The Role of Multispectral Scrap Characterisation and Artificial Intelligence in Efficient Steel Recycling

Recy & DepoTech 2024
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Agenda

- InSpecScrap Project
- Hyperspectral Image Capturing
- Image Segmentation
- Data Analysis and Scrap Composition Optimisation
- Summary and Conclusion

InSpecScrap Project

- INtelligent multiSPECtral characterisation for material analysis on SCRAP yards
- Funded by the Future Fund of the state of Styria
- Objectives:
  - Capturing scrap composition and quality with hyperspectral imaging
  - Image segmentation to distinguish between steel and non-iron particles
  - Finding ideal scrap compositions

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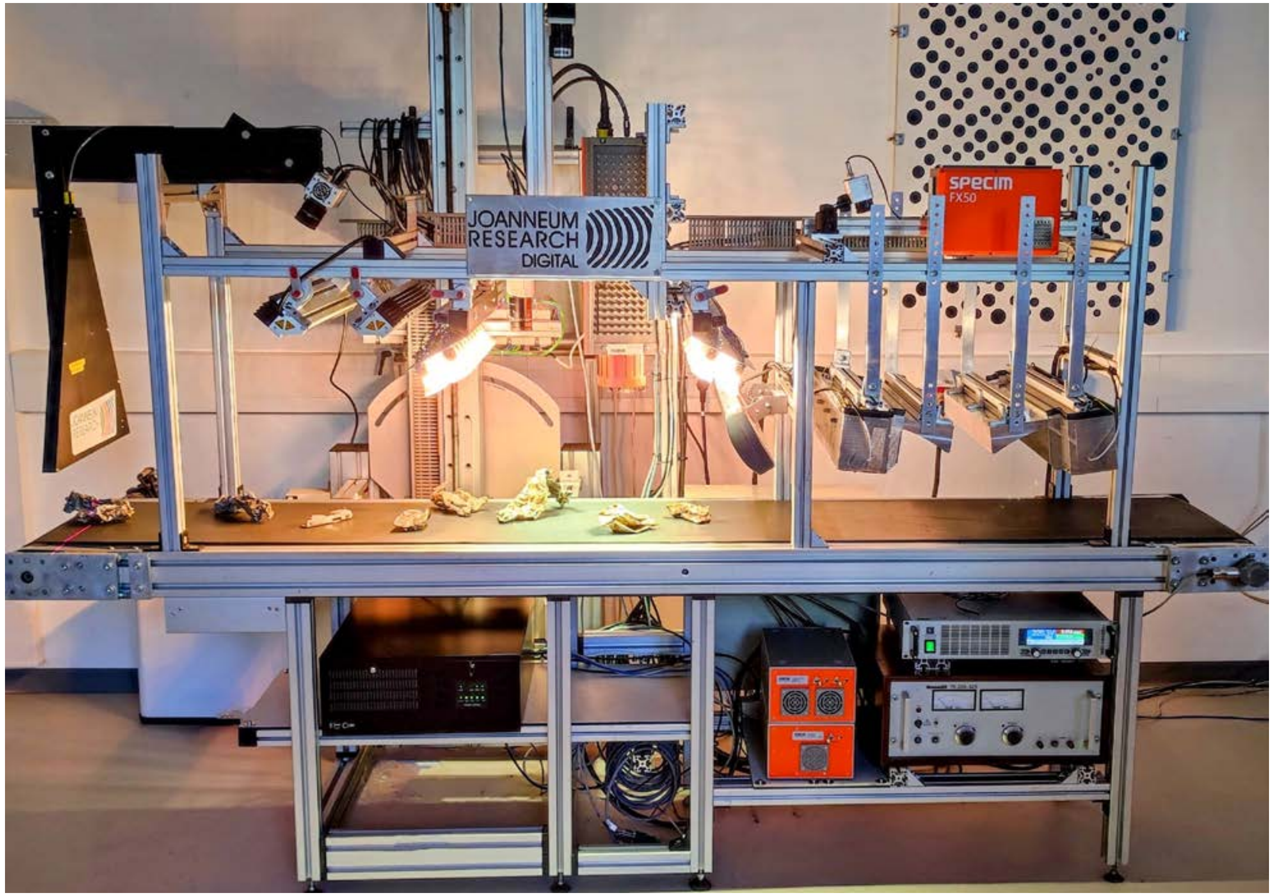
KNOW Center

K1 MET metallurgical competence center

Das Land Steiermark
Wissenschaft und Forschung

ZUKUNFTSFONDS STEIERMARK

Hyperspectral Image Capturing – Setup



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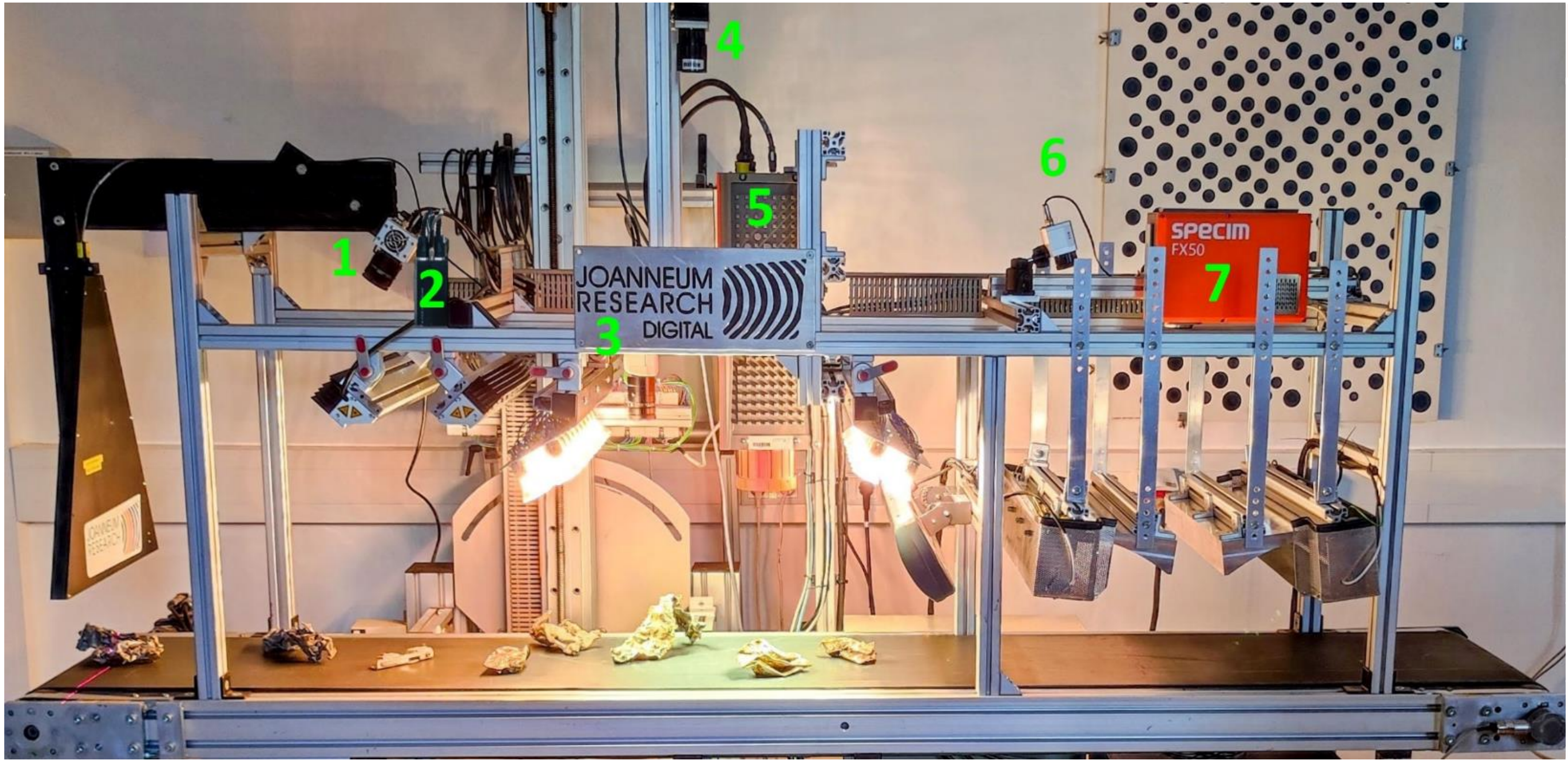
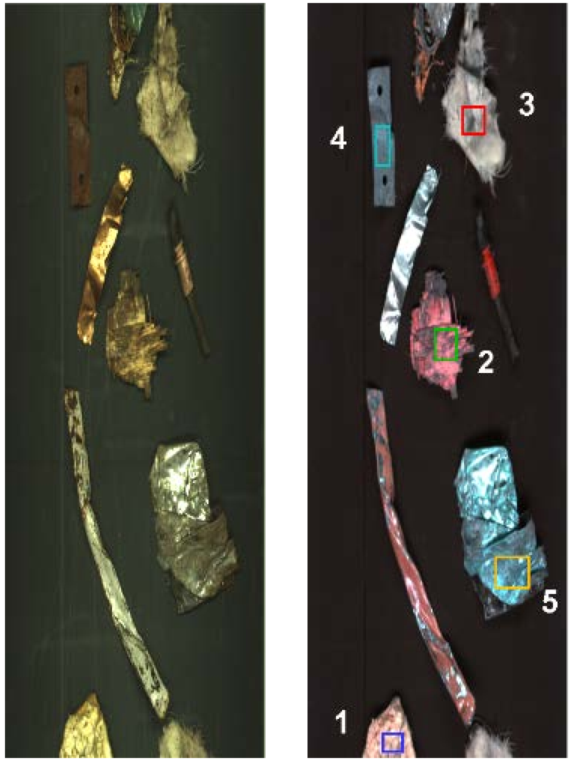
Hyperspectral Image Capturing – Cameras



No.	Camera	Purpose
(1)	AT C4	3D profile
(2)	JAI SW-2001Q	RGB + NIR imaging
(3)	AVT Mako G419 + ImSpector N10	HSI 400 – 1000 nm
(4)	PhotonFocus SWIR + ImSpector N17E	HSI 850 – 1700 nm
(5)	Specim SWIR	HSI 1000 – 2500 nm
(6)	Optris PI640	Thermal imaging
(7)	Specim FX50	HSI 2700 – 5300 nm

Hyperspectral Image Capturing – Results



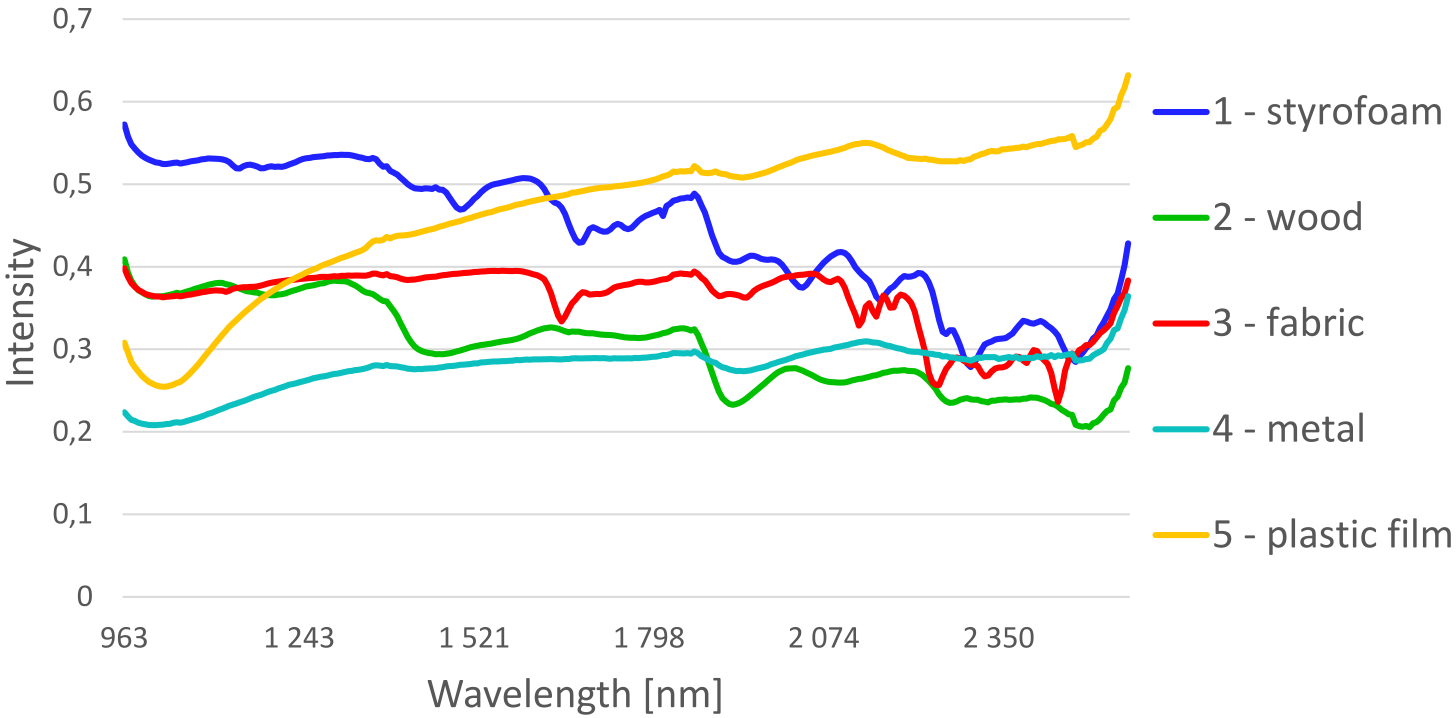
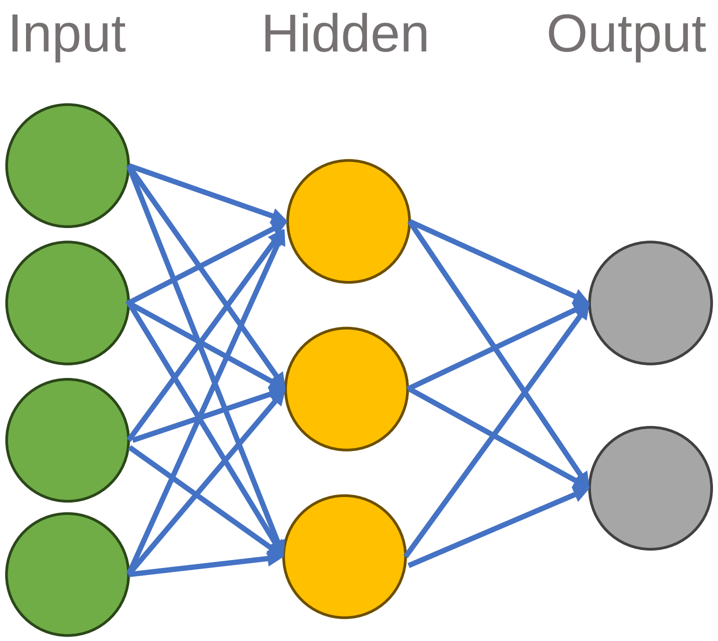


Image Segmentation



- Image segmentation with 2D Deep Neural Network
  - Three layers:
    - Input neurons equal to number of spectral channels
    - 256 neurons on the hidden layer
    - Number of output neurons equal to number of material classes
- Activation function
  - Internal Layer - Rectified Linear Units (ReLU)
  - Output layer - softmax
- Adam optimizer with learning rate of $1e-3$
- Batch size of 256 and cross entropy loss
- Normalisation of input vectors to have zero mean and unit variance

Image Segmentation – Training Data

- Industrial steel scrap
  - 160 parts
  - Sorted and annotated by hand
- Acquired with SWIR camera
  - 1,000–2,500nm
  - Split into 288 channels
- 10 classes
  - Steel as the target class
  - Nine other classes, e.g., wood, plastic, fabric, etc.

Image Segmentation – Qualitative Results

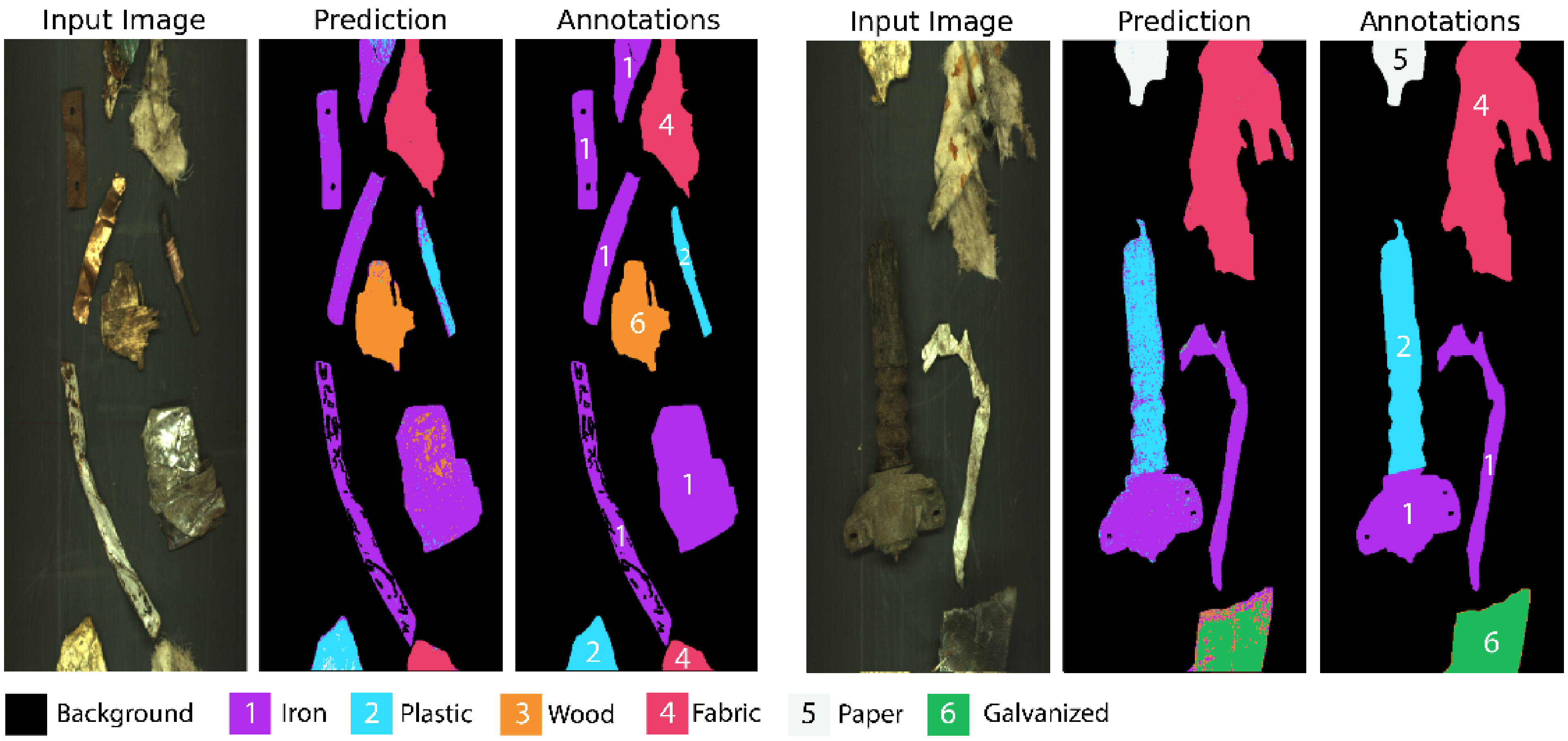
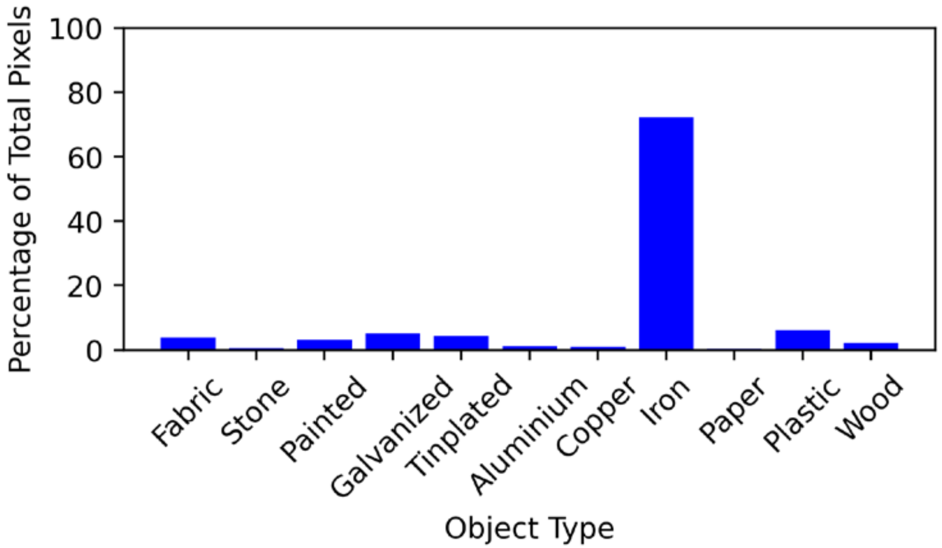
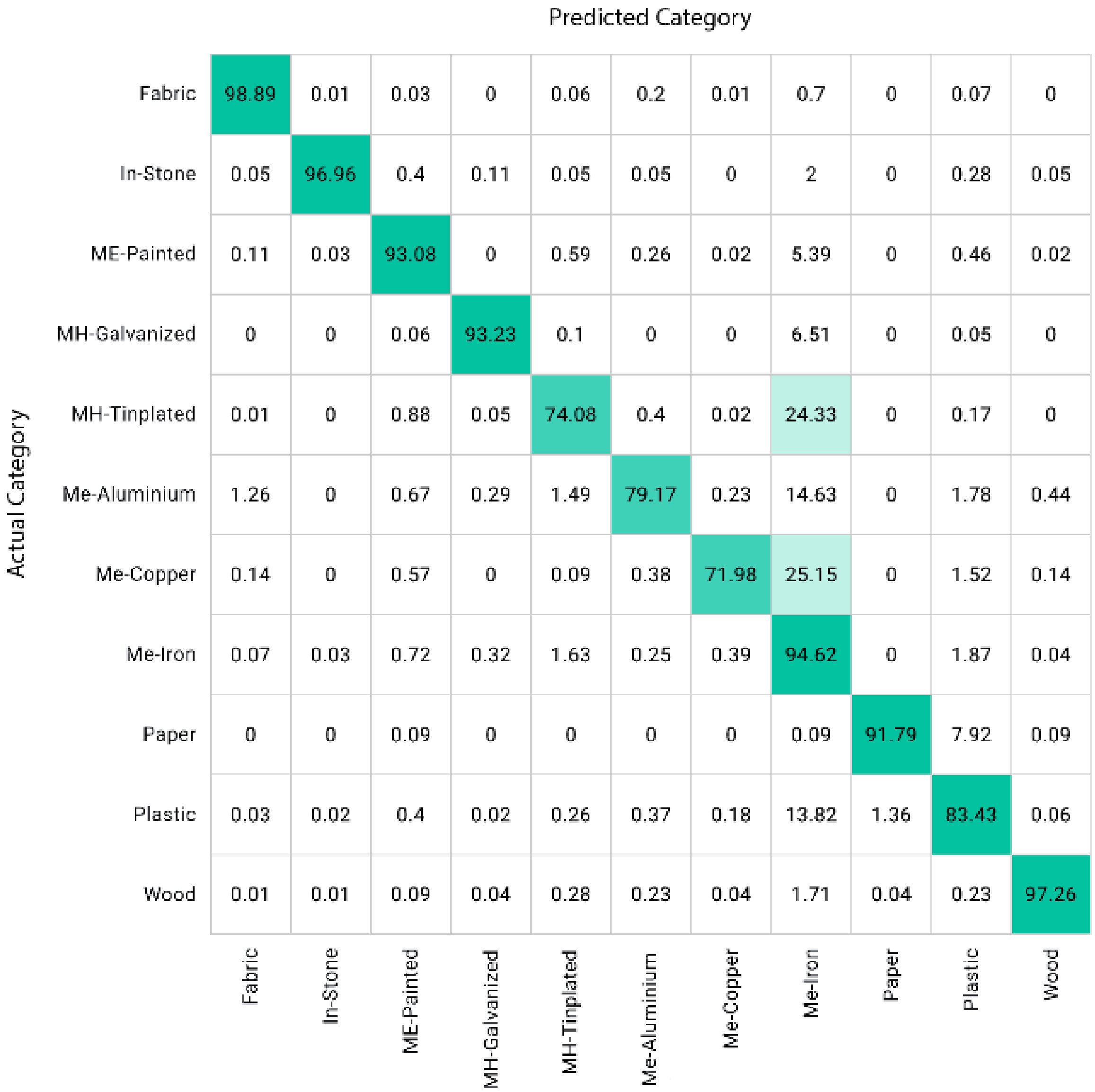


Image Segmentation – Quantitative





Predicted Category

Actual Category

	Fabric	In-Stone	ME-Painted	MH-Galvanized	MH-Tinplated	Me-Aluminium	Me-Copper	Me-Iron	Paper	Plastic	Wood
Fabric	98.89	0.01	0.03	0	0.06	0.2	0.01	0.7	0	0.07	0
In-Stone	0.05	96.96	0.4	0.11	0.05	0.05	0	2	0	0.28	0.05
ME-Painted	0.11	0.03	93.08	0	0.59	0.26	0.02	5.39	0	0.46	0.02
MH-Galvanized	0	0	0.06	93.23	0.1	0	0	6.51	0	0.05	0
MH-Tinplated	0.01	0	0.88	0.05	74.08	0.4	0.02	24.33	0	0.17	0
Me-Aluminium	1.26	0	0.67	0.29	1.49	79.17	0.23	14.63	0	1.78	0.44
Me-Copper	0.14	0	0.57	0	0.09	0.38	71.98	25.15	0	1.52	0.14
Me-Iron	0.07	0.03	0.72	0.32	1.63	0.25	0.39	94.62	0	1.87	0.04
Paper	0	0	0.09	0	0	0	0	0.09	91.79	7.92	0.09
Plastic	0.03	0.02	0.4	0.02	0.26	0.37	0.18	13.82	1.36	83.43	0.06
Wood	0.01	0.01	0.09	0.04	0.28	0.23	0.04	1.71	0.04	0.23	97.26

Data Analysis

- Create a common data base
  - Results from the image segmentation
  - Existing process data
  - Additional inputs from other systems (e.g., logistics)
- Unification of coordination systems
  - Time vs. feed organisation
  - 1D, 2D, and 3D coordinates
- Create new services
  - Support systems (e.g., dashboards, predictive warnings)
  - Optimisations and planning
  - Virtual sensing

Optimisation

- Objective
  - Find the ideal scrap mix
- Input
  - Scrap classification from the image recognition
  - Energy and additives needed per scrap class
  - Desired steel product alloy and quality
- Constraints
  - Equal usage for available scrap classes
  - Minimise energy and additives needed
- Result
  - Ideal scrap mix
  - Best possible proven solution

Summary and Outlook

- Hyperspectral imaging provides valuable insights into material composition
- Deep Neural Networks can handle hyperspectral data for image segmentation
- Environment in heavy industry is challenging
  - Sensitive cameras
  - Intensive lighting
- Data fusion for data-driven services
  - Optimisation of scrap composition
  - Dashboards and worker support
  - Virtual sensing

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