ESTEP SPRING DISSEMINATION EVENT

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Eyes on Steel: AI-Powered Monitoring for Enhanced EAF Safety and Efficiency

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ESTEP

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Safety on the steelworks, with a focus on EAF

Most common causes of serious incidents in steel industry	
Moving machinery	
Falling objects	
Falling from height	
Asphyxiation or gassing	
Cranes	

- 85 casualties in Italy in 2024
- Probabiliti of incidents double compared to other sectors

Motivation

- A steel plant is a dangerous place for workers
- Several operations to mitigate risk
  - Training programmes
  - Maintenance
  - Protections

The next step: enhance hazard identification from manual to **automated**

AI can detect **early sign of incidents** through a continuous monitoring

The ISteelExpert project

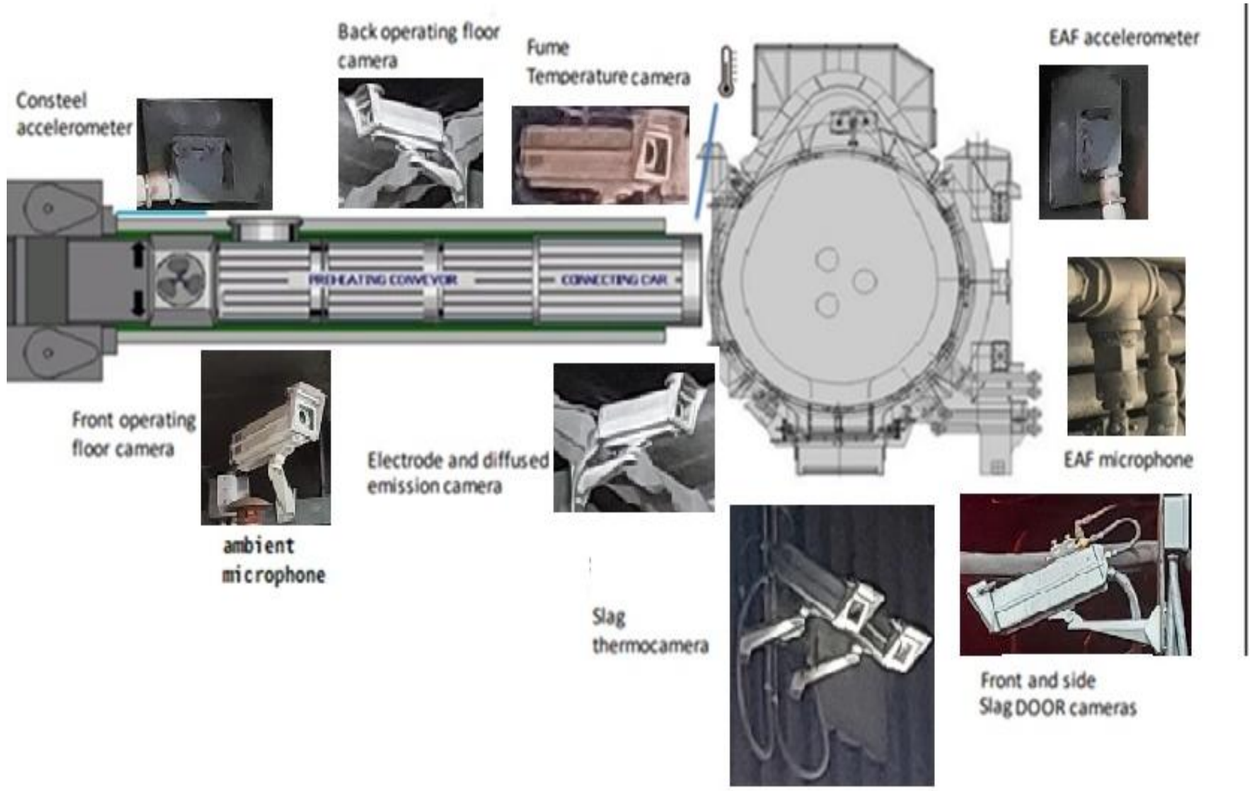
Motivation

- In the melting area of steelworks situation awareness is a key to ensure process reliability, health and safety at the workplace
- iSteel-Expert implements a remote expert virtual system that monitors 24/7 the progress of the process, analyses the information and suggests actions

EAF and safety

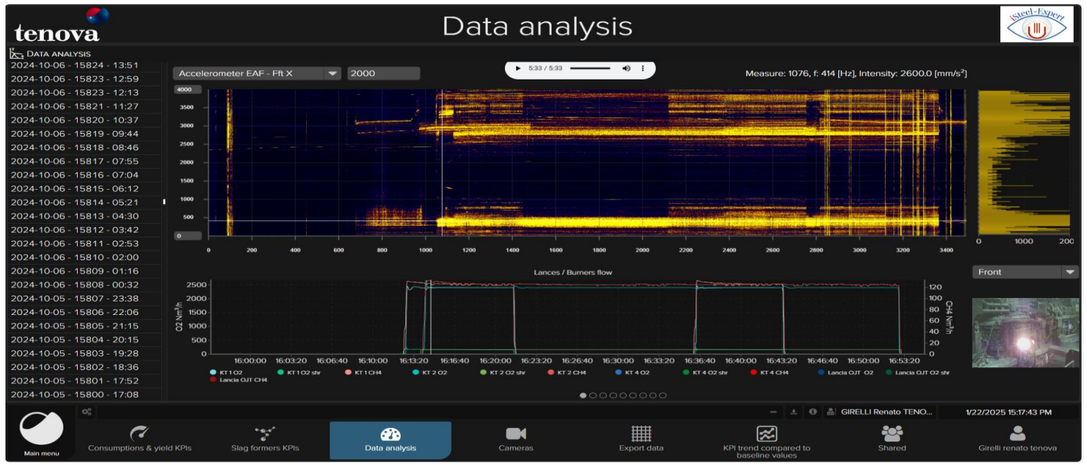
Hazards: temperatures, electric arcs, toxic gases, smoke…

The ISteelExpert project



An impressive infrastructure

- Cameras, microphones, accelerometers
- IT to collect all these data
- A dashboard for analysis, visualization and downloading of data



Event detection tasks

1. **Person Detection Around the EAF**: Identifies unauthorized or accidental human presence in hazardous zones, triggering immediate alarms
2. **Slag Door Status :** Monitors and classifies the slag door as open or closed, flagging unsafe or abnormal openings
3. **Clamp Detection for Electrode:** Detects the presence and movement of electrode clamps, identifying irregularities that may indicate maintenance needs
4. **Smoke Detection:** Detection of vapor, fumes, and dense smoke, alerting operators to abnormal emissions
5. **Furnace Tilt Detection:** Classifies the furnace as upright or tilted, enabling or disabling electrode monitoring accordingly.

Why is this work important?

- The use of CV algorithms to improve **safety** and increase **operational efficiency** in the steel industry has received **limited attention**
  - The steelworks harsh environment is not only dangerous, but also complicate!

- experiments with **numerous state-of-the-art object detectors** for a variety of object detection tasks for our datasets.
- significant contribution to the existing **body of knowledge** by assessing commercially available CV systems

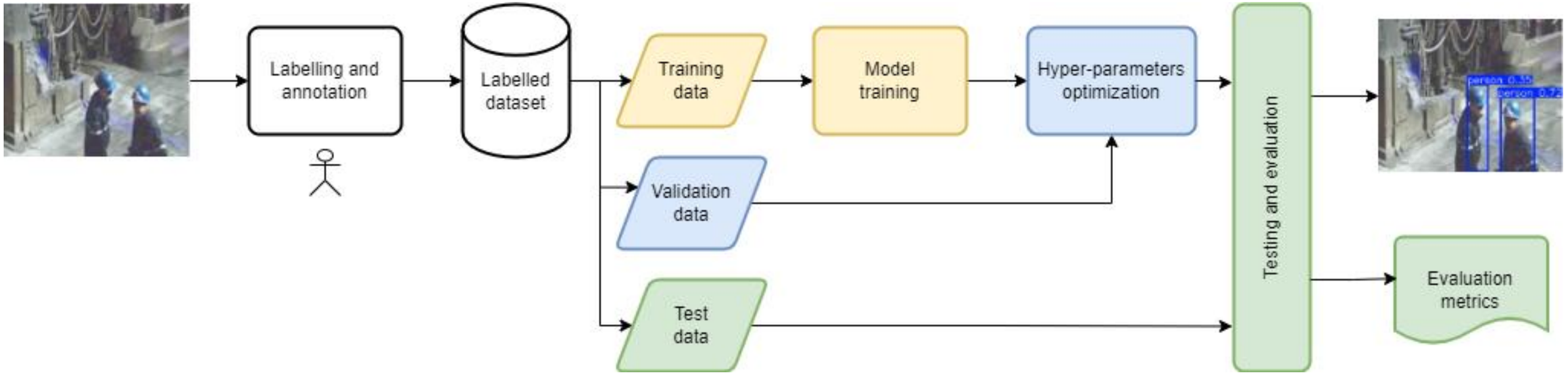
Tested models and dataset

Model families

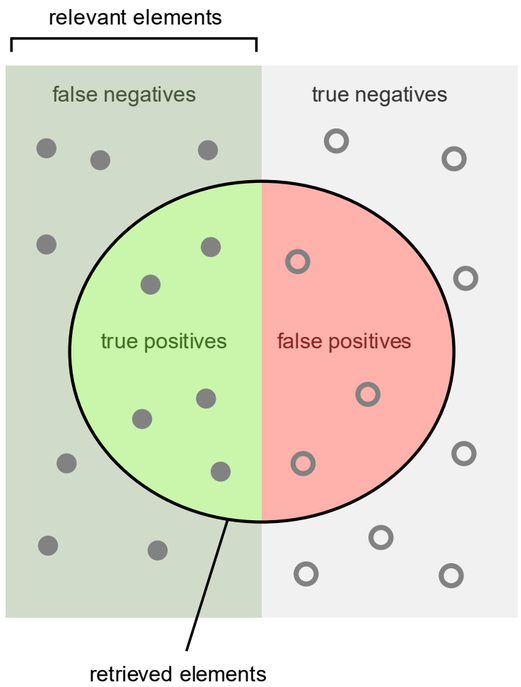
- **One-stage detectors**
  - first generate region proposals and then classify and refine them
  - *R-CNN, Fast R-CNN, Region Proposal Networks (RPN), Mask R-CNN, Cascade R-CNN*
- **Two-stages detectors**
  - perform object localization and classification in one step, enabling faster inference ideal for real-time applications
  - *Yolo 1-11, RetinaNet*

Task	Train Samples	Validation Samples	Test Samples
Clamp Detection	788	112	114
Furnace Tilted	686	146	150
Person Detection	2427	305	307
Slag Door Detection	992	211	213
Smoke Detection	429	91	94

Pipeline


Labelling and annotation
Labelled dataset
Training data
Model training
Hyper-parameters optimization
Validation data
Test data
Testing and evaluation
Evaluation metrics

Results – Metrics and inference time



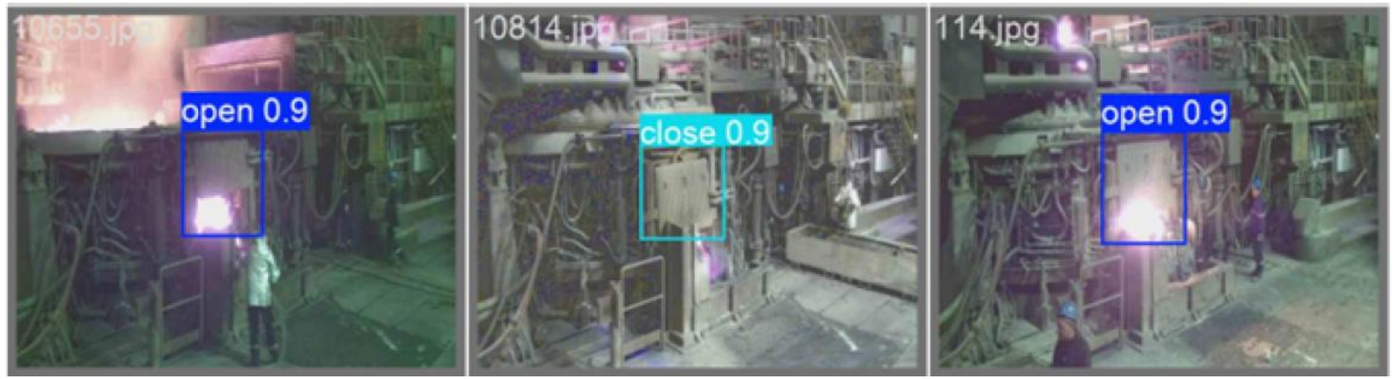
Detector Type	Model	Inference Time (seconds)
Two-stage	Cascade R-CNN	0.01656
	Faster R-CNN	0.0255
	Mask R-CNN	0.0124
Single-stage	YOLO11s	0.0050
	YOLO11m	0.0066
	YOLO11x	0.0128
	YOLOv10s	0.0061
	YOLOv10m	0.0072
	YOLOv10x	0.0120
	YOLOv9s	0.0098
	YOLOv9m	0.0081
	YOLOv9e	0.0155
	YOLOv8s	**0.0039**
	YOLOv8m	0.0060
	YOLOv8x	0.0147
	RetinaNet	0.0118
	RT-DETR-l	0.0222
	RT-DETR-x	0.0284

Results – Person detection

Detector Type	Model	Precision	Recall
Two-stage	Cascade R-CNN	0.4484	0.5418
	Faster R-CNN	0.4674	0.5578
	Mask R-CNN	0.3093	0.4387
Single-stage	YOLOv11s	0.9447	0.8848
	YOLOv11m	0.9397	0.8848
	YOLOv11x	0.9264	0.8940
	YOLOv10s	0.9403	0.8810
	YOLOv10m	0.9316	0.8362
	YOLOv10x	0.9645	0.8522
	YOLOv9s	**0.9375**	**0.8906**
	YOLOv9m	0.9428	0.8887
	YOLOv9e	0.9349	0.8714
	YOLOv8s	0.9031	0.8791
	YOLOv8m	0.9475	0.9005
	YOLOv8x	0.9427	0.8845
	RetinaNet	0.4909	0.5780
	RT-DETR-l	0.9411	0.9079
	RT-DETR-x	0.9175	0.9178

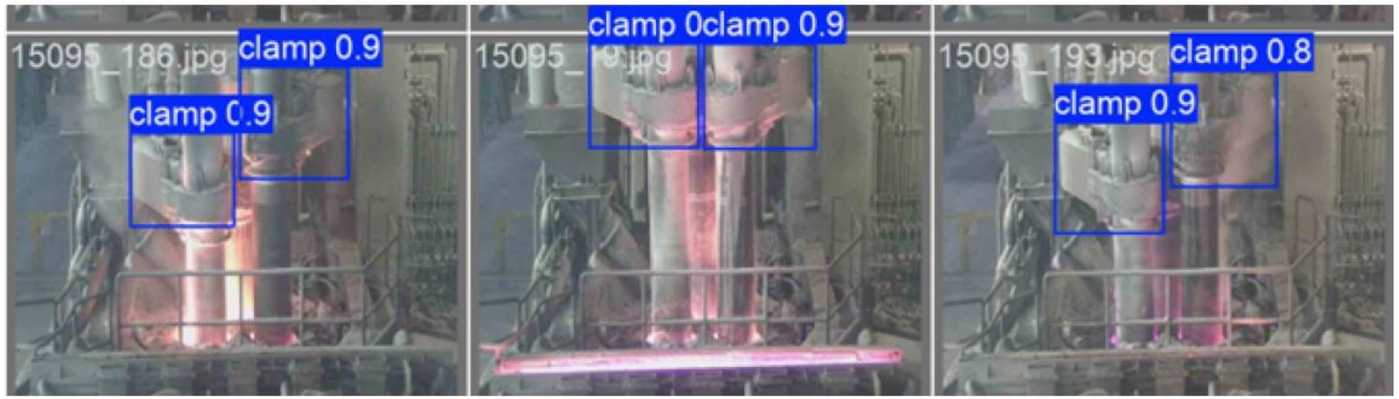
Results – Slag door status

Detector Type	Model	Precision	Recall
Two-stage	Cascade R-CNN	0.5607	0.6027
	Faster R-CNN	0.5865	0.6274
	Mask R-CNN	0.4666	0.5367
Single-stage	YOLOv11s	0.9985	0.9953
	YOLOv11m	0.9990	0.9953
	YOLOv11x	0.9990	0.9978
	YOLOv10s	0.9899	0.9973
	YOLOv10m	1.0000	0.9941
	YOLOv10x	0.9976	0.9833
	YOLOv9s	0.9990	0.9953
	YOLOv9m	0.9992	0.9937
	YOLOv9e	0.9960	0.9953
	YOLOv8s	**0.9982**	**0.9997**
	YOLOv8m	0.9961	0.9996
	YOLOv8x	0.9968	0.9953
	RetinaNet	0.7746	0.8204
	RT-DETR-l	0.9968	0.9997
	RT-DETR-x	0.9175	0.9190



Results – Clamp detection

Detector Type	Model	Precision	Recall
Two-stage	Cascade R-CNN	0.5607	0.6027
	Faster R-CNN	0.5865	0.6274
	Mask R-CNN	0.4666	0.5367
Single-stage	YOLOv11s	0.9997	1.0000
	YOLOv11m	1.0000	0.9857
	YOLOv11x	0.9991	0.9868
	YOLOv10s	1.0000	0.9922
	YOLOv10m	0.9308	0.8816
	YOLOv10x	0.9933	0.9803
	YOLOv9s	**0.9997**	**1.0000**
	YOLOv9m	0.9995	0.9803
	YOLOv9e	0.9934	0.9864
	YOLOv8s	0.9997	1.0000
	YOLOv8m	0.9966	0.9934
	YOLOv8x	0.9995	0.9868
	RetinaNet	0.5854	0.6396
	RT-DETR-l	0.9962	0.9868
	RT-DETR-x	0.9793	0.9868



Results – Smoke and furnace tilt

Using pre-trained networks? No sir, nothing is for free!

Detector Type	Model	Precision	Recall
Two-stage	Cascade R-CNN	0.4484	0.5418
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	YOLOv9s	**0.9375**	**0.8906**
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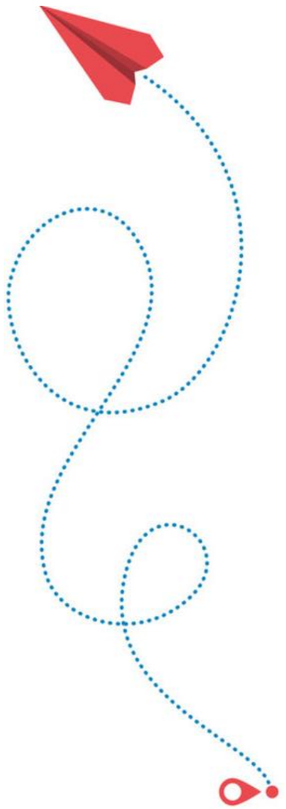
	YOLOv8s	0.9031	0.8791
	YOLOv8m	0.9475	0.9005
	YOLOv8x	0.9427	0.8845
	RetinaNet	0.4909	0.5780
	RT-DETR-l	0.9411	0.9079
	RT-DETR-x	0.9175	0.9178

Pre-trained

Model	Precision	Recall
YOLO11s	0.782447	0.501259
YOLO11m	0.860793	0.508816
YOLO11x	0.879238	0.516373
YOLOv10s	0.793482	0.511335
YOLOv10m	0.839958	0.498741
YOLOv10x	0.861850	0.565709
YOLOv9s	0.802217	0.521411
YOLOv9m	0.741112	0.523929
YOLOv9e	0.840371	0.602015
YOLOv8s	0.842354	0.528967
YOLOv8m	0.850136	0.586902
YOLOv8x	0.820129	0.594458
RT-DETR-l	0.886911	0.612397
RT-DETR-x	0.857422	0.659950

Wrapping it up, toward the future

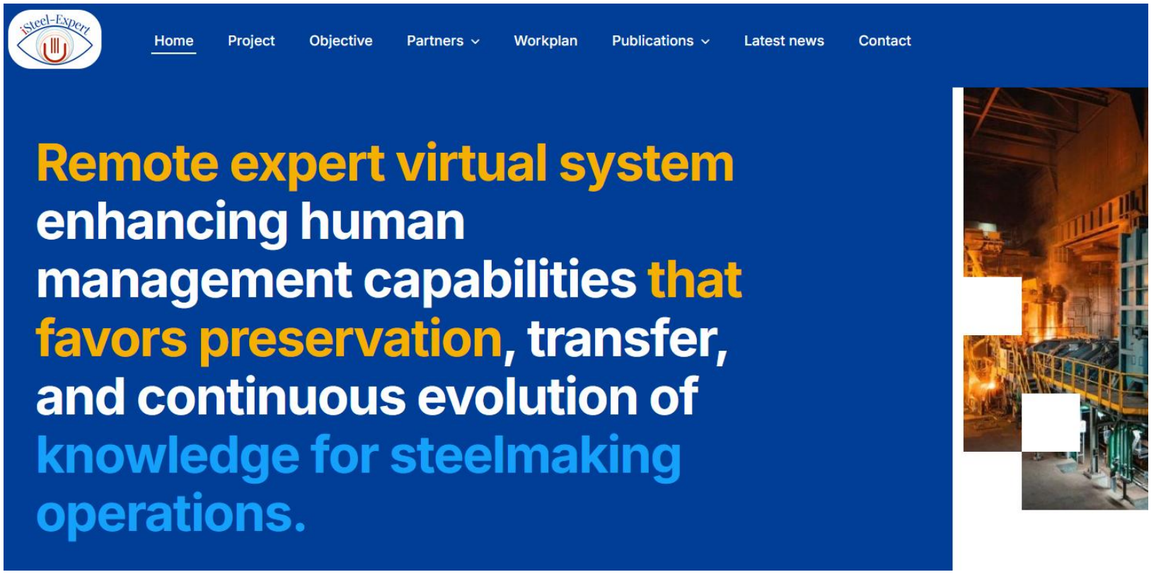


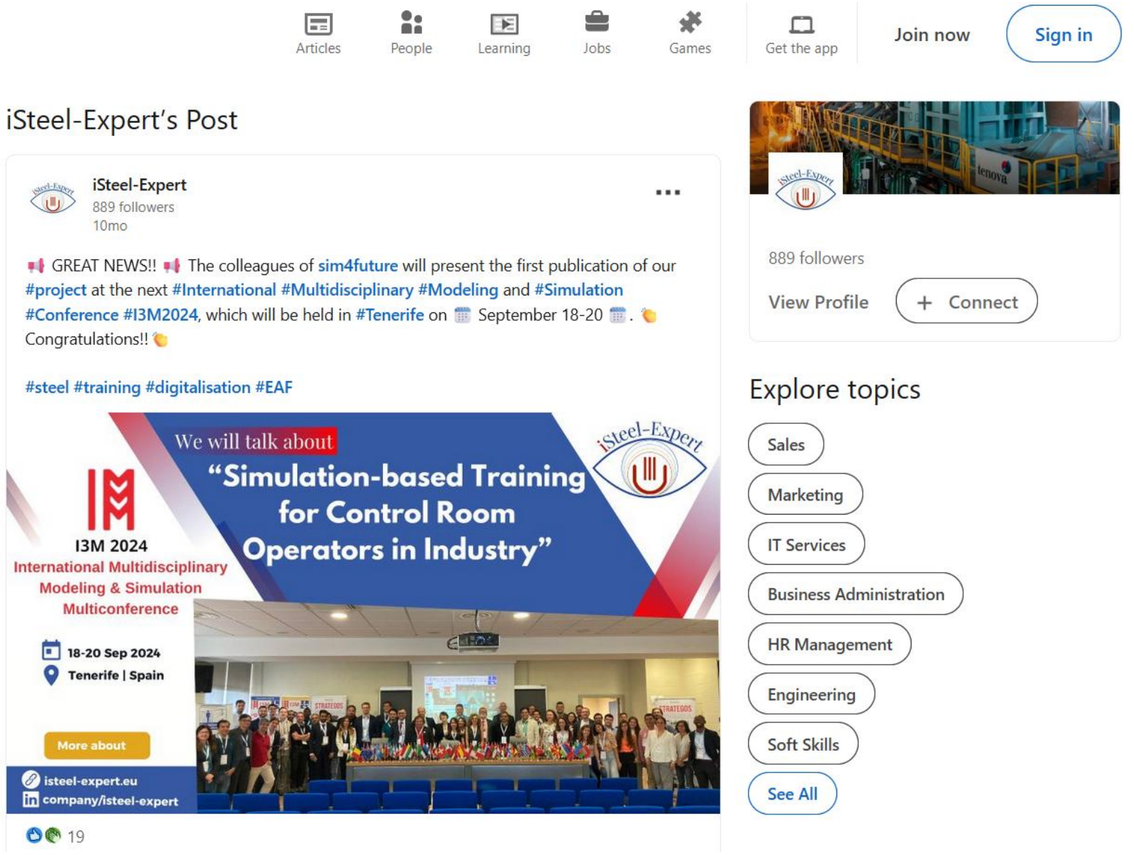
- YOLO family offers significant advantages for real time monitoring
- YOLO 9 is the best performing one in precision, recall and inference time
- pre-trained models are not convenient
- Inference time is satisfactory for real time deployment on the industrial context

- More fine tuning is possible
- Extendo to other (many) safety and efficiency related tasks

Get in touch with ISteelExpert!

https://www.isteel-expert.eu/





Thank you for your attention.

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