Autonomous integrated systems in flat metal production: reaching ultimate quality in a full safe environment

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IFAC MMM 2016 - Future Perspectives Sessions

INTERNATIONAL FEDERATION OF AUTOMATIC CONTROL

DANIELI AUTOMATION

DANIELI TEAM
A CENTURY
OF PARTNERSHIP
EXPERIENCE

OUTLINE

An existing autonomous plant for flat metal

Advanced Process Control as routine

New control loops is flat metal production

Future roles of human

Services via remote supervision

Mechanics and automation co-design

Situation awareness and conlusions

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- An existing autonomous plant for flat metal
- **Advanced Process Control as routine**
- New control loops is flat metal production
- Future roles of human
- Services via remote supervision
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TODAY PERSPECTIVE

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A comparison: the autonomous car

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A comparative example in flat metal production (a central Europe installation for Special alloys)

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The today perspective:

1) Human far from machines

(human safety & human dedicated to higher level tasks)

2) Realisation of ultimate quality through APC

(missing defects on material)

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The today perspective:

1) **Human far from machines**
   (human safety & human dedicated to higher level tasks)
2) **Realisation of ultimate quality through APC**
   (missing defects on material)

This is today, not yet future perspective

TODAY APC IS ROUTINE

ECONOMIC OPTIMISATION

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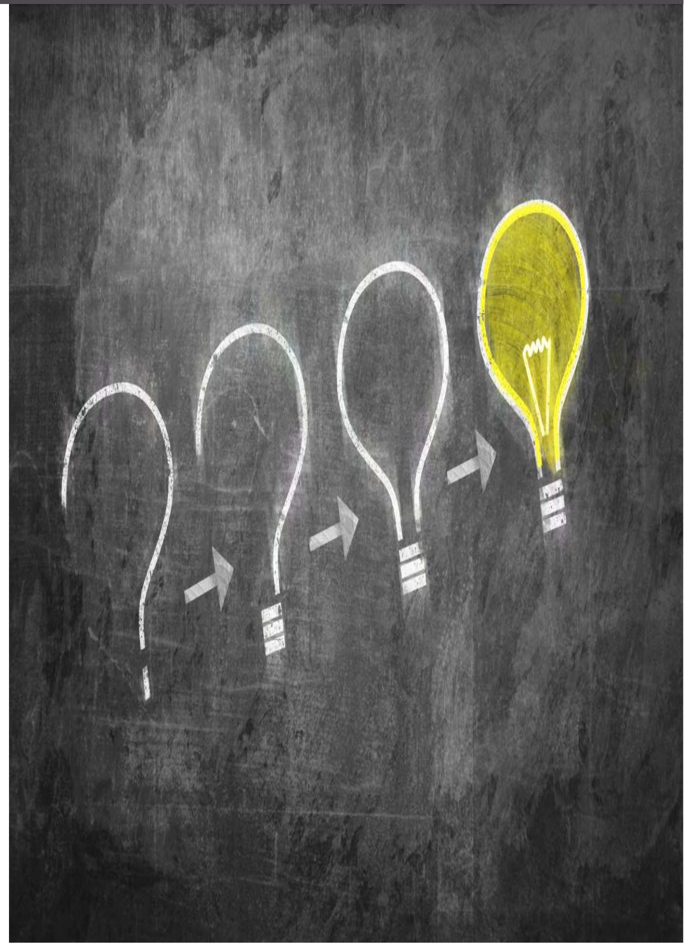
Control in the Process Industries

Ian Craig, Chris Aldrich, Richard Braatz, Francesco Cuzzola, Elom Domlan, Sebastian Engell, Juergen Hahn, Vladimir Havlena, Alexander Horch, Biao Huang, Maryam Khanbaghi, Alkis Konstantellos, Wolfgang Marquardt, Tom McAvoy, Thomas Parisini, Stratos Pistikopoulos, Tariq Samad, Sigurd Skogestad, Nina Thornhill, and Jie Yu

Introduction

Process control[1] is in many respects a mature technology serving mature industries.[2] It has gone through the emerging phase, the growth phase, and some would argue that it has also gone through the mature phase and is now in decline. The shares of companies operating in industries where process control is widely used, such as the petroleum industry, show typical signs of maturity—high dividend yields and low price-earnings ratios that reflect limited growth prospects.

The maturity of process control technology is also borne out by the decline in research funding for this area over the last decade or so, especially in the U.S. Paradoxically, this decline has occurred precisely because process control research has been so successful in addressing industry concerns. Although PID control been the king of the regulatory control loop for many decades, advanced process control has over the last few decades moved beyond the laboratory to become a standard in several industries. Many vendors now routinely offer advanced solutions such as model predictive control (MPC) technology, with its ability to economically optimize multivariable, constrained processes. Although there is always room to improve upon existing control solutions, it becomes harder to make an argument for research funding if vendors can adequately address most of their customers' control problems.



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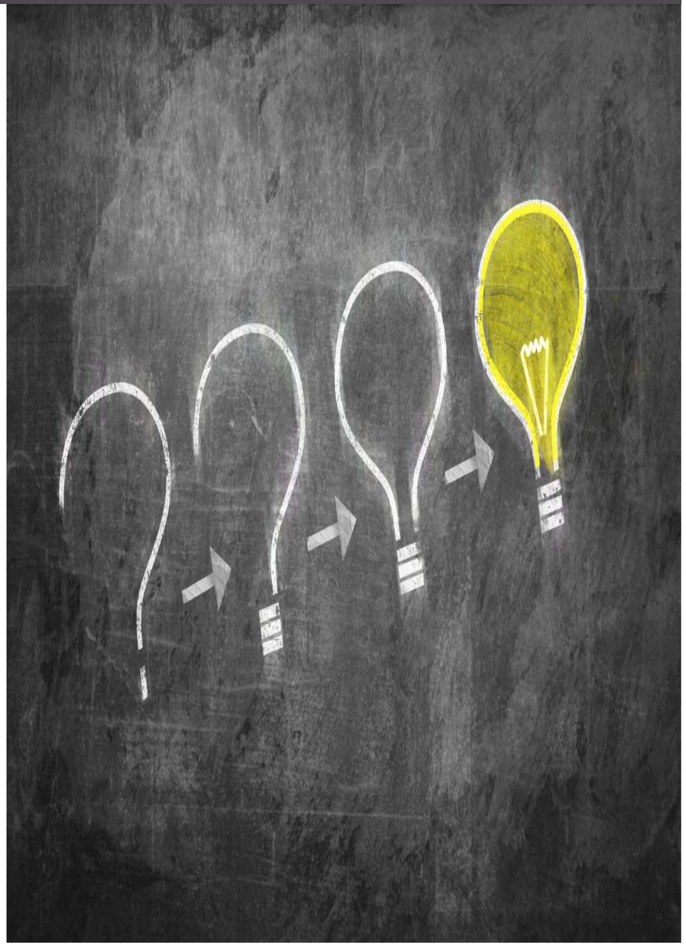

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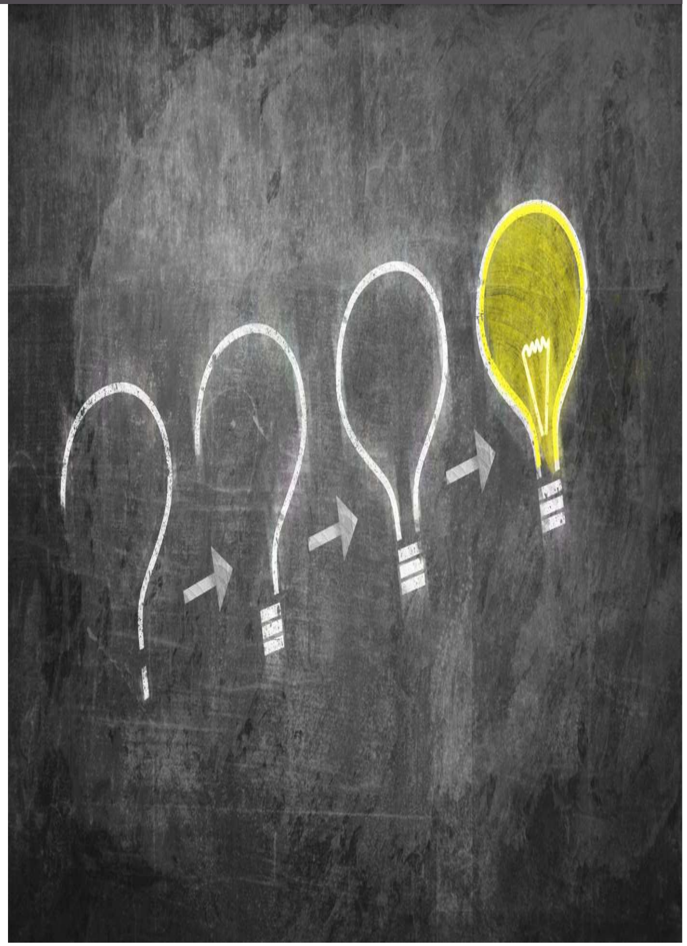

TODAY APC IS ROUTINE — ECONOMIC OPTIMISATION

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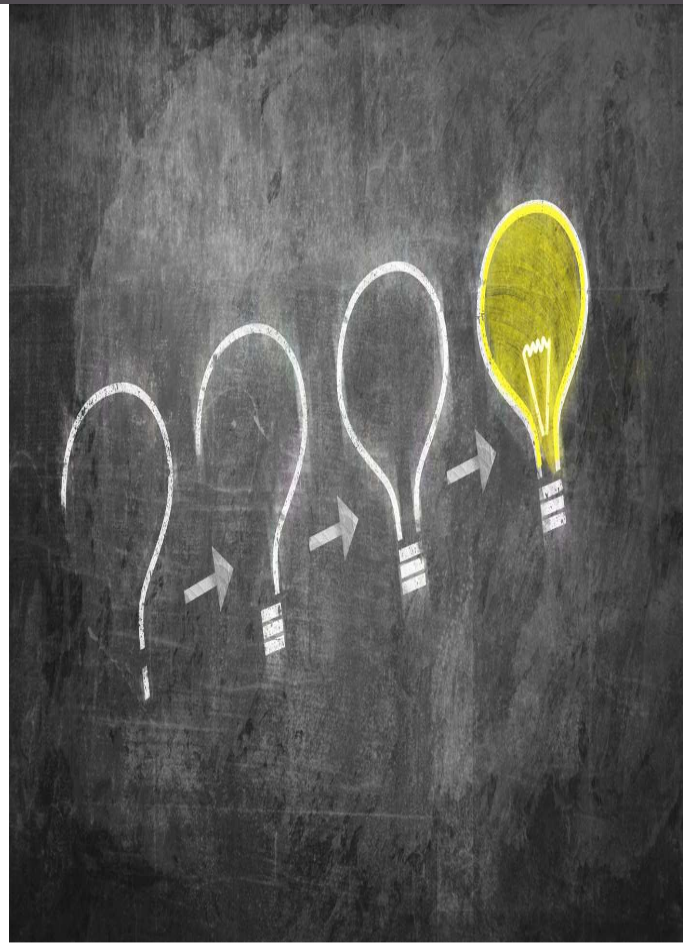

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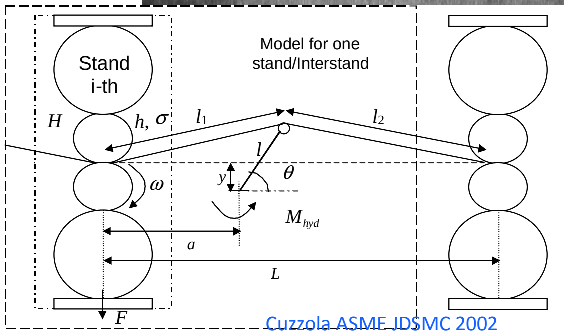
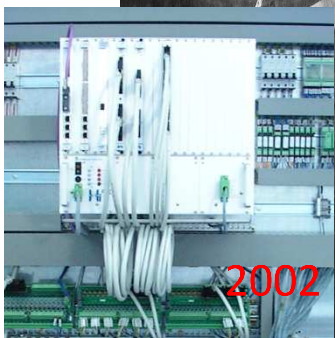


Cuzzola ASME IDSMC 2002



2012

NEW CONTROL LOOP: KPI CONTROL

Adding an outer automatic control loop:

- ***Automatic performance monitoring***
- ***Automatic decision/suggestion of counteractions***

=> Two tools: PPI & AuPiC

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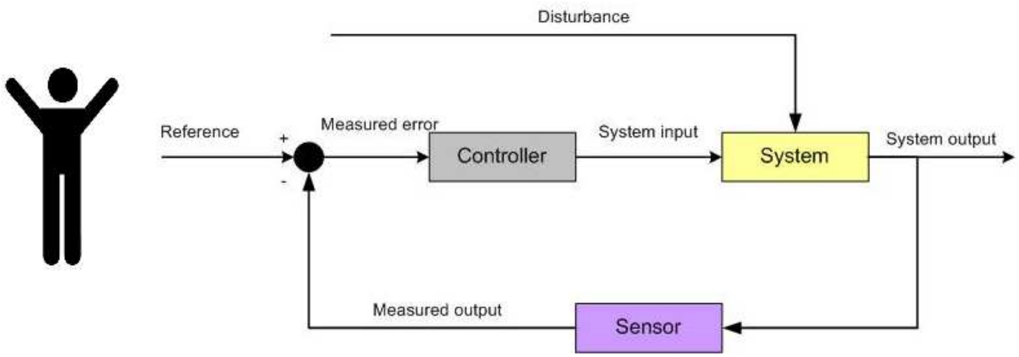

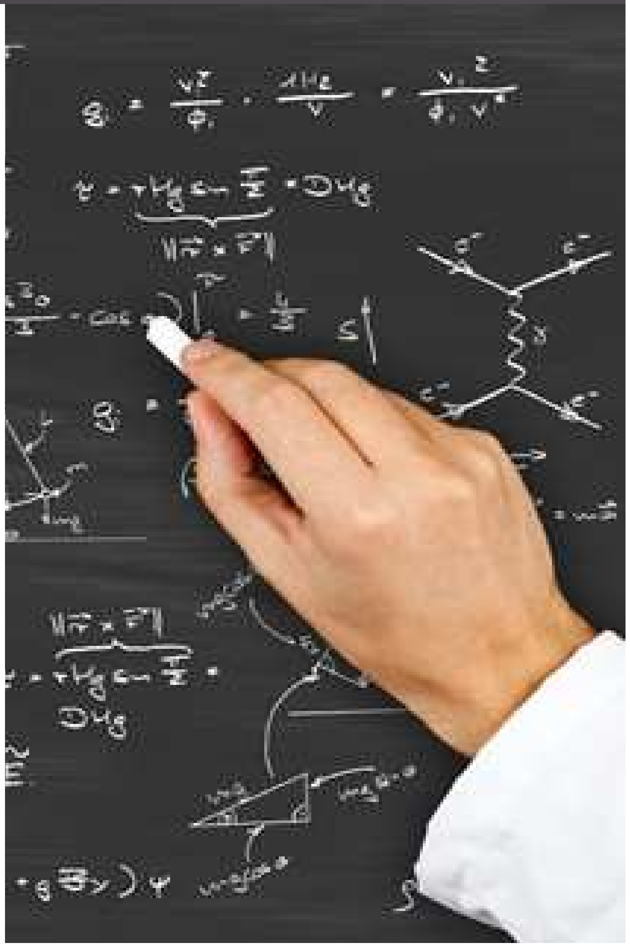

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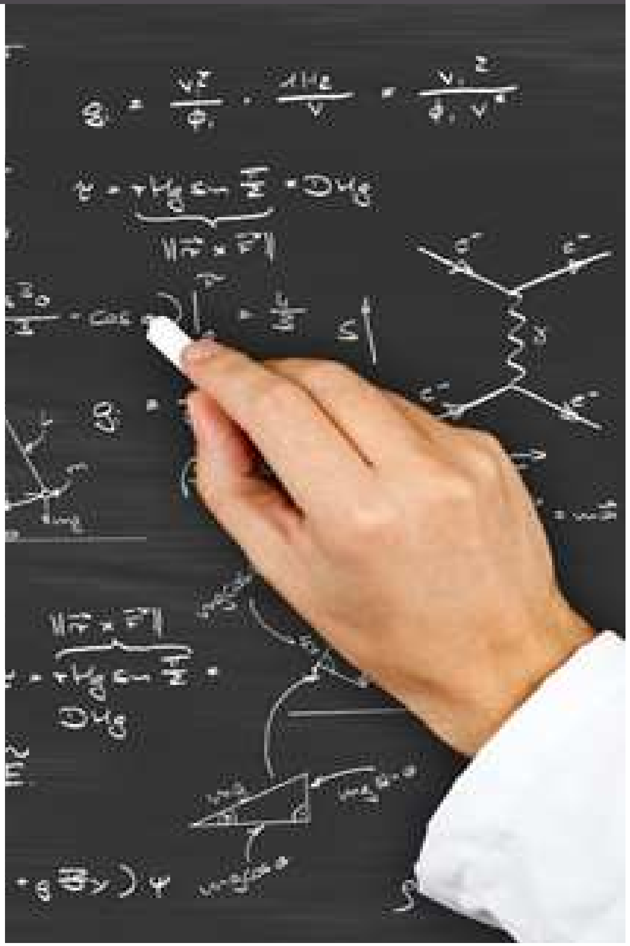

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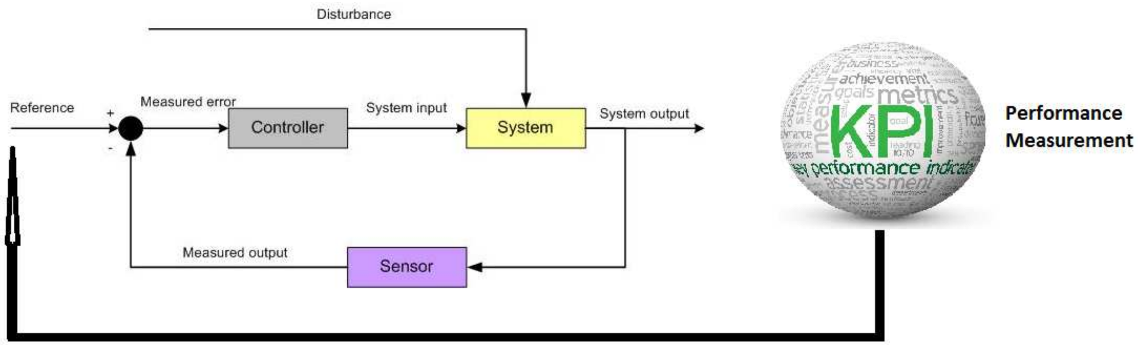

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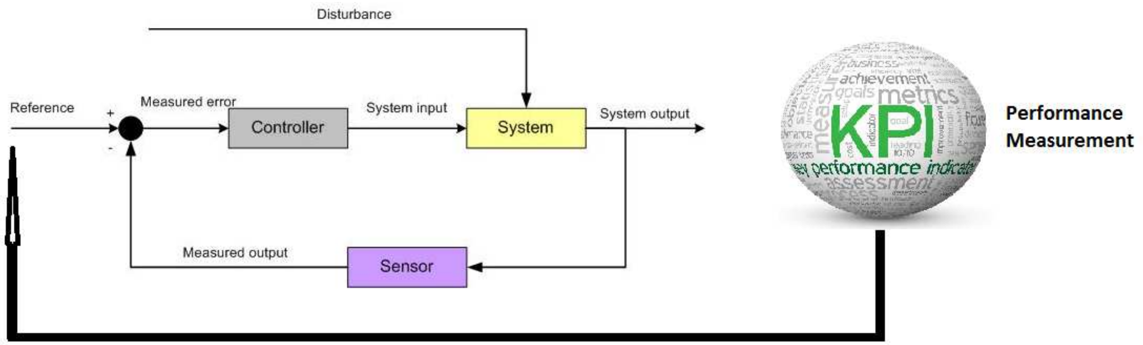
PPI (Plant Performance Indicator)



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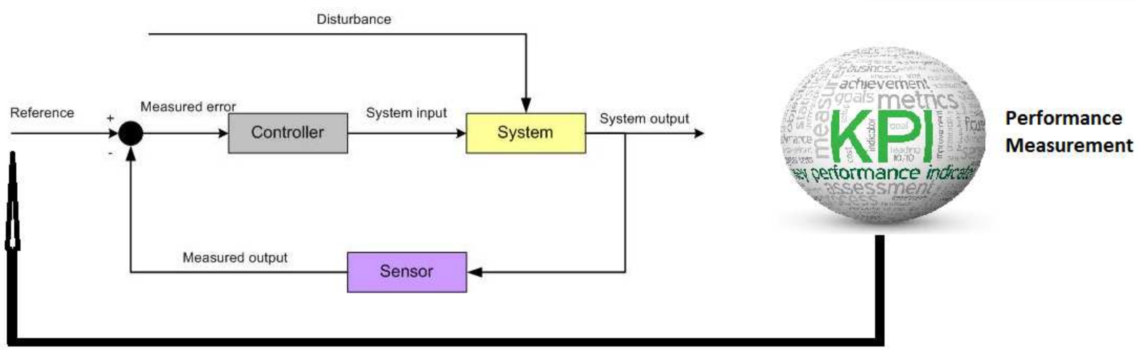

AuPiC (Auto-Pilot Controller)

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NEW CONTROL LOOP: KPI CONTROL

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What is mature
(e.g. subject to improvement)

- IT infrastructures
- Control platforms
- Databases
- Drives and motors
- Advanced Process Control (APC)
- Instrumentation
- Organisation tools
- Etc.

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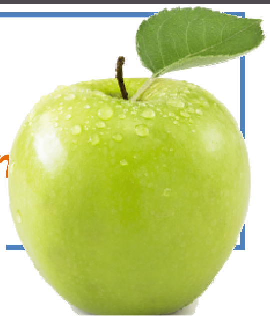
What is a challenge



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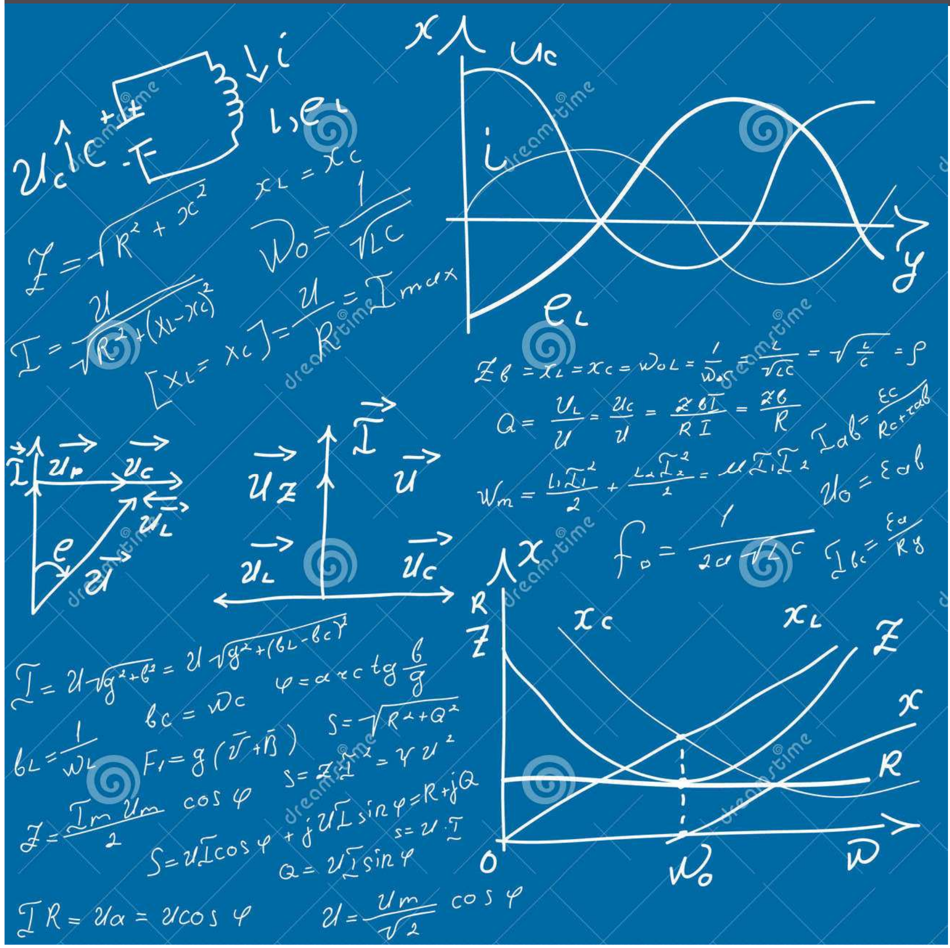
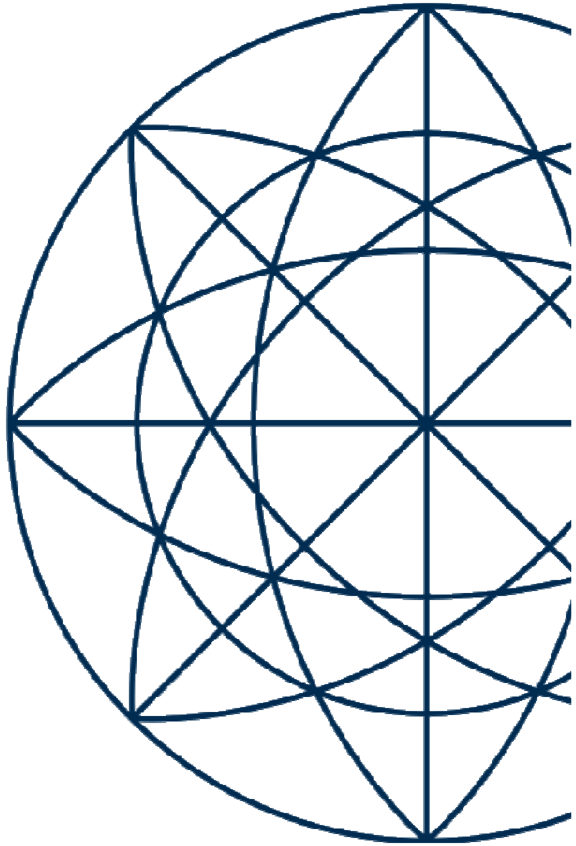
- Unsupervised learning
- Human-Machine interaction
- Formal verification
- Software auto-generation
- Safety & Situation Awareness
- Advanced Robotics

NEW CONTROL LOOP: KPI OPTIMISATION





ENLARGING THE CONTROL SCOPE

NEW CONTROL LOOP: KPI OPTIMISATION

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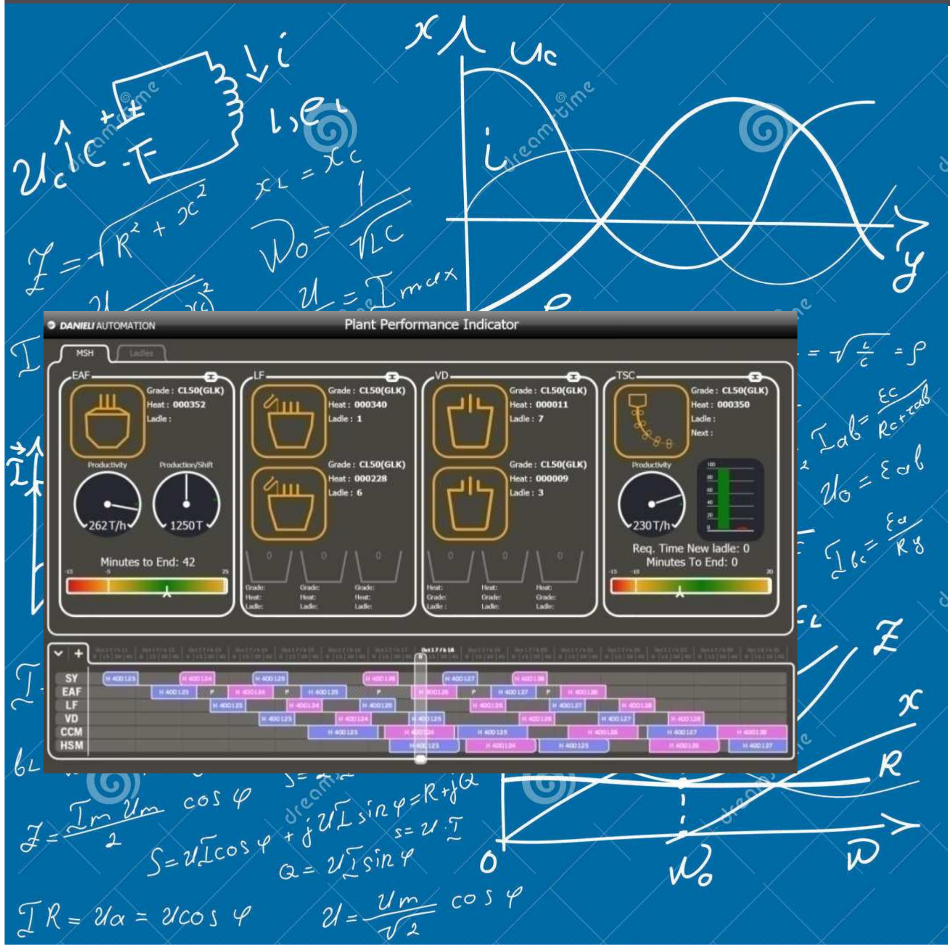

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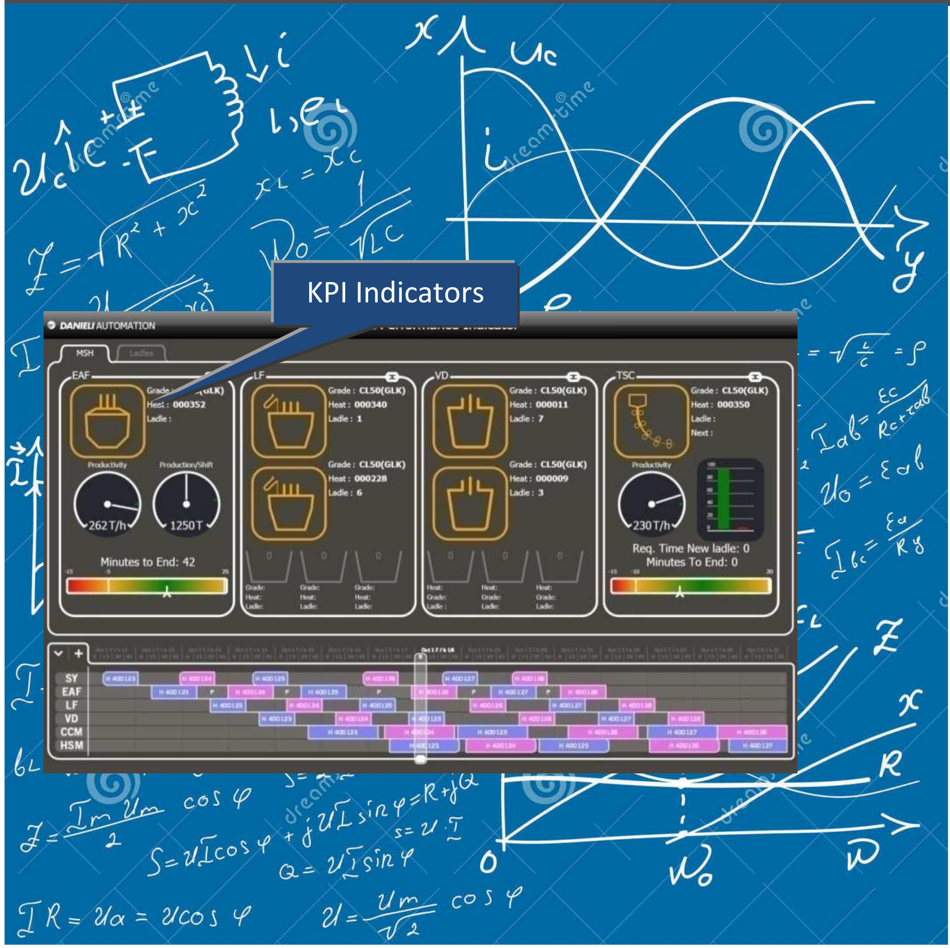

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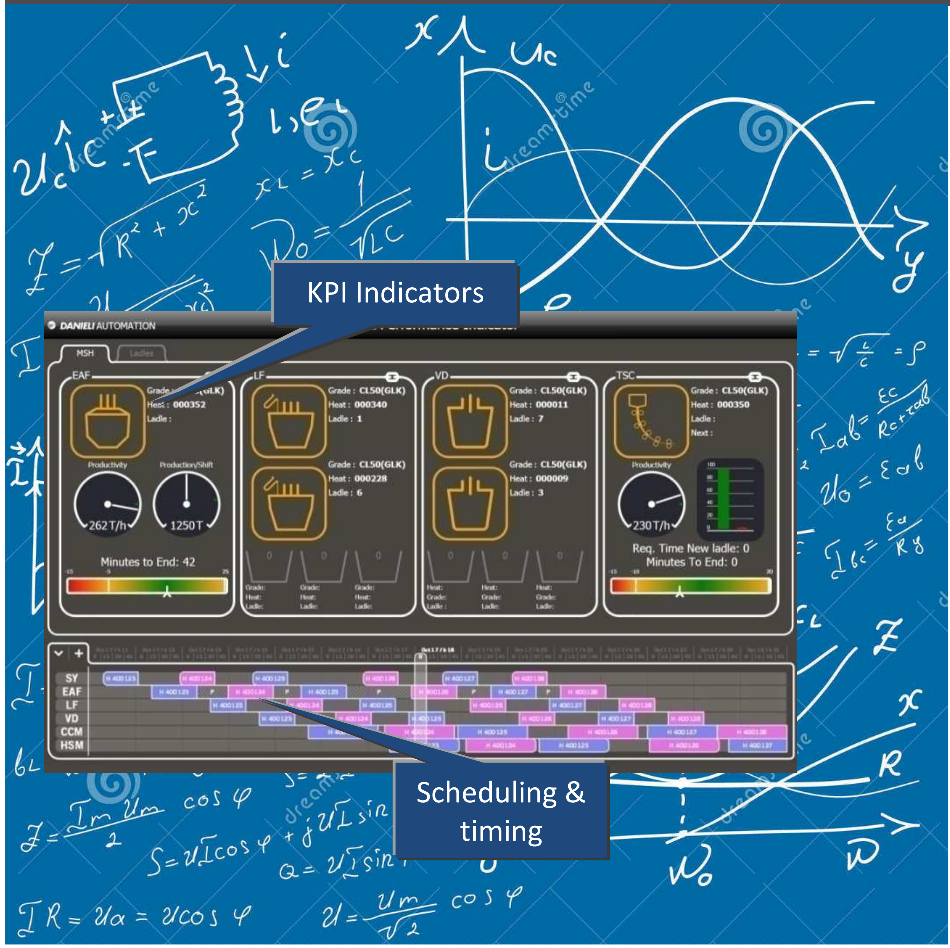

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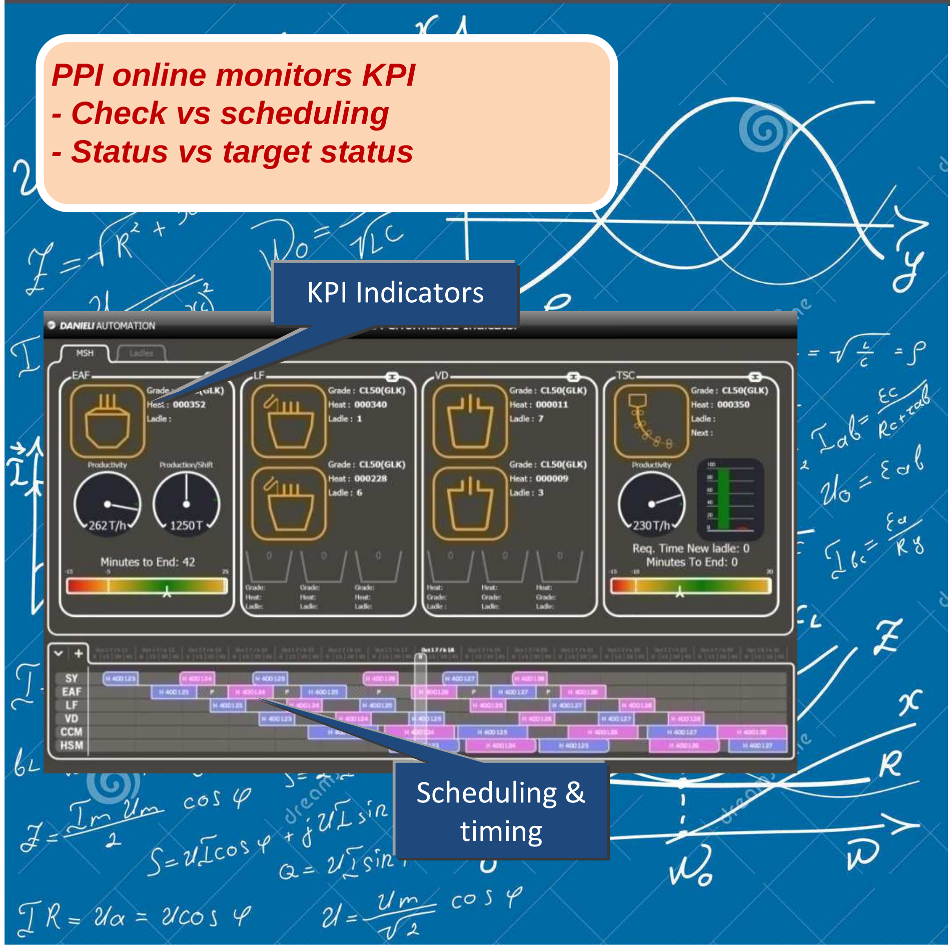
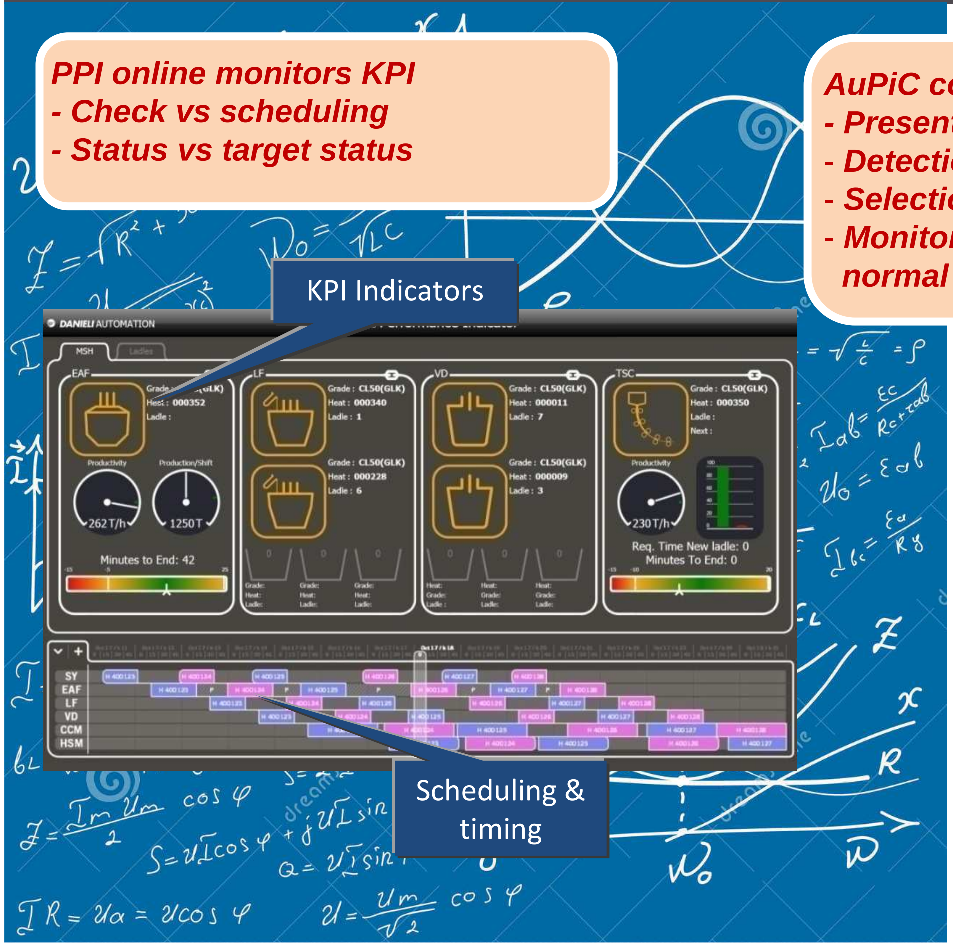
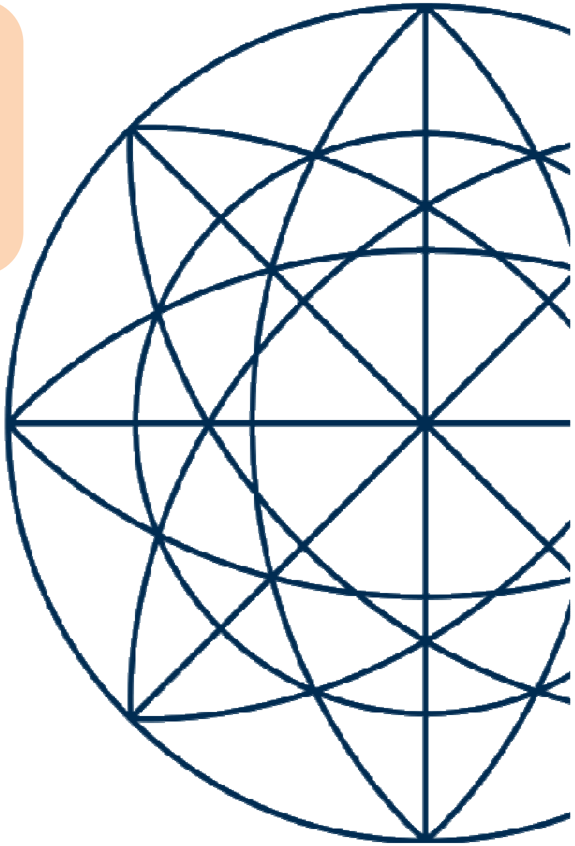


NEW CONTROL LOOP: KPI OPTIMISATION

PPI online monitors KPI
- Check vs scheduling
- Status vs target status

AuPiC contains a process model
- Presents current situation
- Detection of abnormal conditions
- Selection of counter-actions
- Monitoring of results till return to normal situation





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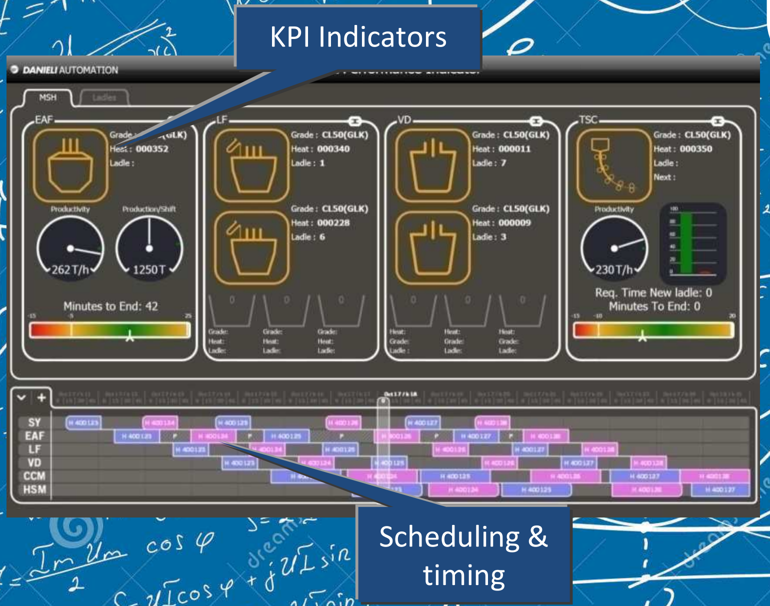

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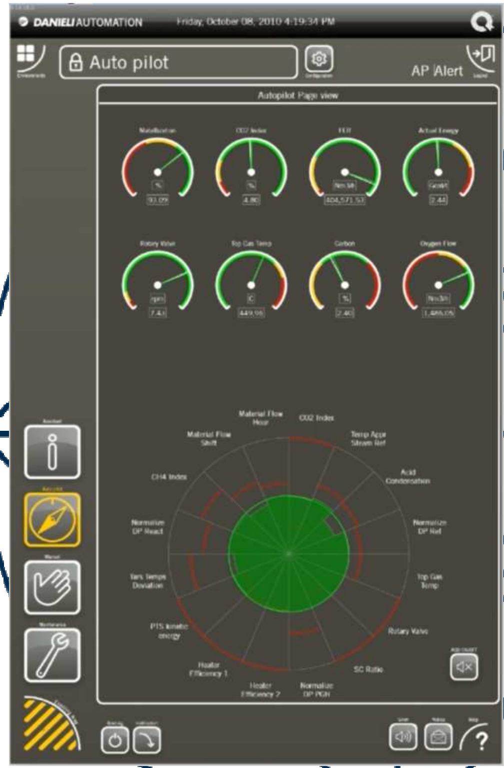

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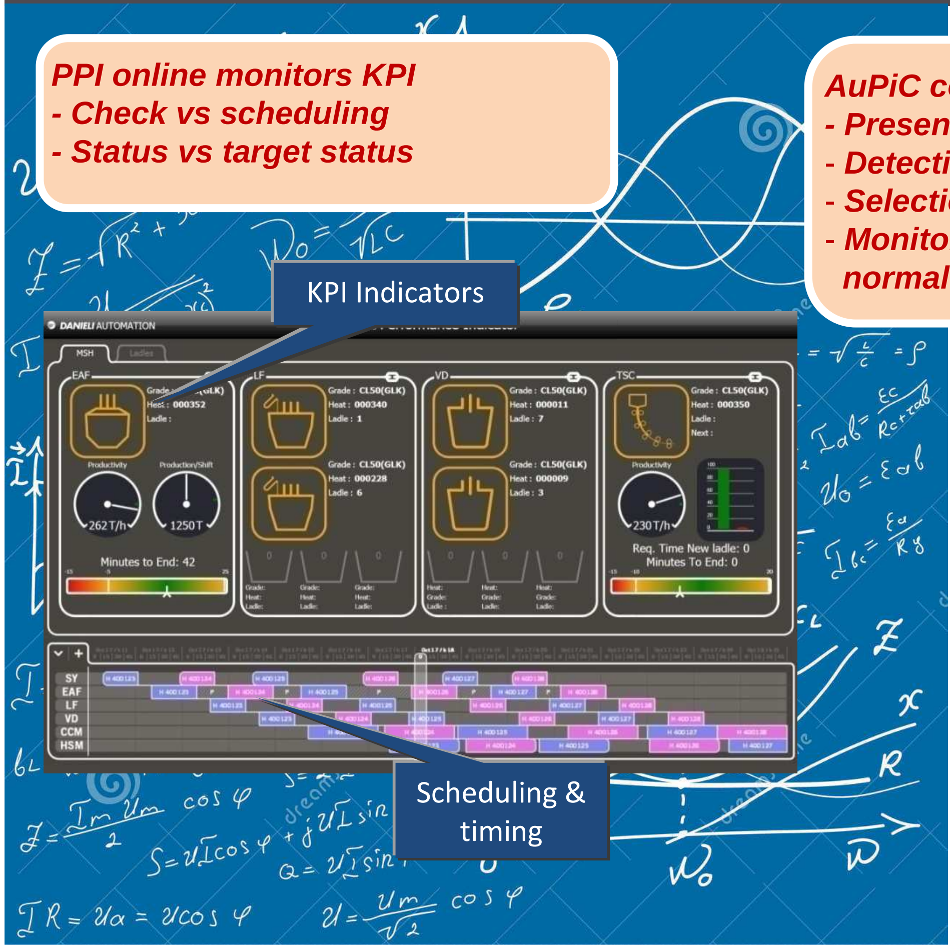

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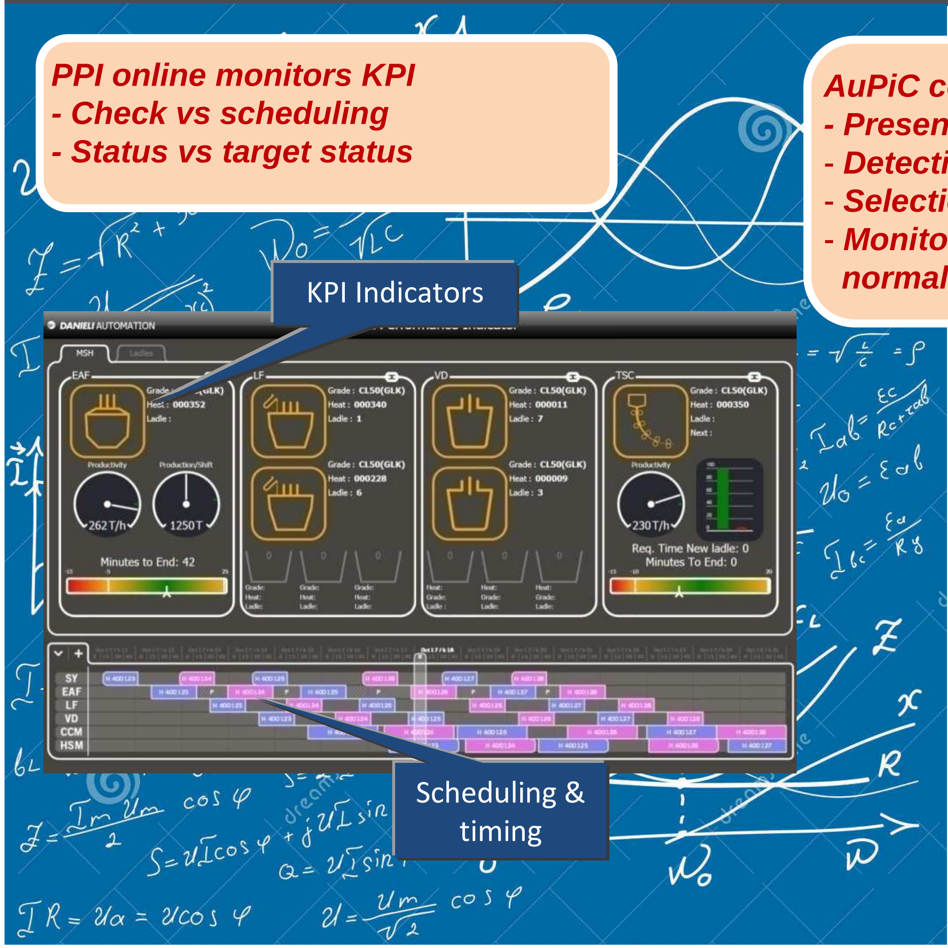

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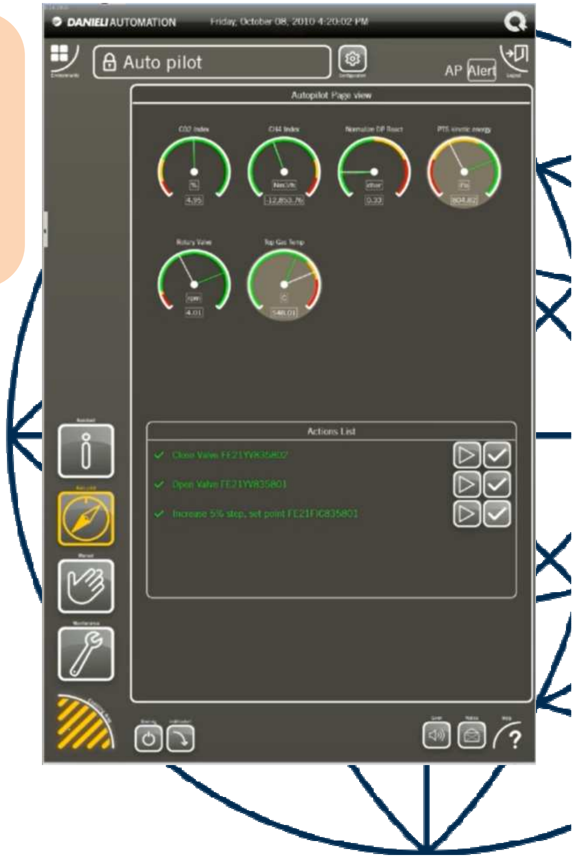

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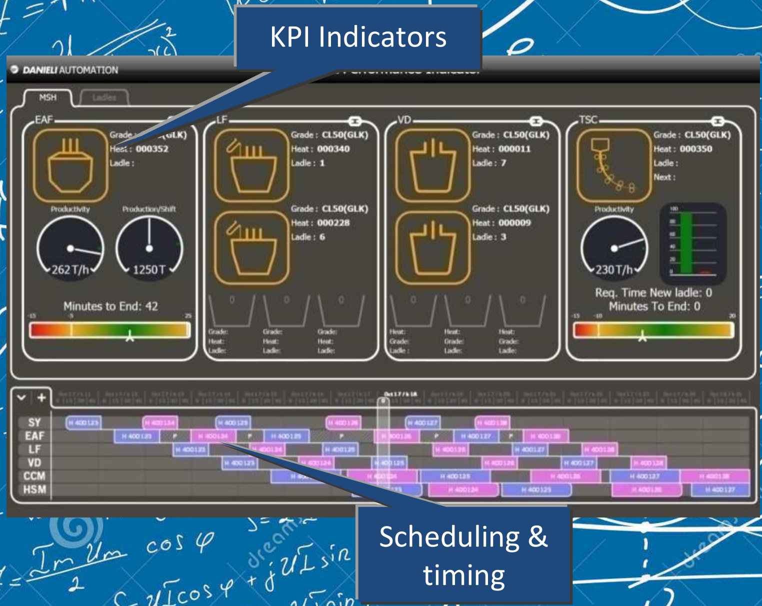

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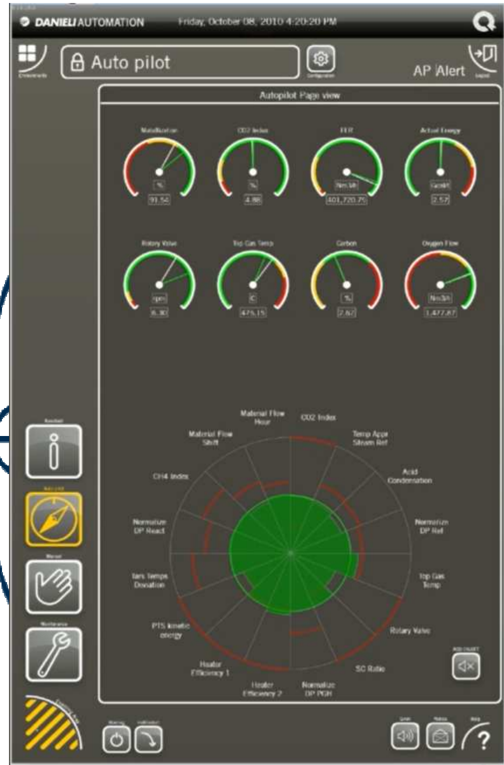

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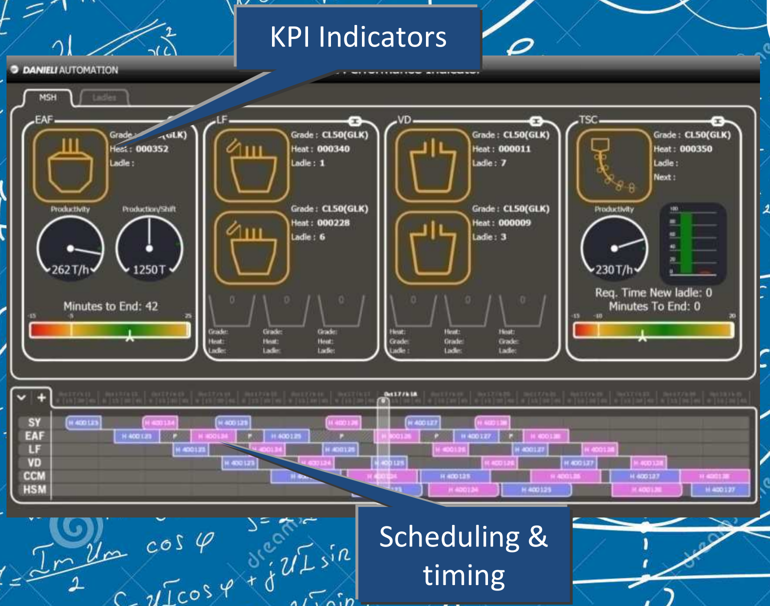

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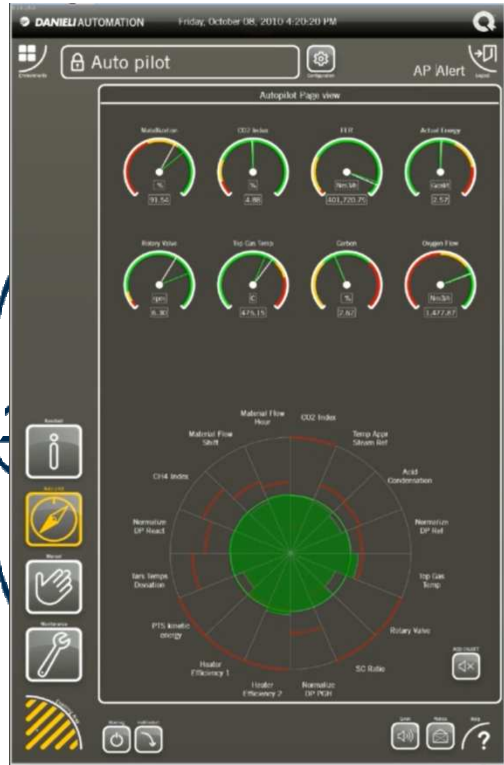
Example pickling process
Aurora, Cuzzola, Sclauzero ISA/O3NEIDA 2009



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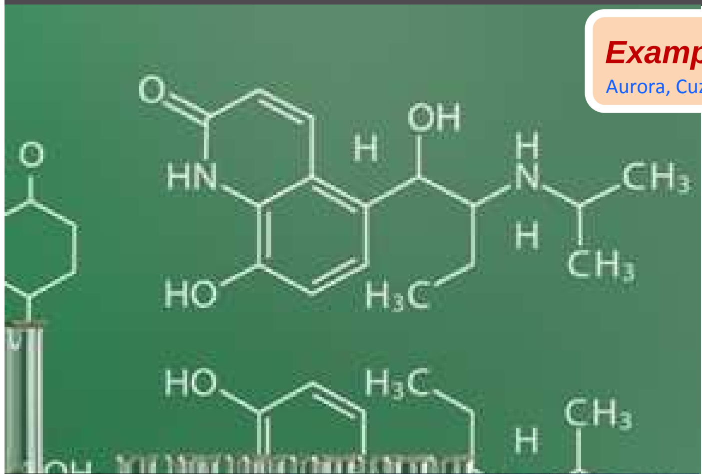

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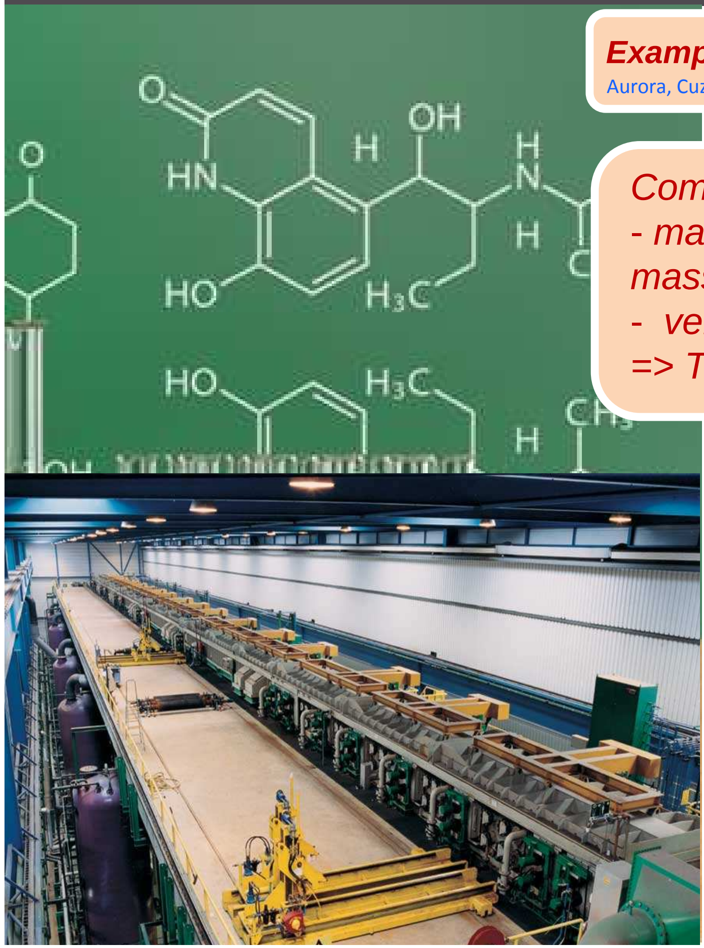

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Complexity in decision making:

*- many control variables (acid refilling, flow temperature, recirculation mass flow, **processing speed**, etc.)*

- very slow dynamics – time constant: 4 days => human cannot observe

=> The human approach is highly conservative

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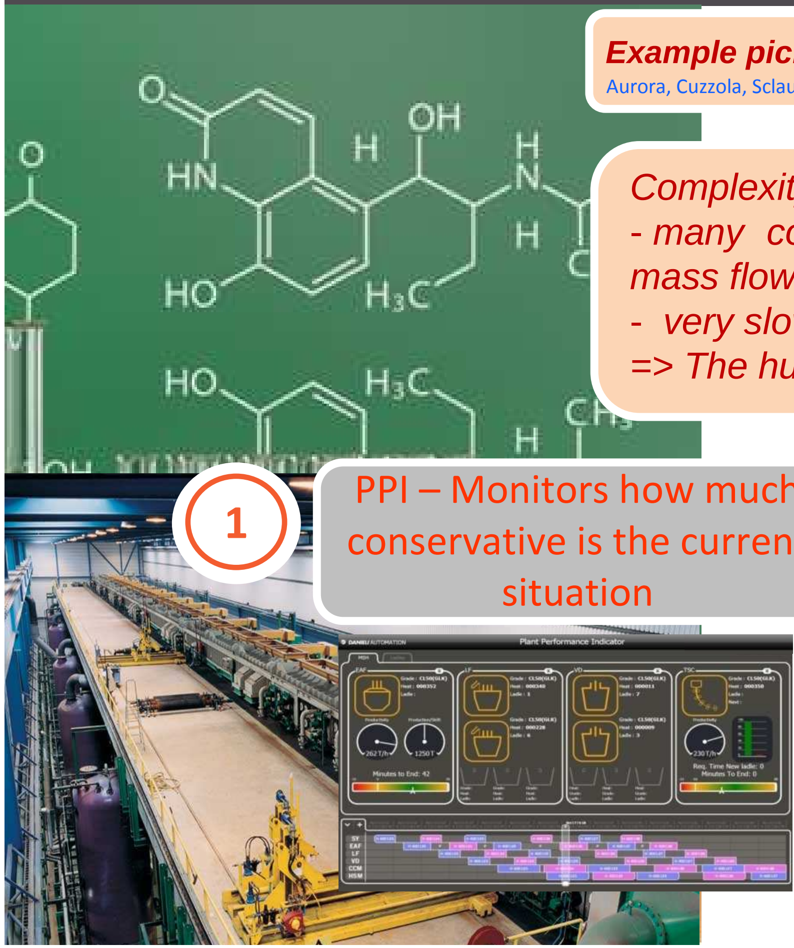

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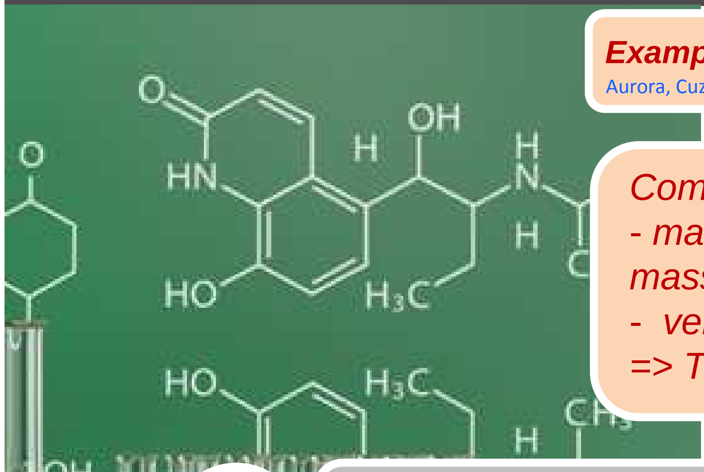
NEW CONTROL LOOP: KPI OPTIMISATION



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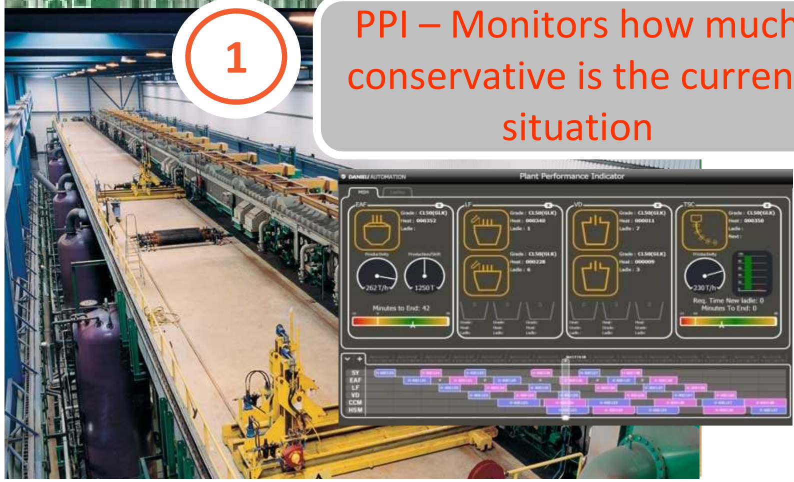

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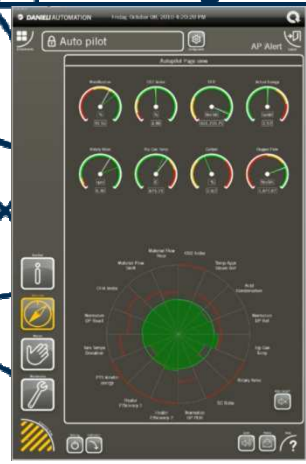

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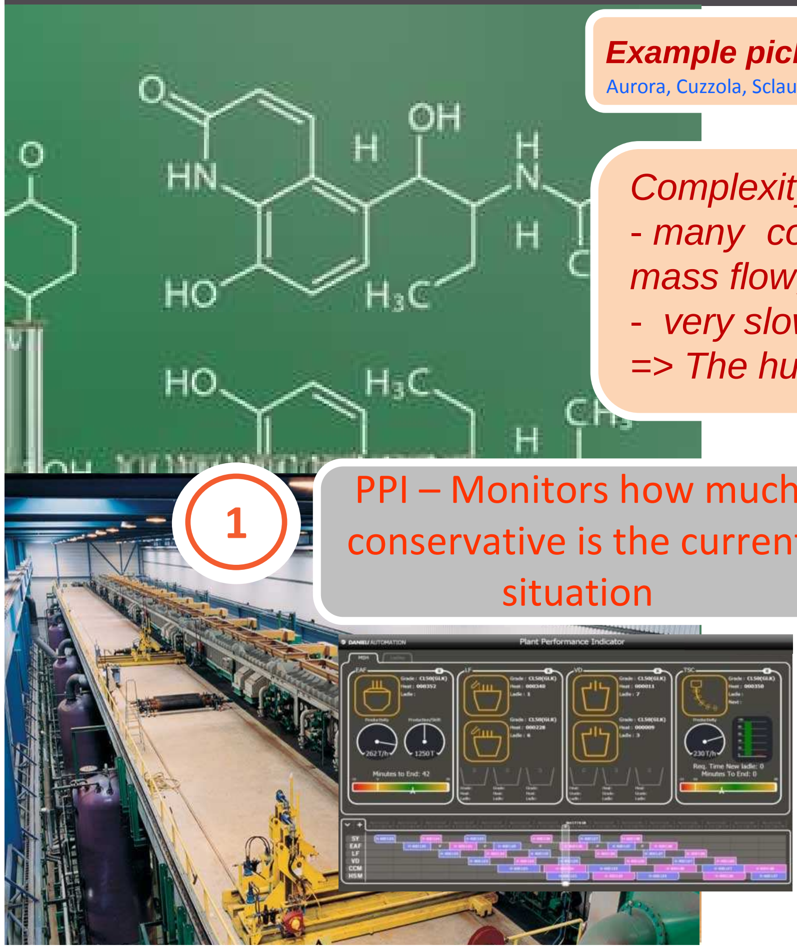

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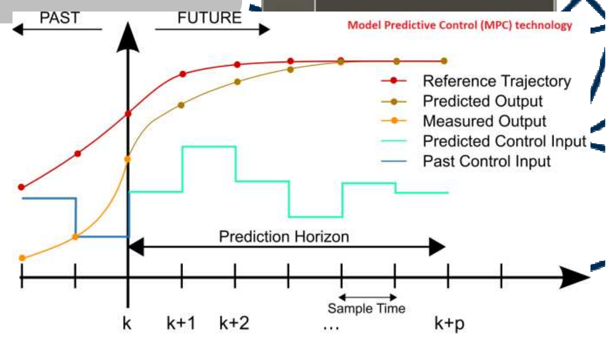

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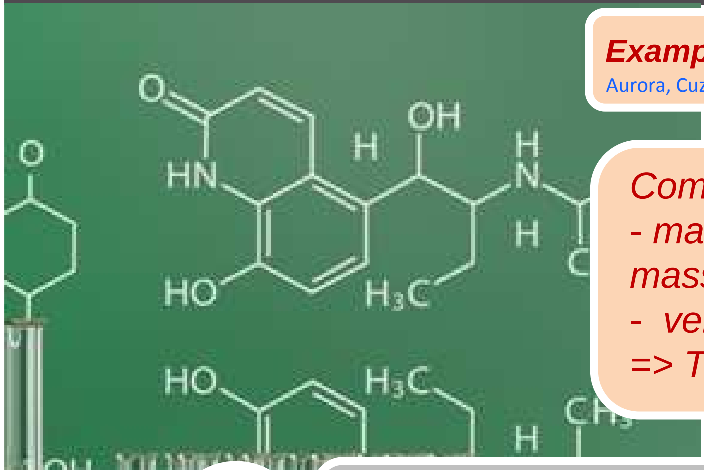

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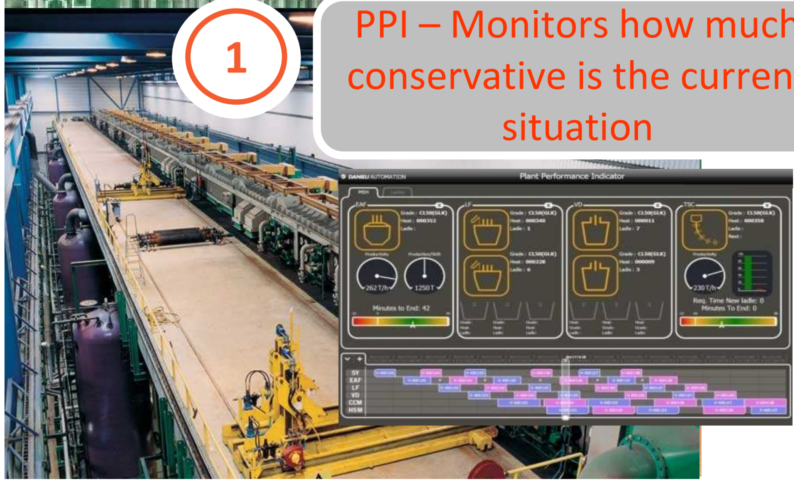
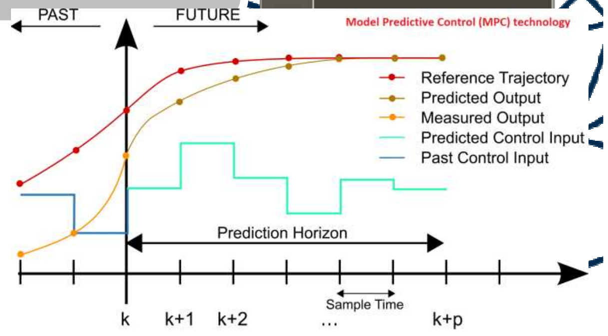


1 PPI – Monitors how much conservative is the current situation

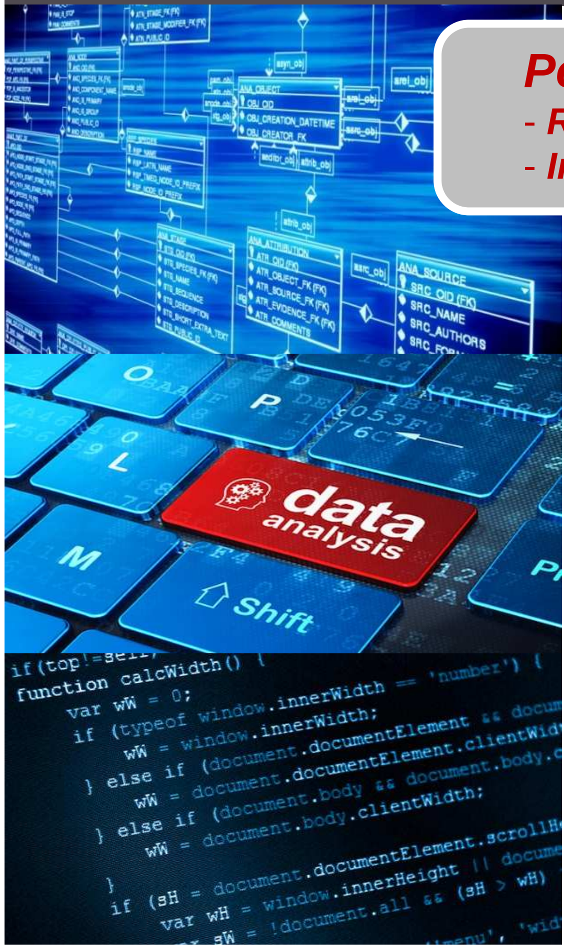
2 AuPiC – Selects the most proper control action

PPI => AuPiC:

Why material speed is so low now? An action is short term, another in long term



HUMAN DEDICATED TO HIGHER LEVEL TASKS



People further away from processes / machines closer

- ***Reduce costs / Increase safety***
- ***Increase productivity***

HUMAN DEDICATED TO HIGHER LEVEL TASKS

DANIELI

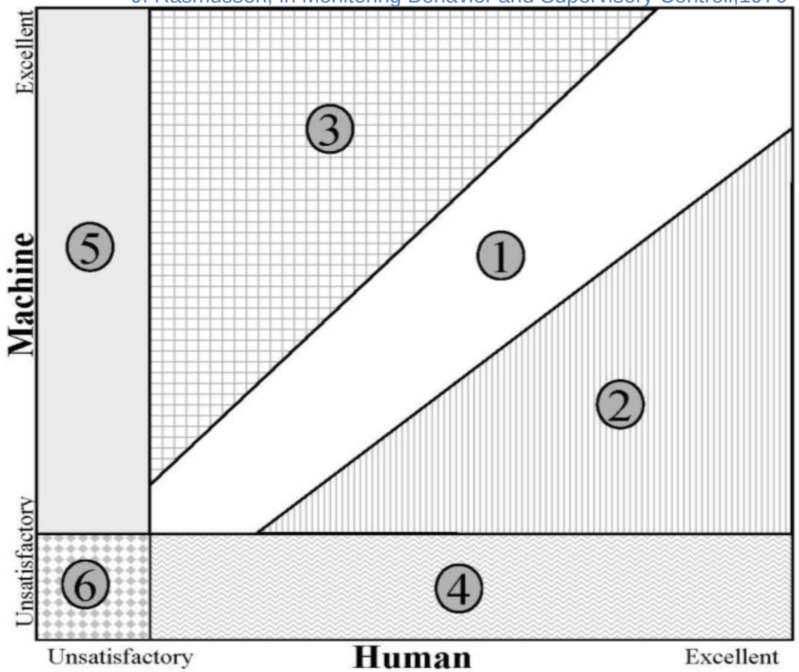
People further away from processes / machines closer
- ***Reduce costs / Increase safety***
- ***Increase productivity***

There are tasks where
- Human is the best decision maker
- or Machine prevails on human performance

*"…**uncertainty** in the world, additional human interaction is necessary to maintain satisfactory performance"*

*"…machine to prevent the operator from becoming either **too overloaded** with tasks or **too bored** due to a lack of stimulating tasks."*

J. Rasmussen, in Monitoring Behavior and Supervisory Controll,1976



HUMAN DEDICATED TO HIGHER LEVEL TASKS

People further away from processes / machines closer

- **Reduce costs / Increase safety**
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Conventional organization
In production sites

Future organization
(human monitors production)

CAPEX/OPEX OPTIMISATION

Metal industry counts a good amount of success stories in Advanced Process Control (APC)

Samad, Annaswamy, IEEE CSS 2014

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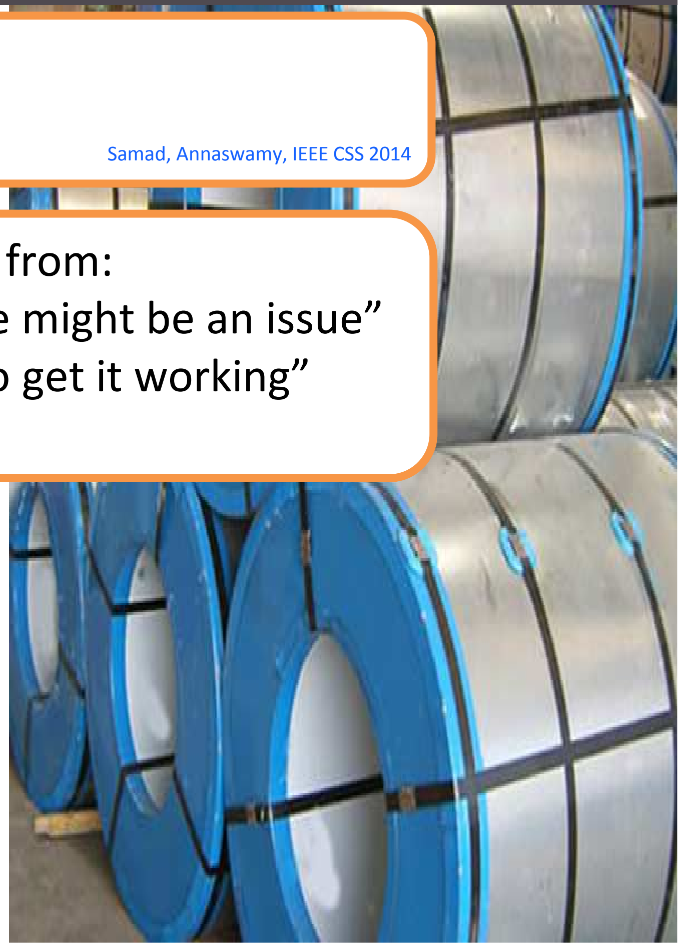
Samad, Annaswamy, IEEE CSS 2014

Resistance to introduction of advanced solutions can come from:

end user => “when I will be alone its maintenance might be an issue”

commissioning staff => “I will not be able alone to get it working”

Two point of views for the same problem...



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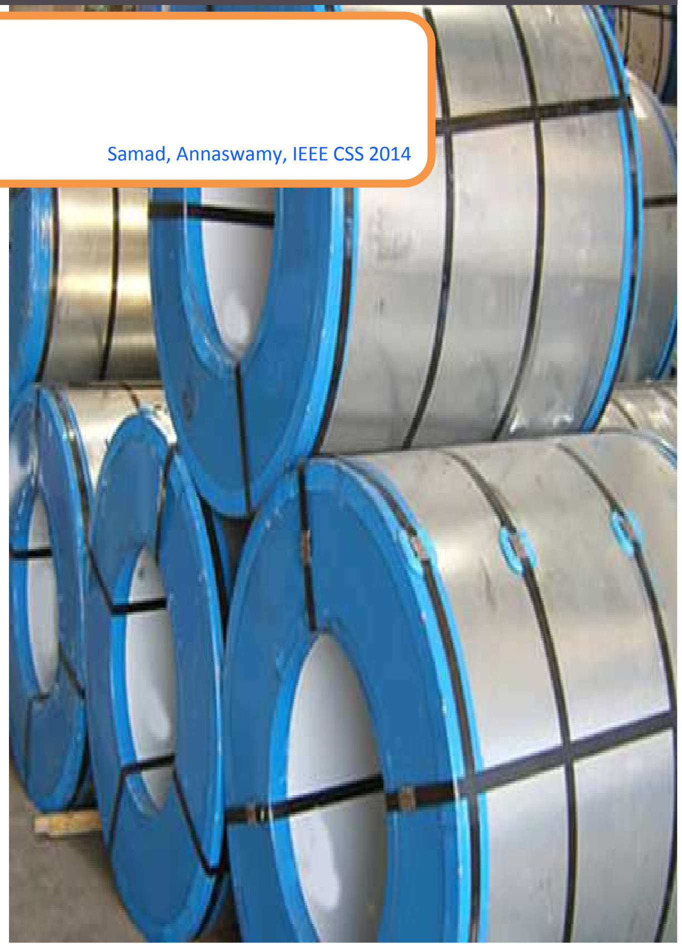

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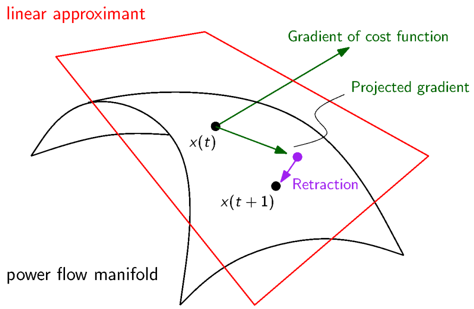
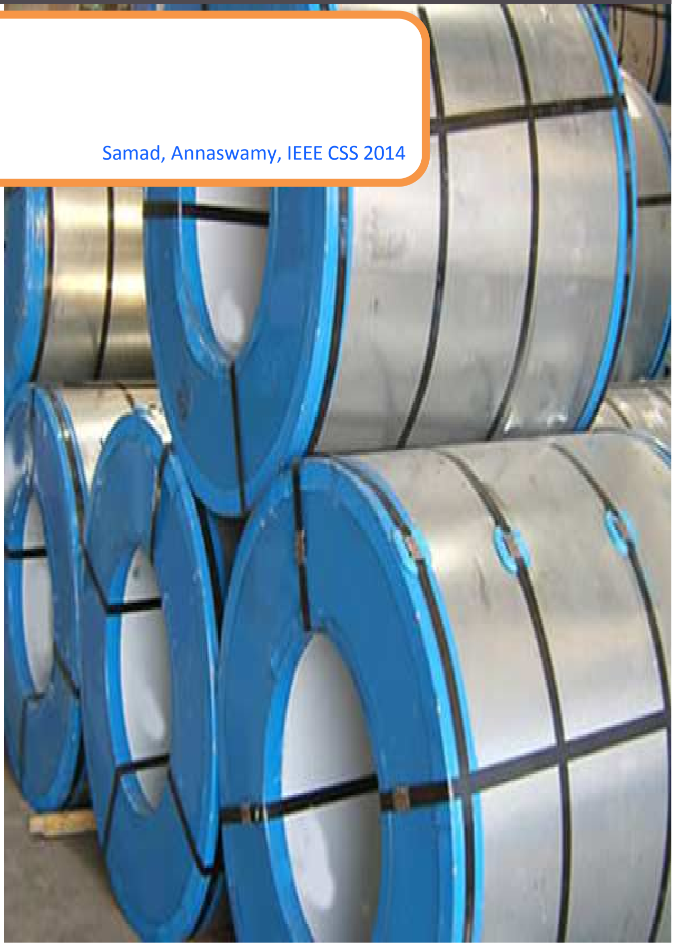


Traditional APC is statically implemented
- High degree of customisation
- High level of competences required for commissioning
- Commissioning staff / end user will get advantages/(dis) of the more complex solution



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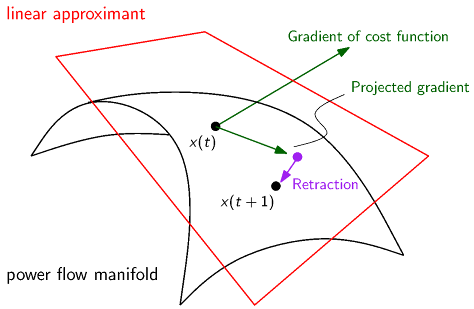

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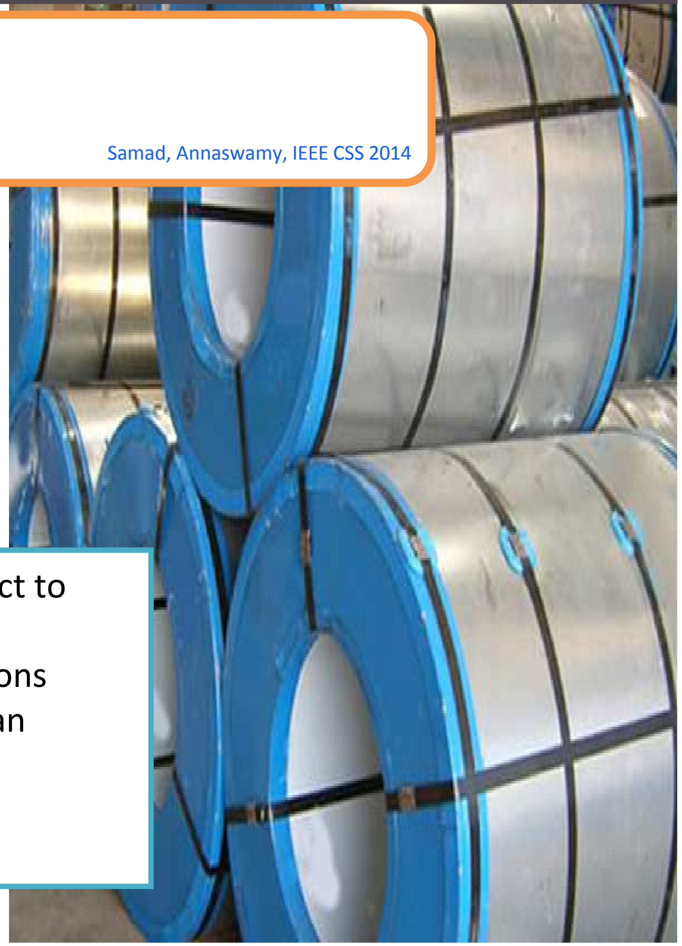
"New generation APC" is is subject to auto-adjusting
- Able to face unexpected situations
- Comprehensible / near to human approach
-Self-commissioned



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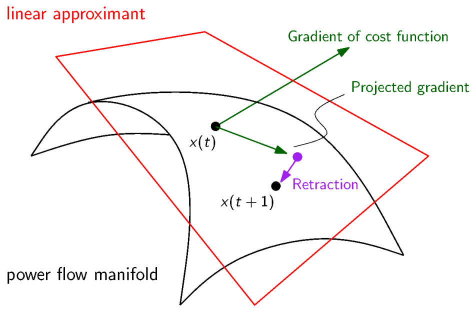

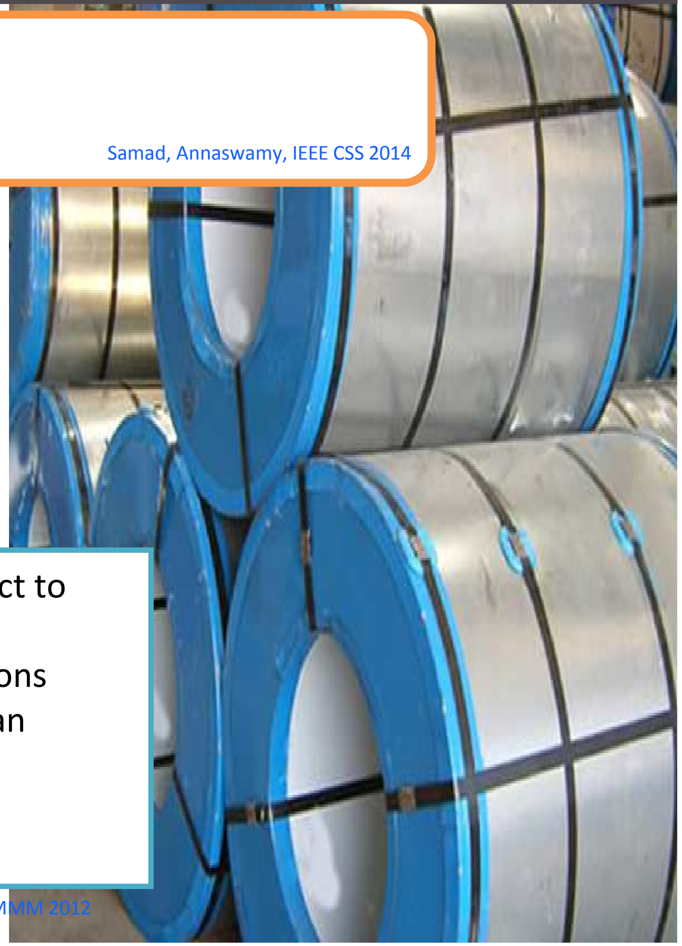

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Cuzzola, Aurora, Sclauzero IFAC MMM 2012

FROM PRODUCT TO SERVICE:
WIN-WIN APPROACH

PARTNERSHIP INSTEAD OF SELLING

DANIELI

Data elaboration at Danieli HQ

Model technology library sharing with plant

PLANT

Aurora, Cuzzola IEEE MIPRO 2016

VPN LINK

DANIELI

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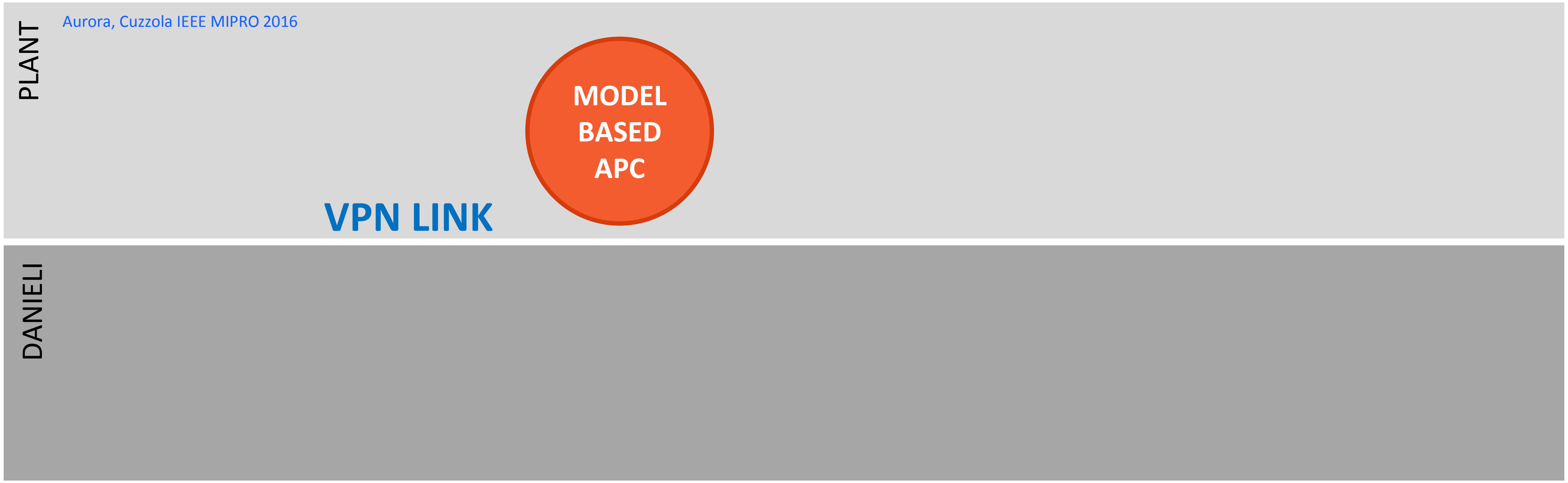

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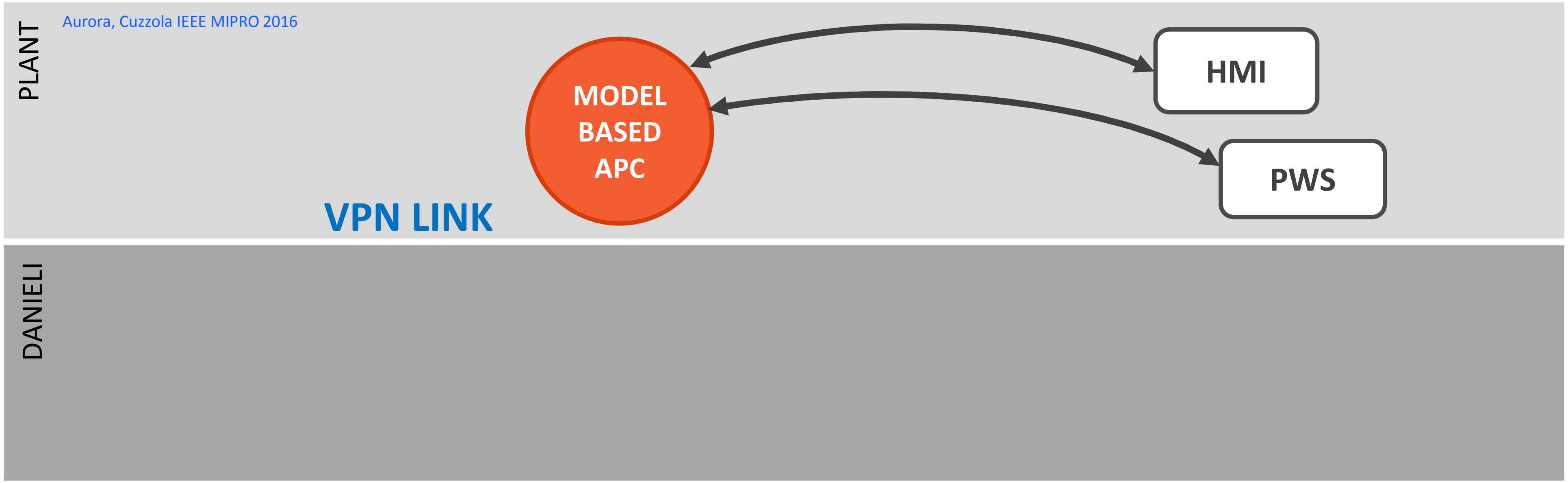

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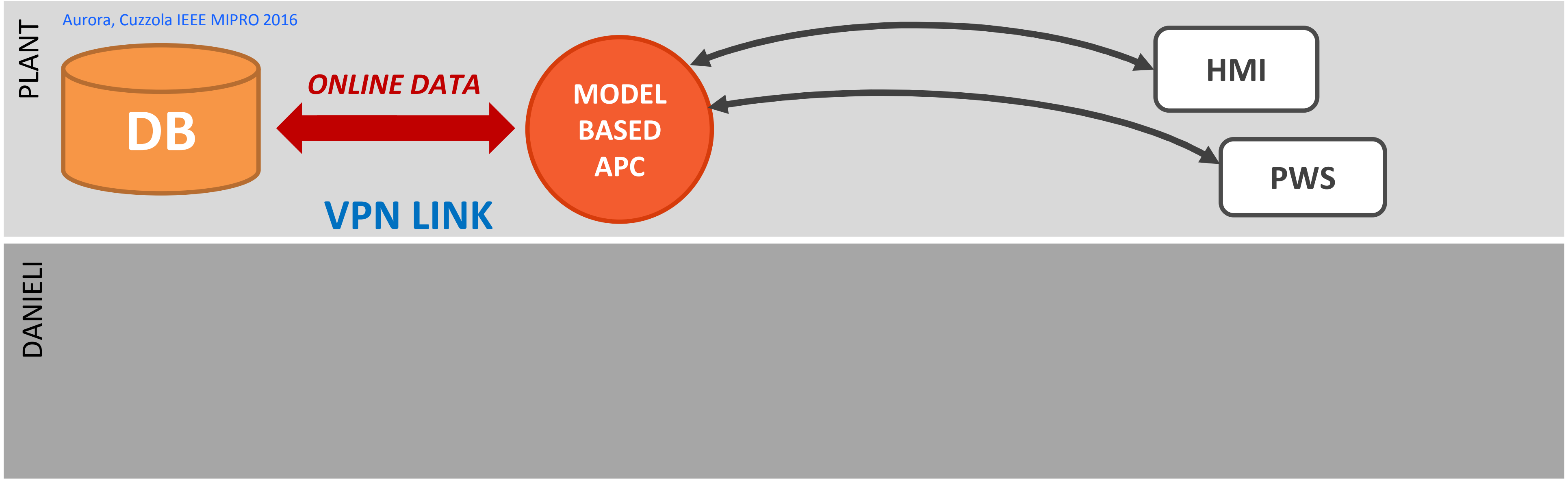

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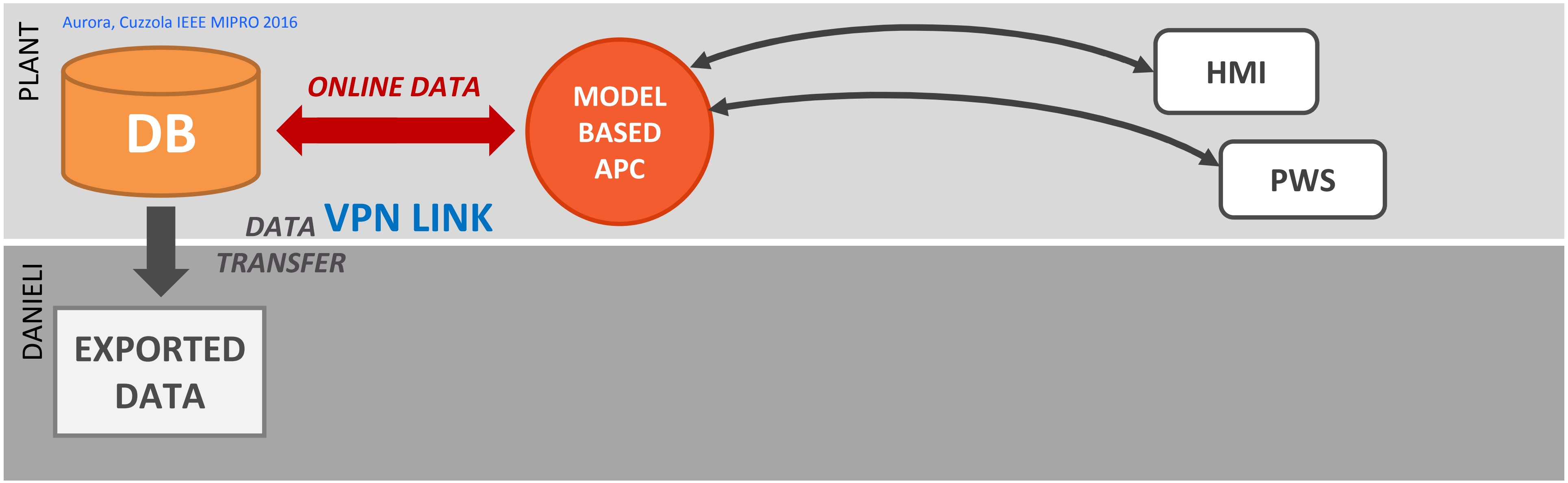

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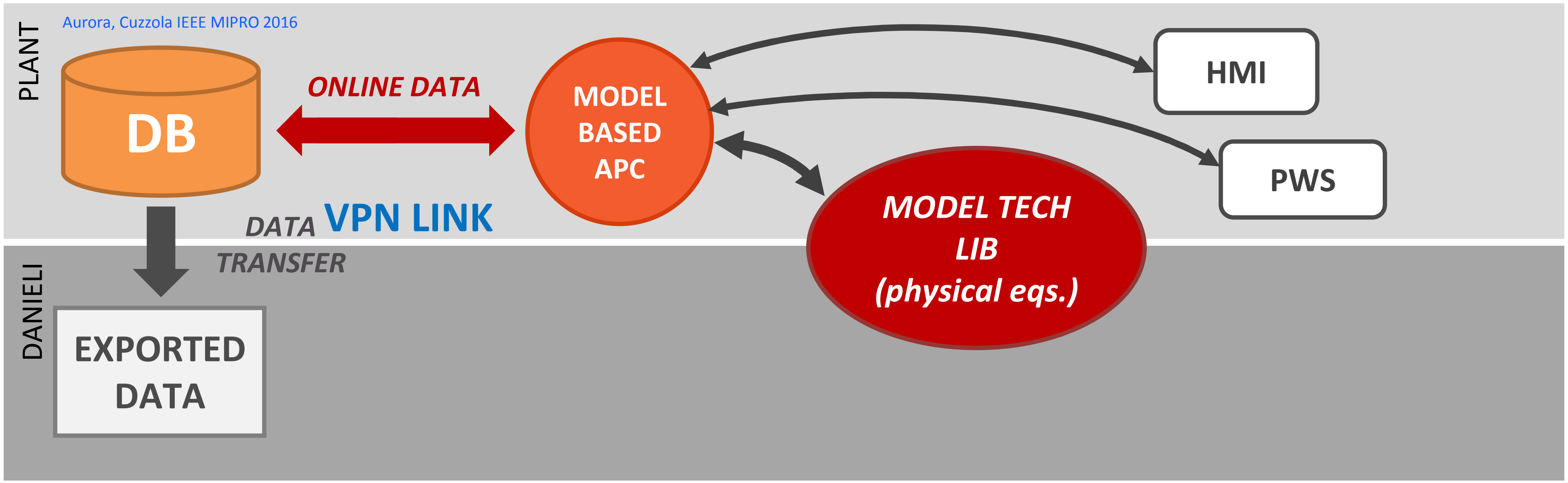

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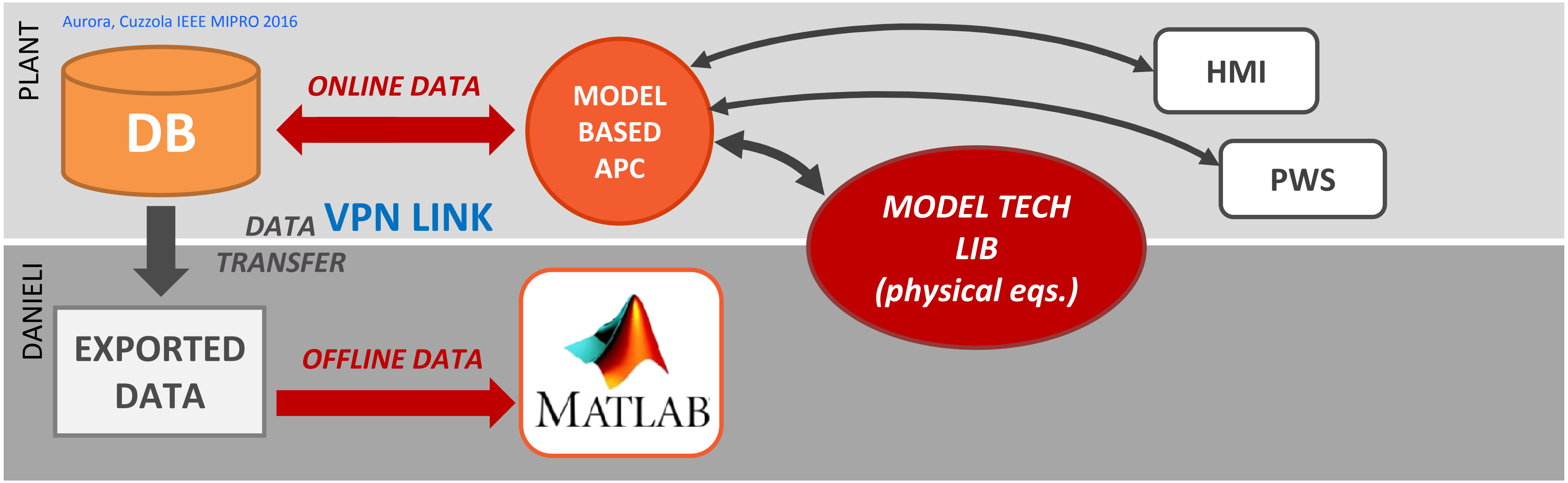

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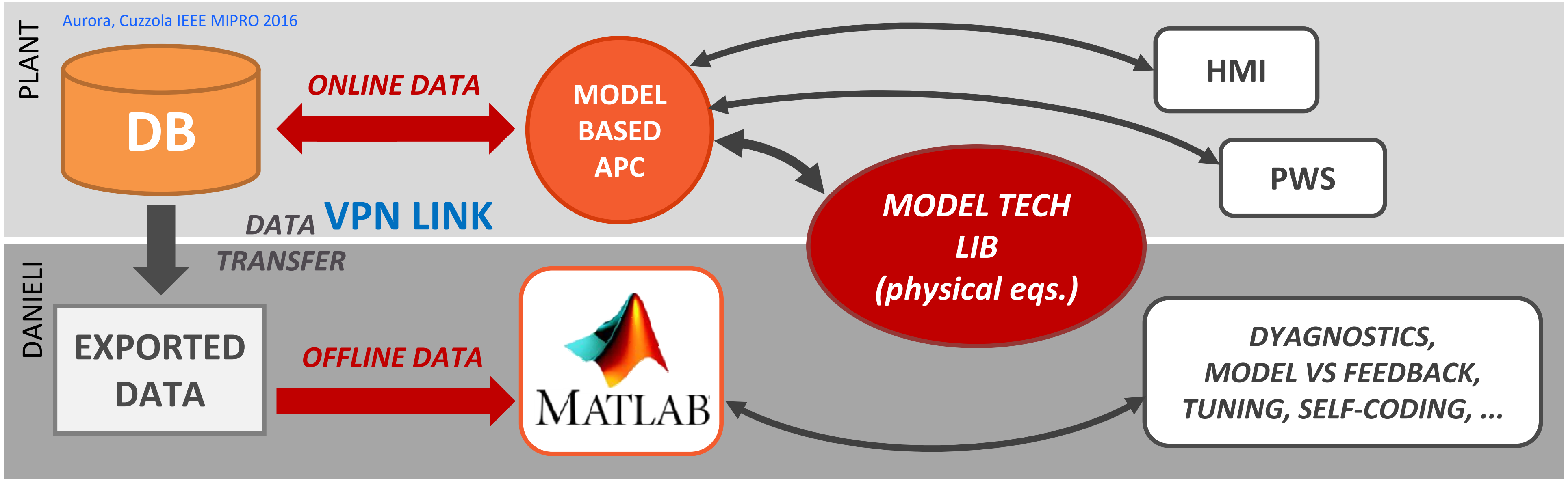

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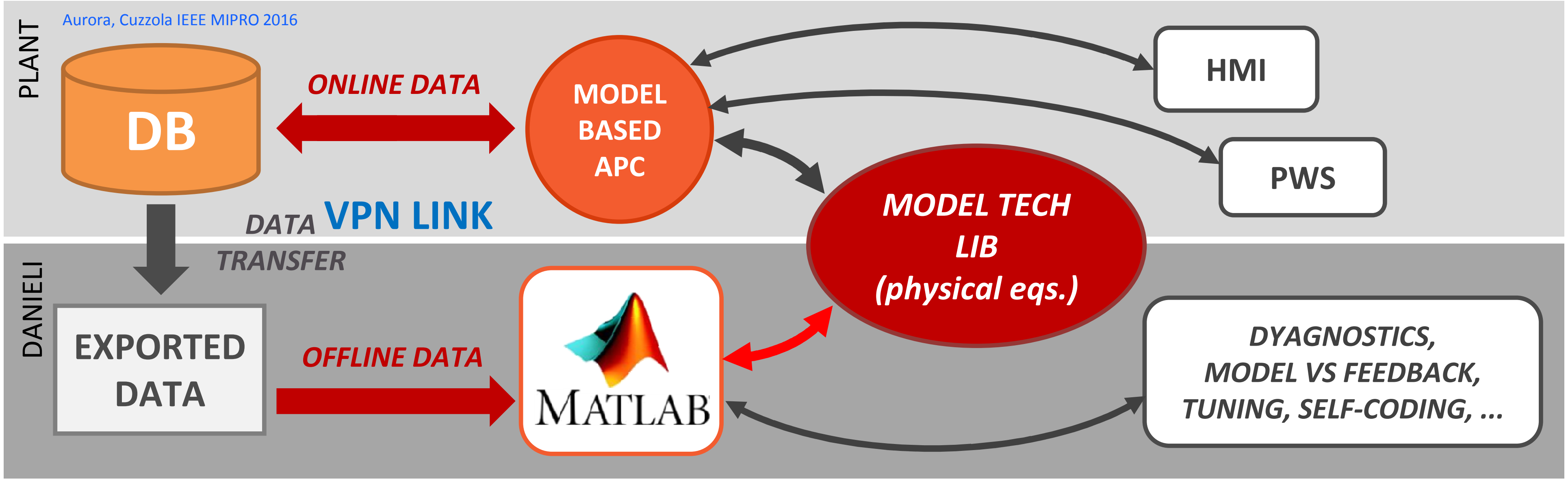

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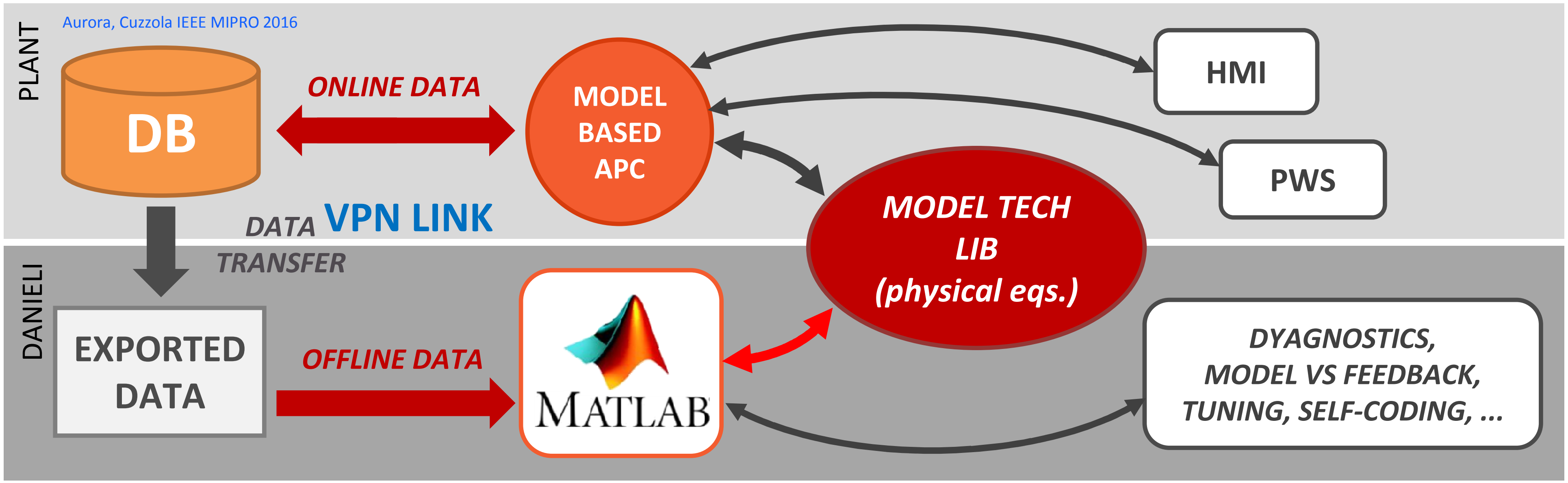

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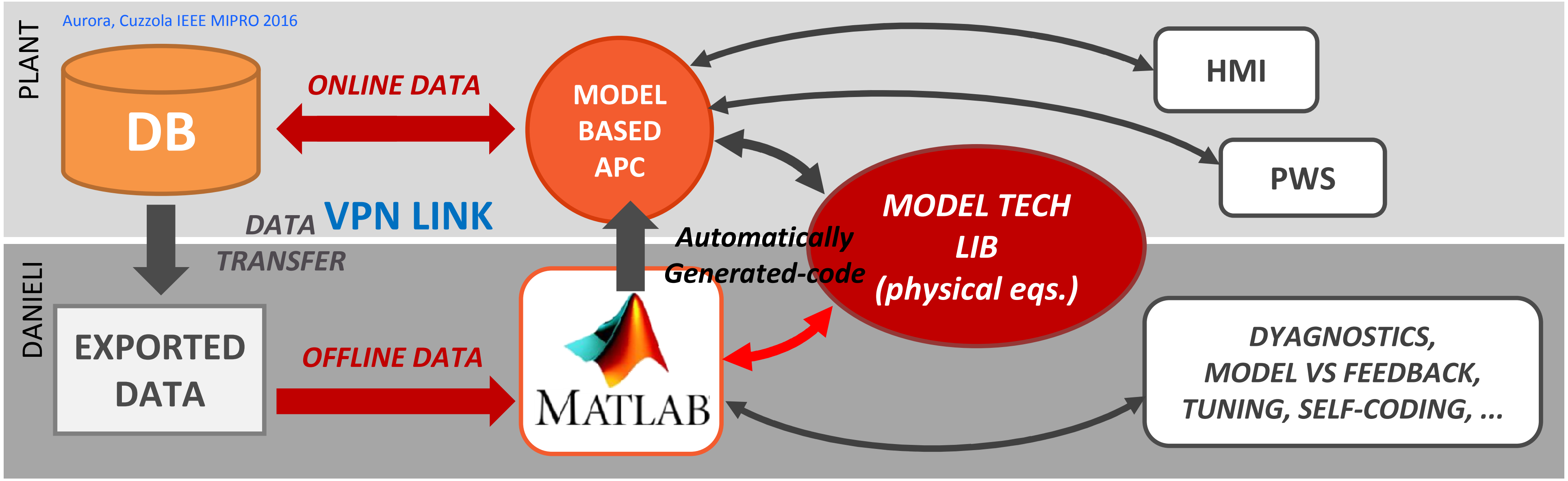

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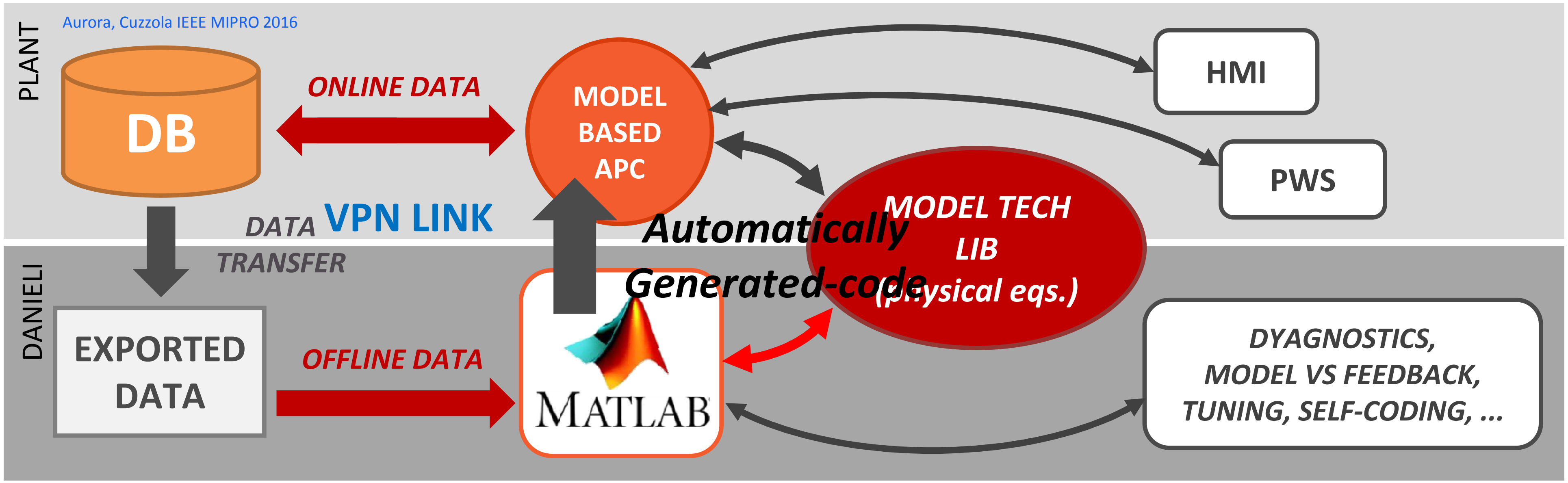


ADVANCED SERVICES

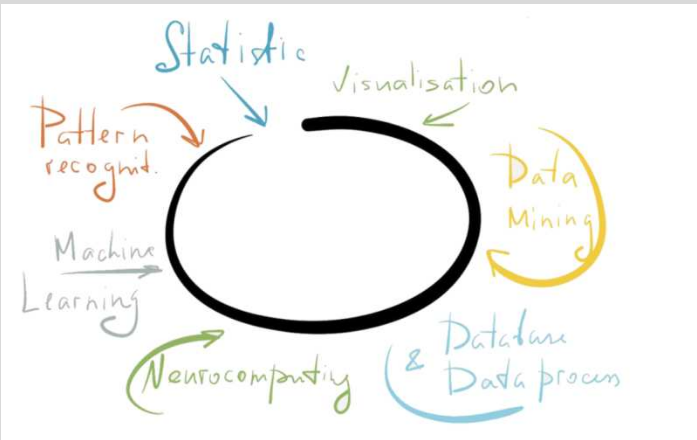
Advanced analysis methods:
executed in background and remotely

Plant operation feedbacks of large complex

LOAD

STORE

ELABORATED FEEDBACK DATA INTO DATABASE



ADVANCED SERVICES

Advanced analysis methods:
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STORE

Process unsupervised monitoring (quality monitoring/latent fault detection/funct. extension/...)

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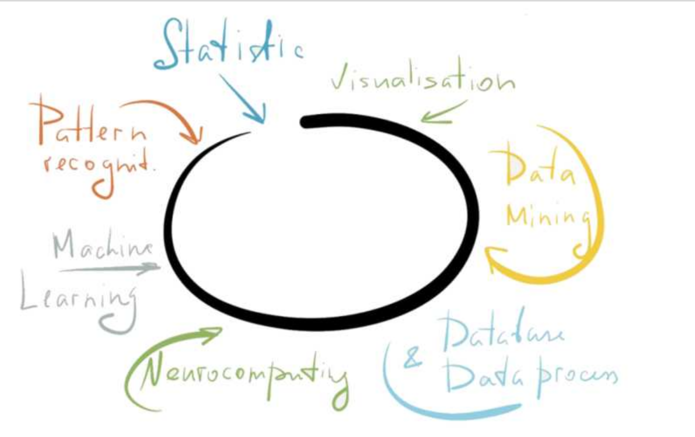
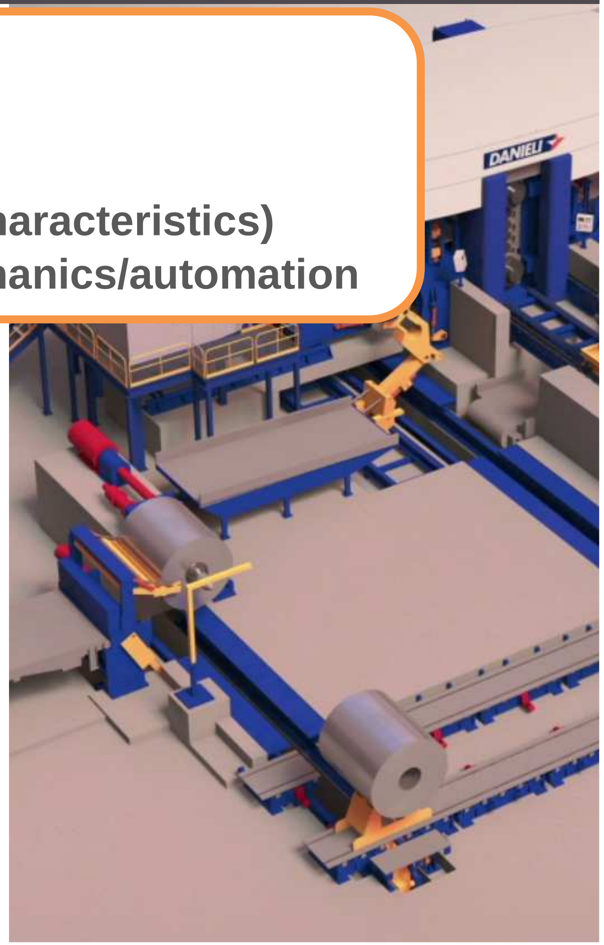


MECHANICS AND AUTOMATION CO-DESIGN

Complexity in process design:

- **process needs a *fast* evolution**
- **performance is to be evaluated in advance**
- **superposition of other constraints (e.g. sensors characteristics)**

=> Process design is more and more a synergetic issue mechanics/automation



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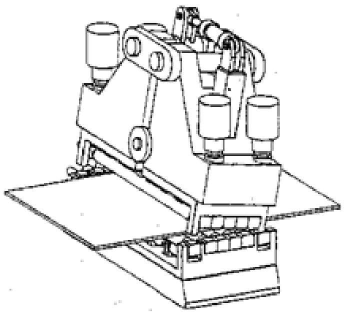
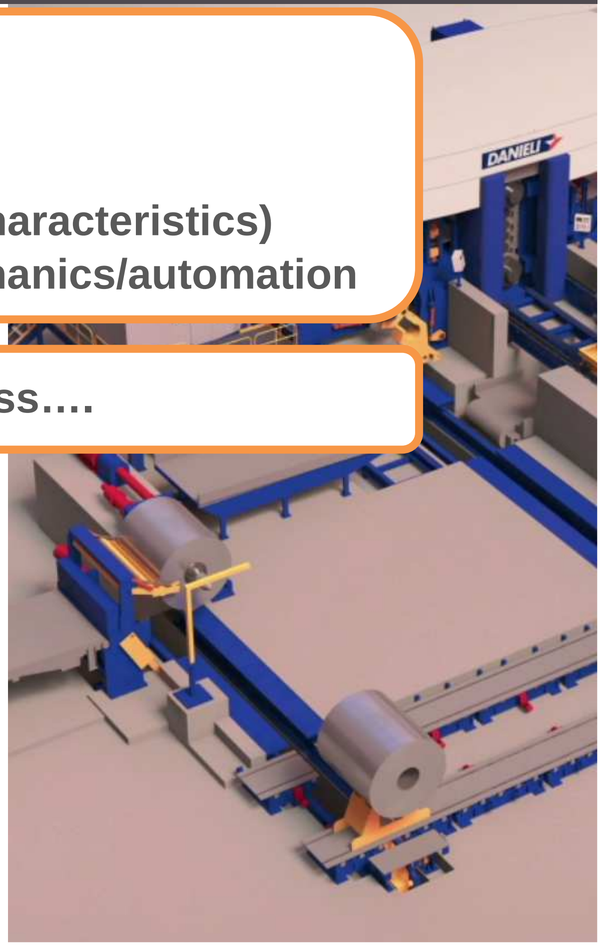


7 actuators



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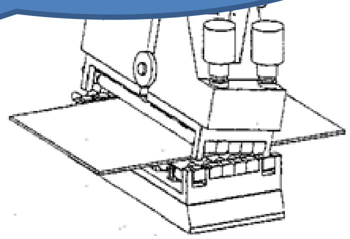

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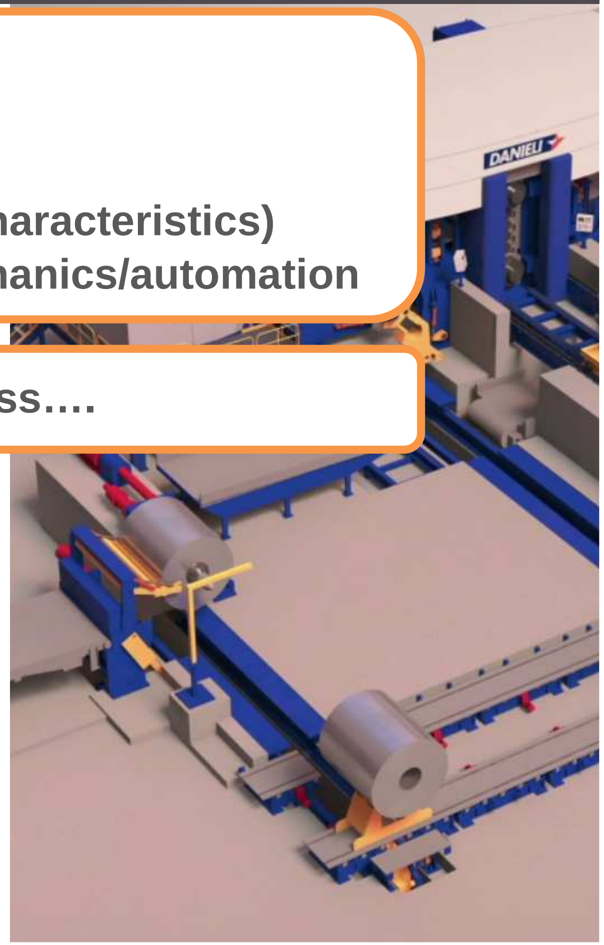

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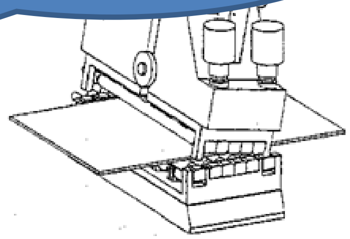

... But now the levellers are very different

7 actuators

MECHANICS AND AUTOMATION CO-DESIGN

DANIELI

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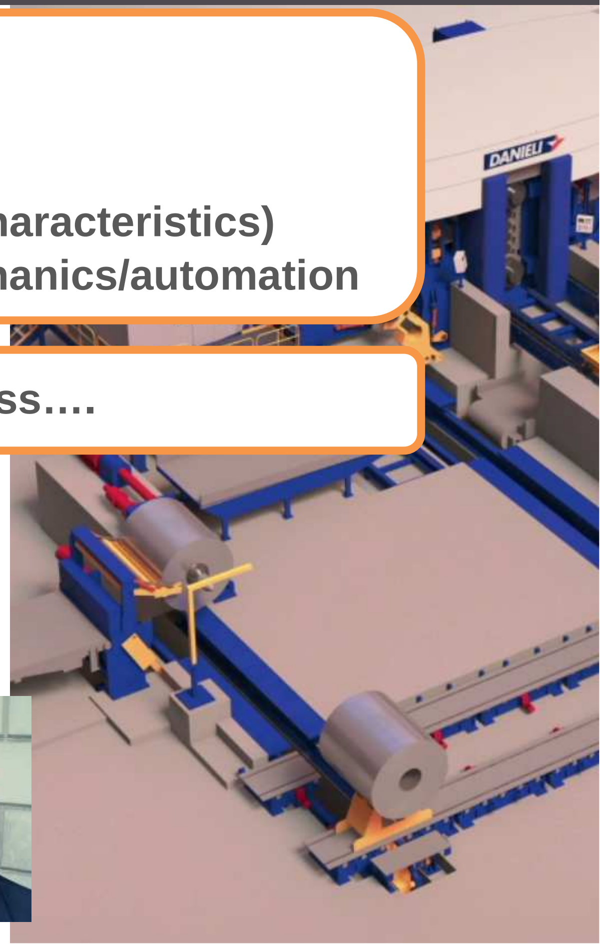

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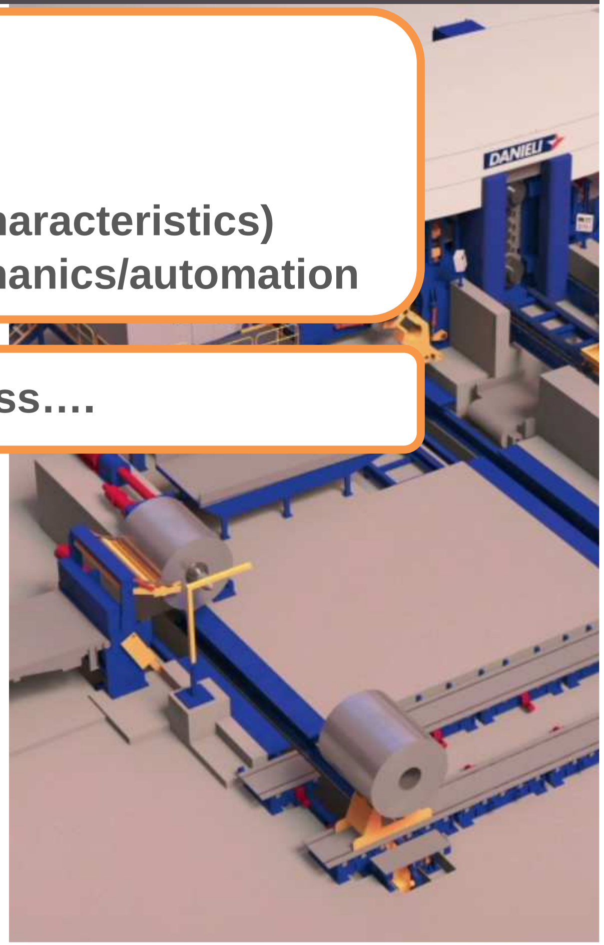

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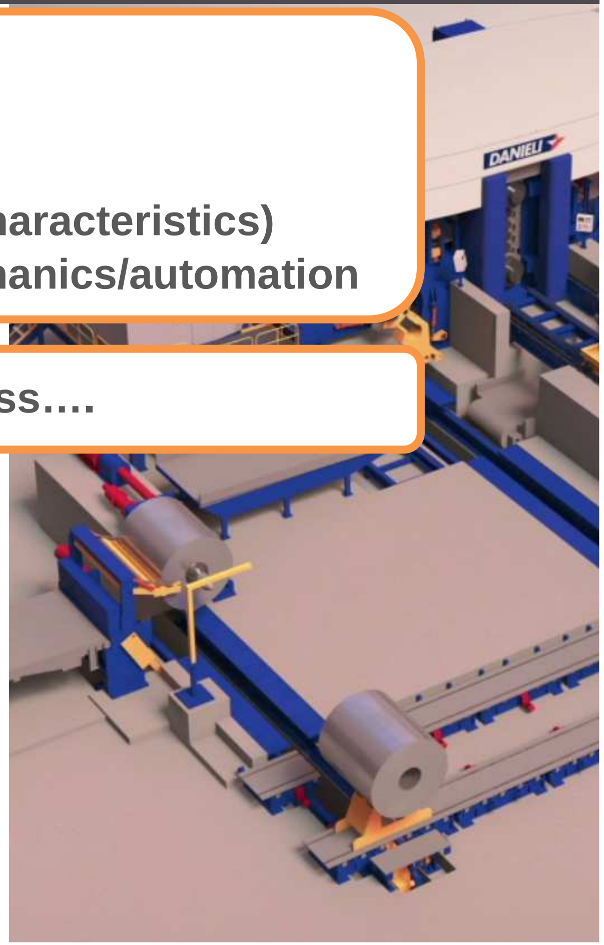

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18-20 actuators

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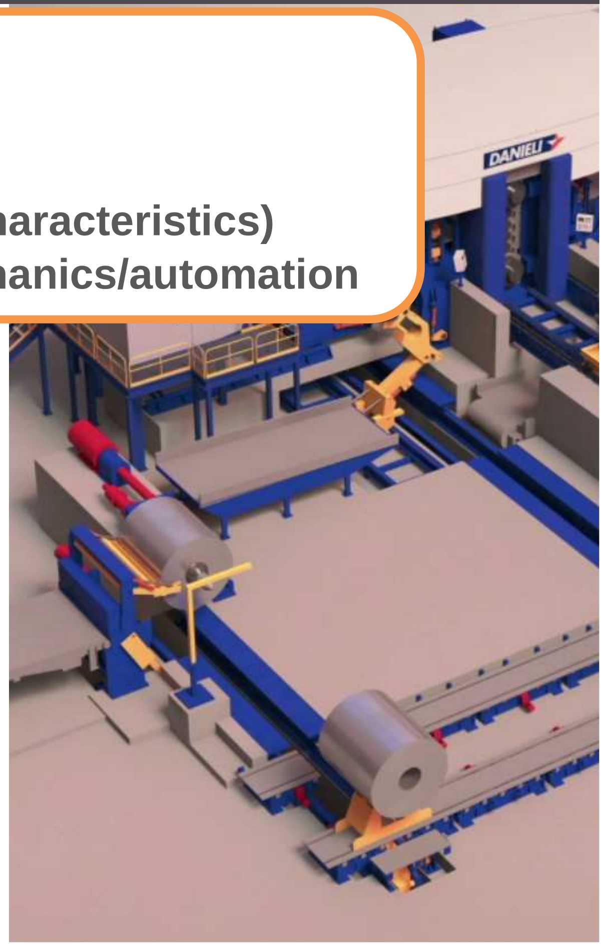

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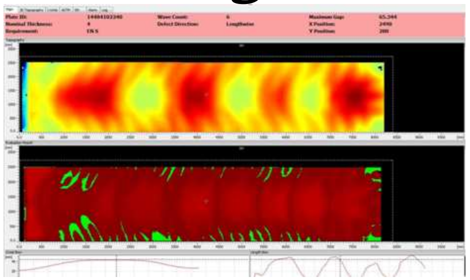
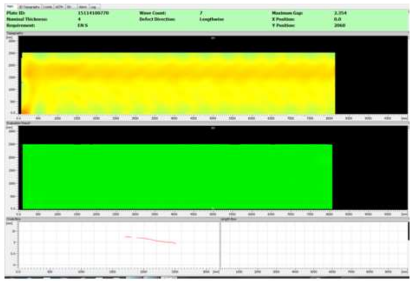
Incoming material



Target material



18-20 actuators

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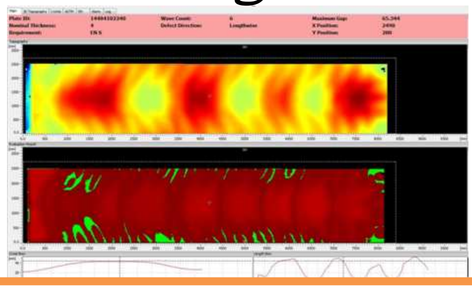

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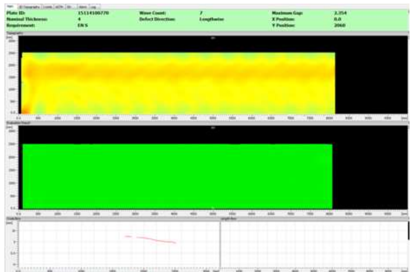

The control is more complex => The process design starts from:

- computing capability in automation
- mechanical potentialities / quality targets
- new available sensors

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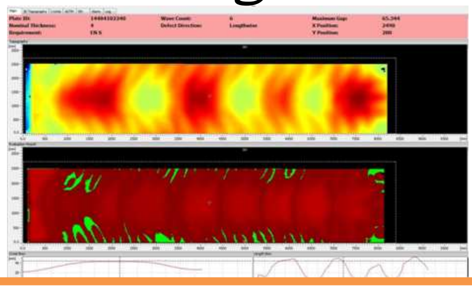

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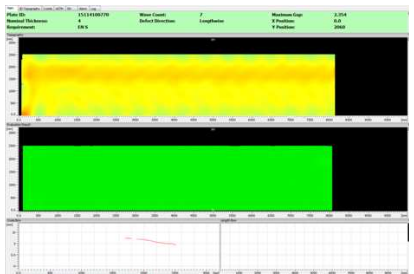

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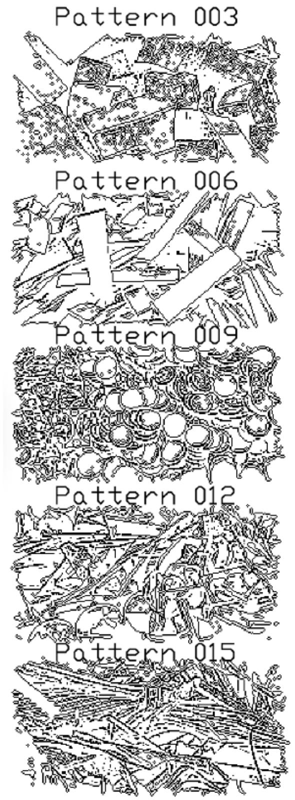
All these aspects are "process" (DIGIMET methodology)

Automatic scrap management (computer vision / pattern recognition/ optimization)

Automatic scrap management (computer vision / pattern recognition/ optimization)

- **Classification**

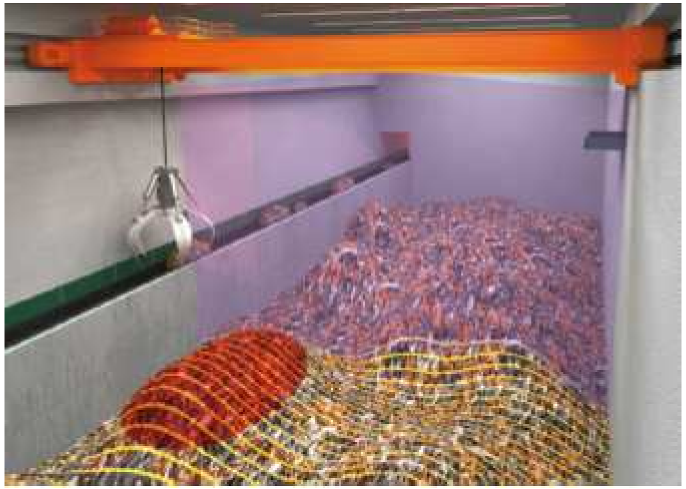


Automatic scrap management (computer vision / pattern recognition/ optimization)

SAFETY AND SITUATION AWARENESS

Automatic scrap management (computer vision / pattern recognition/ optimization)

- Volumetric Scan
  (keep tack of volumes, position, type)

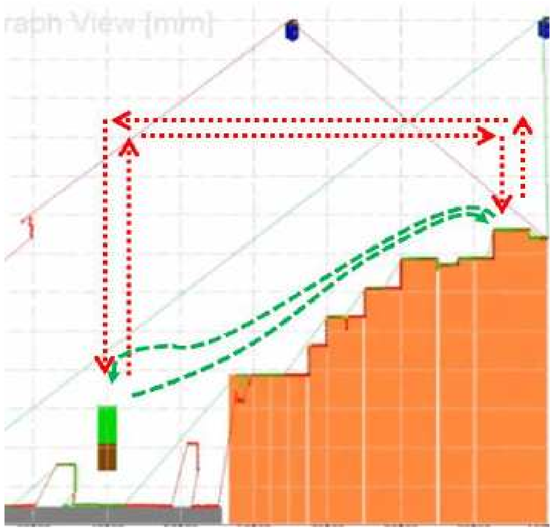


Automatic scrap management (computer vision / pattern recognition/ optimization)

SAFETY AND SITUATION AWARENESS

Automatic scrap management (computer vision / pattern recognition/ optimization)

- **Yard Unsupervised Optimization (reduction operations)**



Automatic scrap management
(computer vision / pattern recognition/
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Automatic scrap management (computer vision / pattern recognition/ optimization)

Use of drones for inspection

SAFETY AND SITUATION AWARENESS

Automatic scrap management (computer vision / pattern recognition/ optimization)

Use of drones for inspection

- **Inaccessible/dangerous zones inspection**

Automatic scrap management (computer vision / pattern recognition/ optimization)

Use of drones for inspection

SAFETY AND SITUATION AWARENESS

Automatic scrap management (computer vision / pattern recognition/ optimization)

Use of drones for inspection

- **Automatic recognition of unsafe situations (eg safety fences statuses)**

Automatic scrap management (computer vision / pattern recognition/ optimization)

Use of drones for inspection

SAFETY AND SITUATION AWARENESS

Automatic scrap management (computer vision / pattern recognition/ optimization)

Use of drones for inspection

- **Haptic feedback**

Automatic scrap management (computer vision / pattern recognition/ optimization)

Use of drones for inspection

SAFETY AND SITUATION AWARENESS

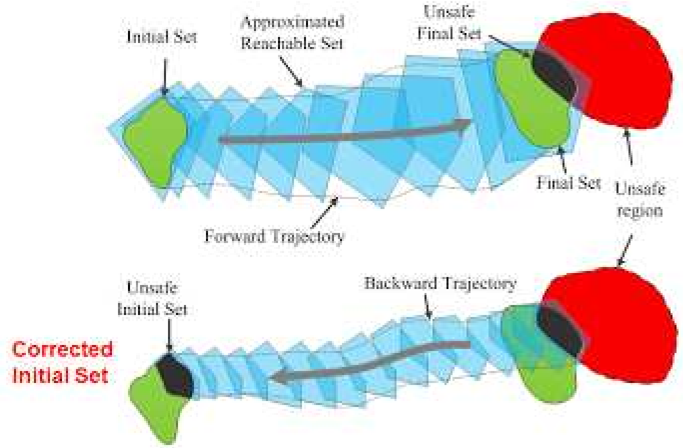
Automatic scrap management (computer vision / pattern recognition/ optimization)

Use of drones for inspection

Formal verification for safety critical

Automatic scrap management (computer vision / pattern recognition/ optimization)

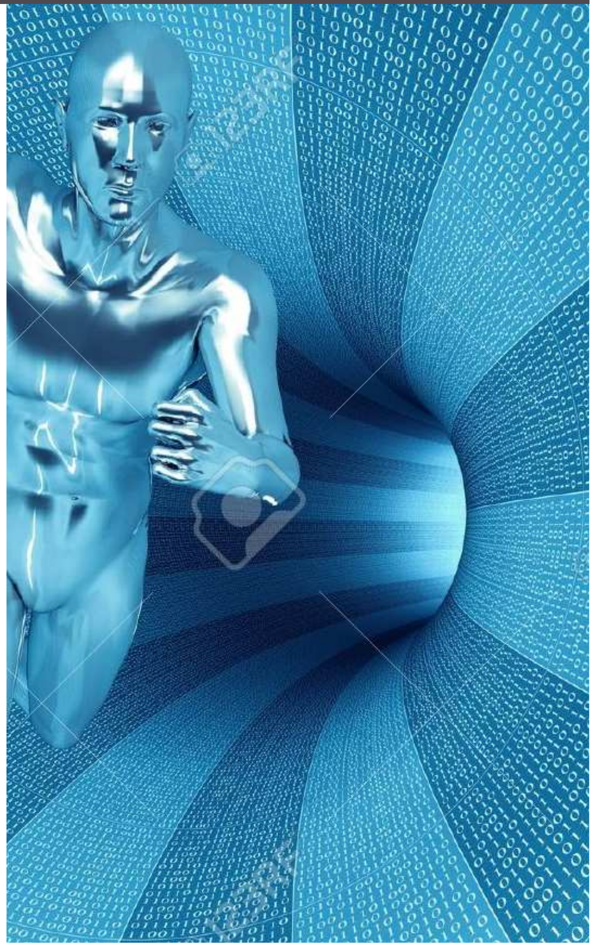
Use of drones for inspection



Formal verification for safety critical

- **Reachability analysis (hybrid systems)**

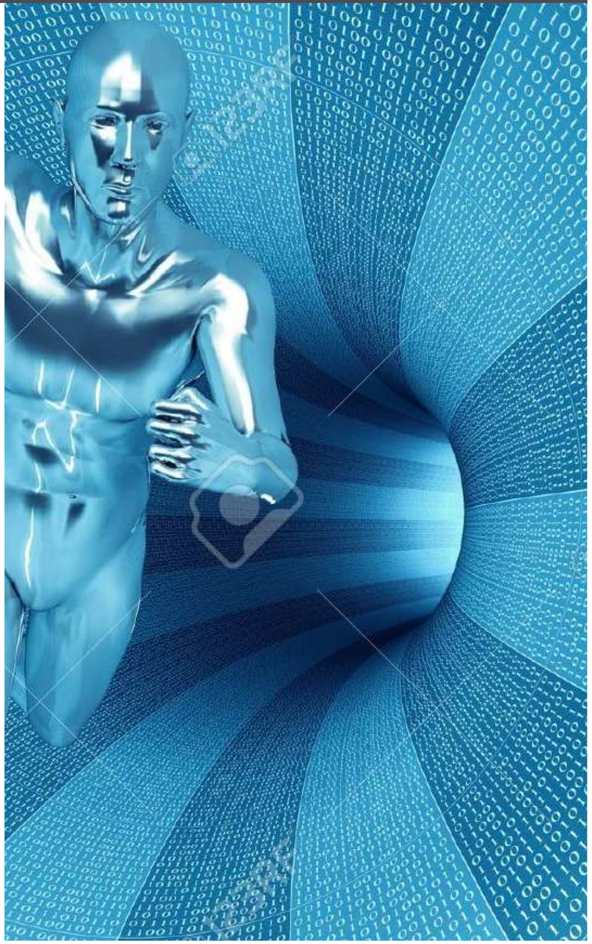
CONCLUSIONS



CONCLUSIONS

DANIELI

Keep Robotizing



CONCLUSIONS

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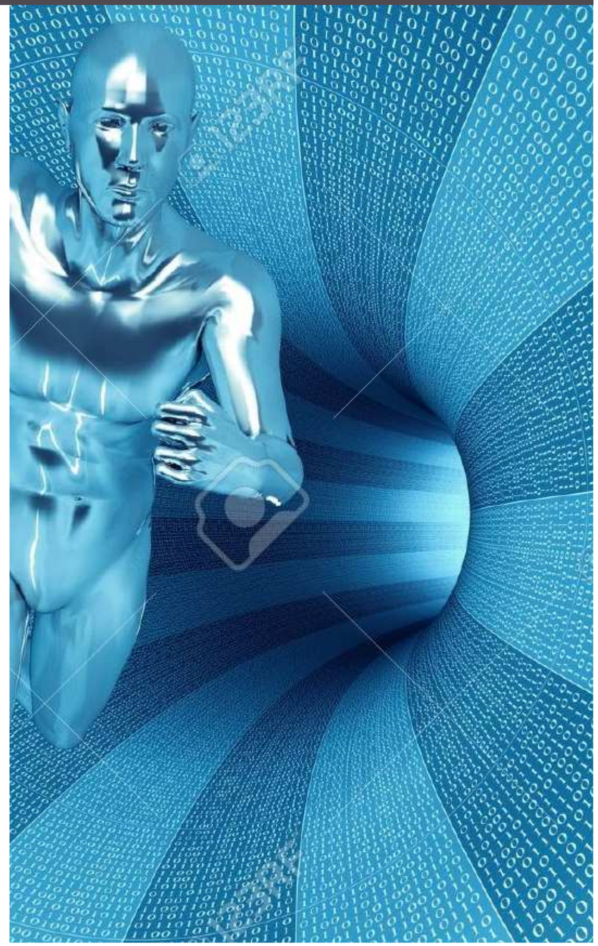

CONCLUSIONS

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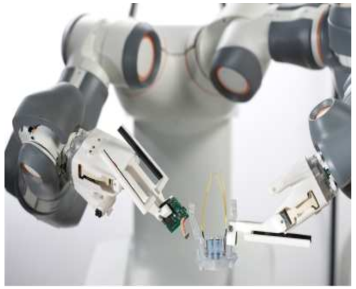

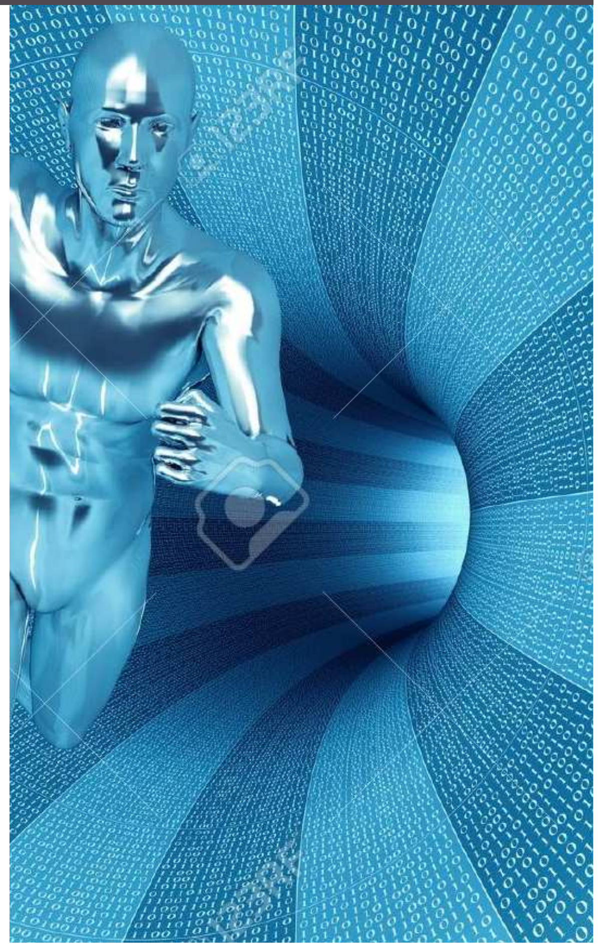

CONCLUSIONS

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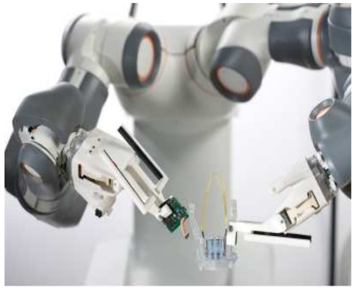

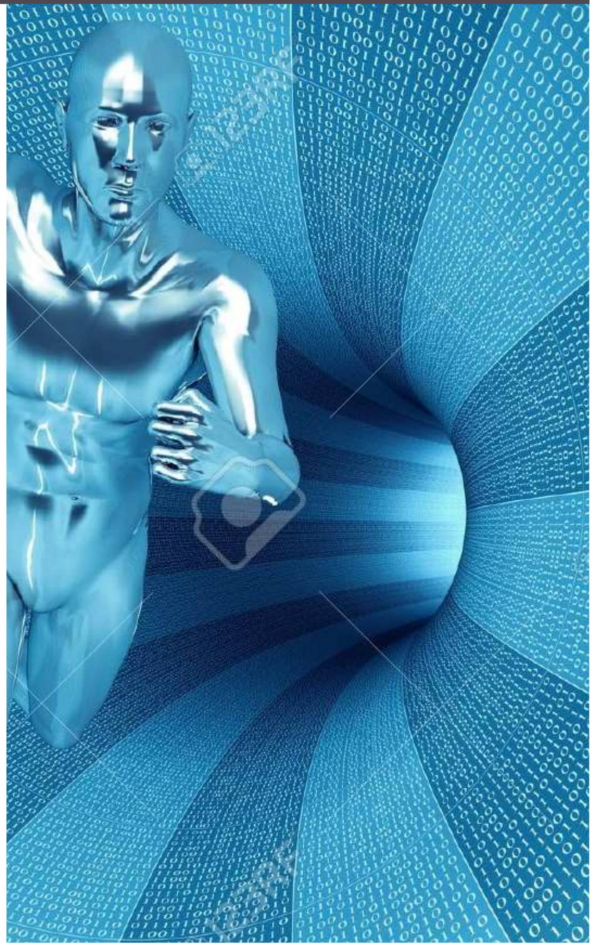

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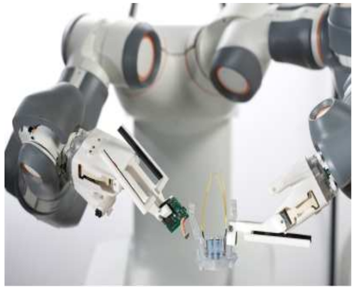
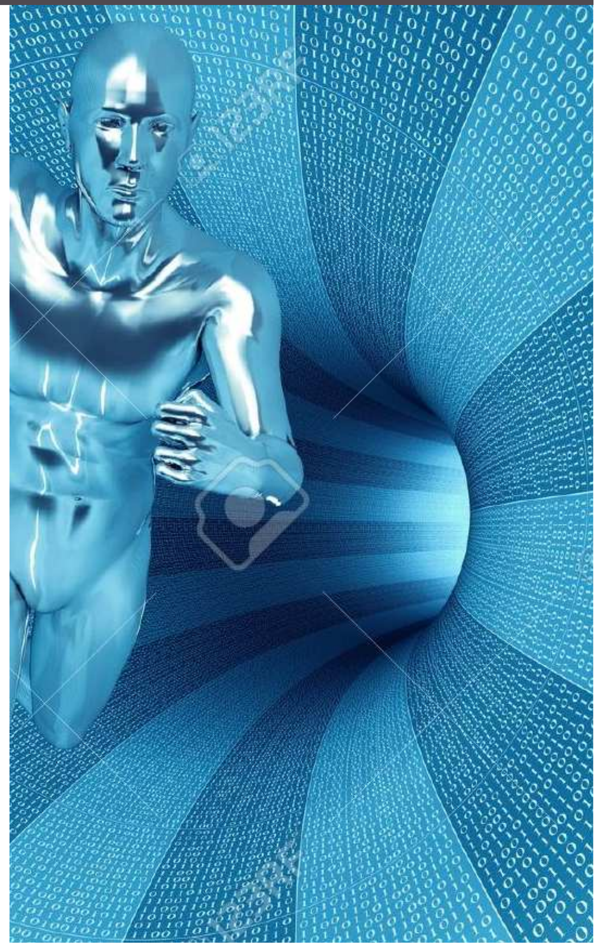


New sensors
on the field



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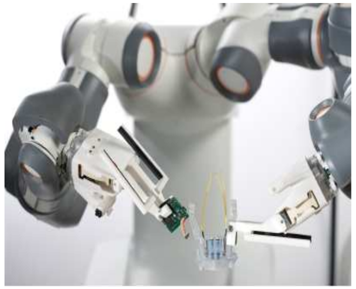

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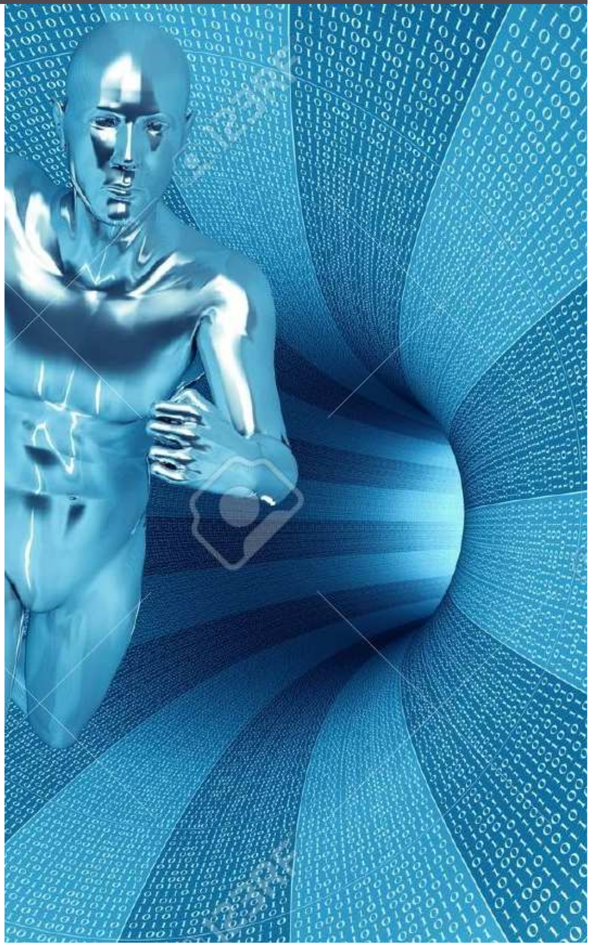

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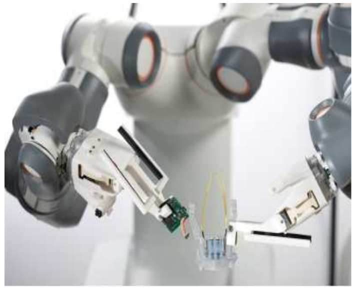
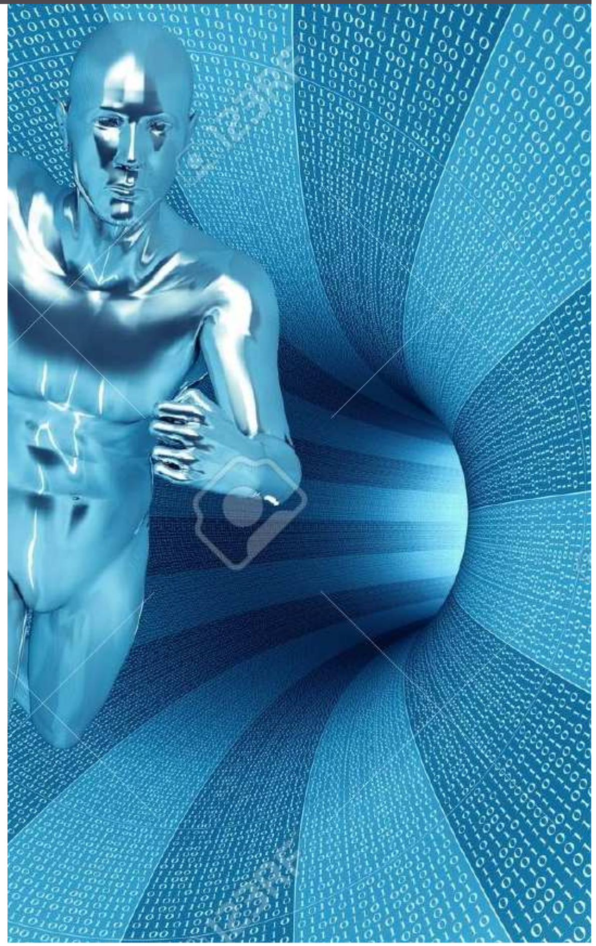


New sensors on the field

No man on floor



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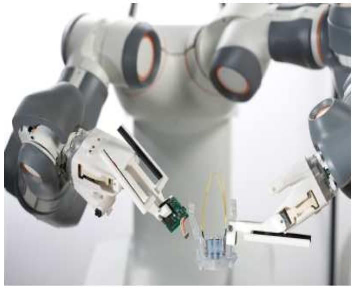

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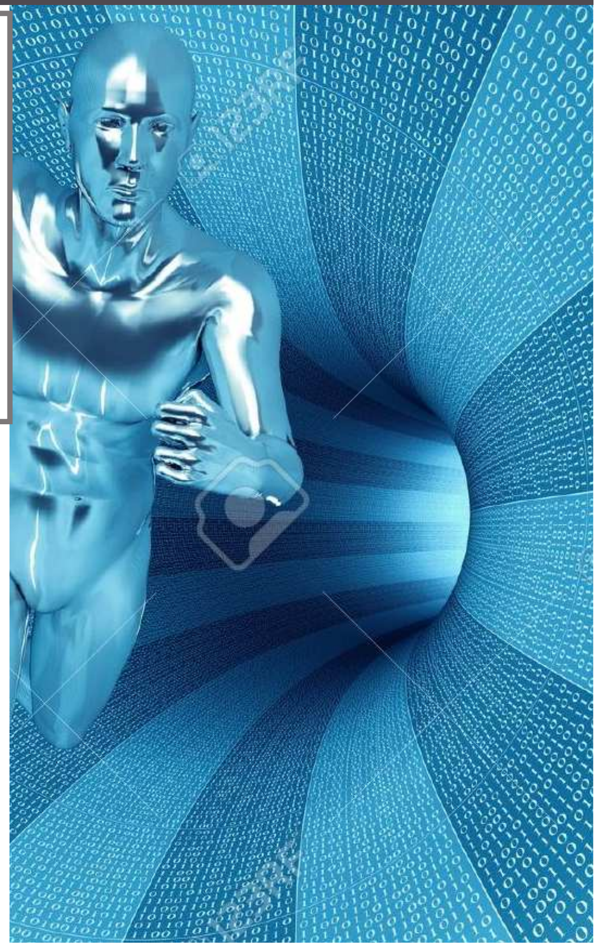

CONCLUSIONS

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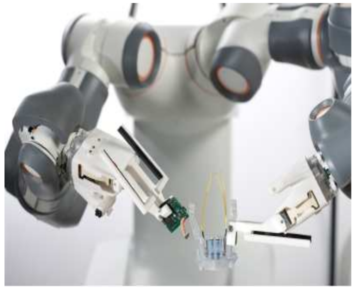

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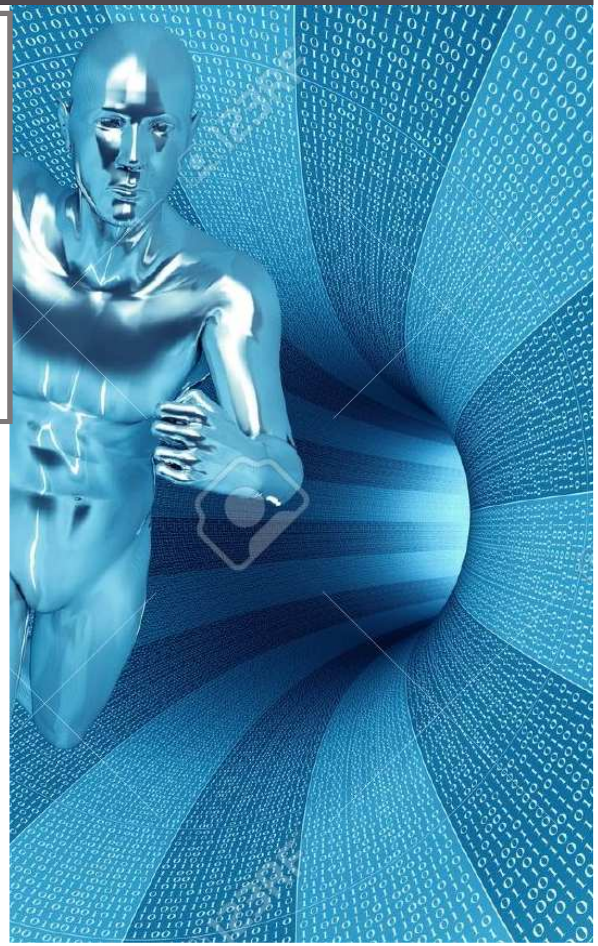

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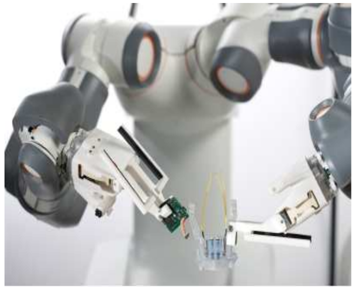

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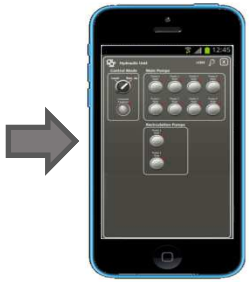

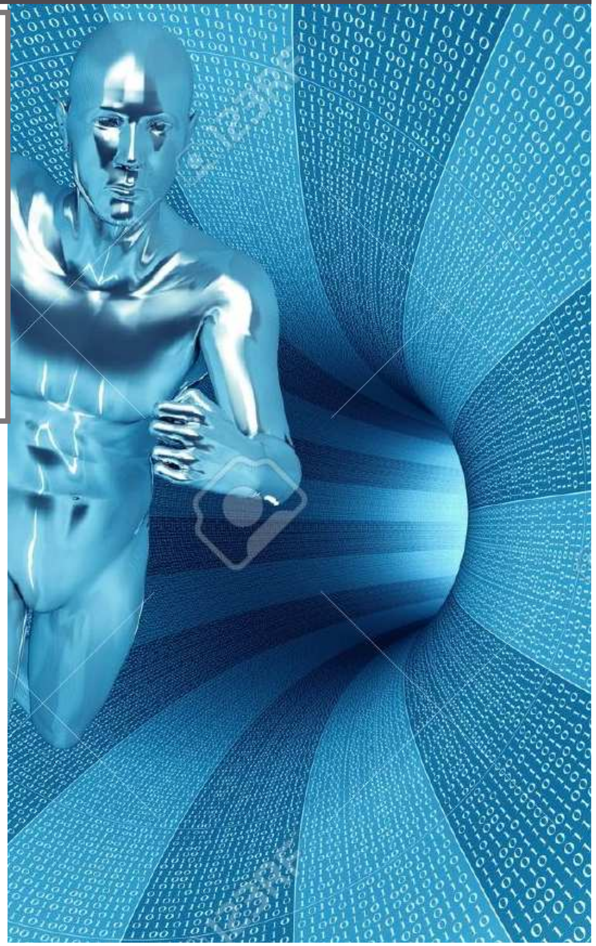

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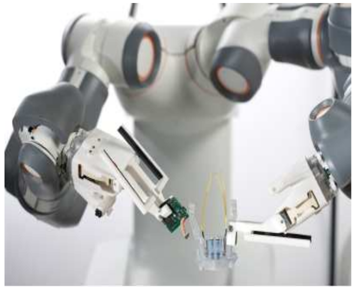

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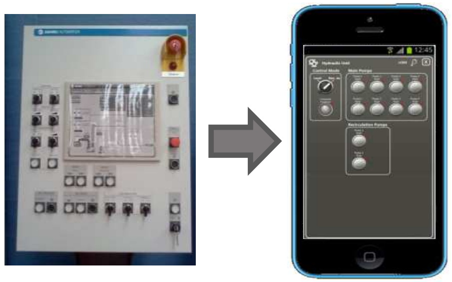

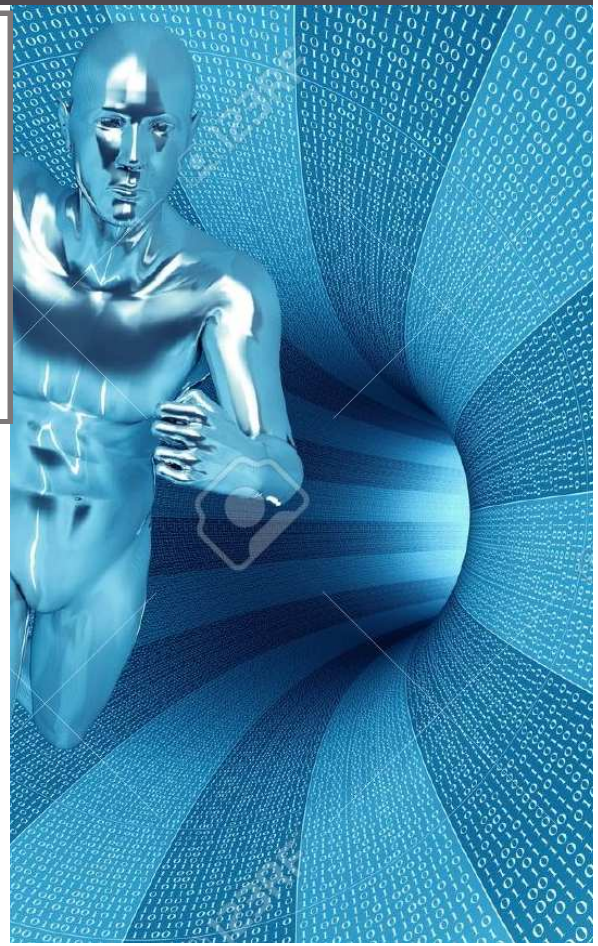

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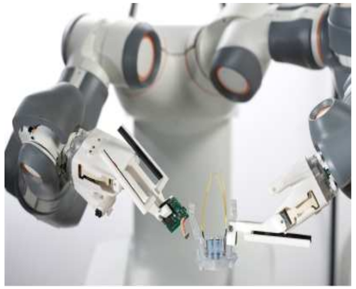

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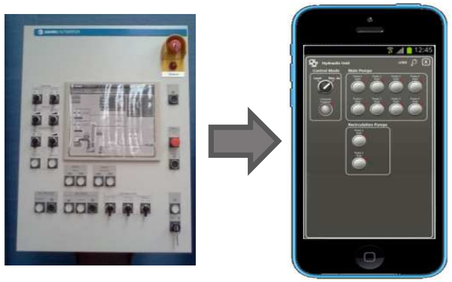
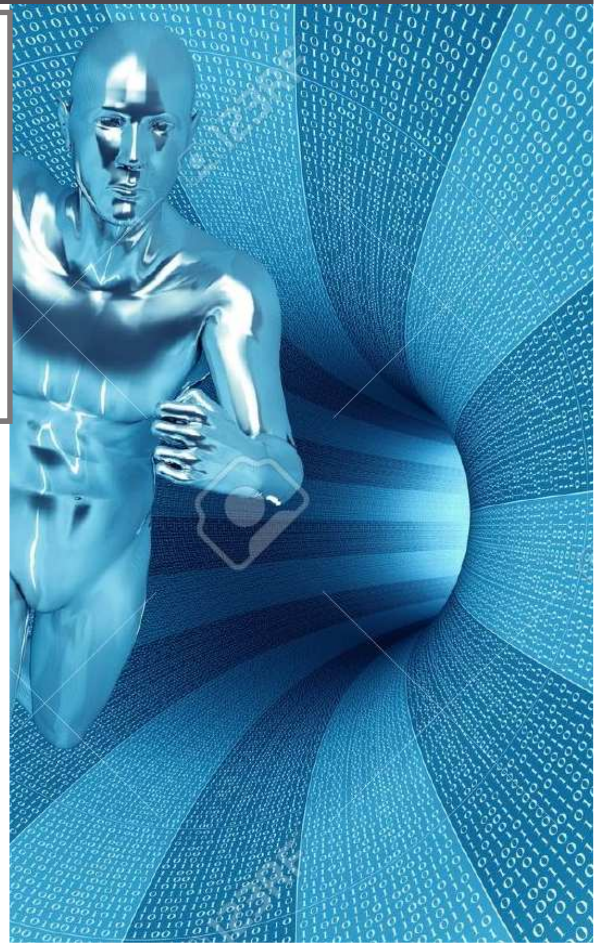


Learning from data



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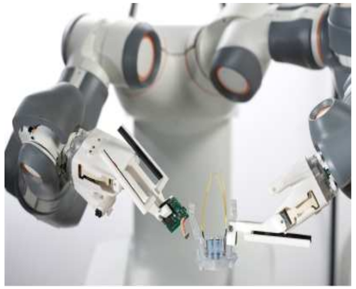

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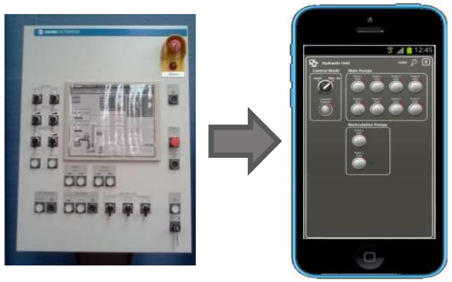

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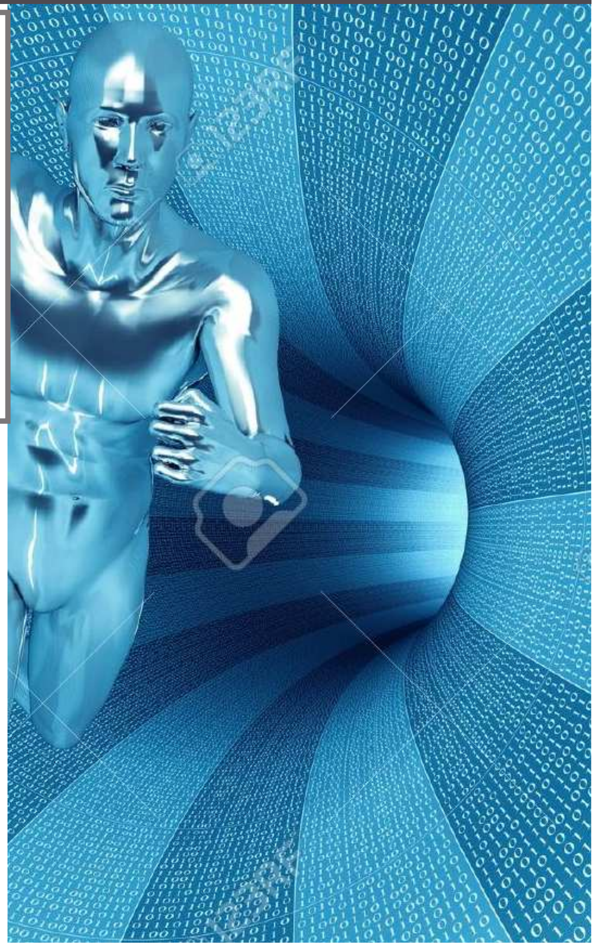

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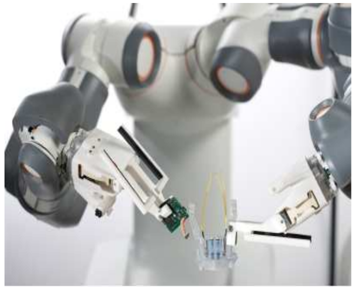

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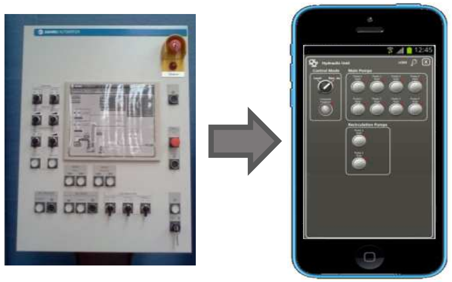

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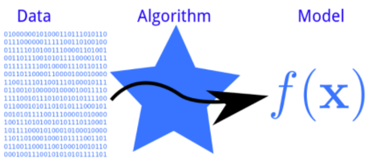

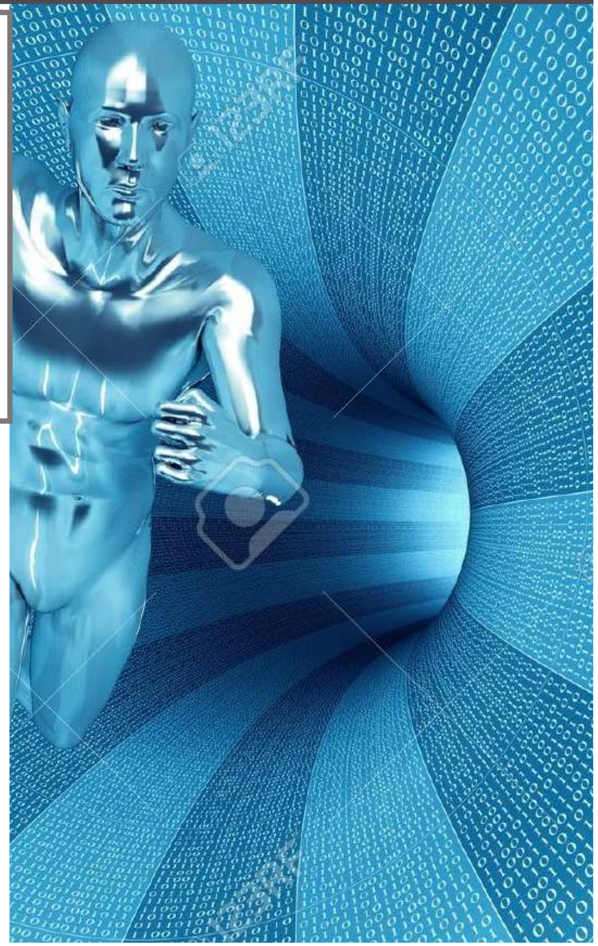

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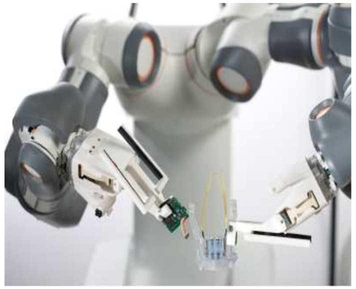

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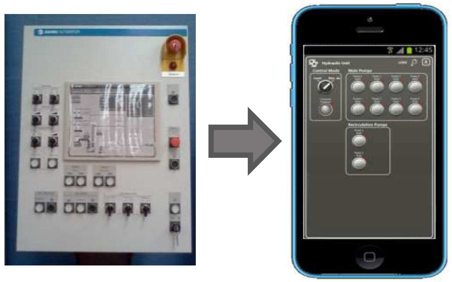

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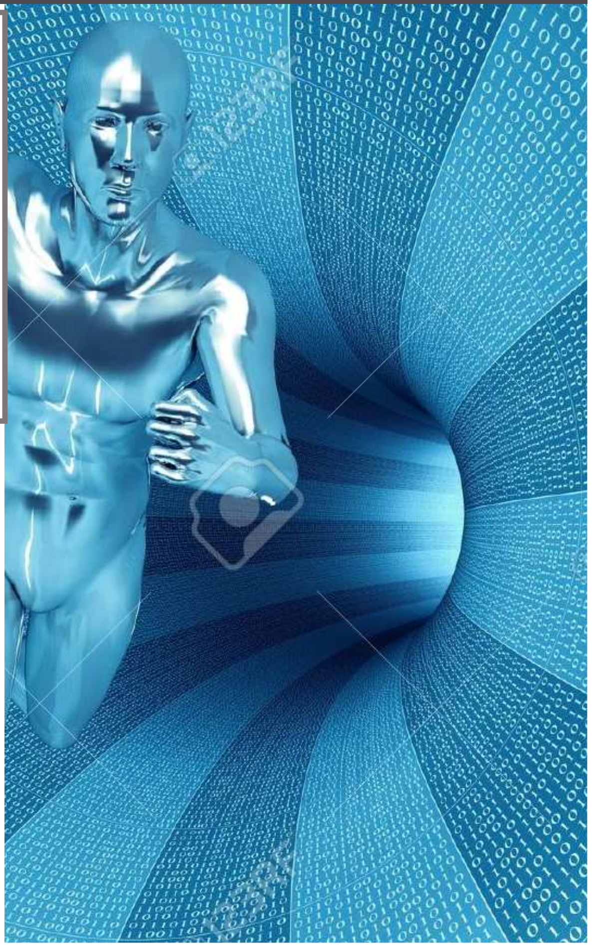

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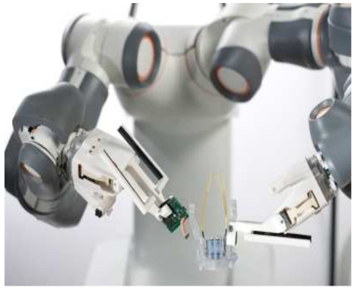

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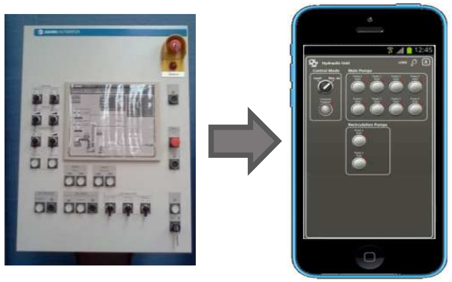

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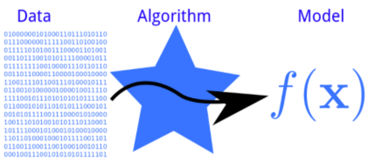

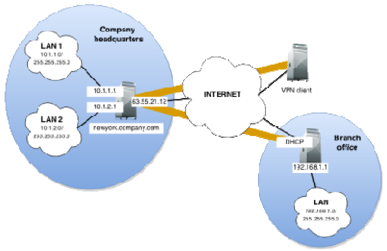

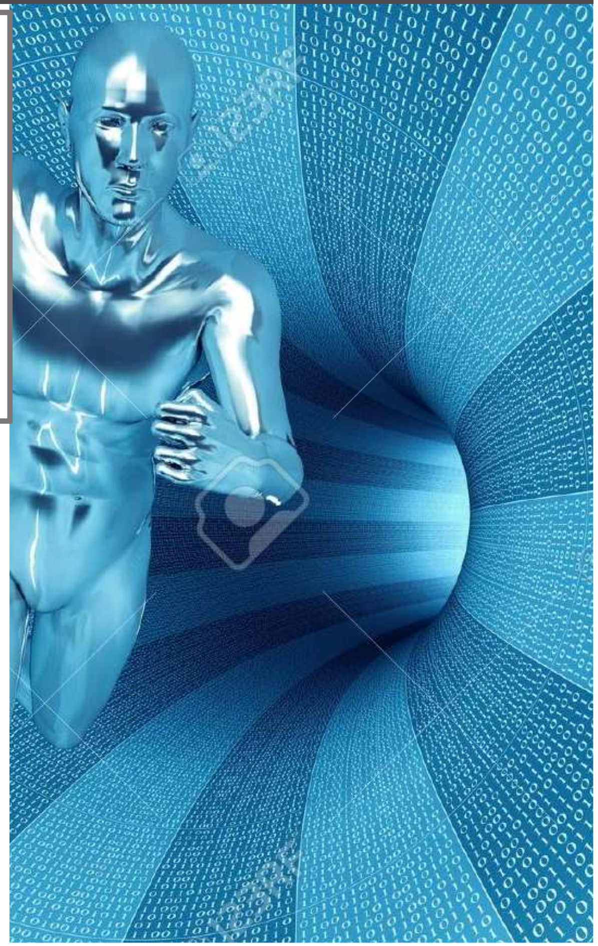

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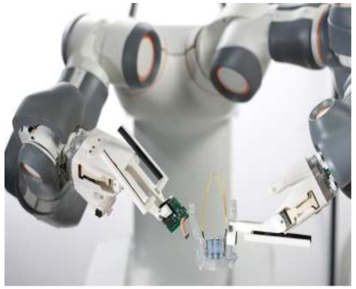

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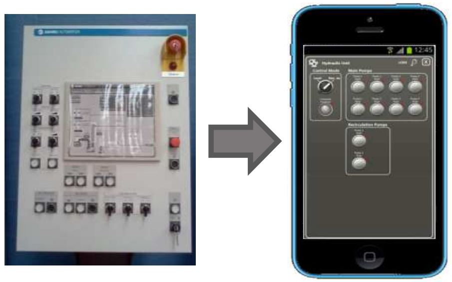

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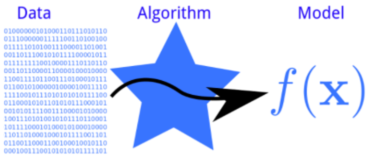
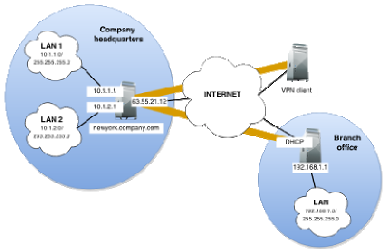
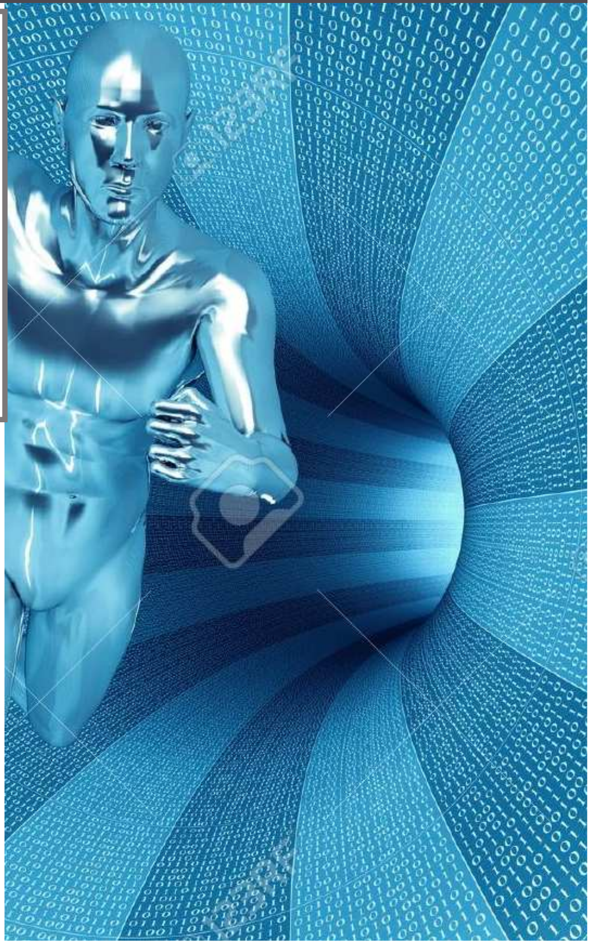


Remote services from internet





CONCLUSIONS

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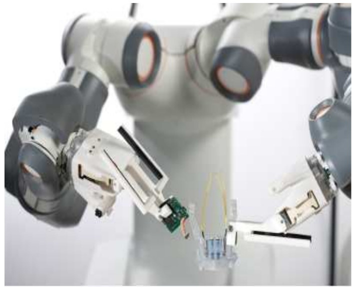

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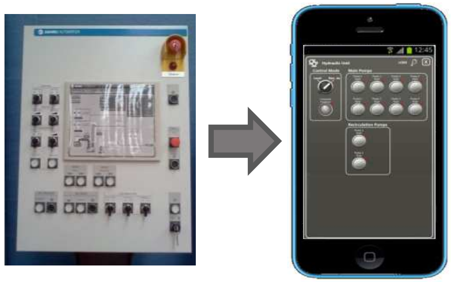

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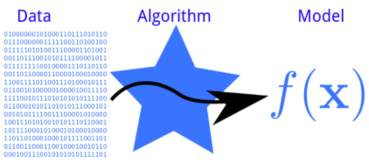

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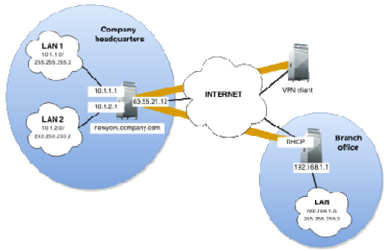

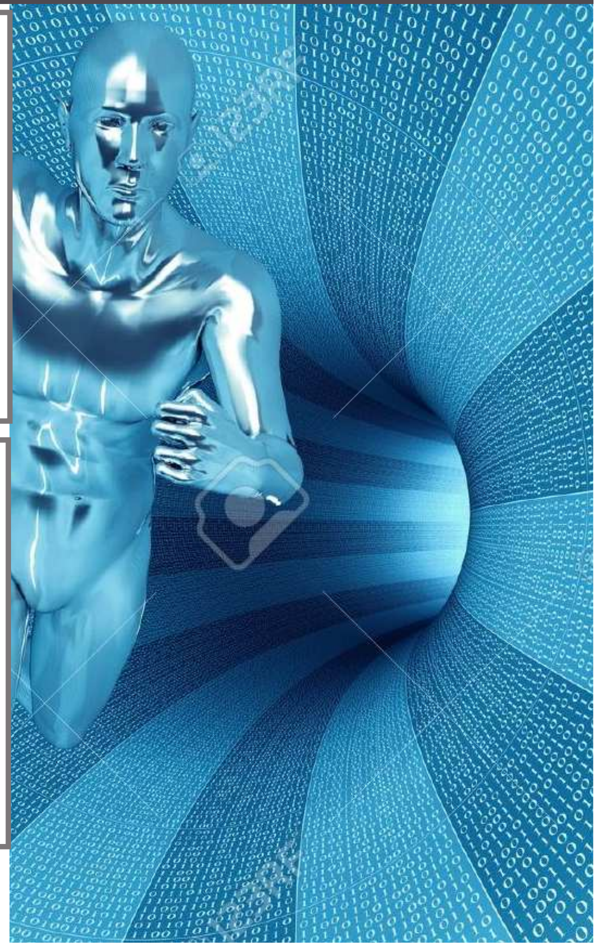

CONCLUSIONS

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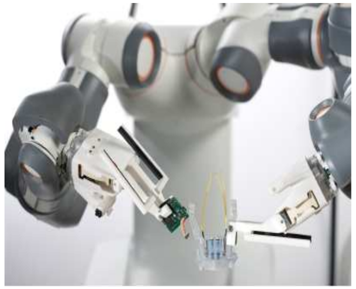

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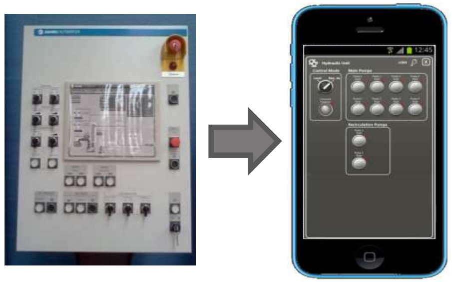

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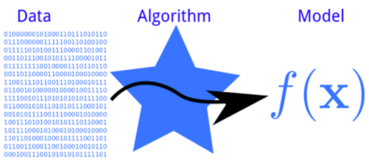

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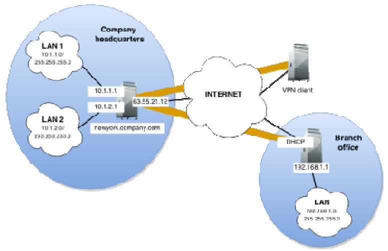

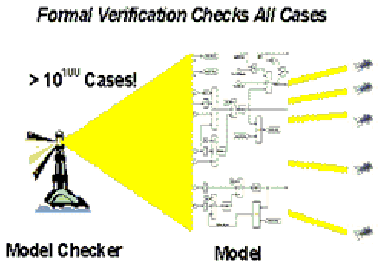

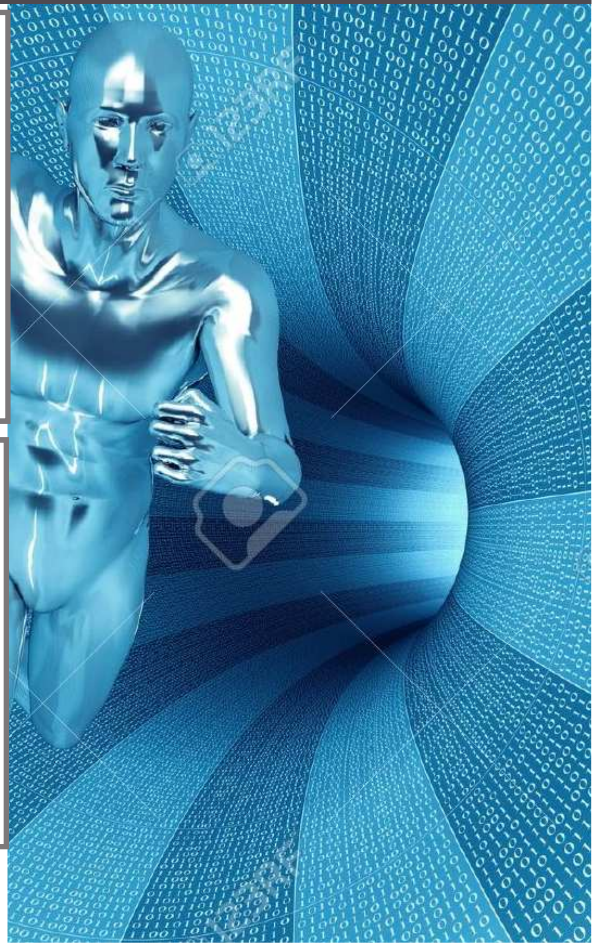

CONCLUSIONS

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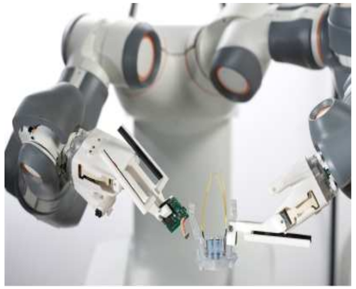

New sensors on the field

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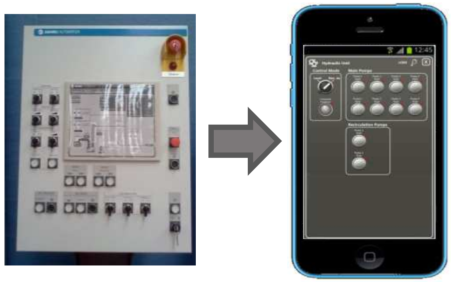

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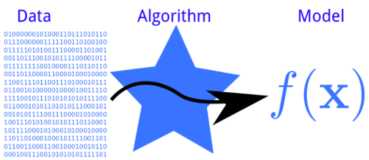

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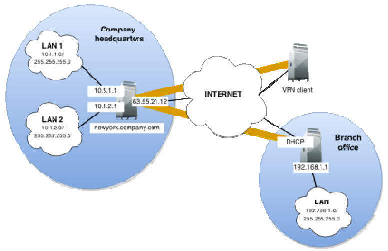
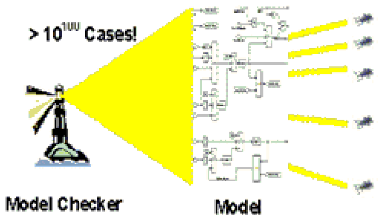
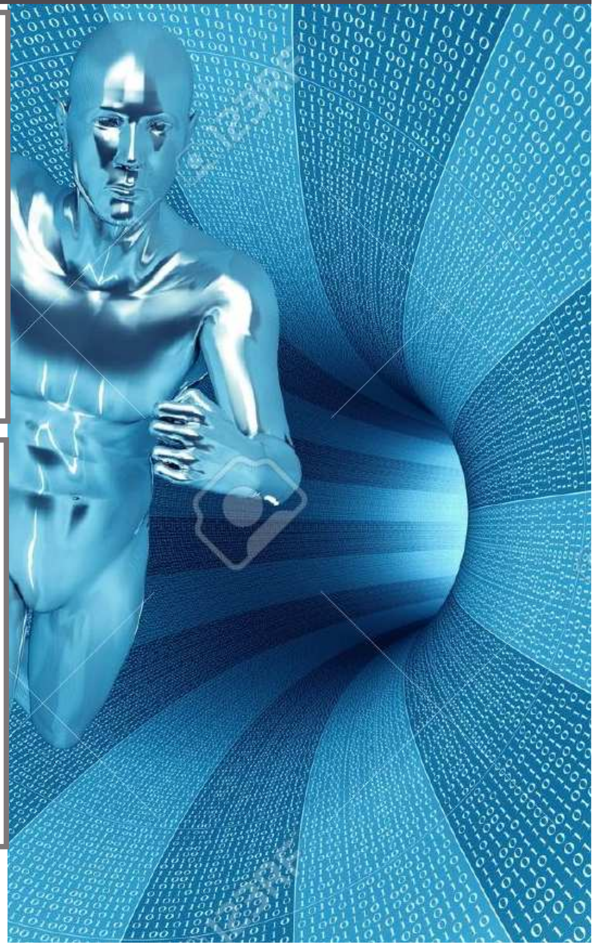


Formal verification of control

Formal Verification Checks All Cases





CONCLUSIONS

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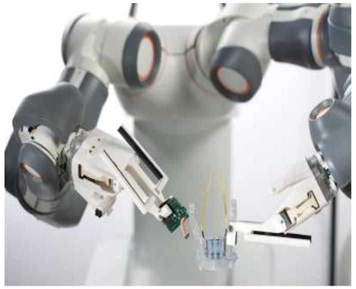
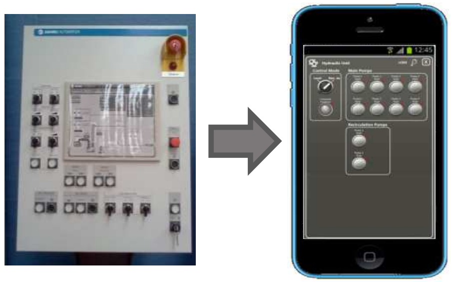


New sensors on the field

No man on floor



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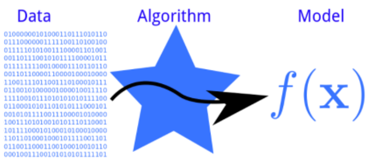

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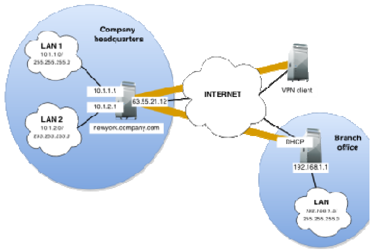
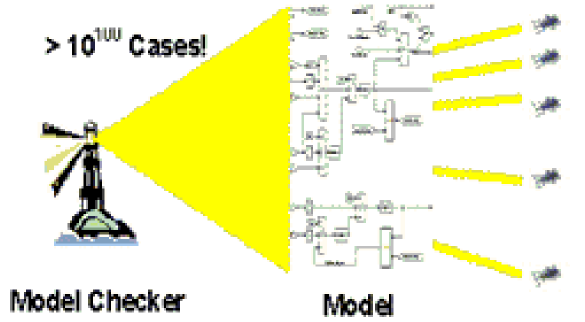
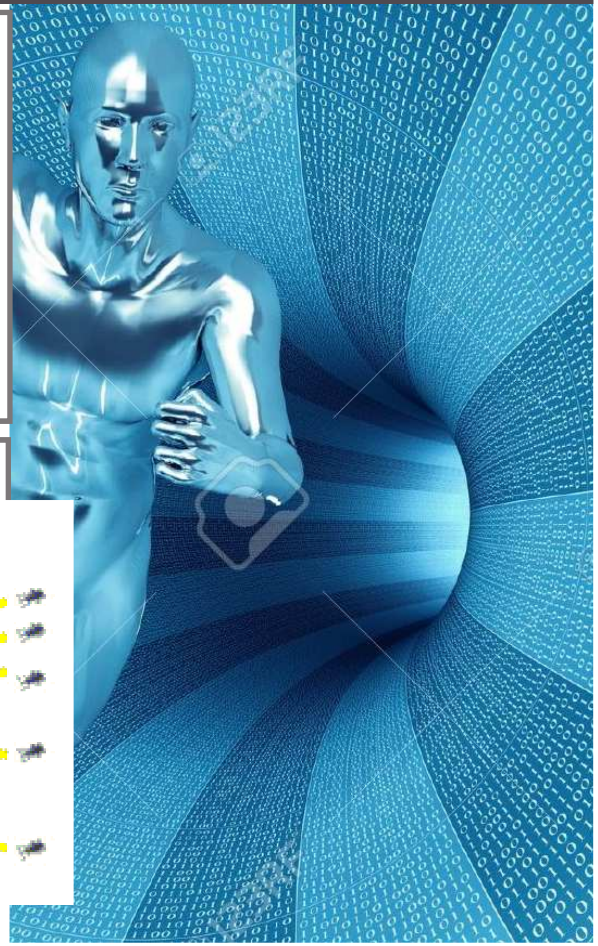


Formal verification

Formal Verification Checks All Cases





CONCLUSIONS

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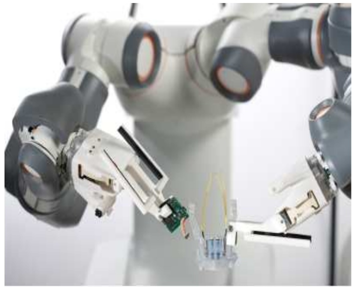

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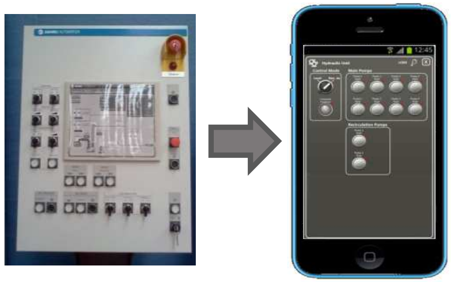
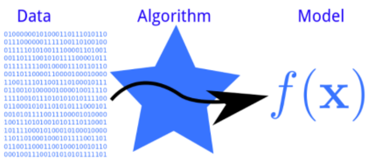
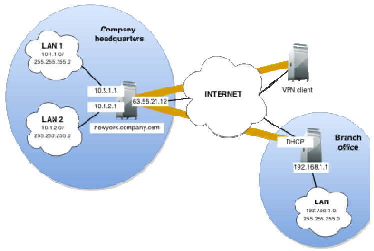
No man on floor

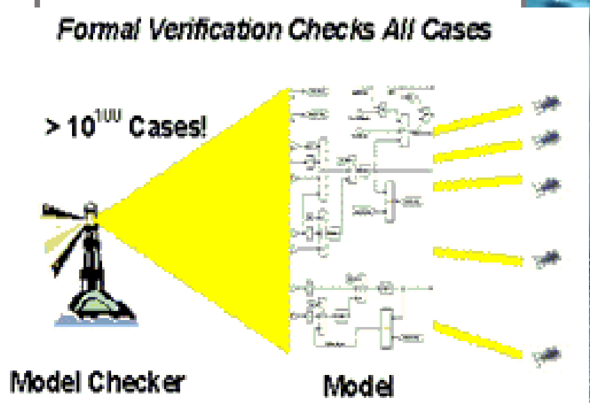


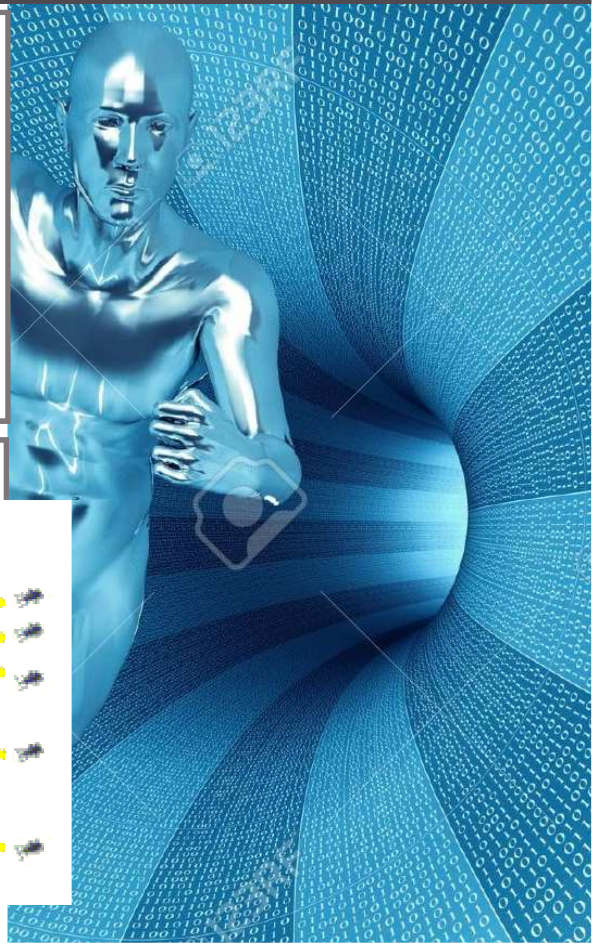
Learning from data



Remote services from internet





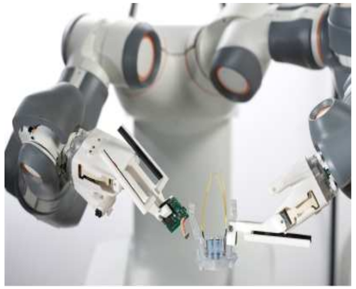


AUTONOMOUS INTEGRATED SYSTEMS IN FLAT METAL PRODUCTION

CONCLUSIONS

DANIELI

Keep Robotizing



New sensors on the field

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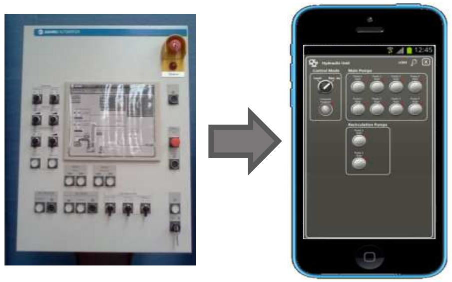

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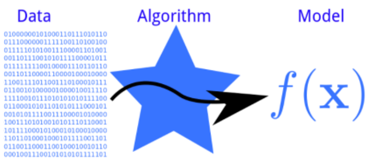

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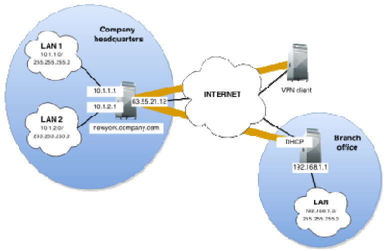

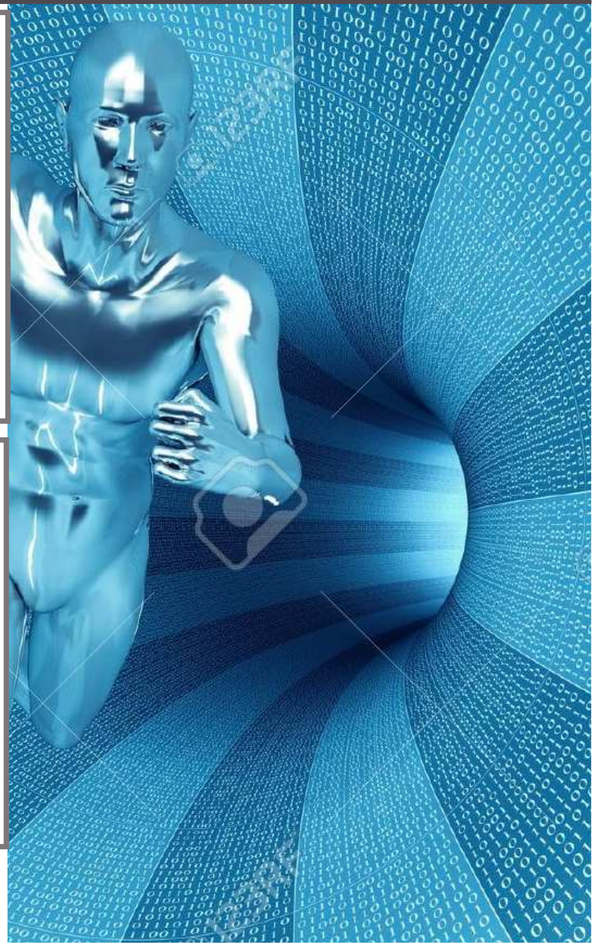

CONCLUSIONS

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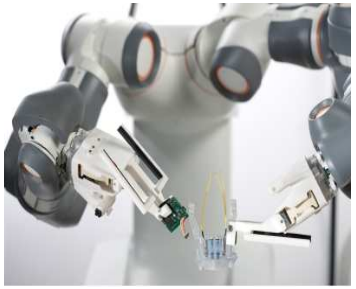

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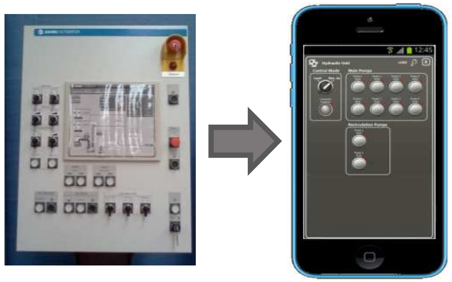

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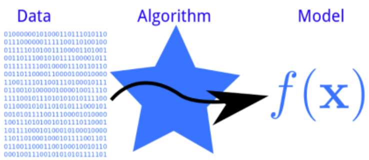

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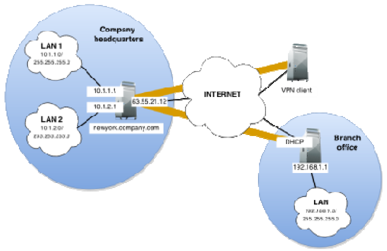
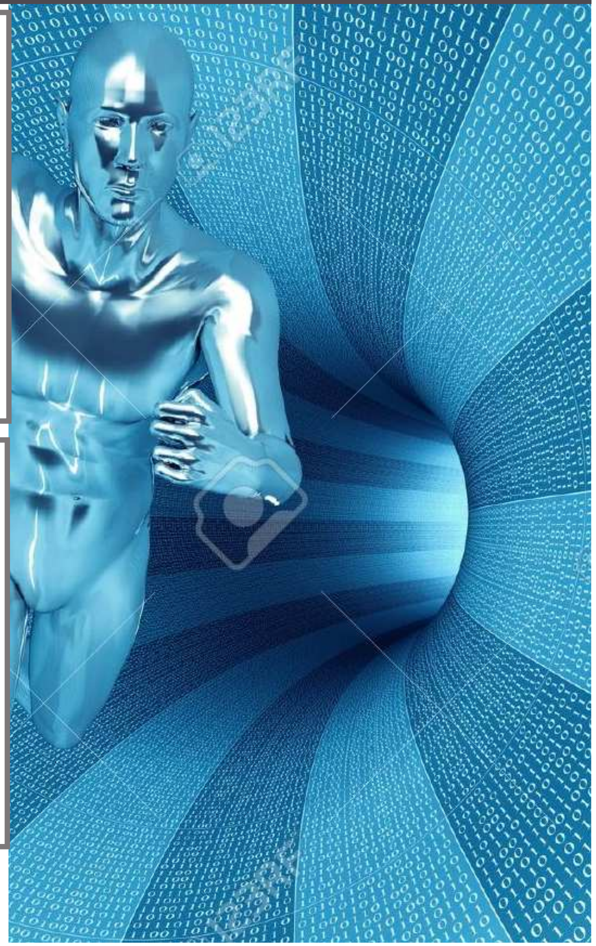


Virtual reality



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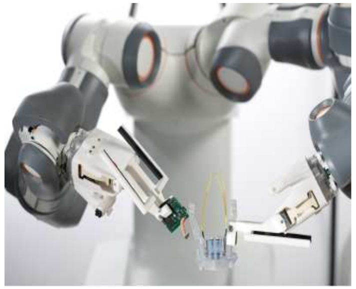

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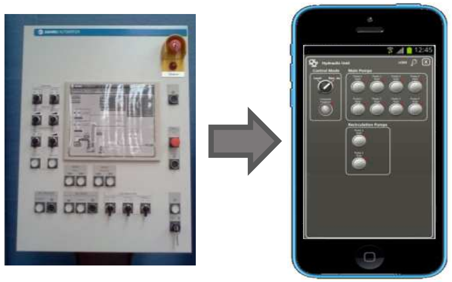

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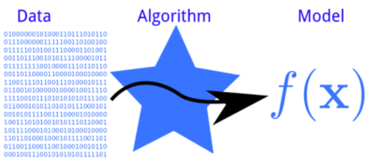

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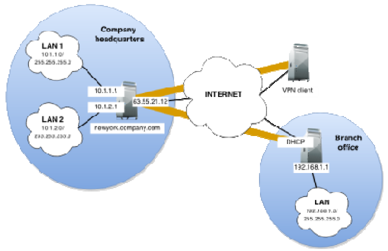

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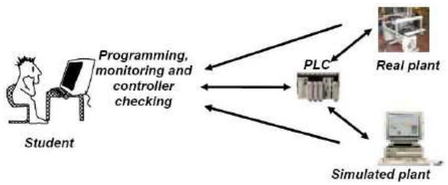

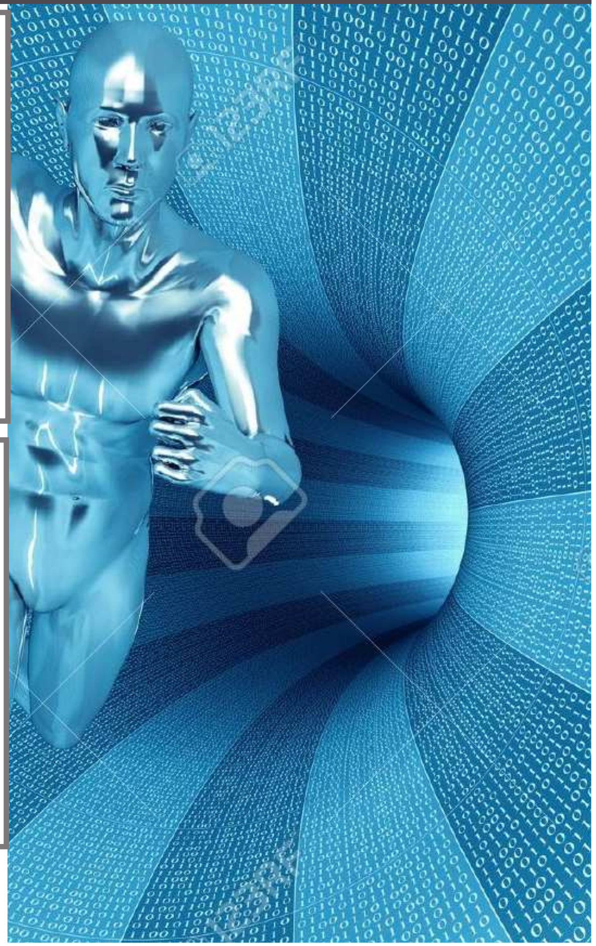

CONCLUSIONS

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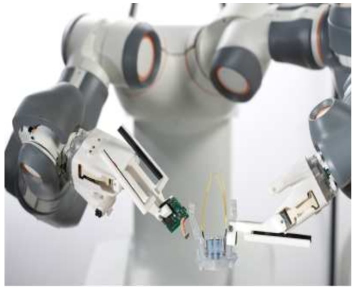

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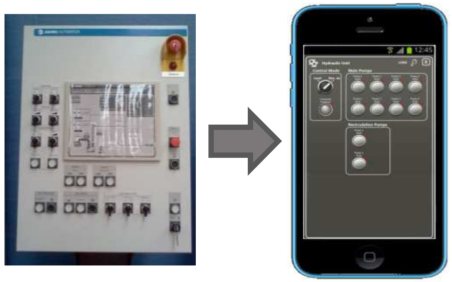

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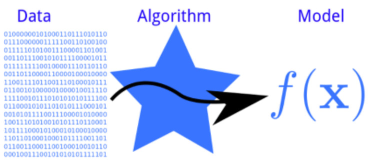

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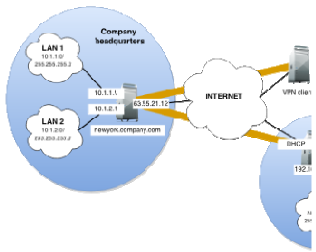

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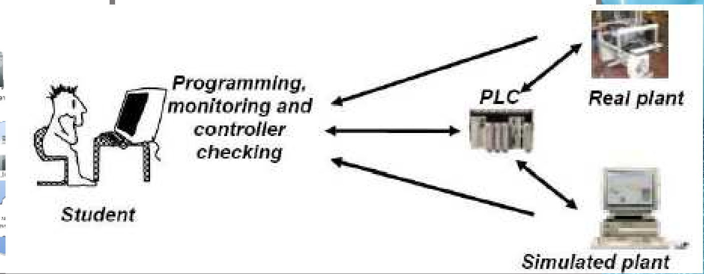
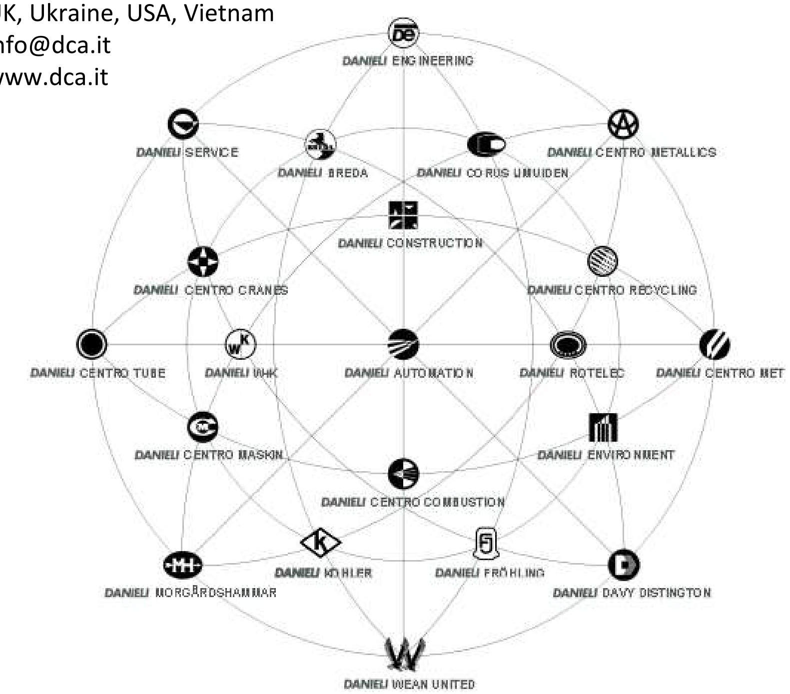


DANIELI AUTOMATION

CONTACT US IF YOU SEE ANY OCCASION OF BUSINESS

DANIELI

Danieli Automation
Brazil, China, Egypt, Germany, India, Italy, Japan, Mexico,
Poland, Romania, Romania , Russia, Thailand, UAE,
UK, Ukraine, USA, Vietnam
info@dca.it
www.dca.it



Danieli Engineering	Turnkey plants and systems engineering
Danieli Automation	Process control systems
Danieli Centro Metallics	Ore processing & direct reduction plants
Danieli Corus Ijmuiden	Integrated steelmaking plants
Danieli Lynxs	Steel recycling plants
Danieli Centro Met	Steelmaking plants
Danieli Davy Distington	Slab casters
Danieli Wean United	Flat product casting, rolling and processing
Danieli Kohler	Wipe equipment for coating
Danieli Fröhling	Specialty mills and strip finishing lines
Danieli FATA Hunter	EPC process industry
Danieli Morgårdshammar	Long products rolling mill
Danieli Centro Tube	Tube processing plants
Danieli W+K	Longitudinal and spiral welded pipe plants
Danieli Centro Maskin	Conditioning, drawing & finishing lines
Danieli Rotelec	EMS and induction heating systems
Danieli Breda	Extrusion and forging plants
Danieli Centro Combustion	Reheating systems
Danieli Environment	Ecological systems
Danieli Centro Cranes	Cranes for the metals Industry
Danieli Construction	TKP construction, erection, systems engineering
Danieli Service	Technical service and spare parts