



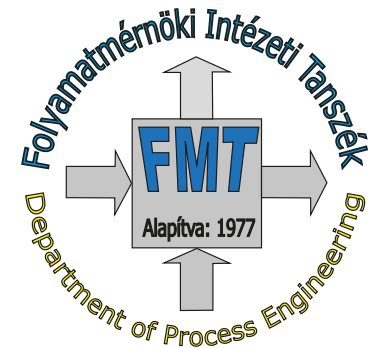
Self-learning Agents in Process and Systems Engineering

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Data-Centric Systems Engineering

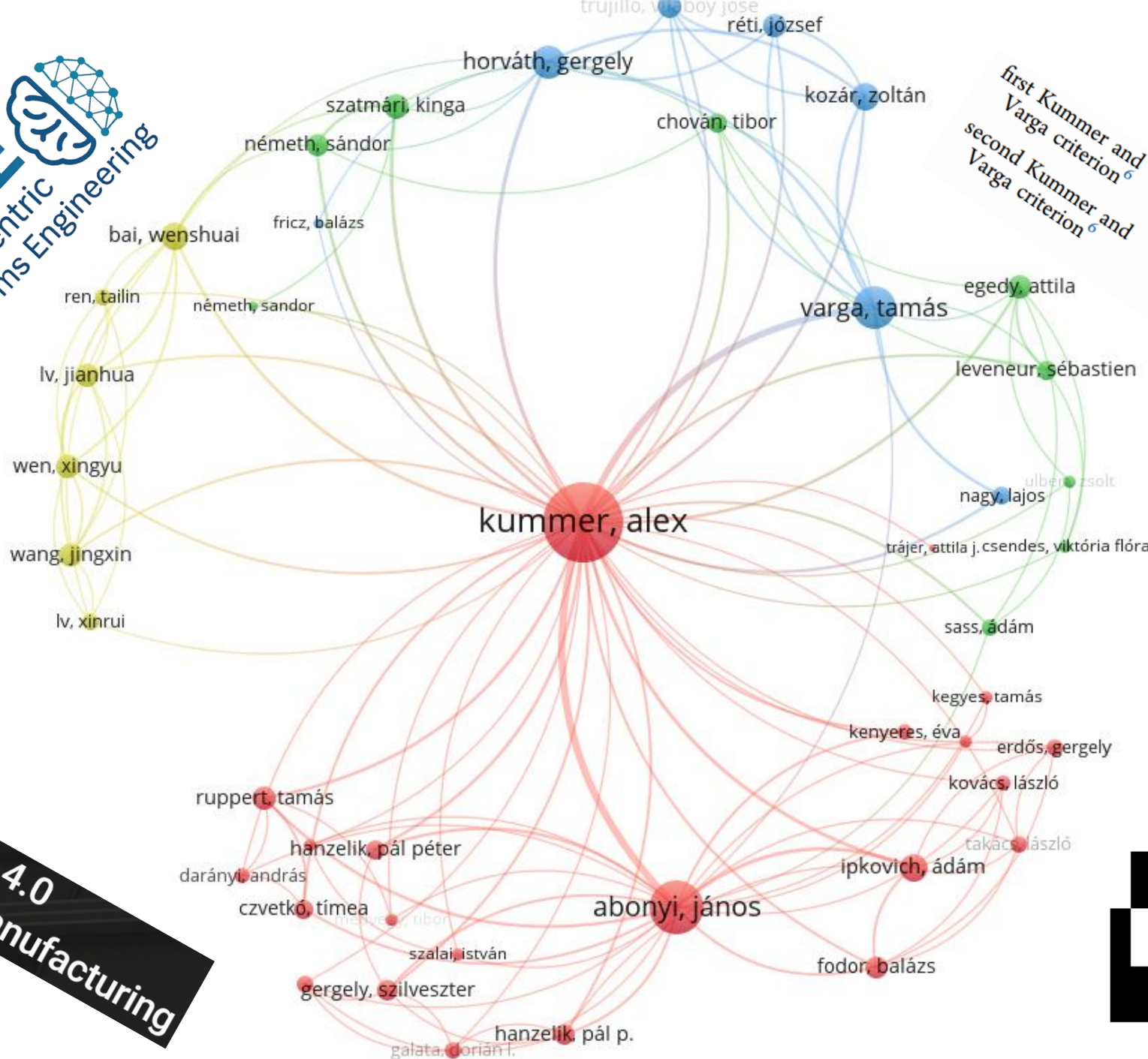
<https://www.datacentricse.com/>



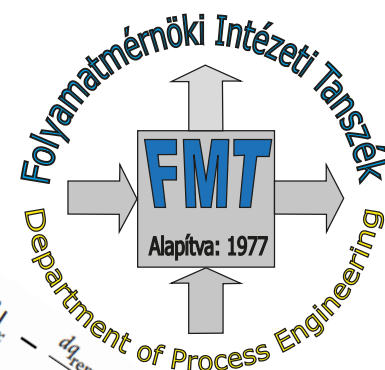
PANNON EGYETEM



Who am I ?



first Kummer and Varga criterion⁶
second Kummer and Varga criterion⁶



$$\frac{\partial q_{gen}}{\partial r} \Big|_x - \frac{dq_{rem}}{dr} \left(1 + \frac{q_{gen}}{q_{rem}} \right) = 0$$
$$\frac{\partial q_{gen}}{\partial r} \Big|_x + \frac{\partial E(x, r)}{\partial x} \Big|_r - \frac{q_{gen}}{q_{rem}} \frac{dq_{rem}}{dr} = 0$$

Operator 4.0
Human-Centered Manufacturing



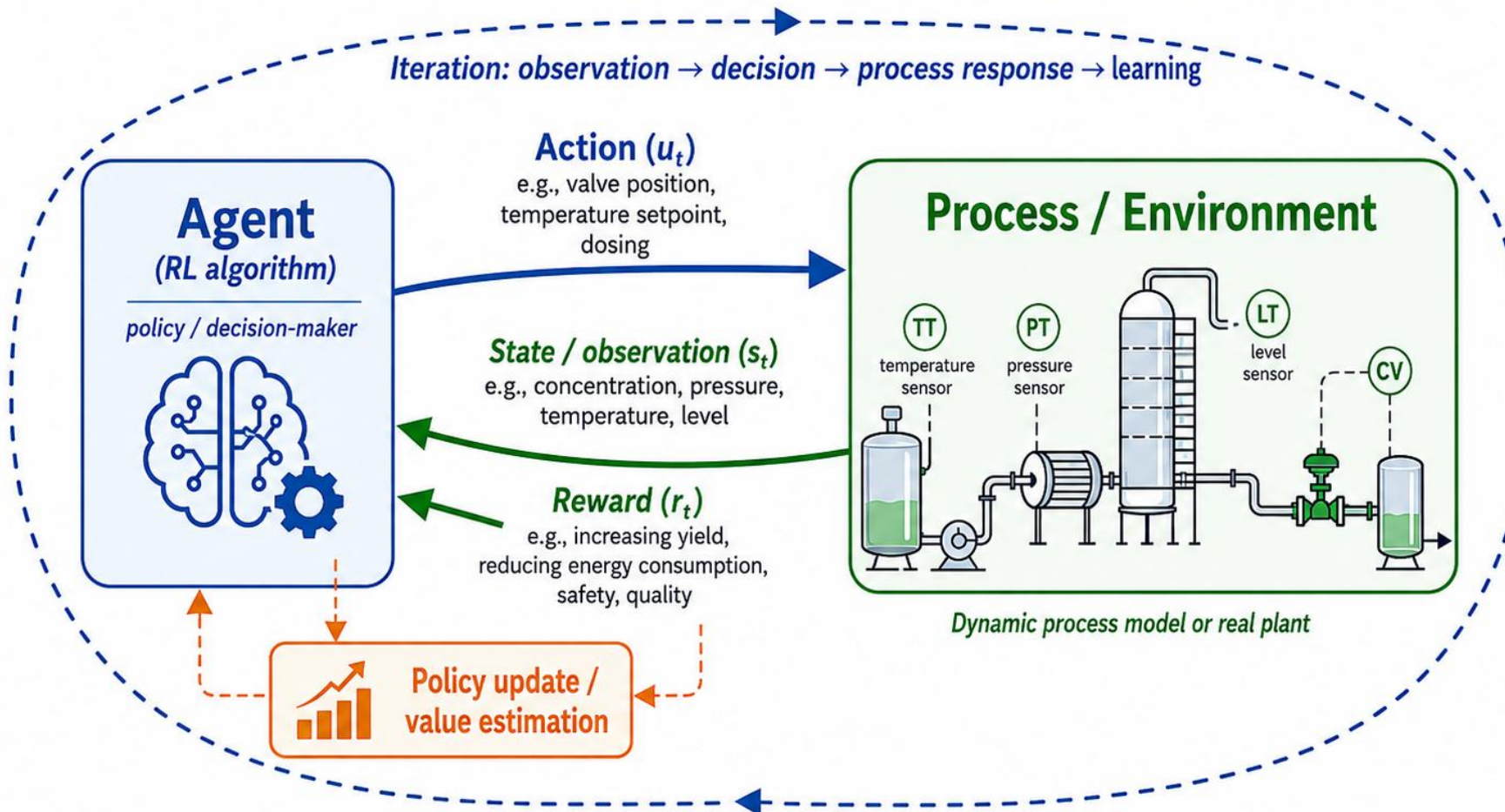
What is AI-enhanced Process and Systems Engineering?



 Higher efficiency	 Safer operation	 Lower cost	 Lower emissions	 Better decisions
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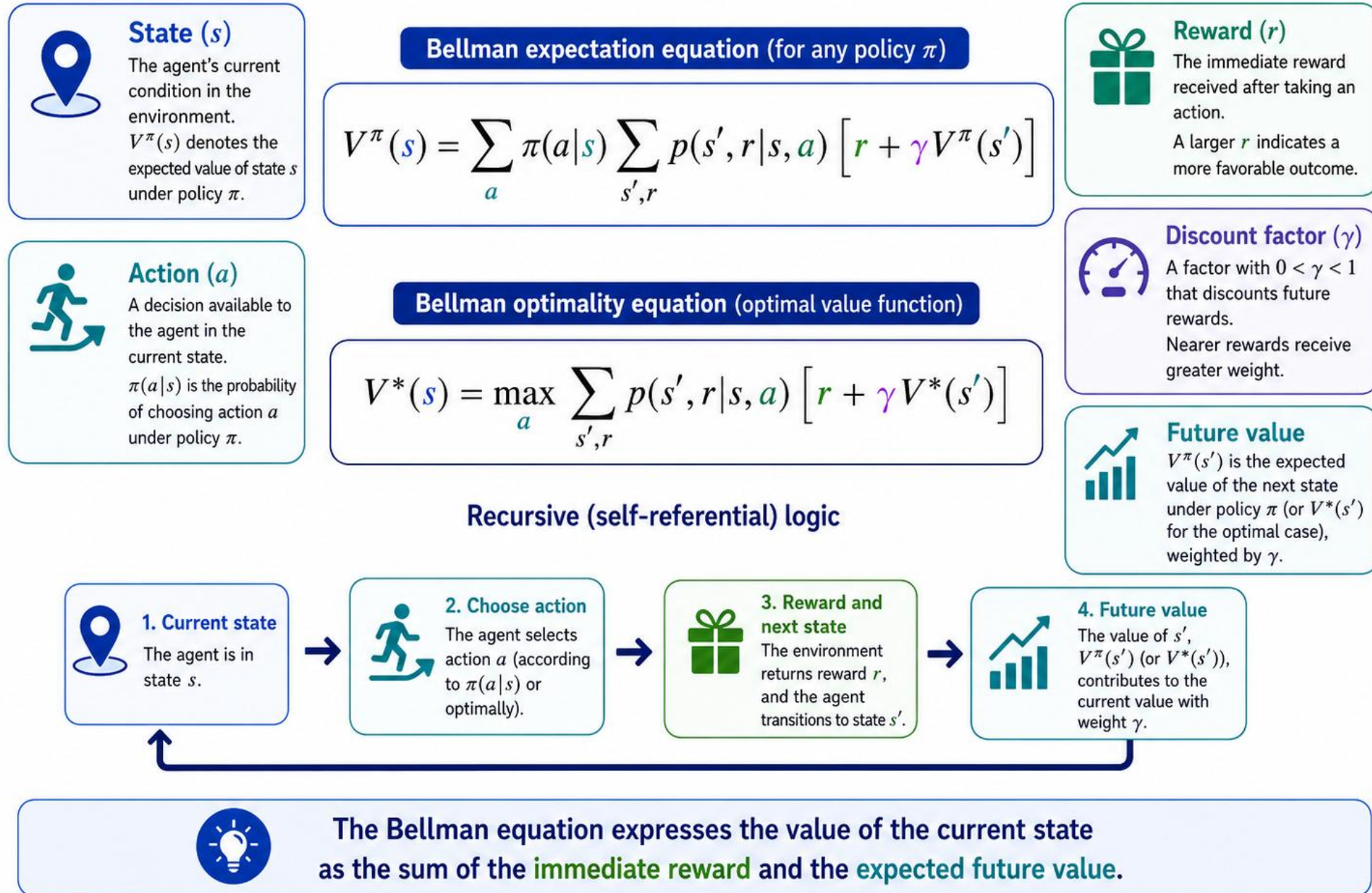
One of my favourites..... self-learning agents

Feedback-based learning cycle between agent and process

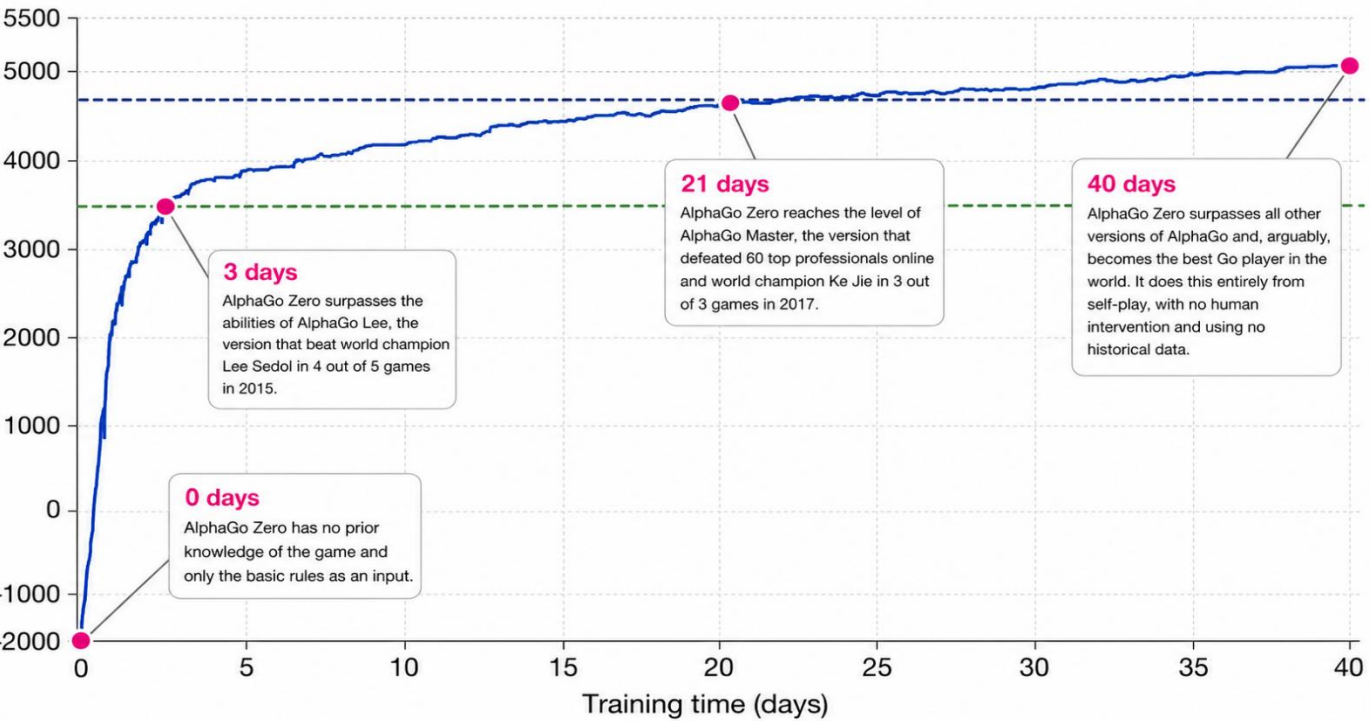


-  **1. Control**
Stable operation, disturbance handling, setpoint tracking.
-  **2. Optimization**
Optimization of yield, energy efficiency, and quality.
-  **3. Scheduling / operational support**
Production scheduling, resource allocation, decision support.

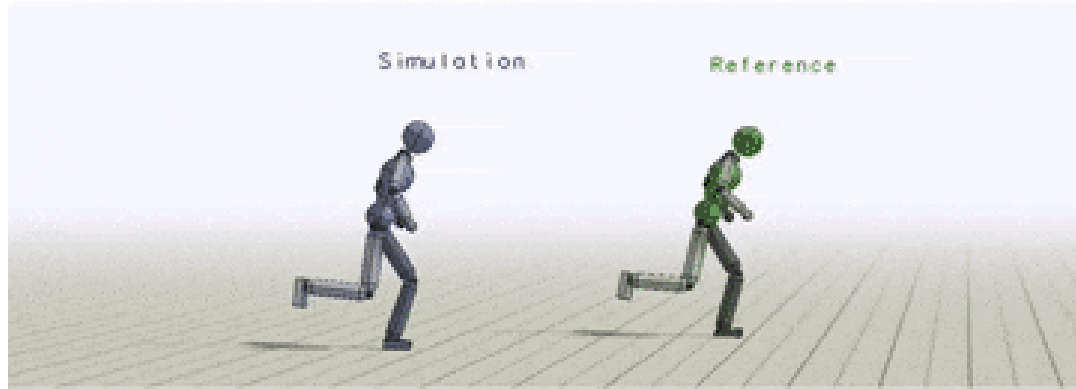
The famous Bellman Equation...



RL Agents have always been at home in games and robotics, but have much more potential in engineering fields



Humanoid: Run



Policy trained to imitate a running clip.

I believe in self- and co-learning systems...

REINFORCEMENT LEARNING AGENT OPTIMIZING CHEMICAL PROCESS CONTROL SAFE • EFFICIENT • ADAPTIVE

REINFORCEMENT LEARNING LOOP

STATE
Process Variables
Sensor Readings
Operating Conditions
Equipment Status

AGENT
RL Policy (Neural Network)

ACTION
Control Signals
Setpoints
Valve Positions
Feed Rates

REWARD
+ Efficiency
+ Product Quality
+ Safety
- Energy / Cost
- Emissions

ACTION EXAMPLES

- Adjust Reactor Temperature +2.5 °C
- Increase Feed Rate +5.0 %
- Open Valve LCV-101 +12 %
- Reflux Ratio -3.0 %

EXPECTED REWARD

+18.7
Reward Signal (Performance)

LEARNING PROGRESS

Cumulative Reward
Policy Performance

Episodes: 0, 2K, 4K, 6K, 8K, 10K

R-101 STATUS

- ONLINE
- TEMPERATURE: 78.6 °C
- PRESSURE: 2.45 bar
- LEVEL: 62 %
- FLOW: 12.4 m³/h
- SAFETY: ALL SYSTEMS NOMINAL

PROCESS OVERVIEW

R-101 REACTOR

TC-301: 78.6 °C
E-201: 2.45 bar
Tc-101: 62 %
Flow: 12.4 m³/h

PLANT PERFORMANCE: OPTIMAL

Let's increase feed rate gradually and monitor the response.

Agreed. Simulating impact... Increasing feed rate by 5%.

ALARMS

0 ACTIVE

CONSTRAINTS

- TEMPERATURE LIMIT: 2
- PRESSURE LIMIT: 0
- SAFETY INTERLOCKS: 0

KEY TRENDS

Temperature (°C)
Pressure (bar)
Level (%)
Flow (m³/h)

MANUFACTURING KPI

- YIELD: 96.1 %
- ENERGY: -12.3 %
- EMISSIONS: -8.6 % vs. Target

CONTROL RECOMMENDATION

- Increase Feed Rate by +5.0 %
- Predicted Outcome:
 - Higher Yield
 - Lower Energy Use
 - Within Safety Limits

HUMAN + AI STRONGER TOGETHER

HIGHER YIELD

Maximize Product Output

LOWER ENERGY

Optimize Utilities & Costs

SAFE OPERATION

Respect Constraints & Protect Equipment

LOWER EMISSIONS

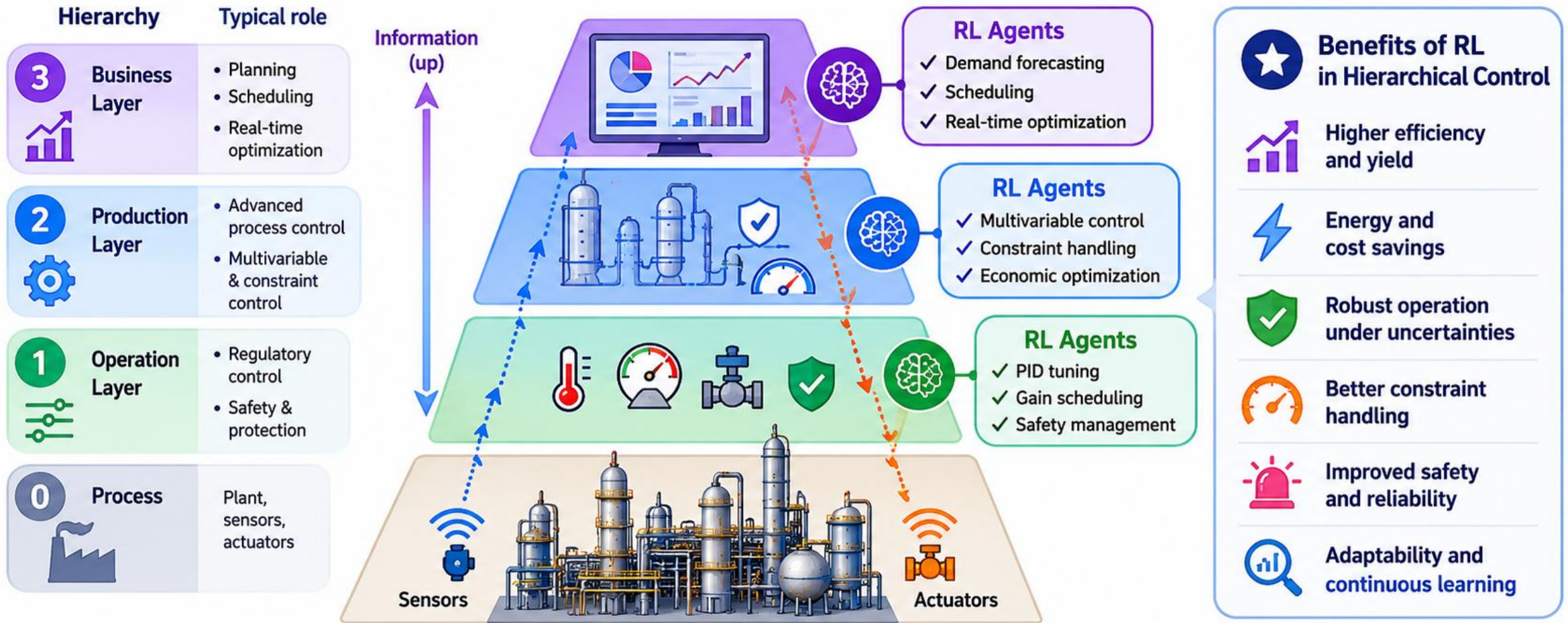
Reduce Environmental Impact

INTELLIGENT CONTROL

CONTINUOUSLY LEARNING.
CONTINUOUSLY IMPROVING.



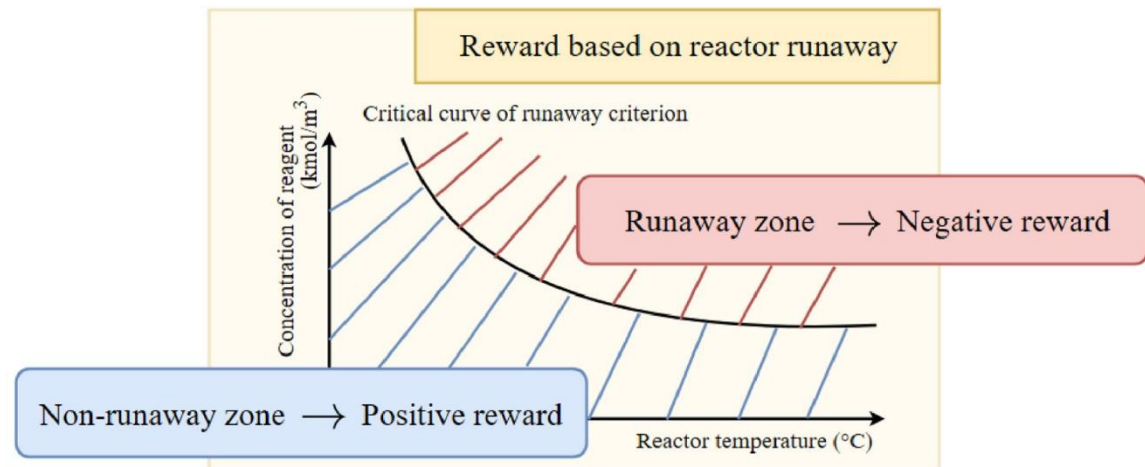
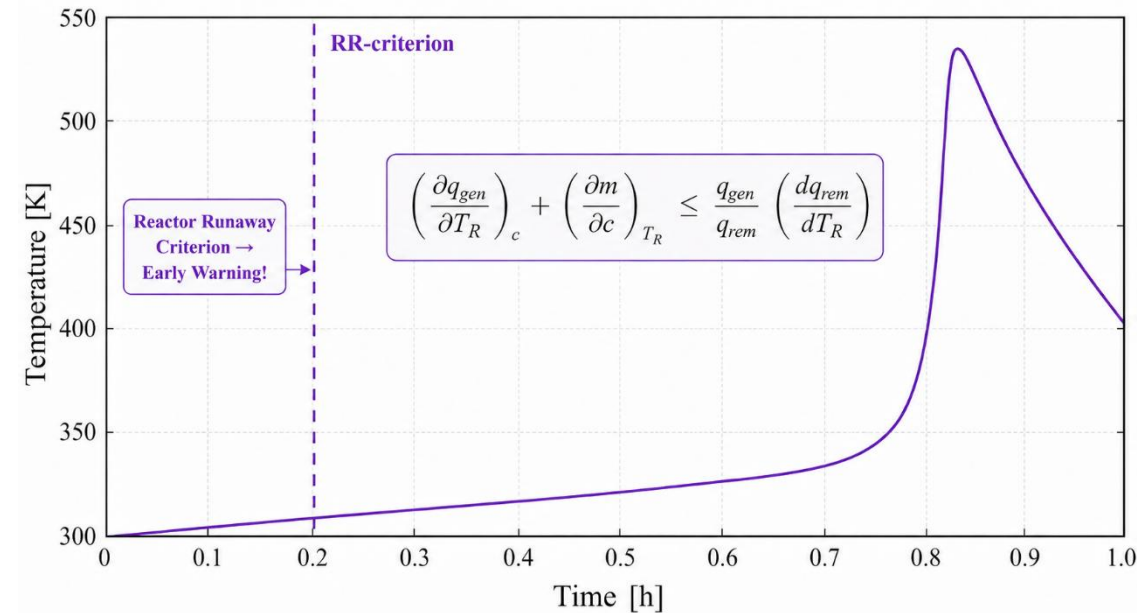
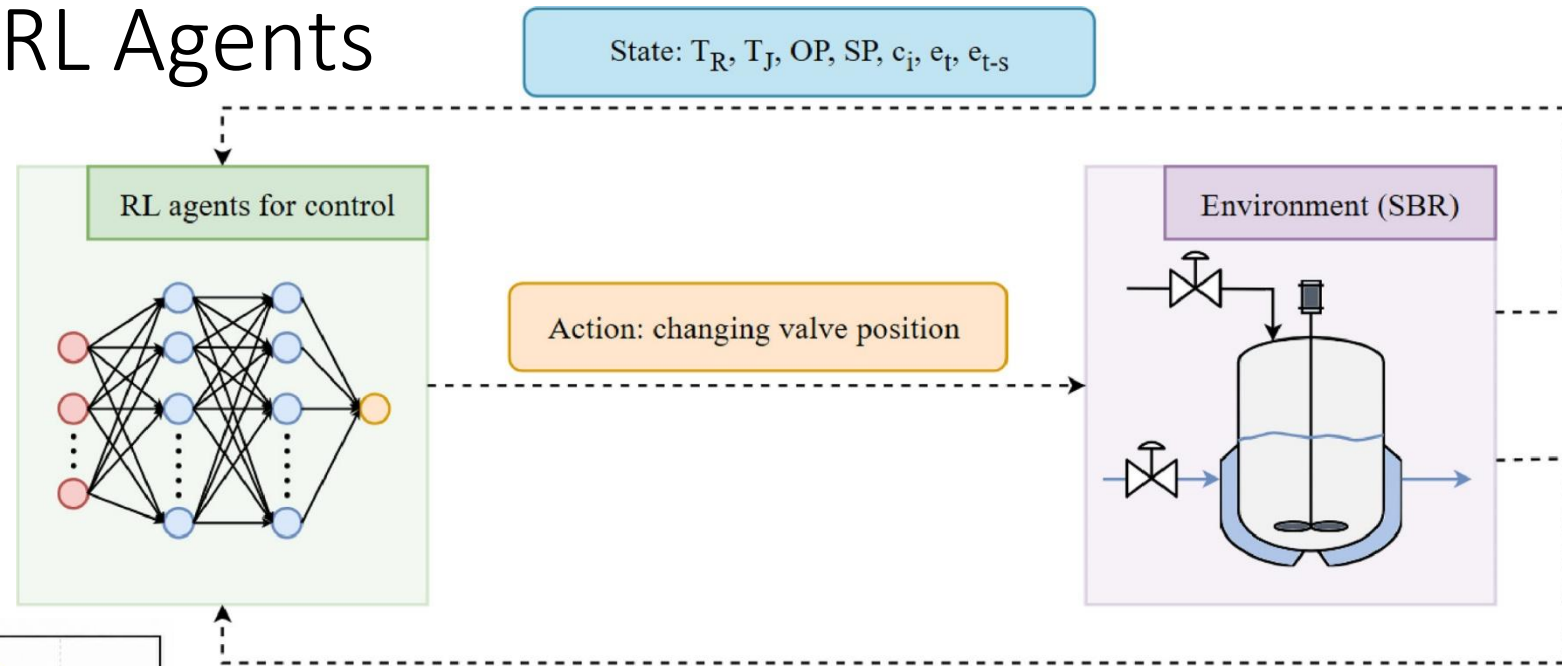
RL Agents in Hierarchical Chemical Process Control



RL agents can be placed at every level of the hierarchy, bringing **intelligence, adaptability, and performance** to chemical process control.

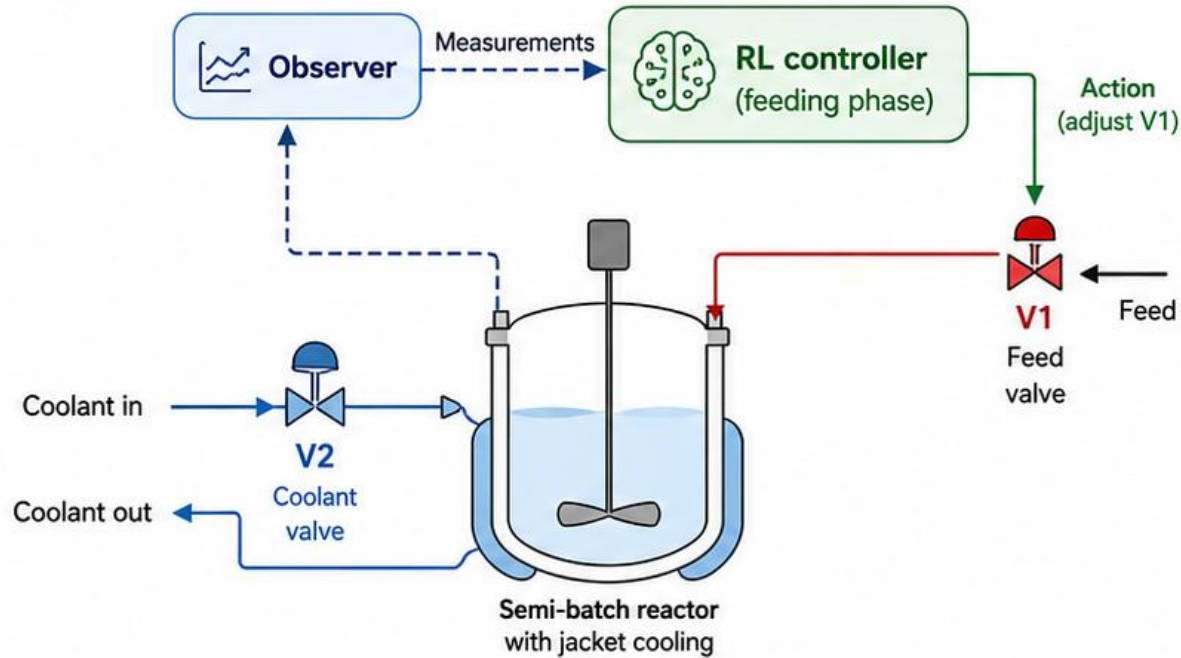
Reactor Runaway aware RL Agents

RR → Sudden temperature increase
 How to detect RRs? → RR Criteria



The RL Agent as a Process Controller

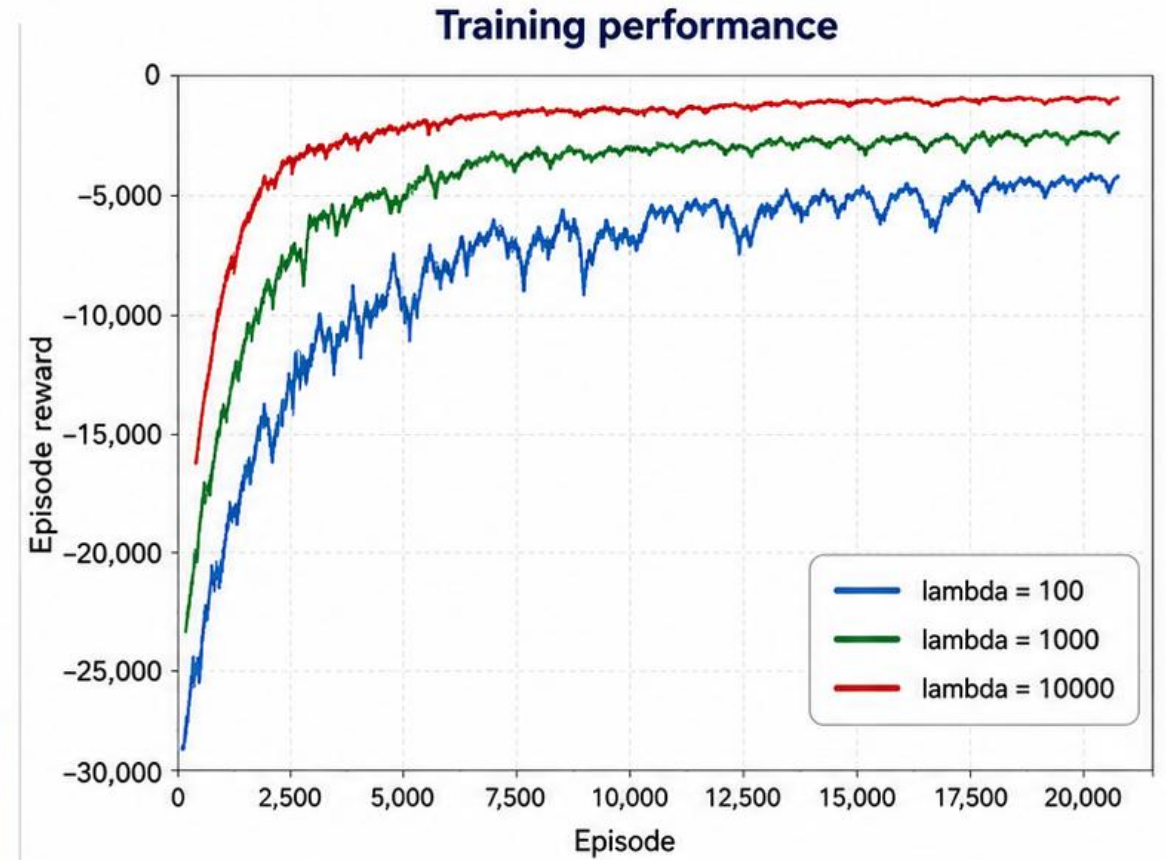
Setpoint tracking with runaway-aware reward shaping



State
 T_R, T_J, OP, c_i ,
control error

Action
Adjust feed
valve V1

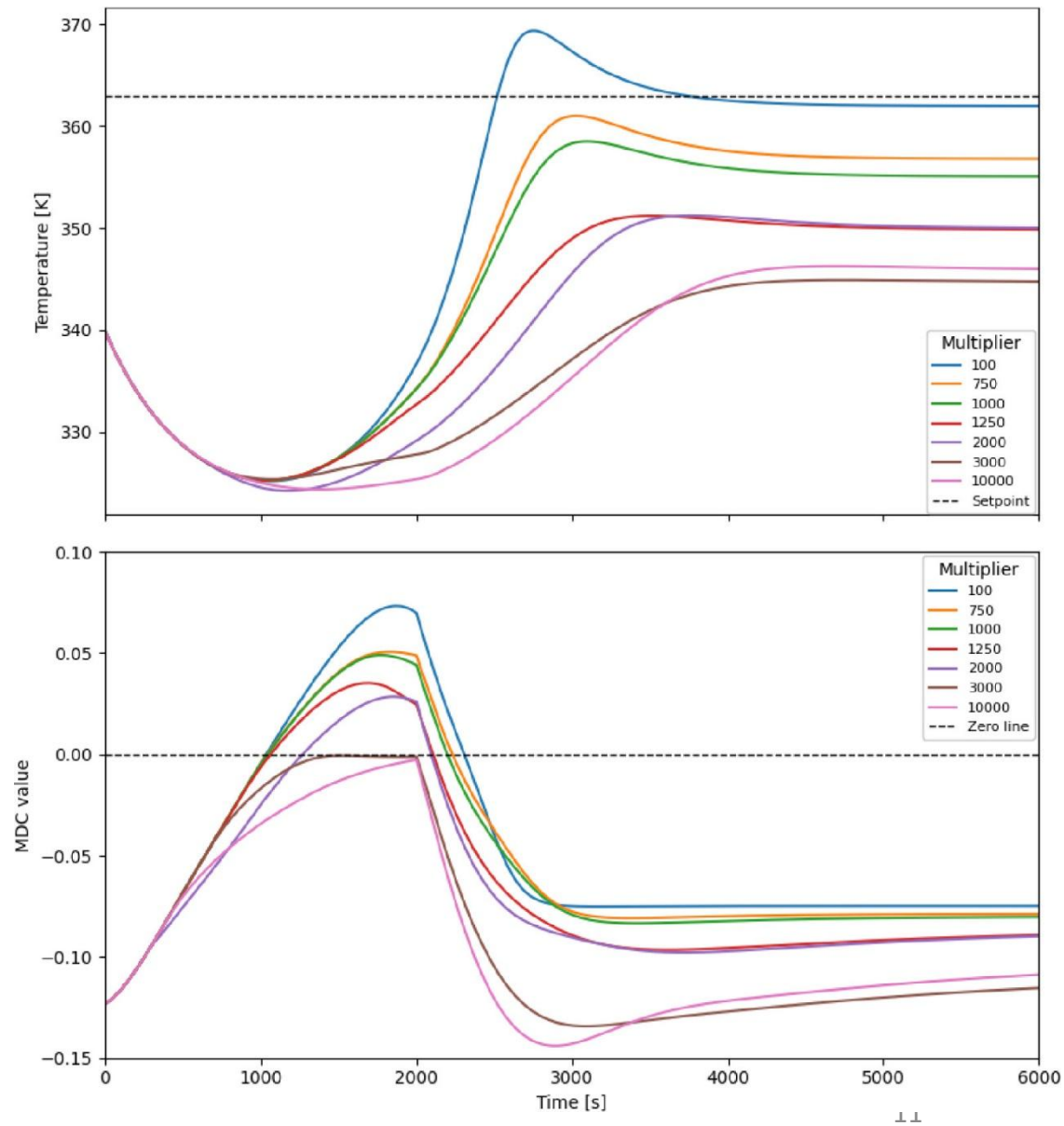
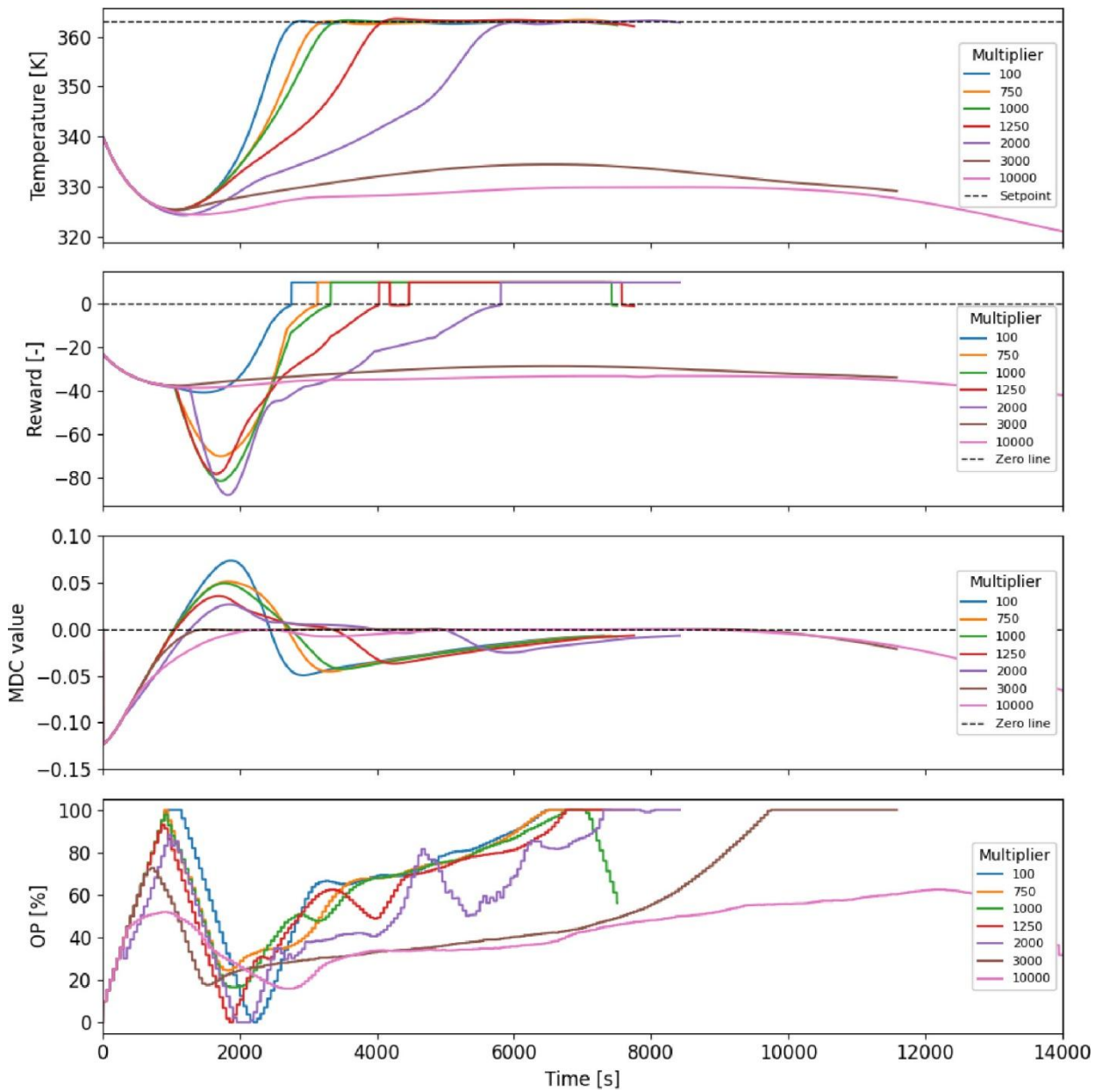
Reward
Tracking reward -
runaway penalty



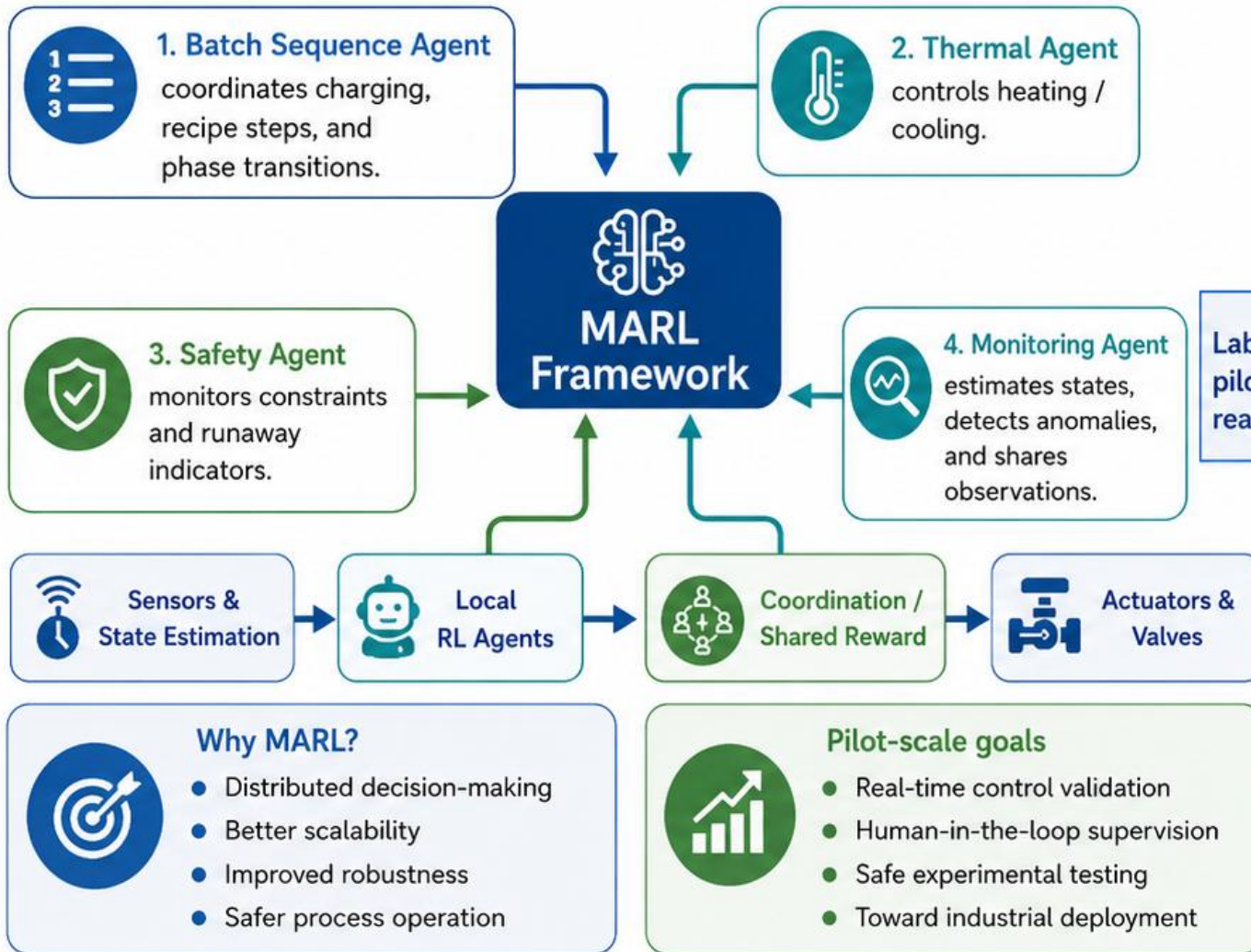
Higher MDC penalty leads to safer but more conservative control.

Key idea: The RL agent learns valve actions that balance temperature control and reactor runaway avoidance.

How much do I penalise my agent for behaving unsafely?



Future work.... Realising RL in a laboratory pilot plant



Goal: Enable safe, efficient and adaptive operation of the pilot batch reactor using cooperative multi-agent reinforcement learning.

Thank you for your attention!

Thanks to my family....



Thanks to my mentors....

