ESTEP SPRING DISSEMINATION EVENT

5-6 JUNE 2025 KRAKOW (POLAND)

AI-Driven Copper Detection in Scrap Metal: Advancing Digitalization in Sustainable Steelmaking

A. Petrucciani, V. Colla, **M. Vannucci**, A. Siddique, M. Ometto, M.Meneghin, C. Pietrosanti

ESTEP

HOTEL ★★★★ GALAXY JORDAN GROUP

Łukasiewicz GIT

BACKGROUND

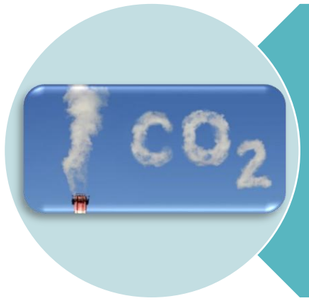
Scrap is a valuable raw material

Currently, not 100 % recyclable

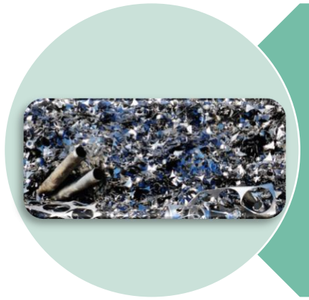
Tramp elements (Cu, Sn, Ni, Mo)

Co-funded by the European Union – GA n. 101092168

BACKGROUND



Around 680 million tons of steel were recycled in 2021, avoiding over one billion tons of CO_2 emissions[1].



The steel industry is expected to face a decrease in scrap availability and quality, leading to an increase in costs.

Novel tools and approaches for monitoring and controlling scrap quality are necessary to improve scrap characterization, reducing tramp elements and optimizing scrap charge.

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[1] WorldSteel Association «Steel - the permanent material in the circular economy» 2023.

THE PROJECT

EU project "**PURESCRAP – PURity improvement of SCRAP metal**"

Objective: increase the use of **low-quality scrap** grades applying the best available technologies to reduce impurities.

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CONSORTIUM

12 Partners

6 Different countries

Researcher organisations

- SWERIM
- K1-MET
- ESTEP

Universities

- Scuola Superiore Sant'Anna
- LTU Luleå tekniska universitet
- TU Dortmund

Scrap recycler

- STENA Recycling

Sensor technologies and Process control

- DANIELI AUTOMATION
- REDWAVE
- SPECTRAL

End users (Steelworks)

- SSAB
- Voestalpine Stahl Donawitz

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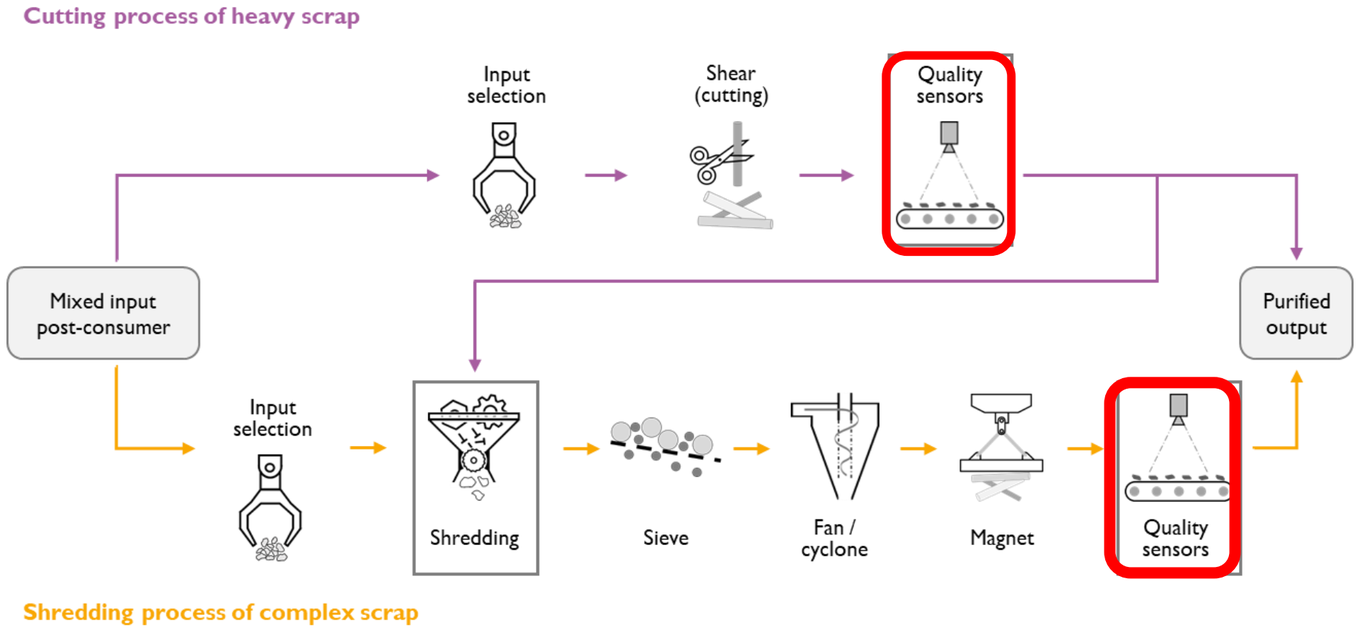
PURESCRAP APPROACH

Provide an integrated set of measuring technologies to increase the average scrap quality optimising the melting furnace's charge

Installation of sensor stations at selected locations: Heavy scrap and Shredded scrap

Large amount of data needs to be transferred, synchronised and merged



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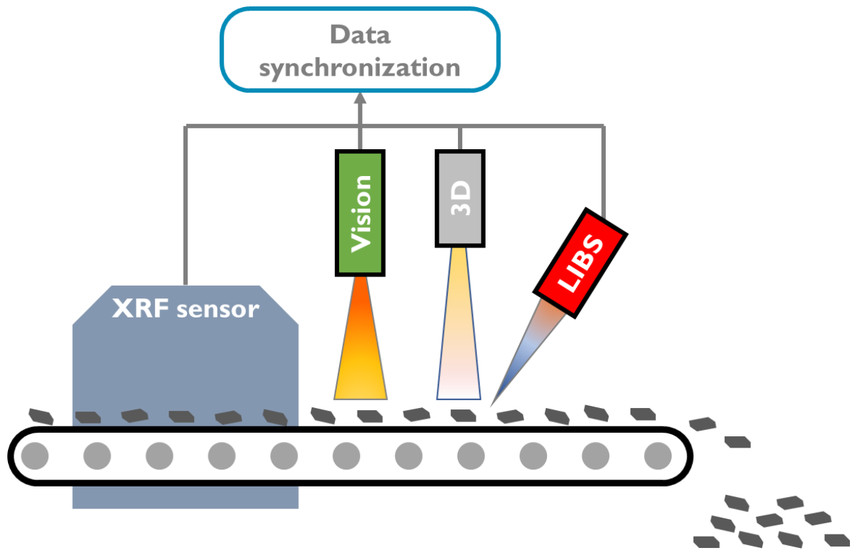
PURESCRAP APPROACH: SHREDDED SCRAP

Sensors Station: Shredded scrap



2D Camera	3D (camera and Lidar)	LIBS and XRF sensor
• Images • Image detection and processing modules • DL solutions for classifying scrap types	• Points Cloud • 3D line profile and optical sensors • Estimating volume and mass of the material	• Chemical analysis • LIBS single spot detection • XRF array of sensors and can cover the belt width but has lower analytical accuracy for the single objects

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PURESCRAP APPROACH: SHREDDED SCRAP

The combination of different types of sensors ensures robustness and reliability of scrap prediction

The effectiveness of the sensor station will be confirmed with (semi-) industrial trial melts.

Validation of the scrap quality and quantification of the maximum possible rate of sorted post-consumer scrap for high quality steel production

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Image Processing: Copper Detection
Data collection and labeling

1281 images are used for copper recognition, after being labelled and split into train, validation and test (60:20:20).

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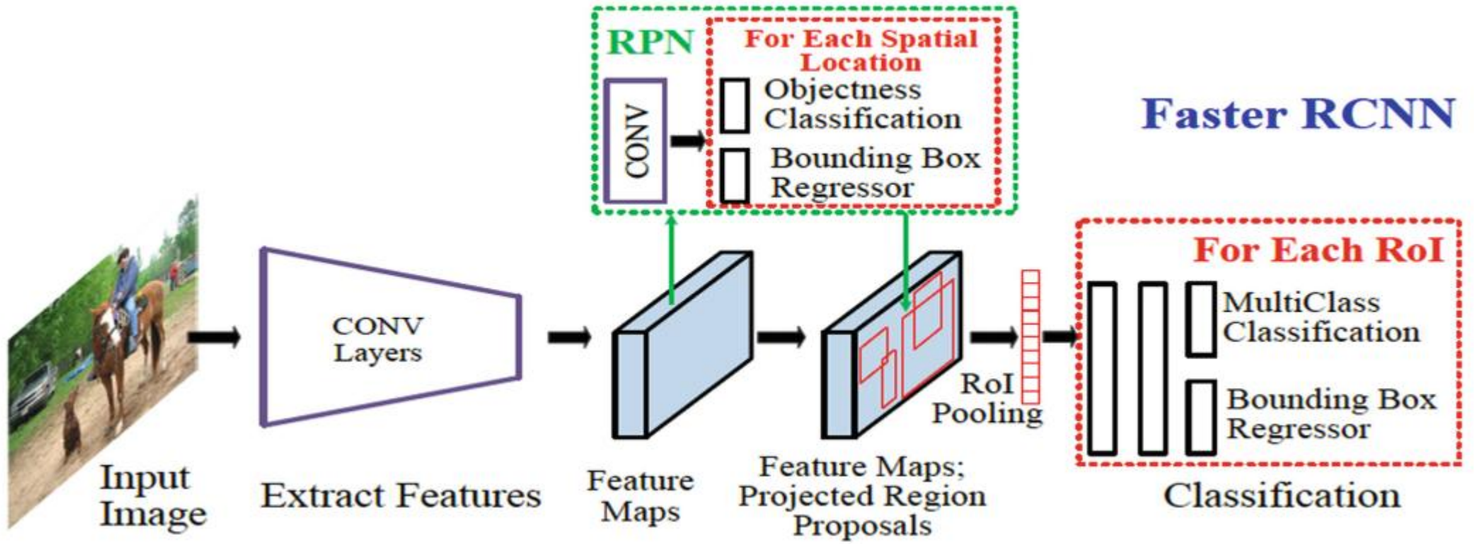
IMAGE PROCESSING: COPPER DETECTION MODELS

A model based on the **FasterRCNN + ResNetX-101** architecture (ImageNet pre-trained ResNext101 weights as a backbone and Feature Pyramid Network (FPN) in Faster RCNN as Neck) was developed to identify the copper.



[1]

[1]Rocha, Á., Adeli, H., Reis, L. P., & Costanzo, S. (Eds.). (2018). Trends and Advances in Information Systems and Technologies: Volume 1

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Image Processing: Copper Detection Models

Model based on the FasterRCNN + ResNetX-101 architecture

Portion	mAP (%)	FP	TP	FN
Test	92,66	76	513	26
Validation	94,46	64	591	25

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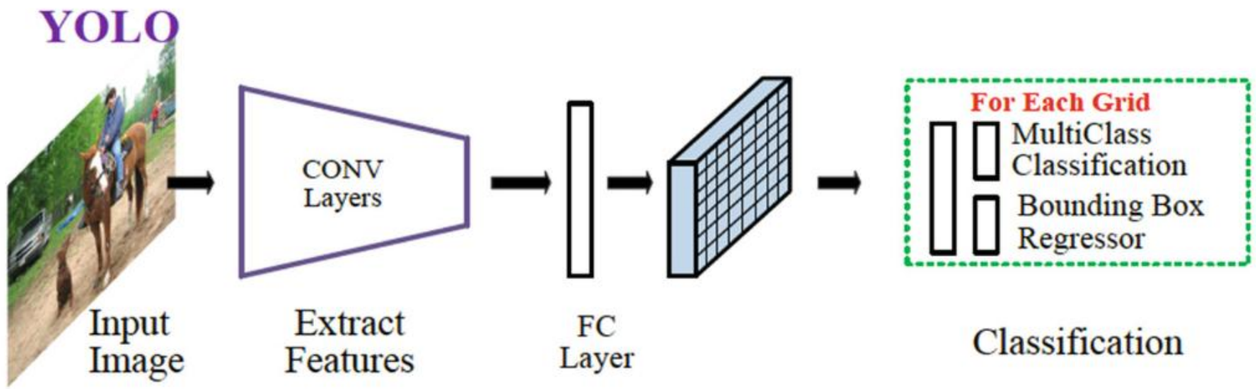
IMAGE PROCESSING: COPPER DETECTION MODELS

A model based on **YOLO architecture,** one-stage detector proposed by Redmon et al[1].

This approach is completely different from the previous one.



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[1] Redmon, J.; Divvala, S.; Girshick, R.; Farhadi, A., "You only look once: Unified, real-time object detection", In Proceedings of the IEEE conference on computer vision and pattern recognition, 2016.

[2]Rocha, Á., Adeli, H., Reis, L. P., & Costanzo, S. (Eds.). (2018). Trends and Advances in Information Systems and Technologies: Volume 1

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Image Processing: Copper Detection Models

Model based on YOLO11 architecture

Portion	mAP (%)	FP	TP	FN
Test	89,96	24	489	50
Validation	91,04	20	567	49

☒ Lower mAP and higher FN

☑ 7 times faster and Lower FP

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FUTURE WORK

Test the model on PRODUCTION LINE

Merge image processing with LIBS data

Synchronization of data

Development of ML model to merge all data and characterize scrap

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Thank you!

Sant'Anna
Scuola Universitaria Superiore Pisa

PURE SCRAP

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