# Self-learning Agents in Process and Systems Engineering


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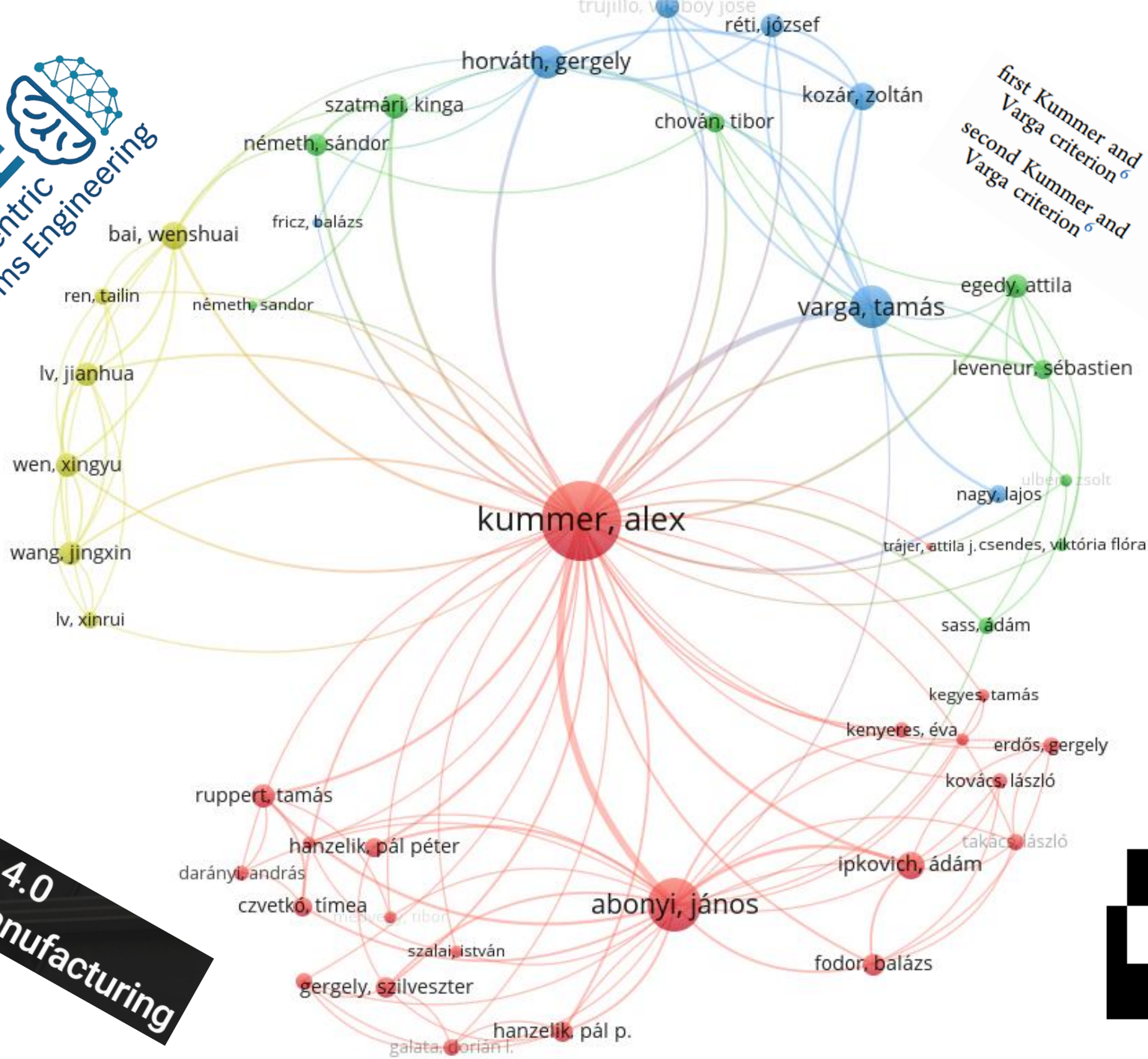
**Data-Centric Systems Engineering**

https://www.datacentricse.com/

# Who am I ?

DCSE
Data-Centric
Systems Engineering




first Kummer and Varga criterion [6]

second Kummer and Varga criterion [6]

$$\frac{dq_{gen}}{d\tau}\Big|_x - \frac{dq_{rem}}{d\tau}\left(1 + \frac{q_{gen}}{q_{rem}}\right) = 0$$

$$\frac{dq_{gen}}{d\tau}\Big|_x + \frac{\partial F_1(x,\tau)}{\partial x}\Big|_\tau - \frac{q_{gen}}{q_{rem}}\frac{dq_{rem}}{d\tau} = 0$$

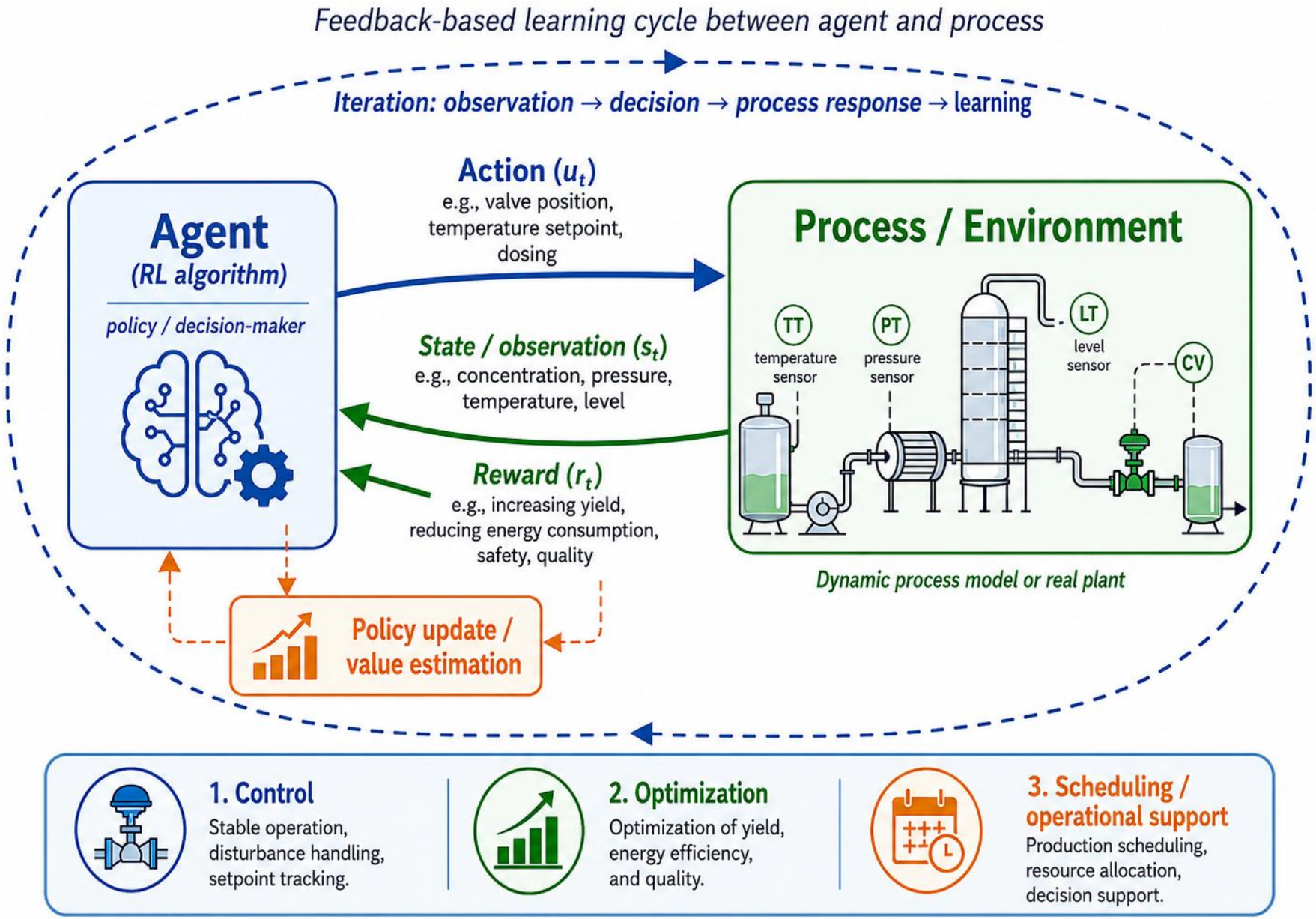
Folyamatmérnöki Intézeti Tanszék
FMT
Alapítva: 1977
Department of Process Engineering

Operator 4.0
Human-Centered Manufacturing

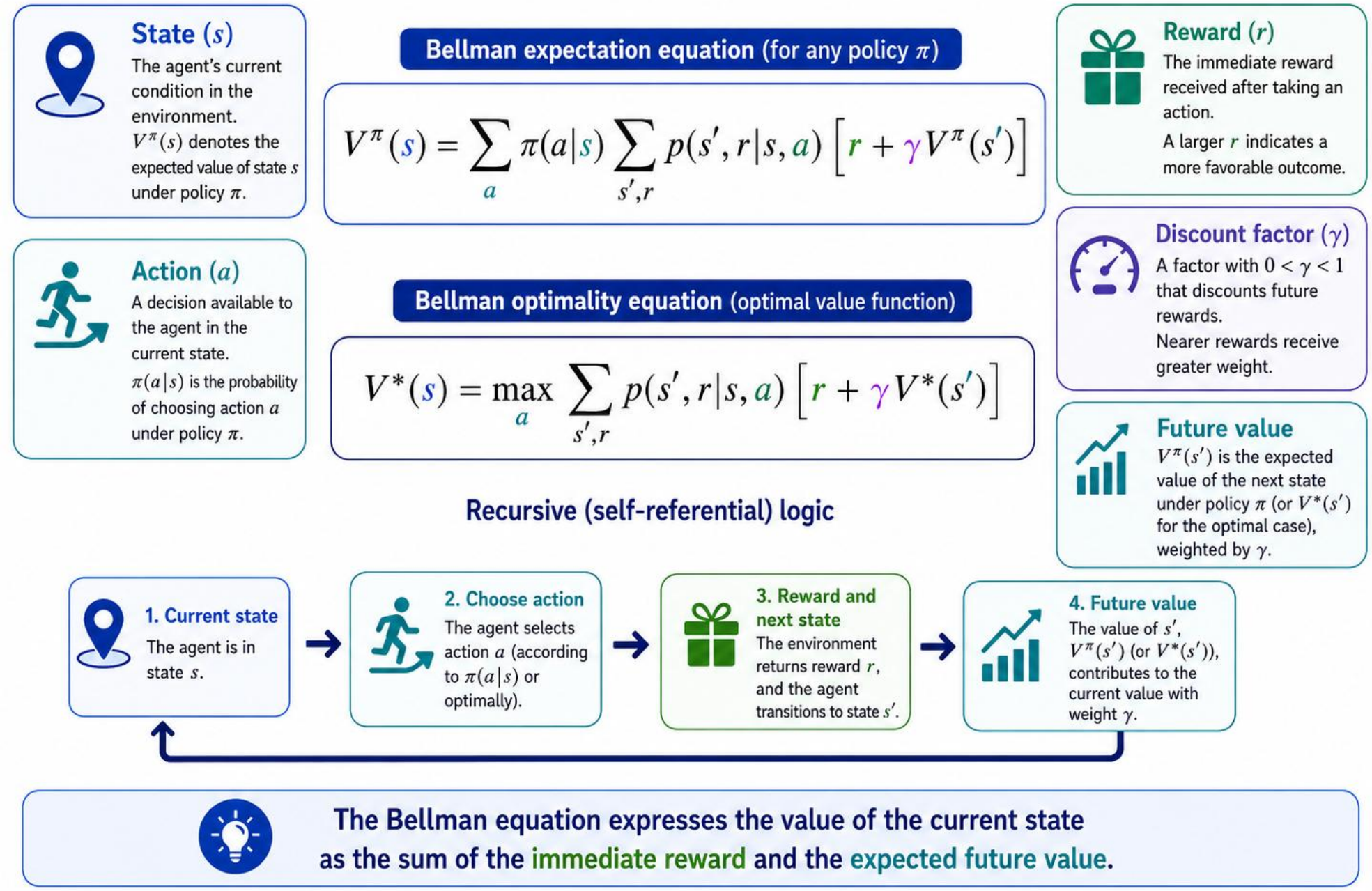
Complex Systems Monitoring
Research Group

# What is AI-enhanced Process and Systems Engineering?

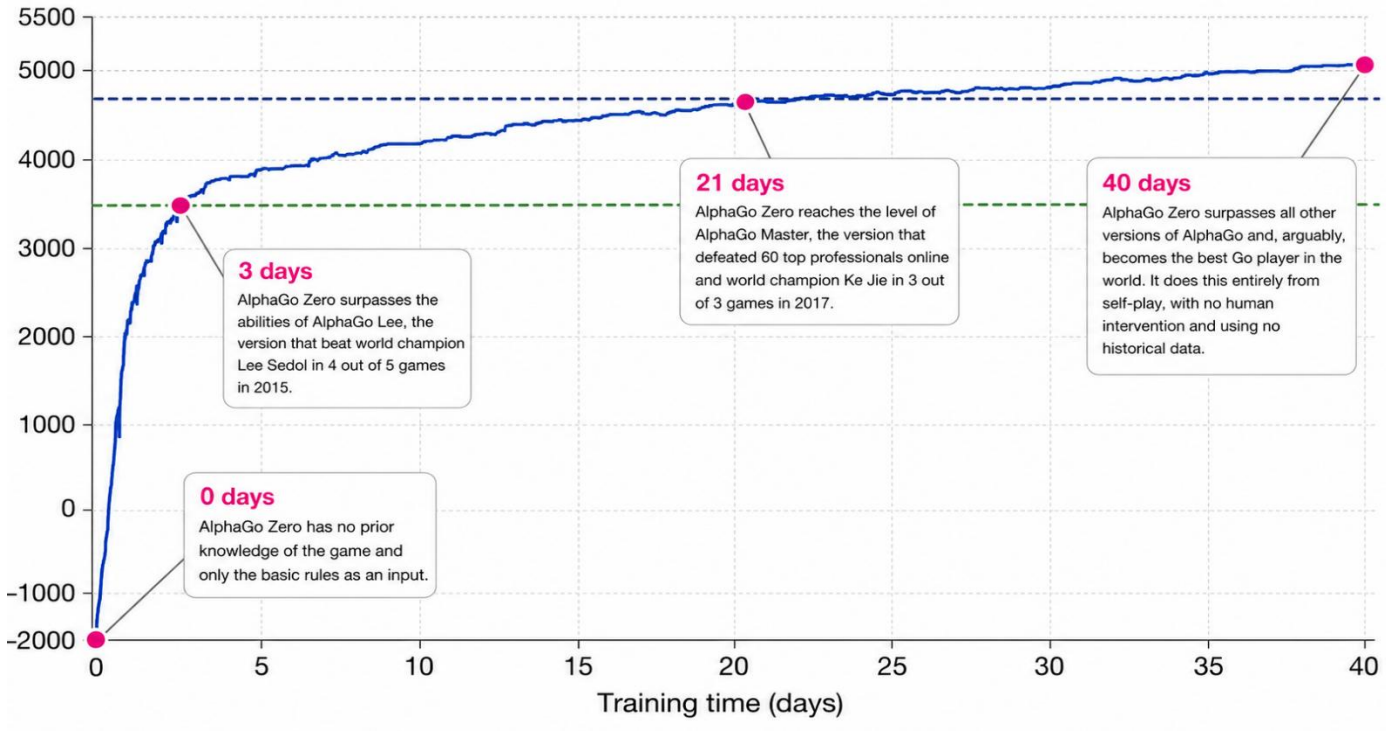
# One of my favourites..... self-learning agents

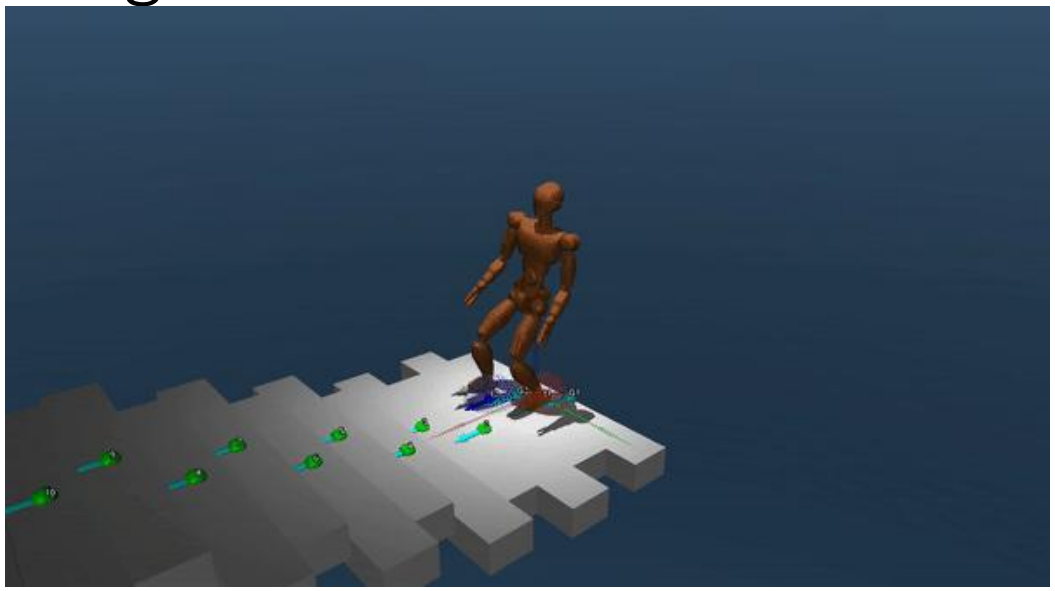


# The famous Bellman Equation…

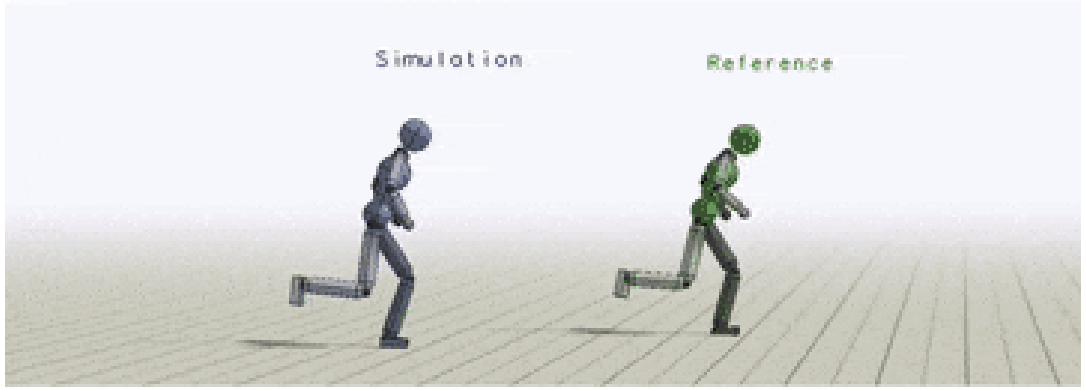


# RL Agents have always been at home in games and robotics, but have much more potential in engineering fields



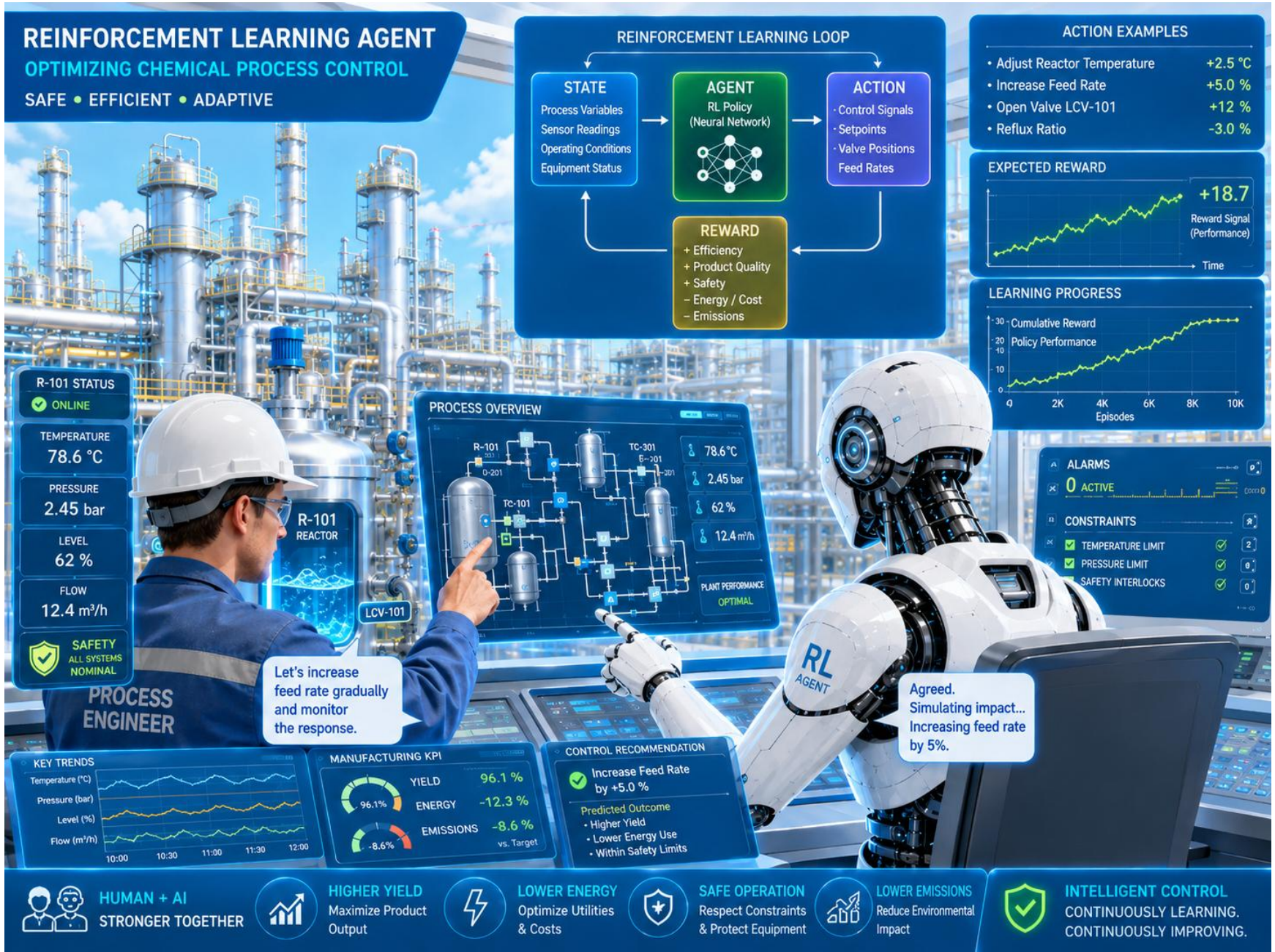



Humanoid: Run

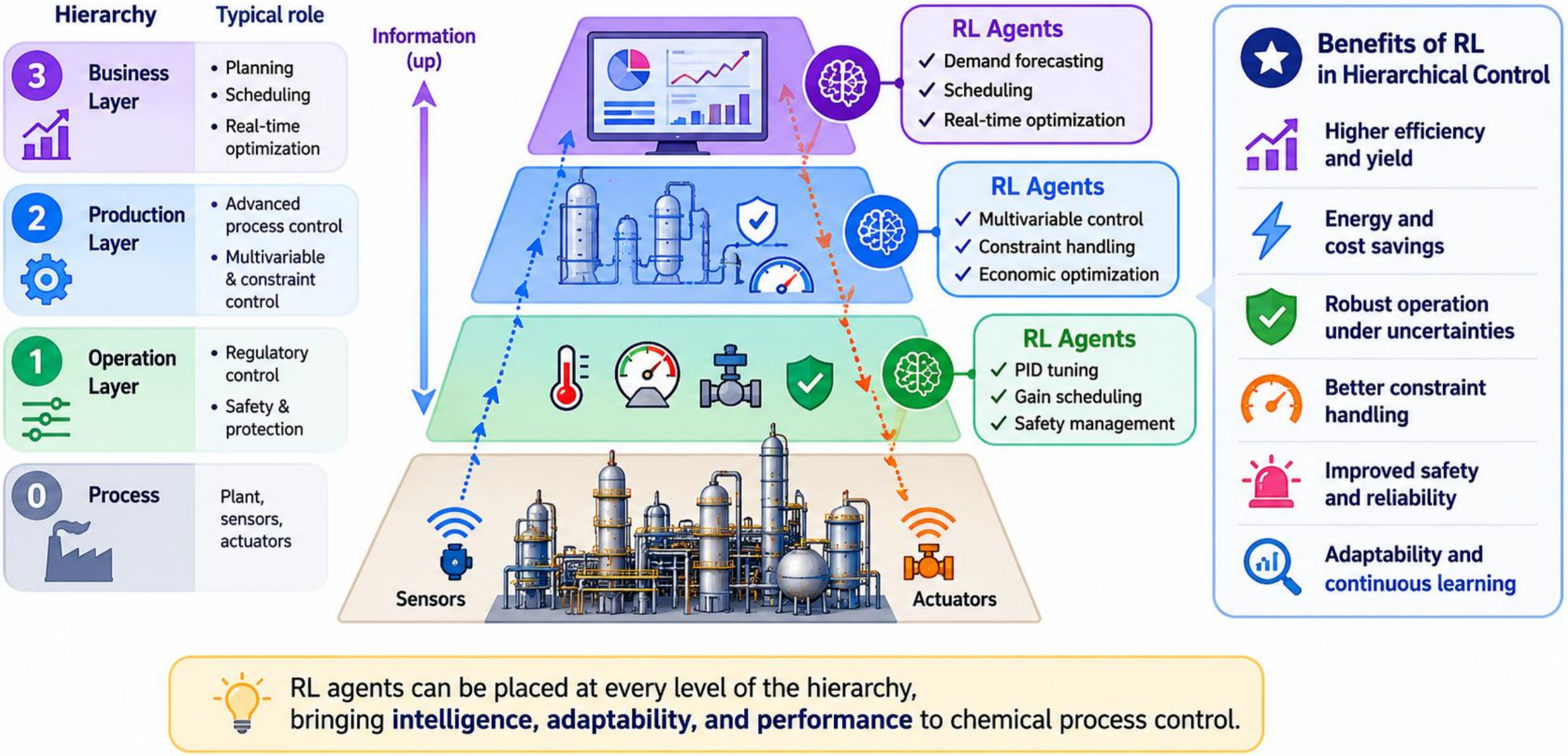



Policy trained to imitate a running clip.

# I believe in self- and co-learning systems…



# RL Agents in Hierarchical Chemical Process Control

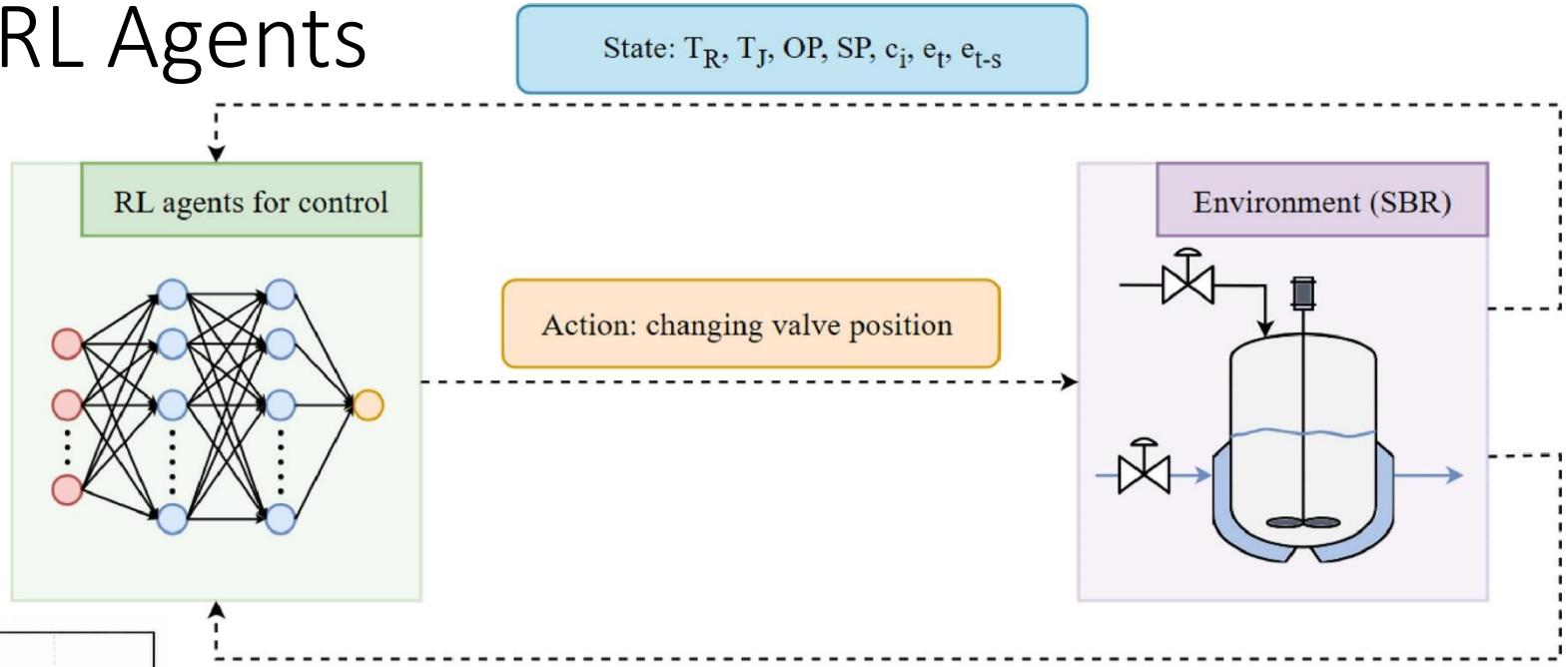


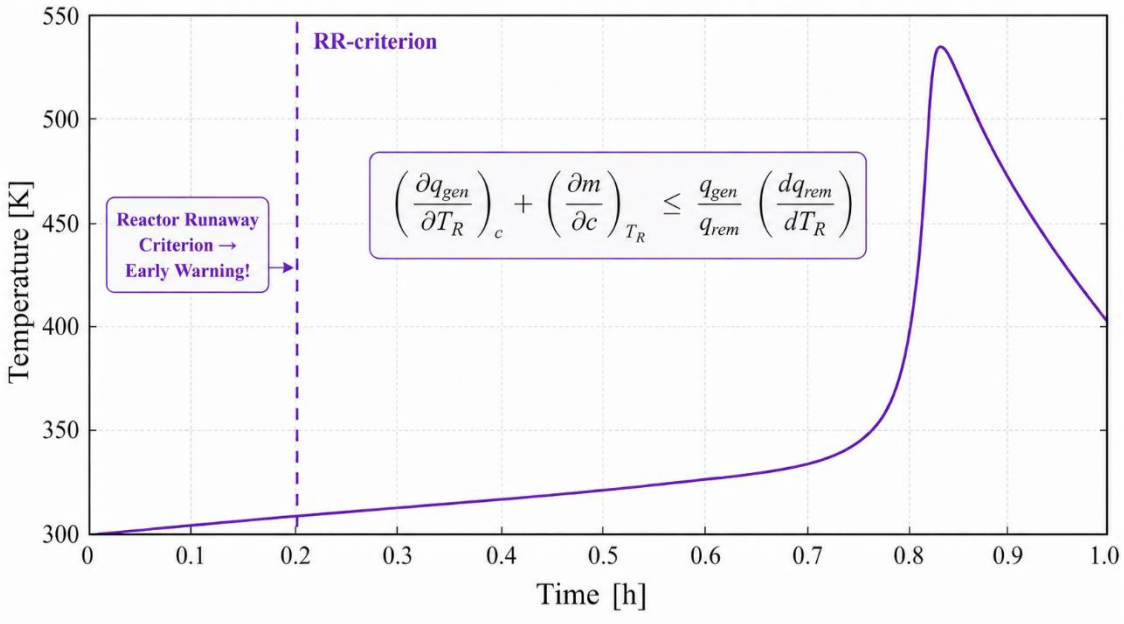

RL agents can be placed at every level of the hierarchy, bringing **intelligence, adaptability, and performance** to chemical process control.

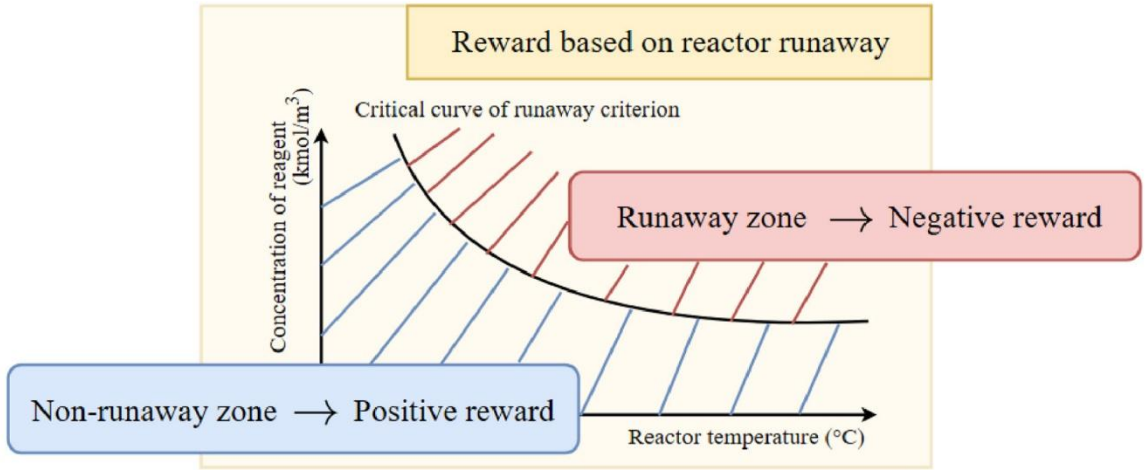
Szatmári, Kinga, et al. "How to support decision making with reinforcement learning in hierarchical chemical process control?" *Chemical Engineering Journal Advances* 22 (2025): 100753.

# Reactor Runaway aware RL Agents

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



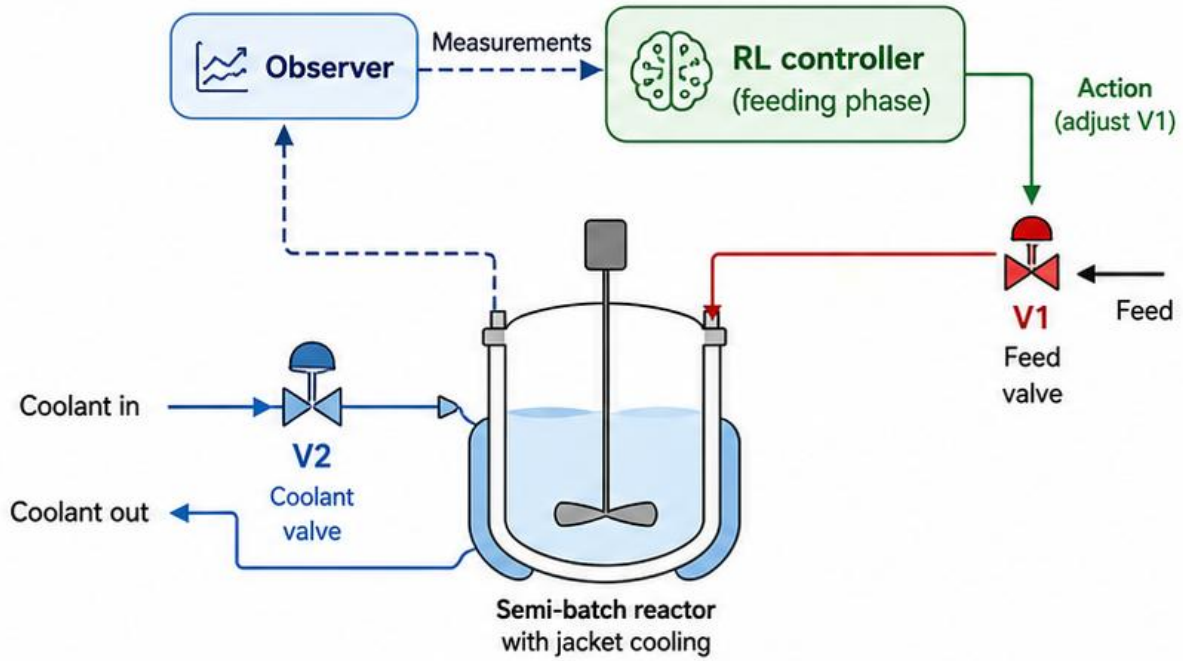




Fricz, B., Szatmári, K., Németh, S., Nagy, L., Bai, W., & Kummer, A. (2026). Reactor runaway aware RL Agents for safe reactor operation. *Computers & Chemical Engineering*, 212, 109704.

# The RL Agent as a Process Controller

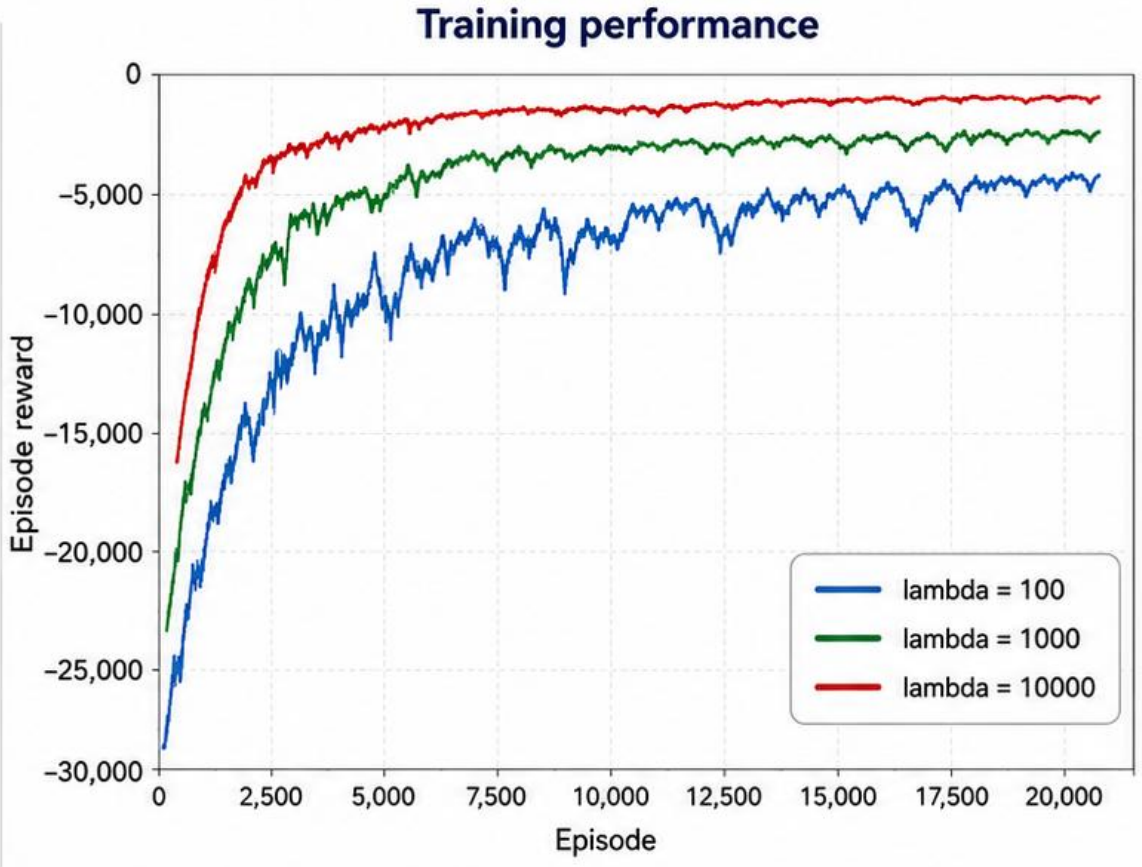
*Setpoint tracking with runaway-aware reward shaping*




**State**
$T_R$, $T_J$, OP, $c_i$, control error

**Action**
Adjust feed valve V1

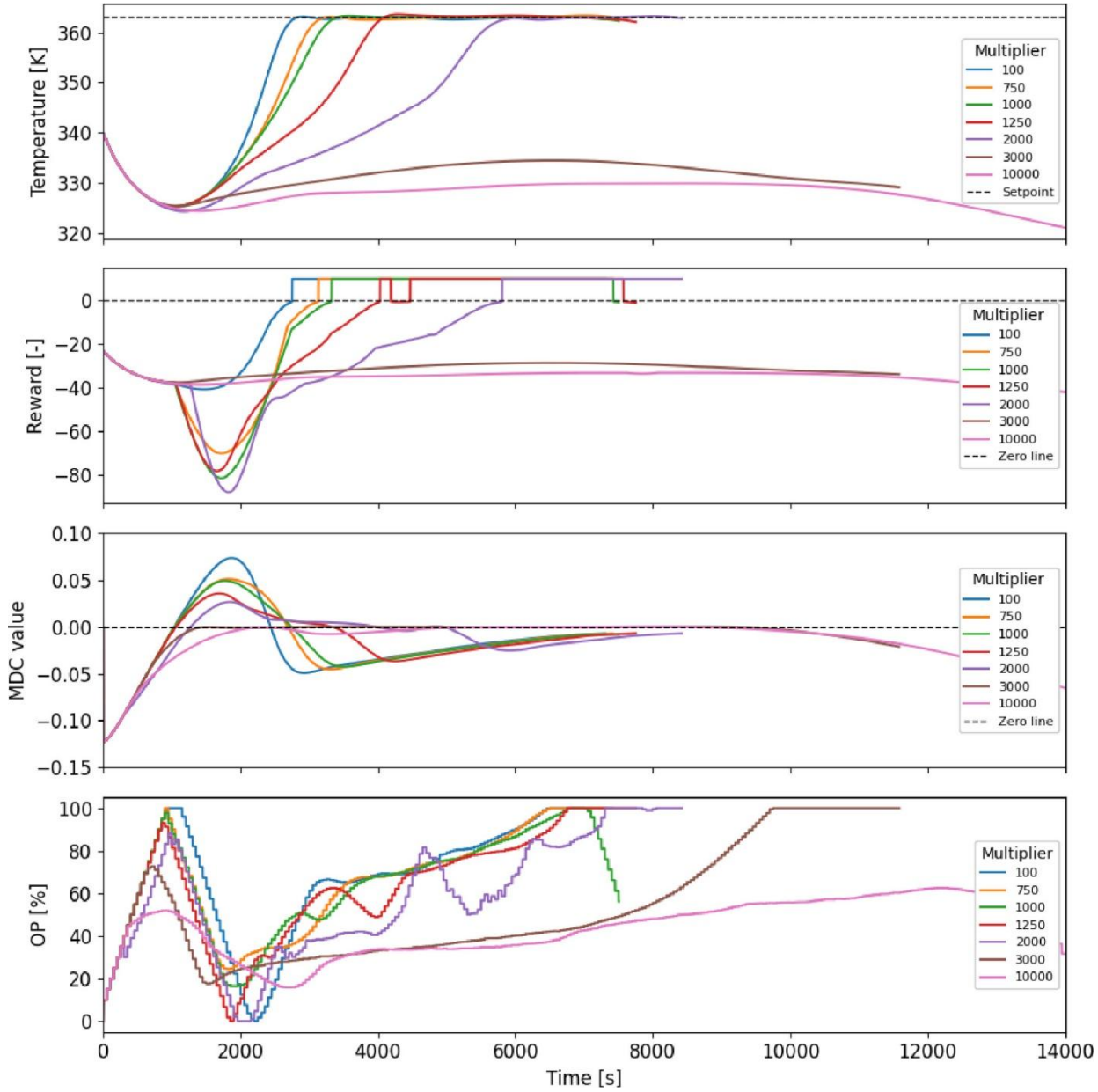
**Reward**
Tracking reward – runaway penalty

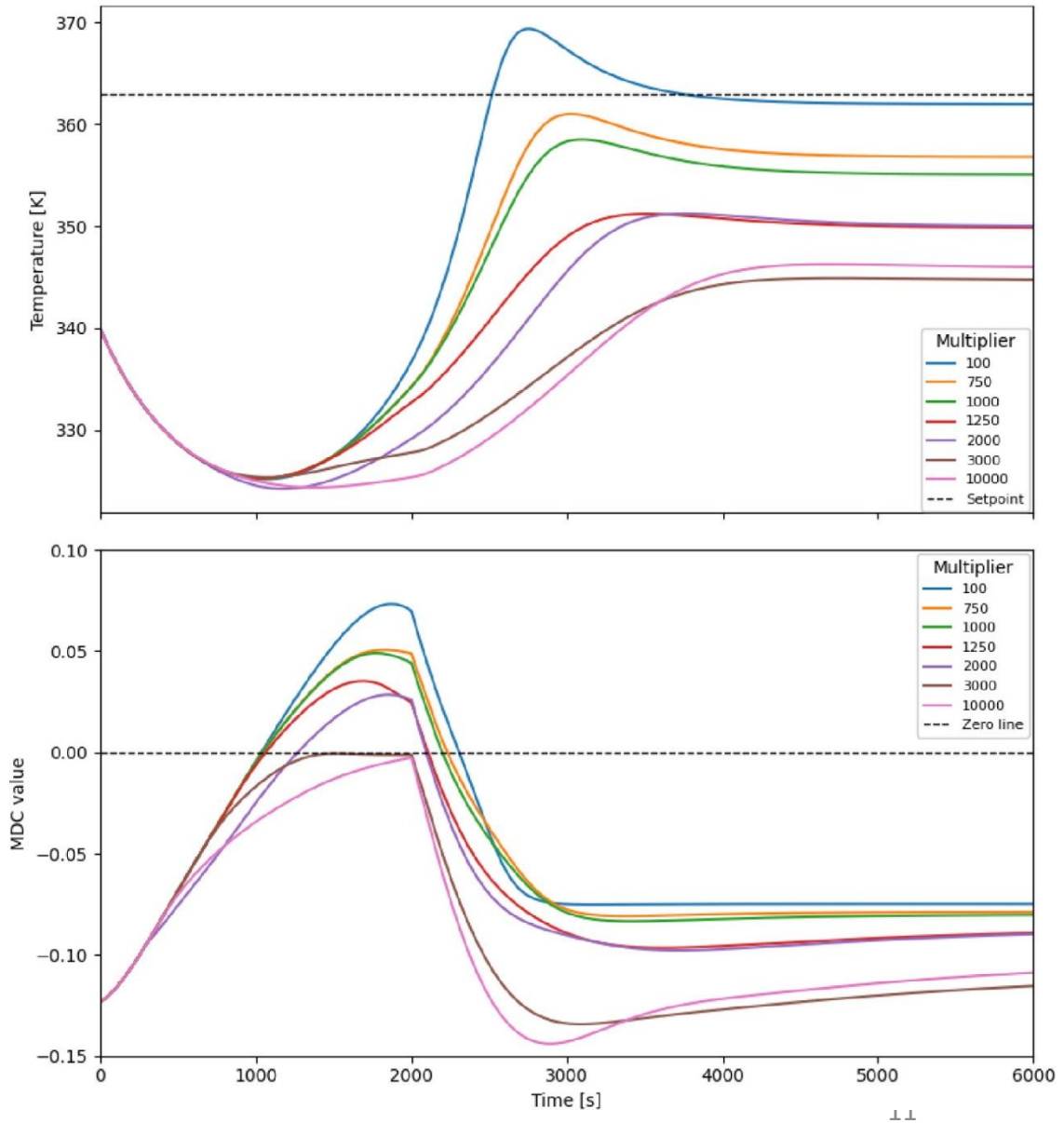



Higher MDC penalty leads to safer but more conservative control.

**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

**1. Batch Sequence Agent**
coordinates charging, recipe steps, and phase transitions.

**2. Thermal Agent**
controls heating / cooling.

**MARL Framework**

**3. Safety Agent**
monitors constraints and runaway indicators.

**4. Monitoring Agent**
estimates states, detects anomalies, and shares observations.

Laboratory pilot batch reactor

Sensors & State Estimation → Local RL Agents → Coordination / Shared Reward → Actuators & Valves

**Why MARL?**
- Distributed decision-making
- Better scalability
- Improved robustness
- Safer process operation

**Pilot-scale goals**
- Real-time control validation
- Human-in-the-loop supervision
- Safe experimental testing
- Toward industrial deployment

**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….