POLITECNICO
MILANO 1863

Digital solutions for smart and green Additive Manufacturing

Marco Grasso, Bianca Maria Colosimo,

Department of Mechanical Engineering, Politecnico di Milano

mecc

DIPARTIMENTO DI ECCELLENZA
MIUR 2018-2022

Additive Manufacturing as key enabling technology of the Twin Transition

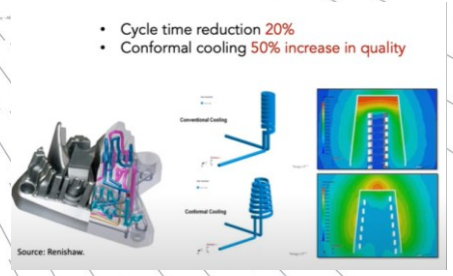
GREEN TRANSITION

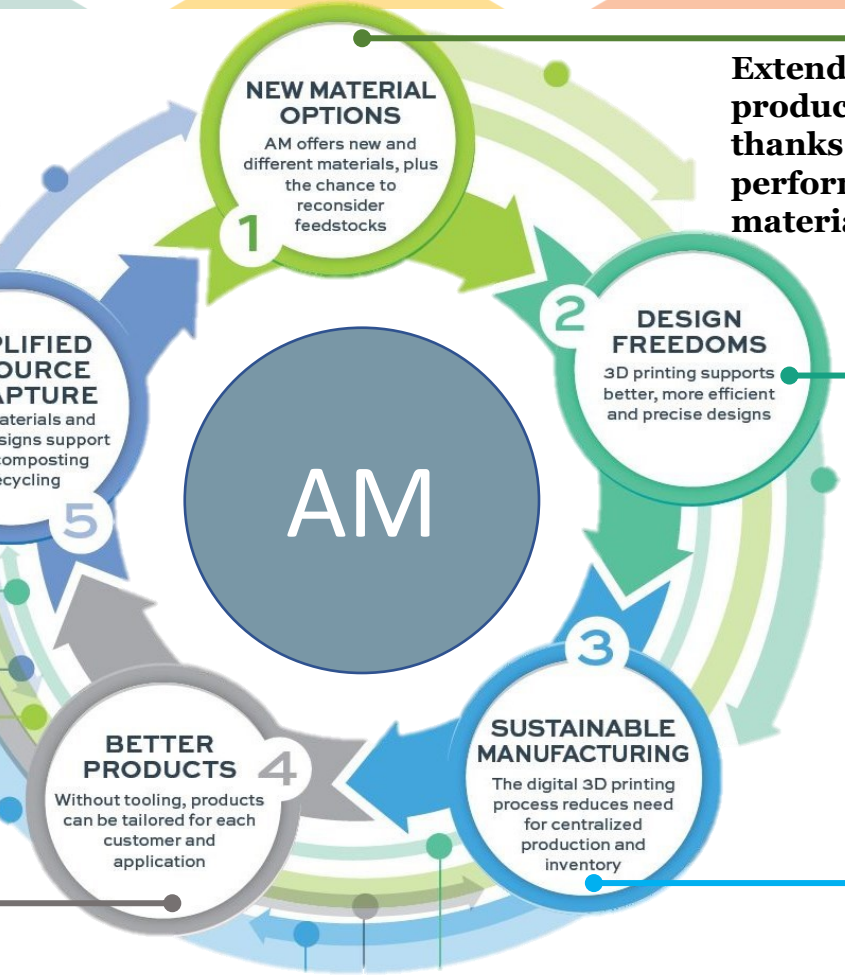
GLOBAL COMPETITIVENESS

DIGITAL TRANSITION

Material recycling and reuse

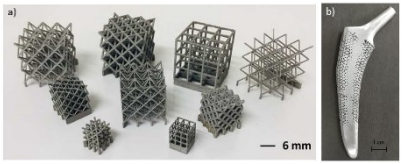
Higher performances, monolithic parts, reduced need for joining and assembling

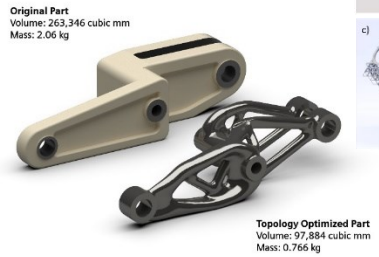




Extended product life thanks to high performance materials

New, green and lightweight designs



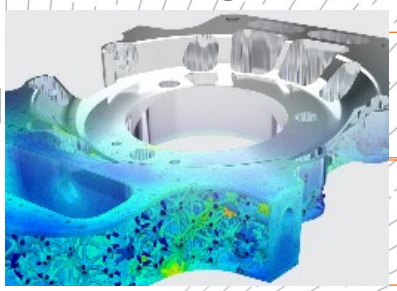
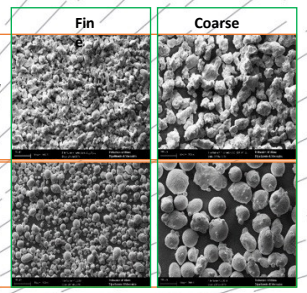


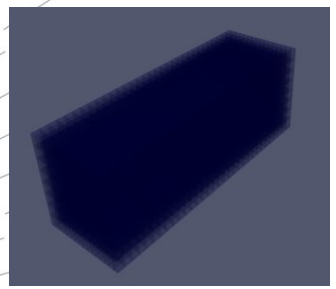
More efficient supply chain, reduced production chain, print on demand,...

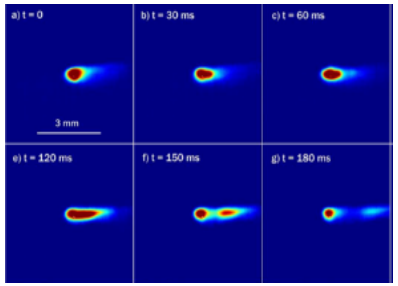
Additivemanufacturing.media

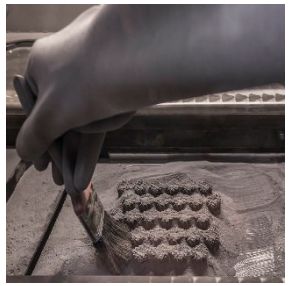
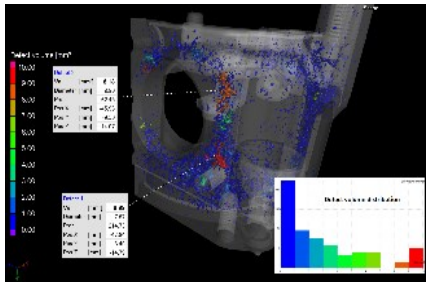
Smart AM for sustainable production

Design | Materials | Simulation | Process | Measurements | Post-process | Qualification





«The limited stability and repeatability of the process still represent a major barrier for the industrial breakthrough of AM systems»

- New shape complexity levels
- New alloys, challenging and expensive materials
- High customization, production flexibility
- Several sources of defects and instability
- Complex process dynamics
- Stringent requirements in most relevant sectors

Opportunities

- Highly digital process
- Big data generated through the whole production chain
- Layerwise paradigm allows closer look into the process
- Digital product ID to feed optimization loops

SUSTAINABLE PRODUCTION

- **Zero waste, first time right**
- **Reduced material utilization (less supports)**
- **Efficient development of AM for new materials**
- **Reduced time-to-market**

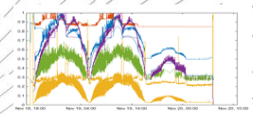
«AI + AM = SMART AM»

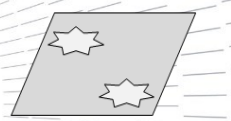
The potential and opportunities provided by AI for smart AM

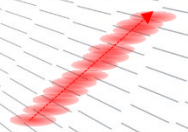
AI for in-situ and in-line process monitoring

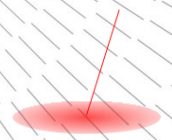
"More 3D printers will have eyes (vision/in-situ monitoring) and brains (machine learning)"
(Additive Manufacturing trends in 2022)

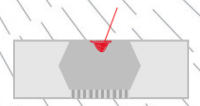
Big data and signals available at multiple levels

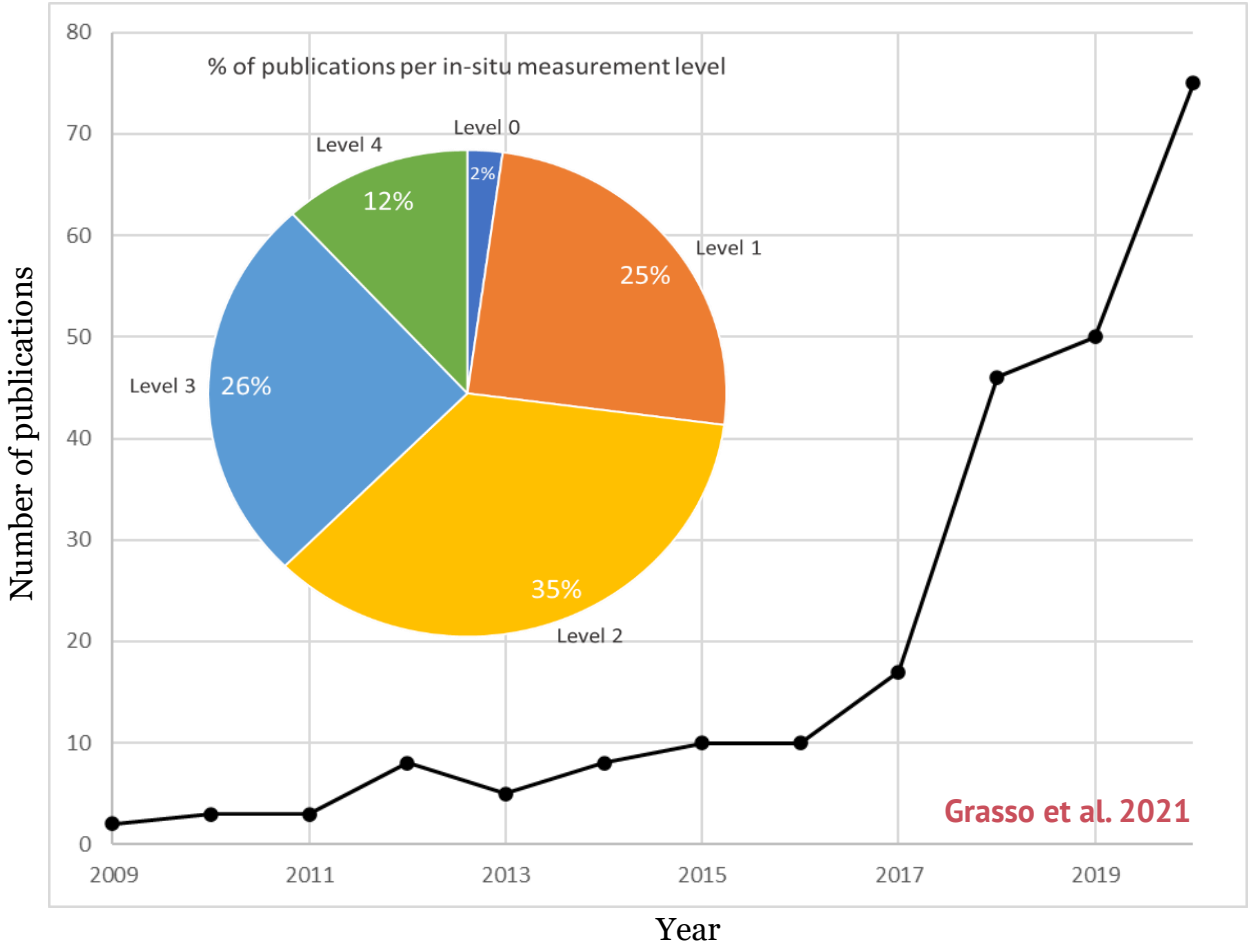
Level 0 
Signals from sensors embedded into the AM system (chamber control, automation, ...)

Level 1 
Powder bed & printed slice (powder bed inhomogenity, geometrical distortions, surface patterns, ...)

Level 2 
Scan track (process by-products: spatters & plume, hot/cold spots, heating/cooling gradients, ...)

Level 3 
Melt pool (stability of size, shape, intensity, temperature distribution, ...)

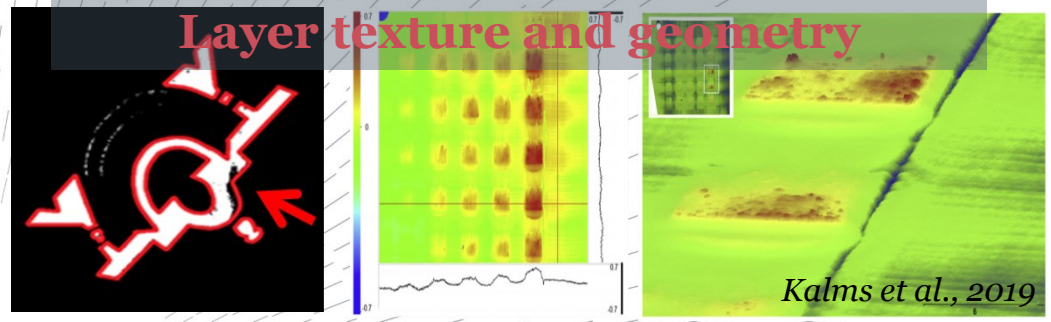
Level 4 
Under the layer (melt pool depth, sub-surface pore and crack formation, support detachment,...)



The potential and opportunities provided by AI for smart AM

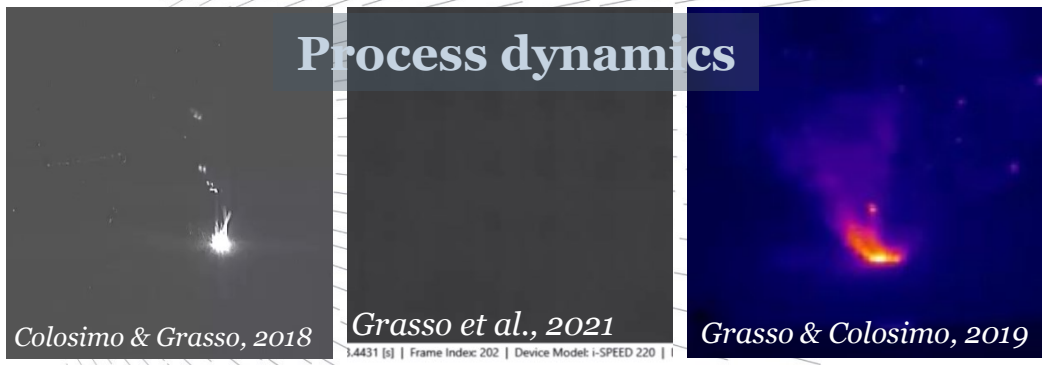
AI for in-situ and in-line process monitoring

Layer texture and geometry



Kalms et al., 2019

Process dynamics

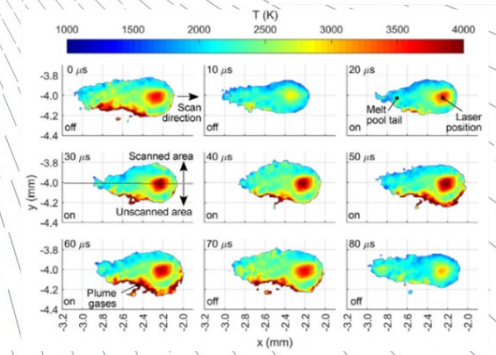


Colosimo & Grasso, 2018

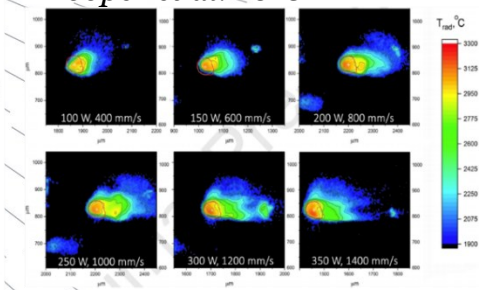
Grasso et al., 2021

Grasso & Colosimo, 2019

Melt Pool

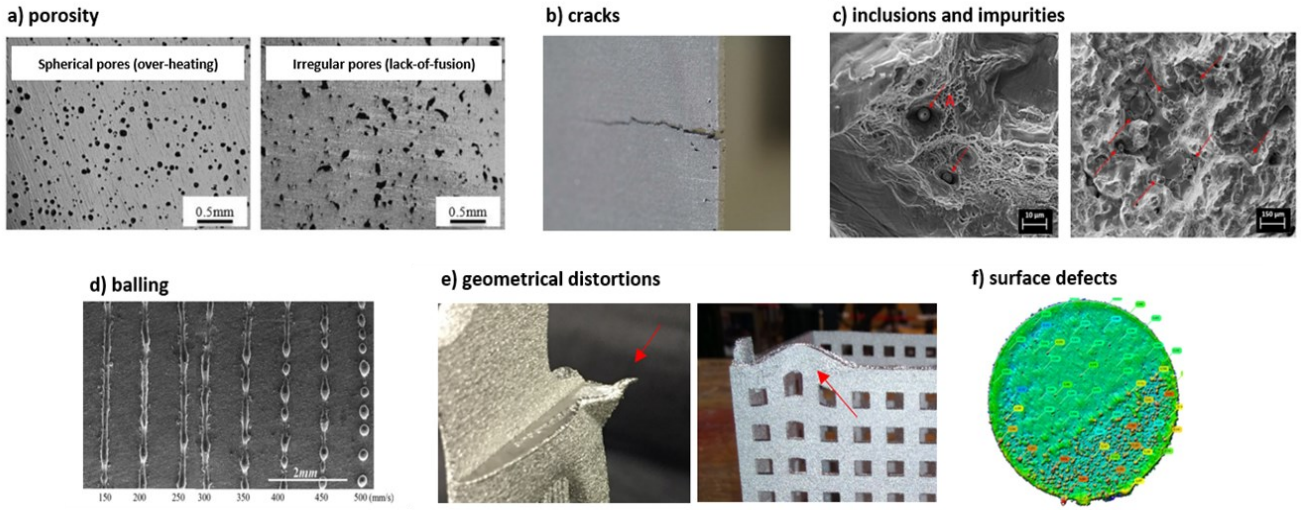


Hooper et al. 2018



Zhirnov et al., 2020

Several types of defects and anomalies



Colosimo and Grasso 2020

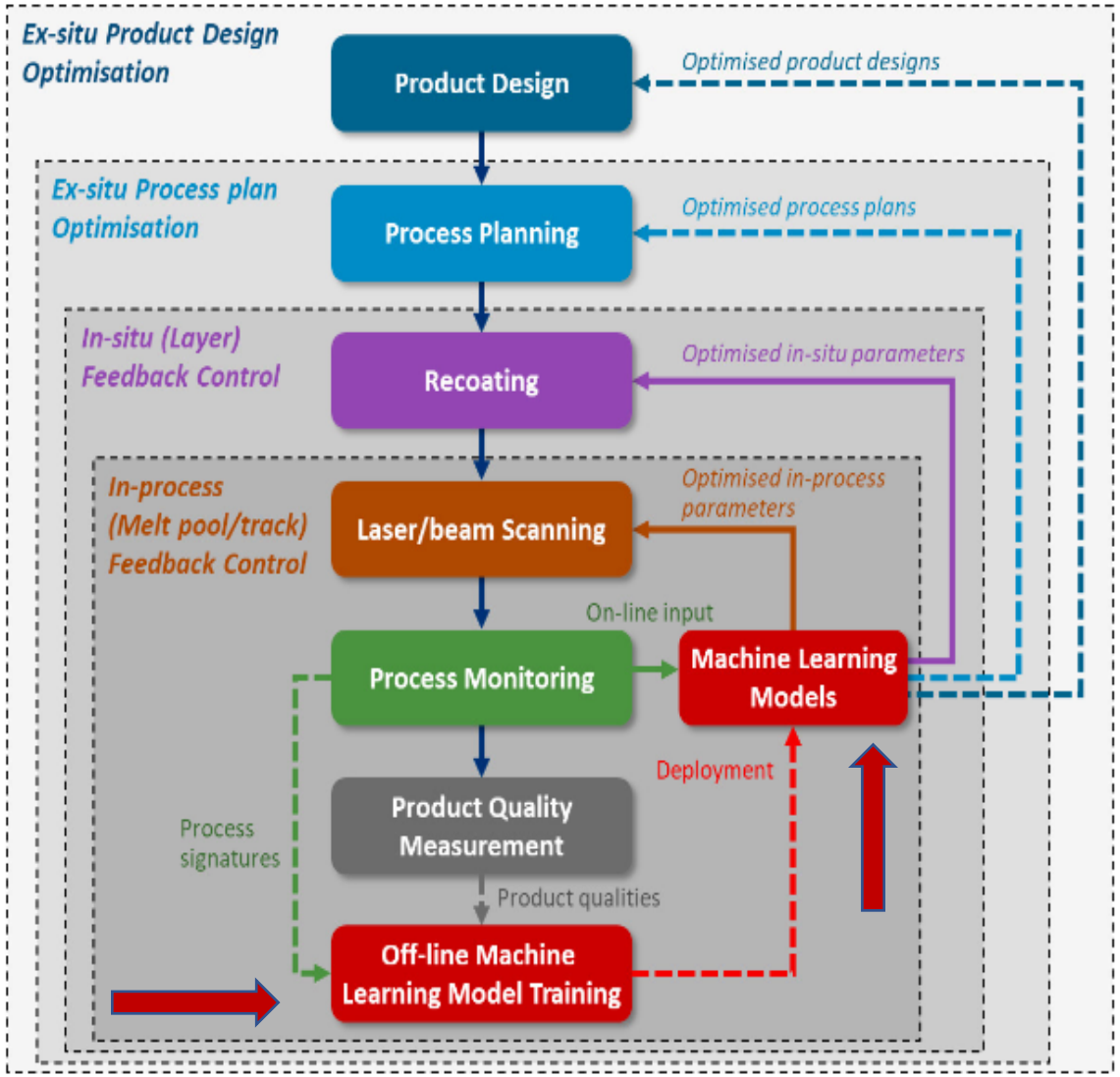
KPIs

- Fast/accurate detection of real anomalies
- Min false alarm rate
- Computational efficiency/data reduction
- Reduction of post-process NDE time and costs
- Generalization to other shapes/materials/machines

The potential and opportunities provided by AI for smart AM

From process monitoring to closed loop control

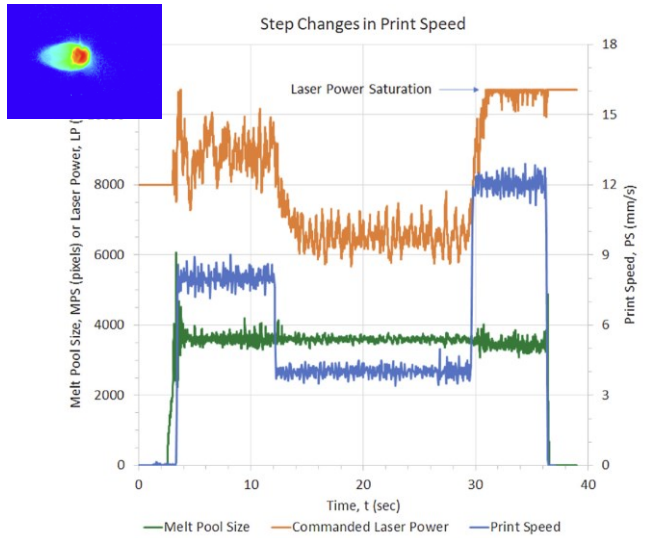
A few examples



Liu et al. 2020

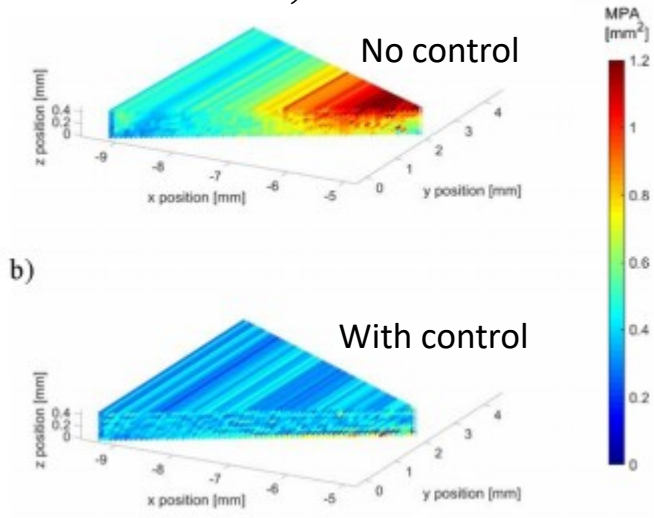
Within-layer adaptive control

Gibson et al., 2020



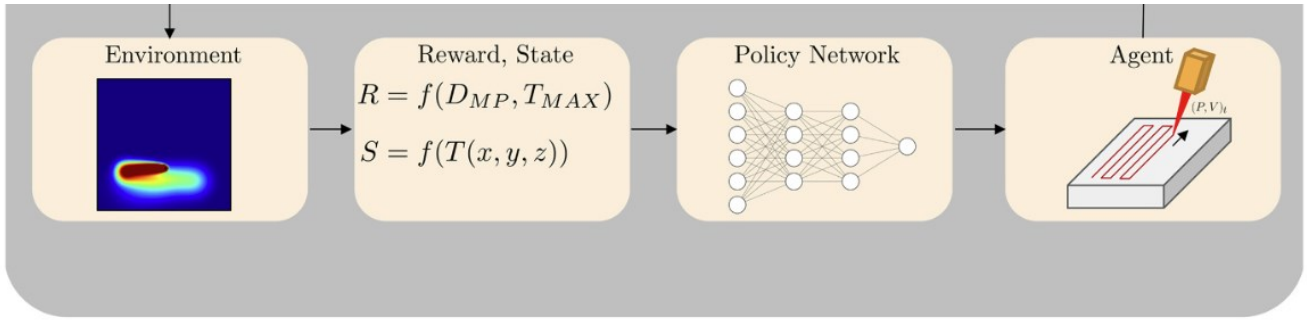
Layerwise adaptive control

Vasileska et al., 2020



Deep reinforced learning for process control

Ogoke and Farimani, 2021



Industrial gaps, open challenges and future perspectives

GAPS to be addressed

- Industrial systems are equipped with sensors but there is still a **lack of embedded intelligence** to make sense of big data gathered at different levels
- **Lack of integrated** and efficient **AI frameworks** for digital ID data use through the whole production chain

Promising research and innovation directions

- ***Adaptive / online learning*** (to deal with highly dynamic and time-varying processes)
- ***Transfer learning*** (to transfer models & knowledge from one material/shape/machine to another)
- ***Physics-informed / hybrid AI*** (to take advantage of available technological information)
- ***White-box AI*** (to make results and decisions interpretable for industrial adoption)
- ***Adoption of AI tools at different levels*** (DfAM, material performance prediction, process optimization, cost prediction, etc.)

mecc

DIPARTIMENTO DI ECCELLENZA
MIUR 2018-2022

CONTACTS

Prof. Bianca Maria Colosimo
biancamaria.colosimo@polimi.it

Marco Grasso
Marcoluigi.grasso@polimi.it

www.ic.polimi.it
www.mecc.polimi.it

@meccpolimi

POLITECNICO
MILANO 1863