Closing the Loop
Machine Learning based Quality Prediction for Laser Welding

Summary

Problem statement
- Complex Systems cannot be modeled reliably
- No feedback signal for closed loop control available
- Time and work intensive setup for open loop

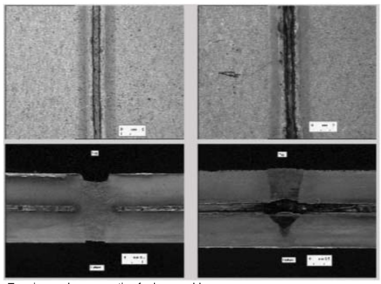
Suggested Solution
- Use Machine Learning to create feedback signal
- Let system learn without human supervision or assistance

Result
- Self-learning and self-improving system
- Transferable approach for open loop systems

Industrial Laser Welding

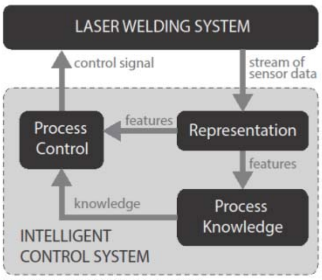
Laser welding in overlap position

- Complex process that is impossible to model
- 2 ms real time requirement
- Highly individual, due to set up
- High noise, due to plasma evaporations
- Variance due to changing environmental or material conditions
- Conclusion: Closed loop control required
- BUT: No feedback available



Top view and cross section for laser welds

An Intelligent Architecture, through Representation, Prediction and Control

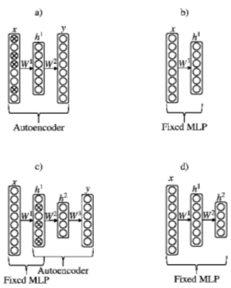


Intelligent Laser Welding Architecture [3, 4]

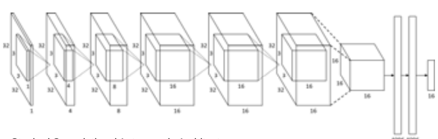
- Creating a closed loop control setting via Machine Learning
- Sensor data consists of camera data and 3 photodiodes
- Inspired by human problem solving, including essential human skills
- Deep Learning for extracting invariant information about the process
- General Value Functions to make (temporal extended) quality Predictions
- Policy Gradient Reinforcement Learning for self-adapting control
- Easily transferable to other processes

Deep Learning for Feature Extraction

- Neural Network based feature extraction
- Inspired by visual cortex
- Combining features to higher level of abstraction
- Extraction of low dimensional, robust features
- Convolutional approach, as seen in cats eyes
- Yields invariant feature extraction
- Autoencoder can learn without human assistance



Deep learning training procedure

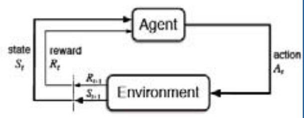


Stacked Convolutional Autoencode Architecture

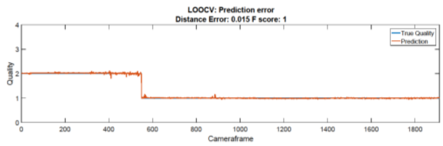
- Encoding architecture
- 10 layers
- 6 convolutions
- 1 max pooling
- 2 fully connected

Reinforcement Learning for Quality Prediction

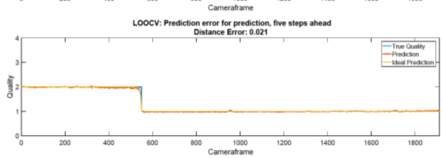
- Algorithm learns from interaction with environment
- Human independent learning
- Can be used for prediction or control
- Learns and predicts relation between state and laser welding quality



The Reinforcement Learning setting [2]



Quality prediction for unknown laser weld



Temporally extended predictions

Quality predictions by the Nexting Algorithm [2]

Special Thanks to

- Our industry partners: Precitec GmbH & Co KG, IREPA LASER, Illkirch, France
- Prof. Richard Sutton and Prof. Patrick Pilarski, University of Edmonton, Canada
- The Alberta Machine Intelligence Institute
- The European funding program Eurostars and the Federal Ministry of Education and Research – Germany

Literature

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2. J. Modayil, A. White, and R. S. Sutton, "Multi-timescale nexting in a reinforcement learning robot," Adaptive Behavior, vol. 22, no. 2, pp. 146–160, 2014
3. J. Günther, P. Pilarski, G. Helfrich, H. Shen, and K. Diepold, "First steps towards an intelligent laser welding architecture using deep neural networks and reinforcement learning," in Proceedings of the International Conference on System-Integrated Intelligence: Challenges for Product and Production Engineering, pp. 474–483, Jul 2014.
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