



SMART-PDM

A Smart Predictive Maintenance Approach based on Cyber Physical Systems

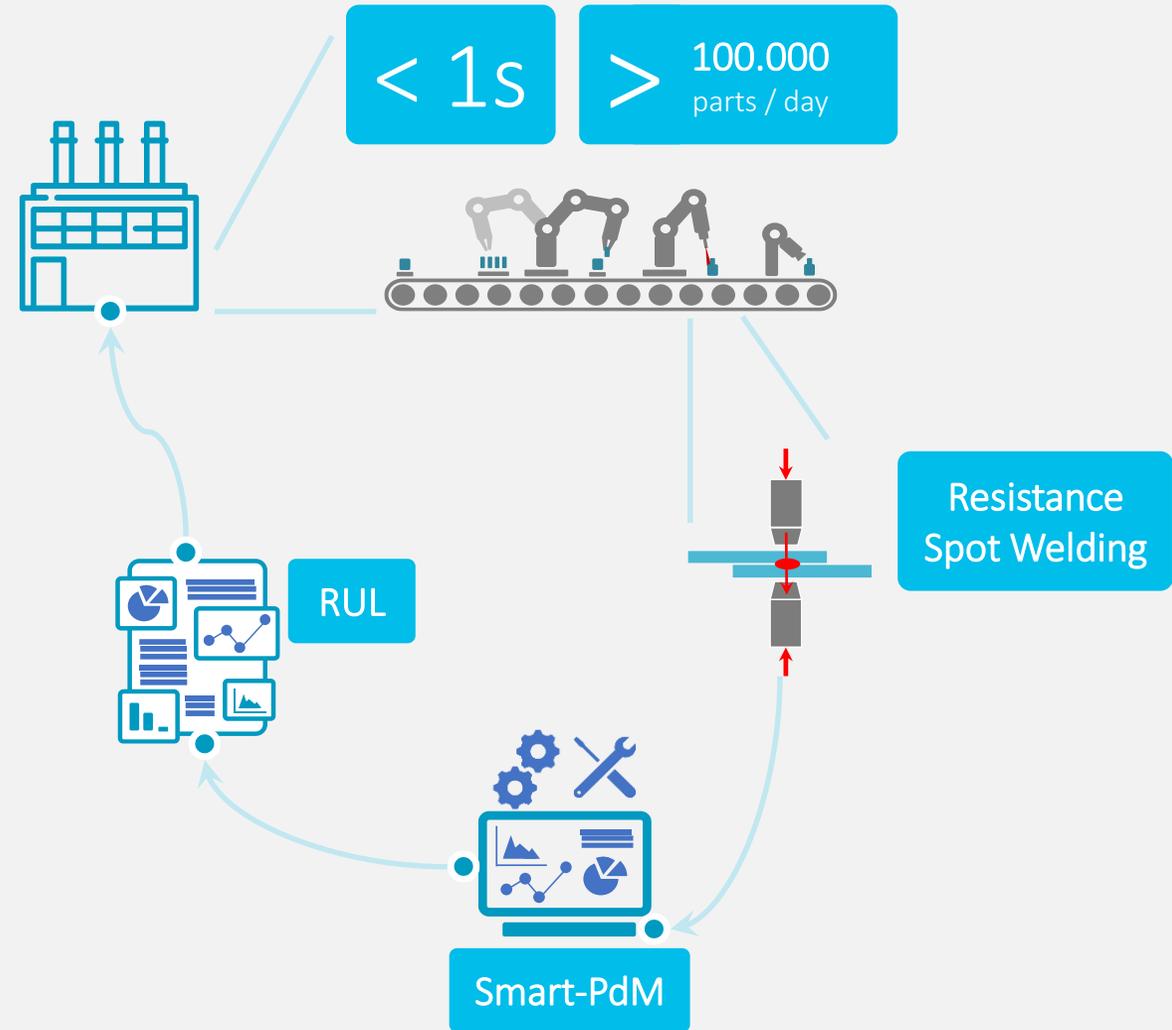
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Within the SMART-PDM Project MONDRAGON ASSEMBLY and LORTEK have worked together to develop tools for Condition Monitoring of resistance spot welding processes.

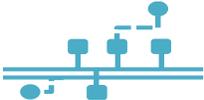
- ✓ Developed tools have been implemented in two industrial productive lines with resistance spot welding process.
- ✓ The aim: determine the current state of the electrode and to predict it's Remaining Useful Life (RUL).
- ✓ Currently, these tools are being tested and validated in close collaboration with process experts and operators of the productive line.





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Developed tools consist of:

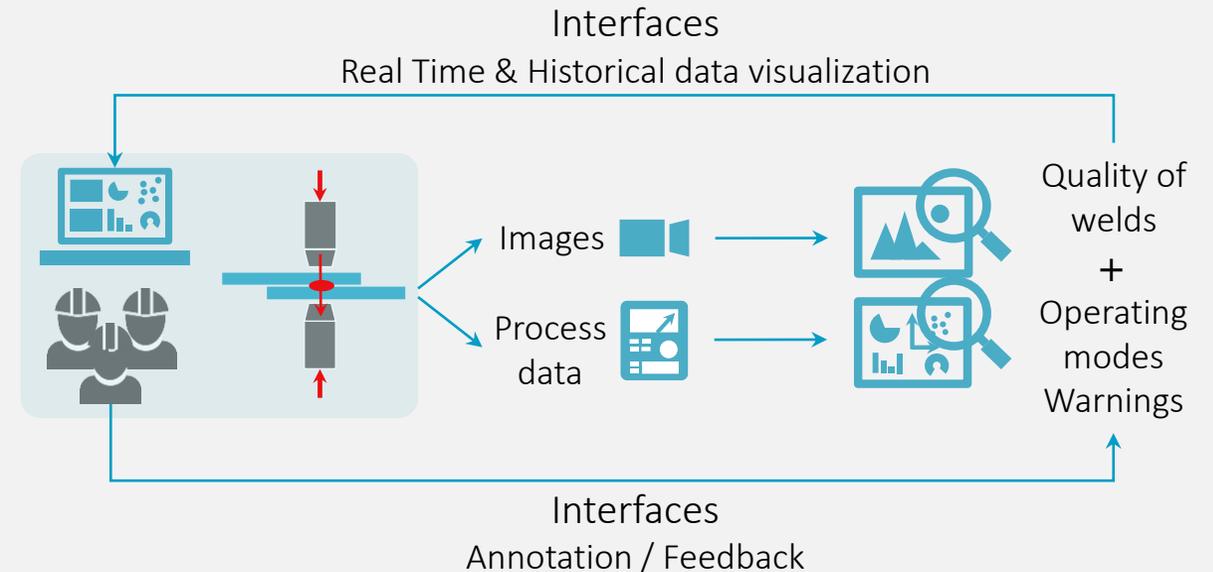
Architecture for Data Retrieval	Software RT Data & Image Analysis	Software Activate / Deactivate Services	Interfaces Data Visualization	Interfaces Feedback Capture
 <p>Close collaboration with providers to add new features to welding machines</p>	 <p>Unsupervised and Supervised methods (ML, DL)</p>	 <p>Web-based interface to check, activate / deactivate services</p>	 <p>Web-based interface RT & historical data visualization Warnings / Predictions</p>	 <p>Validate predictions Annotation of images for model re-training</p>



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Electrode degradation is a progressive process that depends on process parameters and that can be indirectly measured from images of welded regions

- ✓ Image analysis is used to determine the **quality of the Weld**.
- ✓ Process data is used to identify **current operating mode**.
- ✓ **Image & Data analysis software is run in real time** and **results** (predictions and warnings) are **shown in the interfaces** displayed in screens placed nearby the welding station in the productive line
- ✓ **Feedback** from operators and process experts is captured to **adjust Image & Data analysis models**.



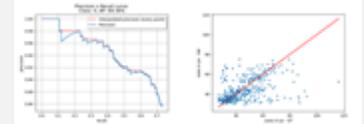


Data and Image analysis:

- ✓ Supervised Deep Learning methods to identify regions in images models for weld Quality detection. Precise but requires large amounts of annotated images.
- ✓ Unsupervised methods to predict the evolution of the Quality of the welds. An alternative way based on CAE and clustering methods that allow dealing with large amounts of images.
- ✓ Unsupervised methods for data analysis to identify operating modes. Classification models are used to determine the operating mode of new welding cycles.

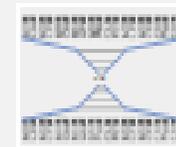
Identify crucial regions in welded regions associated with the Quality of the weld

CNN



Determine the evolution of the Quality of the welds using unsupervised methods

CAE

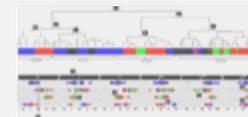


Clustering



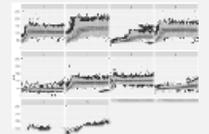
Determine operating modes and intervals of correct functioning

Fuzzy-rules



Clustering

K-NN





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Interfaces:

- ✓ Visualization of Real Time process data, Quality values obtained from image analysis, warnings
- ✓ Visualization of historical data
- ✓ Statistical tools to compare two welding cycles of process data
- ✓ Image annotation tools

Real Time & Historical data visualization



Statistics to compare welding cycles



Annotation of images (model re-training)

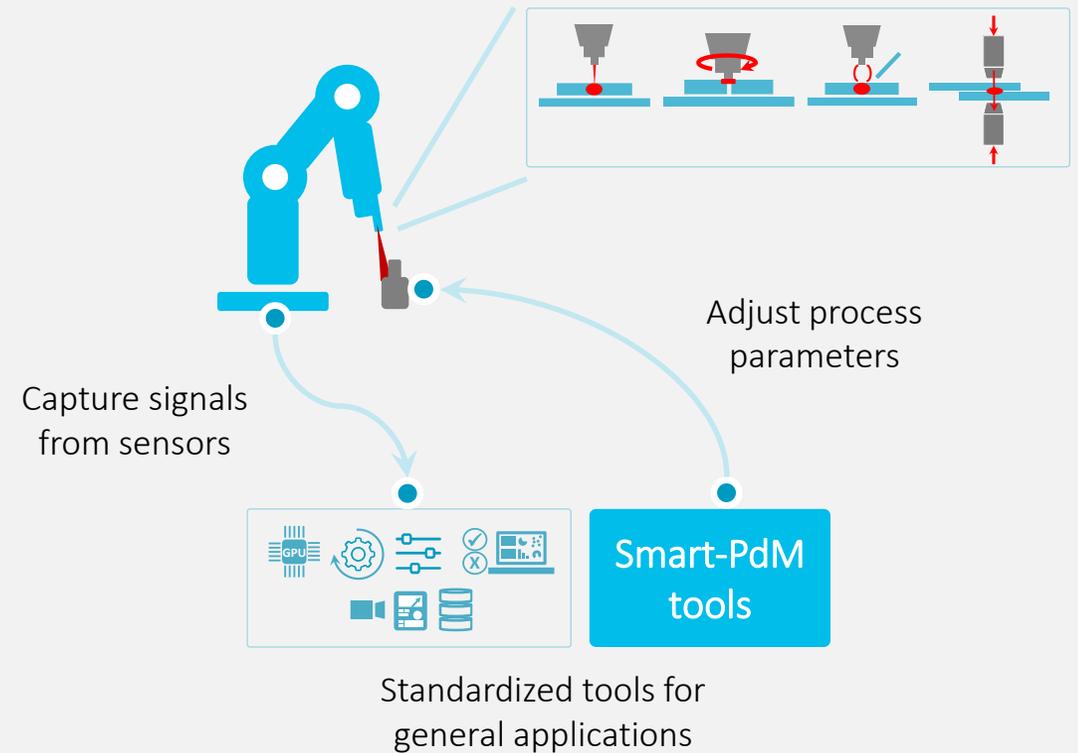


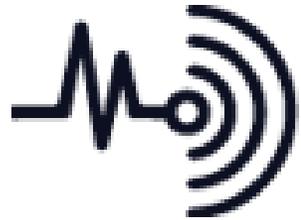


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Future working lines:

- ✓ Currently industrial implementations are being tested and standardized.
- ✓ The objective is to pack all developed tools into modules that can be easily implemented in other similar applications.
- ✓ **Towards automatization:** new features will be added to current tools in order to automate electrode change based on predictions from developed analysis software. This will be done in close collaboration with operators to ensure its correct functioning.





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