  - Recycling rate in many countries is very low

- Sorting issues:
  - Traditional, mechanical sorting methods fail:
    - Plastics can not be distinguished from each other
  - Separation of polymers that affect the quality of recycled material
    - It can make the recycled material unusable

Materials

- Collection of samples based on daily-use products waste
  - Whole wrapping
  - Crushed material
- Materials base includes: LDPE, HDPE, PA, SAN, PET, PP, PS, PVC, PBT, paper, TetraPak

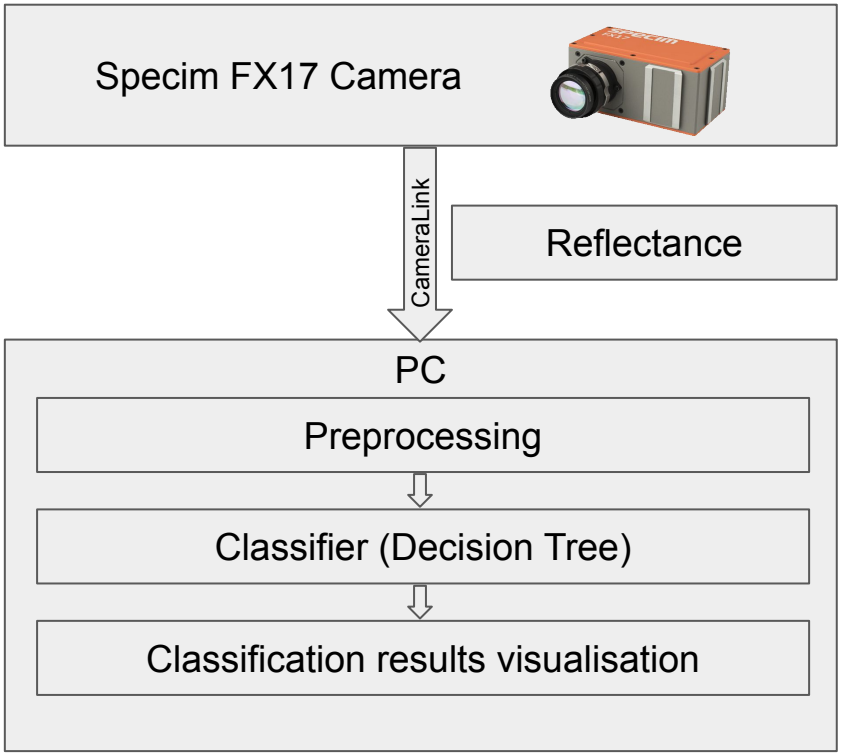
Examples of plastic waste materials - in RGB palette and in one of the wavelengths from NIR range

Hardware

- Camera:
  - Specim FX17 NIR & SWIR (900 - 1700 nm)
- Materials transported on a conveyor belt
- Lighting
  - White halogen lamp
  - Ekonair’s Sun-Rai Halogen G

Measuring stand

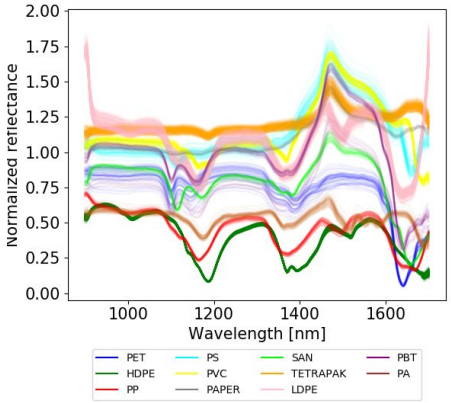
Polymers classification system block diagram



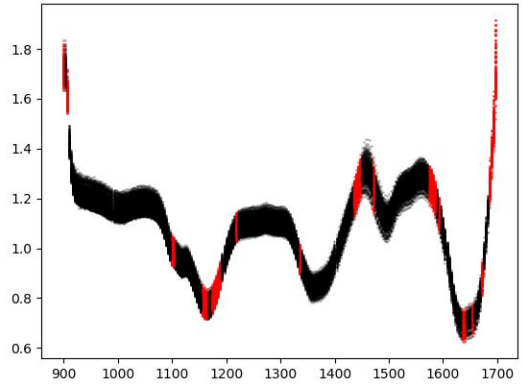
Block diagram of polymers classification system

Preprocessing

- Reflectance measurement in NIR & SWIR range
- Determination of the most significant wavelengths for materials classification
- Classification based on characteristic wavelengths of the reflectance spectrum
- Preprocessing using Savitzky-Golay filtering and mean normalization



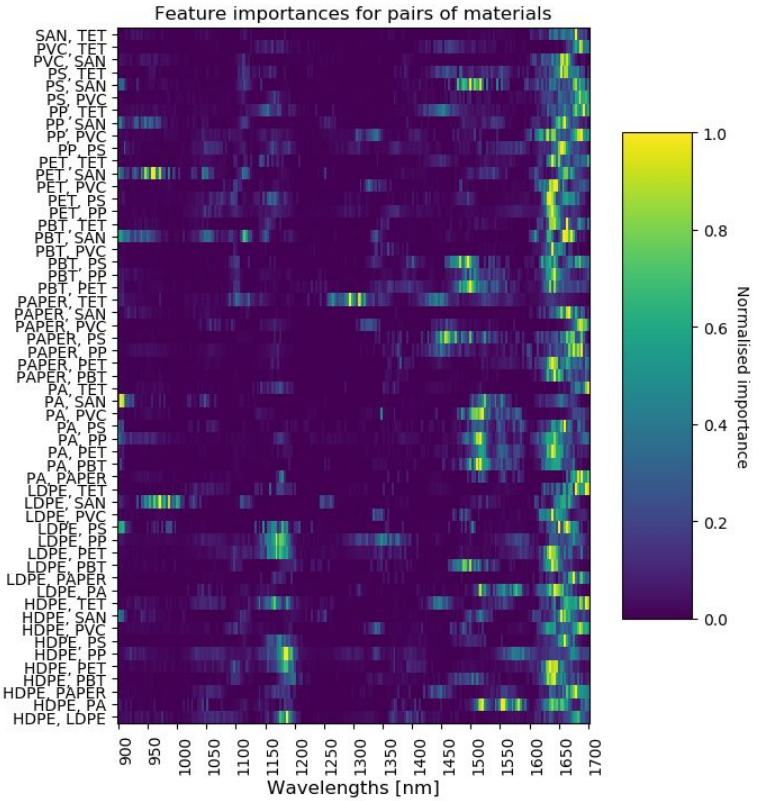
Reflectance of different materials



Most important wavelengths chosen by classifier

Classification

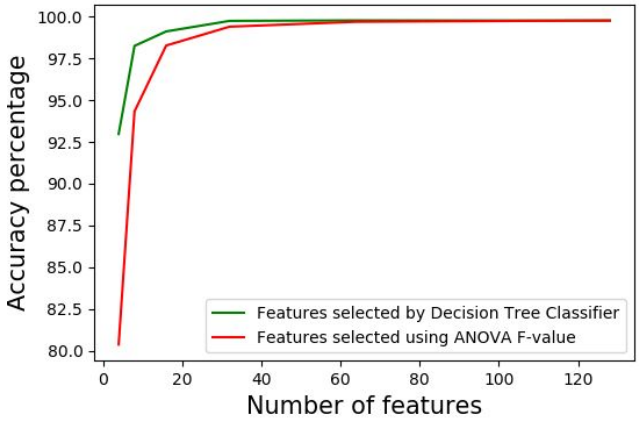
- Classifiers used:
  - Decision Tree
  - Extra Trees Classifier
  - Random Forest Classifier
  - LGBM Classifier
- Parameters for each classifier can be found in the paper



Features importances for pairs of materials

Reduction of spectral channels

- Camera performance with different Spectrum of Interest (SoI)
- Influence on the accuracy
- Optimal number of channels



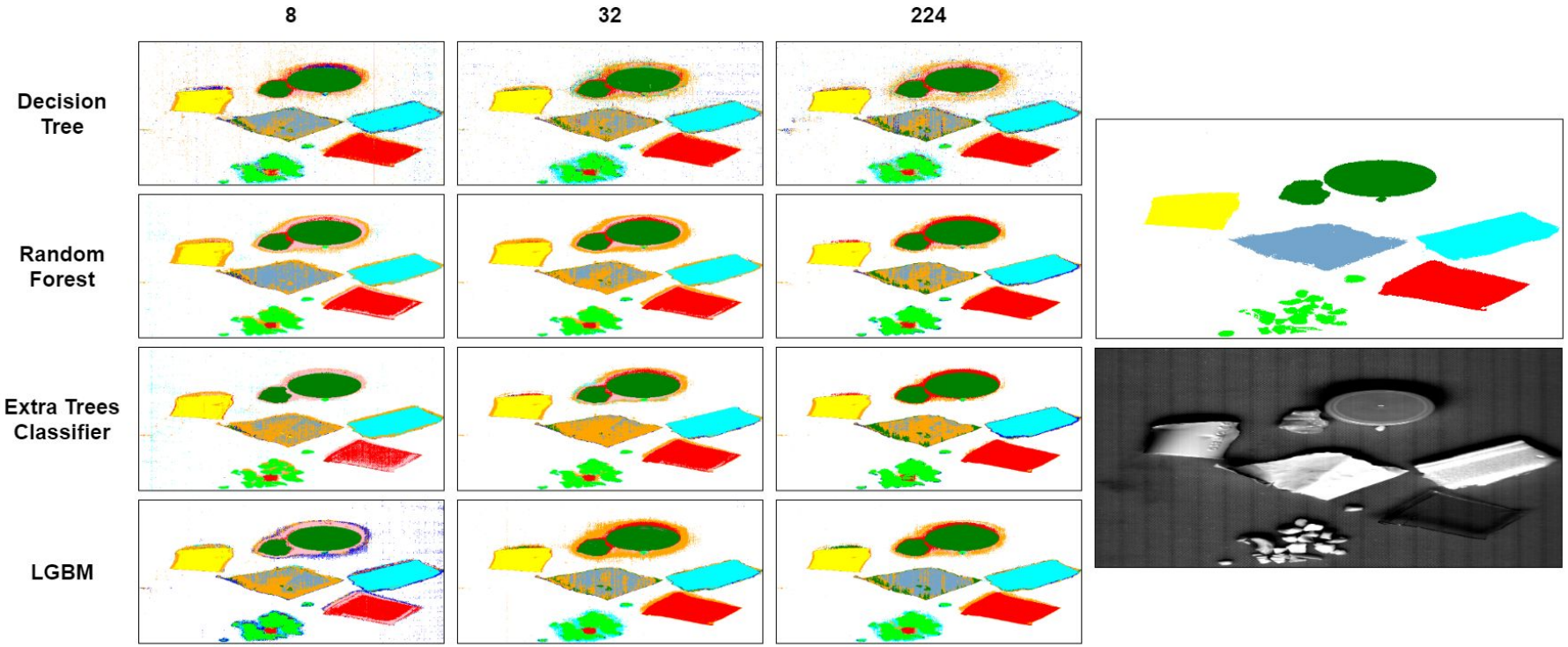
Influence of number of wavelengths on accuracy

Results

	8	32	224
Decision Tree Classifier	**83.3%**	82.2%	82.2%
Random Forest	78.6%	87.8%	80.5%
Extra Trees Classifier	80.9%	86.6%	76.7%
LightGBM	79.9%	**88.3%**	**86.1%**
Decision Tree Classifier + Savitzky-Golay	**83.3%**	82.5%	82.2%
Random Forest + Savitzky-Golay	81.7%	87.8%	80.4%
Extra Trees Classifier + Savitzky-Golay	80.2%	87.3%	76.1%
LightGBM + Savitzky-Golay	80.0%	**88.3%**	**86.0%**
Decision Tree Classifier + mean norm.	83.9%	89.1%	86.5%
Random Forest + mean norm.	**91.8%**	91.2%	85,3%
Extra Trees Classifier + mean norm.	79.6%	90.1%	81.2%
LightGBM + mean norm.	85.8%	**93.1%**	**91.3%**

Results of the classifiers depending on the number of spectral channels

Results



Results of the classifiers depending on the number of spectral channels

Conclusions

- Reflectance measurement using NIR camera and Decision Tree classification can be used in a plastic waste sorting system
- Usage of SoIs resulted in performance speedup and higher accuracy
- Mean normalization resulted in higher classification accuracy in comparison to Savitzky-Golay

Future work

- Black materials require different range of the spectrum
  - Problem of the black materials will be solved in the future by using additional information:
    - RGB
    - SWIR

Thank you

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