Intelligent Co-robots for Complex Welding Manufacturing through Learning and Generalization of Welders Capabilities

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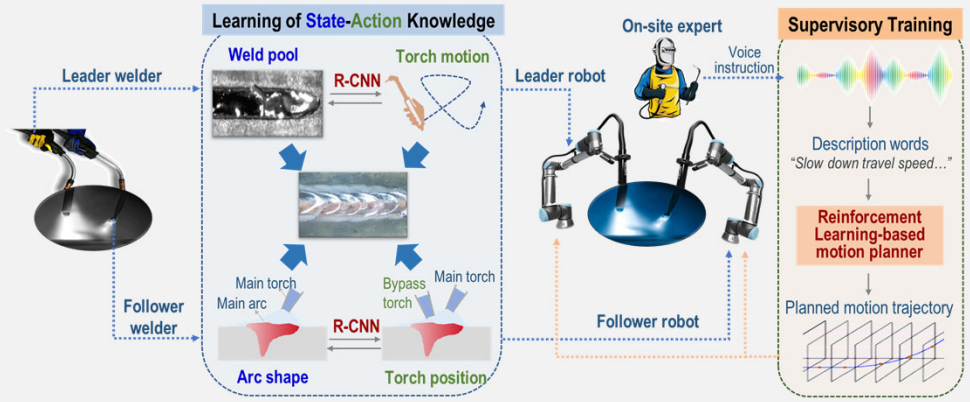
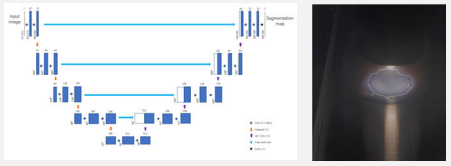
Objective

- Formulate a systematic solution for advancing robotic capabilities on **acquiring domain-specific knowledge**, **interactive learning**, and **adaptive decision making**, for robotic automation of complex welding processes that can only be handled by human in the past.

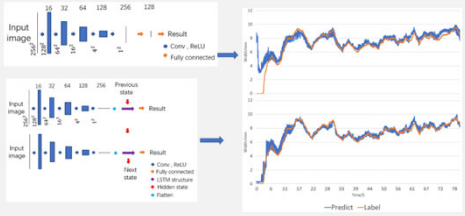


Tracking Welder's Inputs



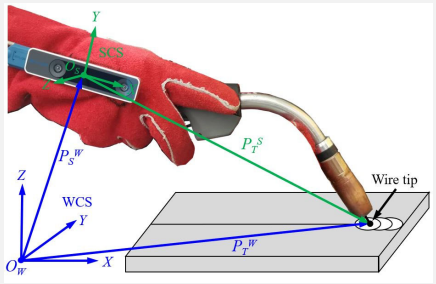
- Welder observation: focuses on pool area;
- Automated segmentation of weld pool from observation;
- Labeling the weld pool boundary: time consuming
- U-net: small data set

Model Welder's Intelligence



- Welder intelligence: estimates weld quality/penetration;
- Based on current weld pool: poor
- Based on serial weld pool: good
- Welder intelligence: based on dynamic serial weld pools

Tracking Welder Operation

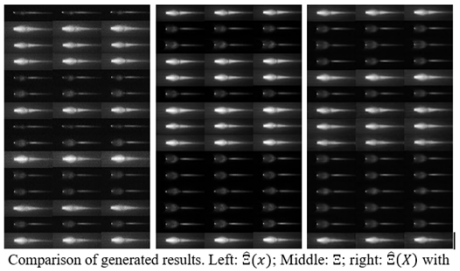


- Using technology developed in a previous industry funded project
- Intel RealSense T265: IMUs with cameras
- Movement in 3D

Robotic Tracking to Image

- Robot carries a camera to image the welding process as the torch is operated by welder;
- One Intel RealSense T265 on the glove and one on the robot; sensors are synchronized to command the robot to move;
- New robot UR 10e just installed and adaptively controlled by computer;
- Still on going to complete the tracking ability;
- An experimental system has been established to conduct the complex process and allow monitoring the human operation and welding process

What Observation Reflects?



Comparison of generated results. Left: $\hat{\Xi}(x)$; Middle: Ξ; right: $\hat{\Xi}(X)$ with $n = 8$

- The phenomena welder observed is determined by the dynamic process evaluation, not just current state;
- Dynamic time tested: 8/60 second
- Images are generated from the state(s).

Intel. Merit & Broader Impact

PhD Students: Rui Yu (EE), Yue Cao (EE), Joseph Kershaw (ME), Edison Muellari (MA).
Collaborator: Professor Qiang YE (MA), Univ. of Kentucky
Major Publications:

Edison Muellari, Rui Yu, Yue Cao, Qiang Ye, YuMing Zhang 2023. "Do We Need a New Foundation to Use Deep Learning to Monitor Weld Penetration?" in review for IEEE Robotics and Automation Letters

Rui Yu, Joseph Kershaw, Peng Wang, YuMing Zhang, 2022. "How to accurately monitor the weld penetration from dynamic weld pool serial images using CNN-LSTM deep learning model?," IEEE Robotics and Automation Letters

Peng Wang, Joseph Kershaw, Matthew Russell, Jianjing Zhang, YuMing Zhang, Robert X. Gao, 2022. "Data-driven process characterization and adaptive control in robotic arc welding," CIRP Annals Manufacturing Technology.

Rui Yu, Joseph Kershaw, Peng Wang, YuMing Zhang, 2021. Real-Time Recognition of Arc Weld Pool Using Image Segmentation Network. Journal of Manufacturing Processes.

Joseph Kershaw, Rui Yu, YuMing Zhang, and Peng Wang, 2021. Hybrid Machine Learning-Enabled Adaptive Welding Speed Control. Journal of Manufacturing Processes.

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