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Deep Reinforcement Learning-Based Control in Industrial Settings

Lleida-Tech

Agrobiotech Park, Gardeny Hill

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NURIA NIEVAS VIÑALS
Industrial PhD Candidate
AI & BD Researcher
Applied Artificial Intelligence unit
Eurecat, Centre Tecnològic de Catalunya
nuria.nievas@eurecat.org

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Introduction

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Static environments

- Stability predictability
- Limited complexity
- Traditional control

Dynamic environments

- Technological advancements
- Increased data availability
- Market demands
- Dynamic control

✓ Benefits of dynamic control in industry

+ Adaptability

+ Efficiency

+ Performance

! Slower adoption in traditional industries

× Integration complexity

× Safety and reliability

× Costs

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Press Hardening Objectives

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Hot Metal Forming –

Press Hardening (Hot Stamping)

- Thermo-mechanical sheet deformation-based process
- Complex shapes and high strength
- Automotive industry

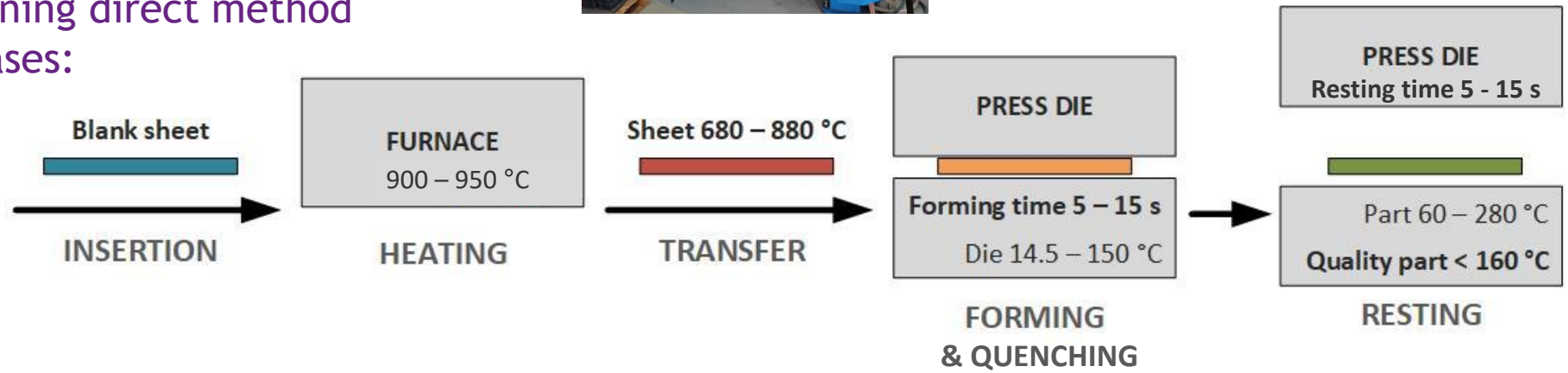
Control parameters

- Forming time: for each cycle
- Resting time: for each cycle

Objective of dynamic control

- Improve operational efficiency: Optimize the total time of a batch production
- Guarantee quality: parts <160ºC

Press hardening direct method process phases:



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Reinforcement Learning Control

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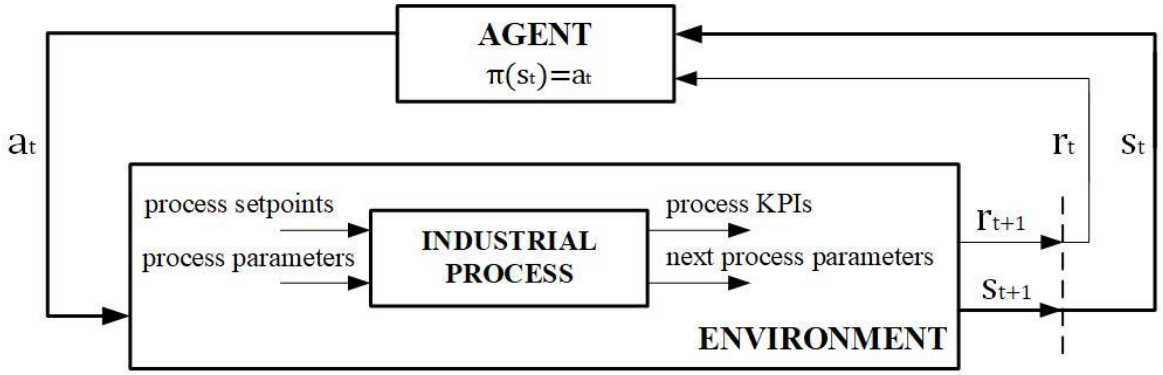
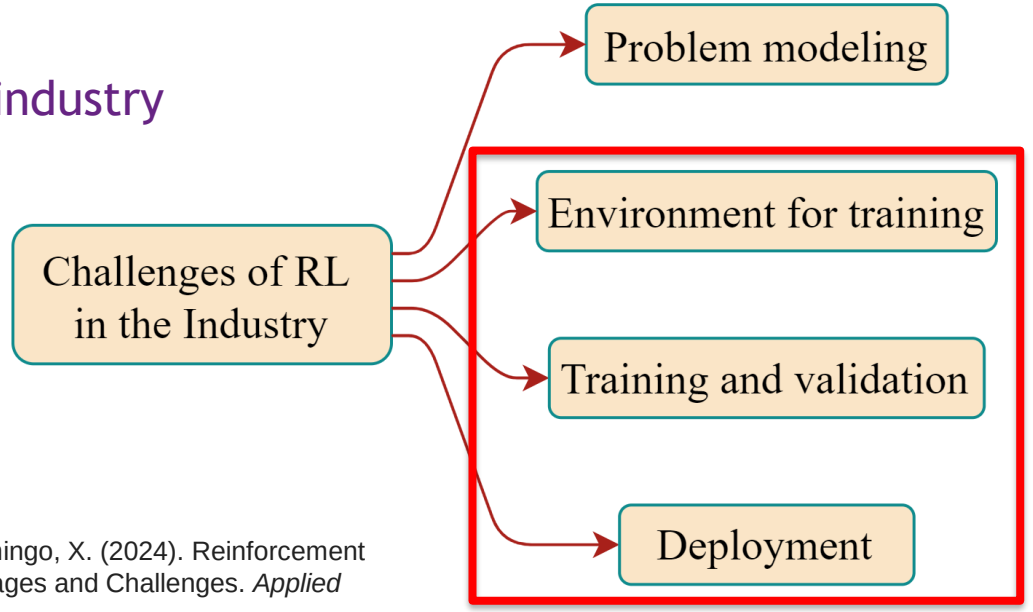
What is Reinforcement Learning?



- Continuous control
- Autonomous learning
- Long-term decision making
- Handle uncertainty

Challenges of Reinforcement Learning in the industry

- Slow training
- Exploration limited
- Safety constraints
- Cost of failures and non-optimal actions



Nievas, N., Pagès-Bernaus, A., Bonada, F., Echeverria, L., & Domingo, X. (2024). Reinforcement Learning for Autonomous Process Control in Industry 4.0: Advantages and Challenges. *Applied Artificial Intelligence*, *38*(1), 2383101.

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Surrogate Model-Driven RL Training

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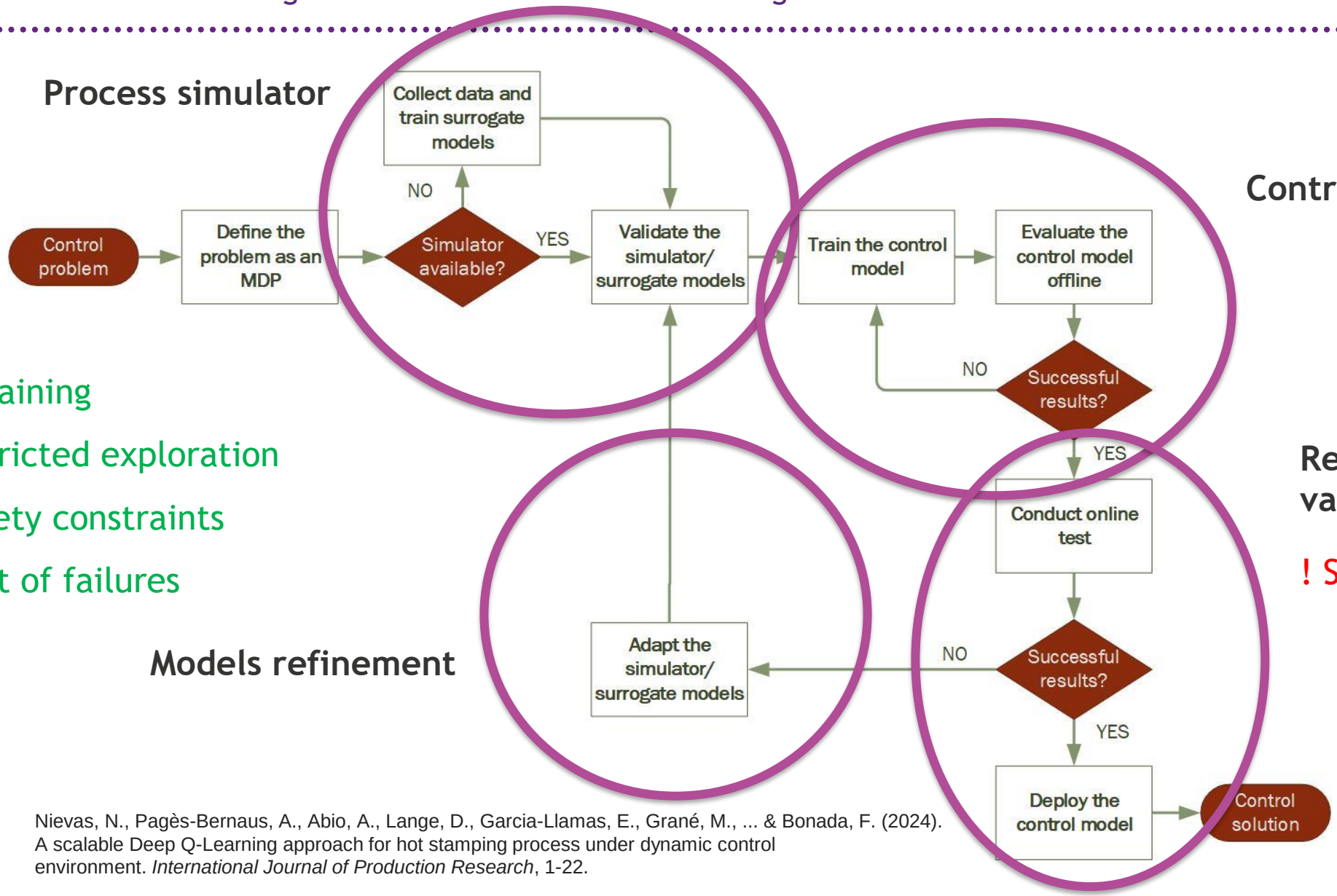

- ✓ Fast training
- ✓ Unrestricted exploration
- ✓ No safety constraints
- ✓ No cost of failures

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Nievas, N., Pagès-Bernaus, A., Abio, A., Lange, D., Garcia-Llamas, E., Grané, M., ... & Bonada, F. (2024). A scalable Deep Q-Learning approach for hot stamping process under dynamic control environment. *International Journal of Production Research*, 1-22.

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Static vs. Dynamic Control

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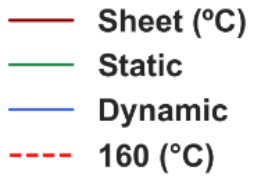
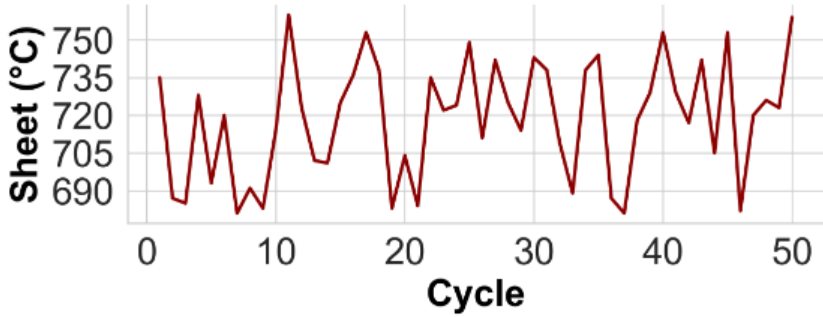
Results of training with a surrogate model of the hot stamping process

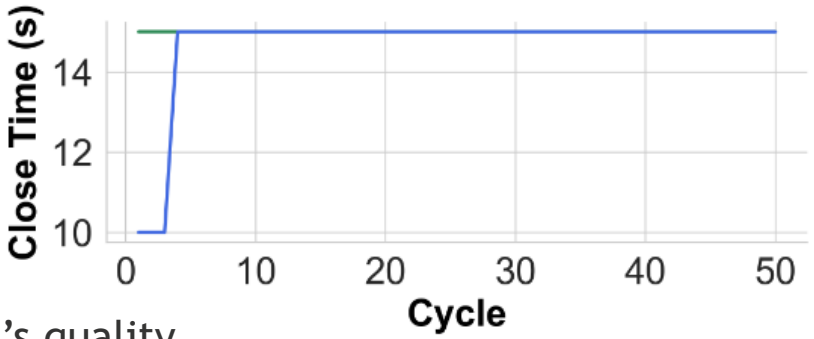
- Dynamics of the environment

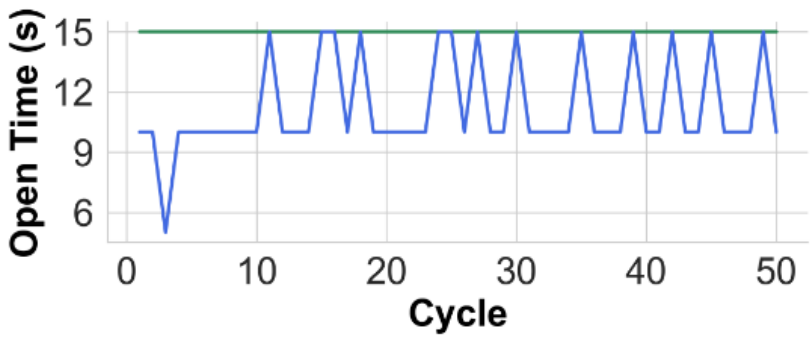
  Production of a batch of 50 parts comparing static versus dynamic approach





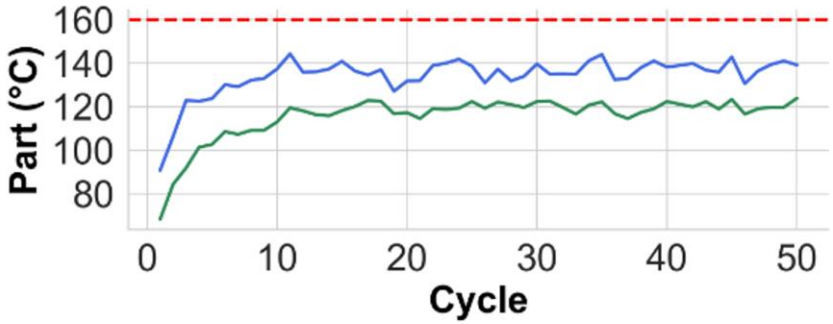
- Controlled variables: forming and resting times





The dynamic approach reduces times

- Final part's quality



The dynamic approach maintains quality

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Thank you!

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