Automatic Control

Research tracks

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Automatic Control

Richard Feynman (Nobel prize 1965)

Physics is mathematics constrained by reality.
Engineering is physics constrained by money.

Automatic Control

Mathematics

Control Theory
Generalized **mathematical** theory
Illustrated in simulation
Usually not directly applicable

Control Engineering
Makes theory **practically useful**
Verified in **reality**.
Generates need for new theory

Applications

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Automatic Control

- Automatic control is built on mathematics and is application agnostic
- Our research focus is to develop theories and methods for
  - designing robust adaptive low complexity optimal feedback control systems for large complex and data-rich systems
  - modelling of large dynamical systems based on data and/or first principles
  - modelling of (statistical) properties for disturbances
  - estimation and classification of system properties from large data sets.
- As a control engineering subject, we always apply and verify methods in real life

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First publication

Many application areas – Same methods (almost)
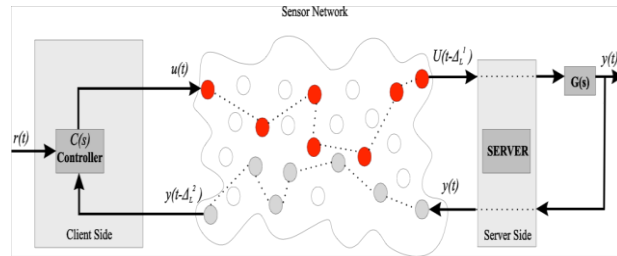
Distributed Estimation & Control

Pulp & Paper
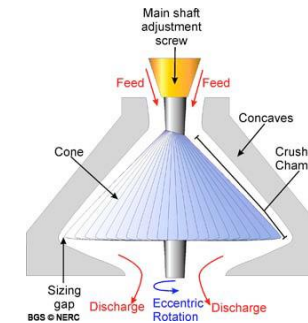
Mining
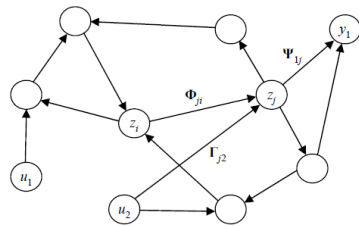
Structural Analysis
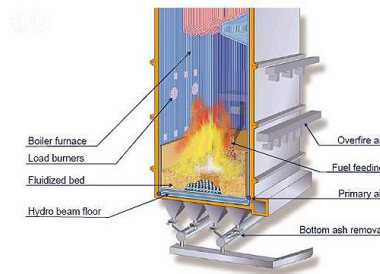
Sustainable Energy and Environment

Field Robotics - Autonomous vehicles

Process industries are large scale and complex

- We need to deal with large scale complex systems
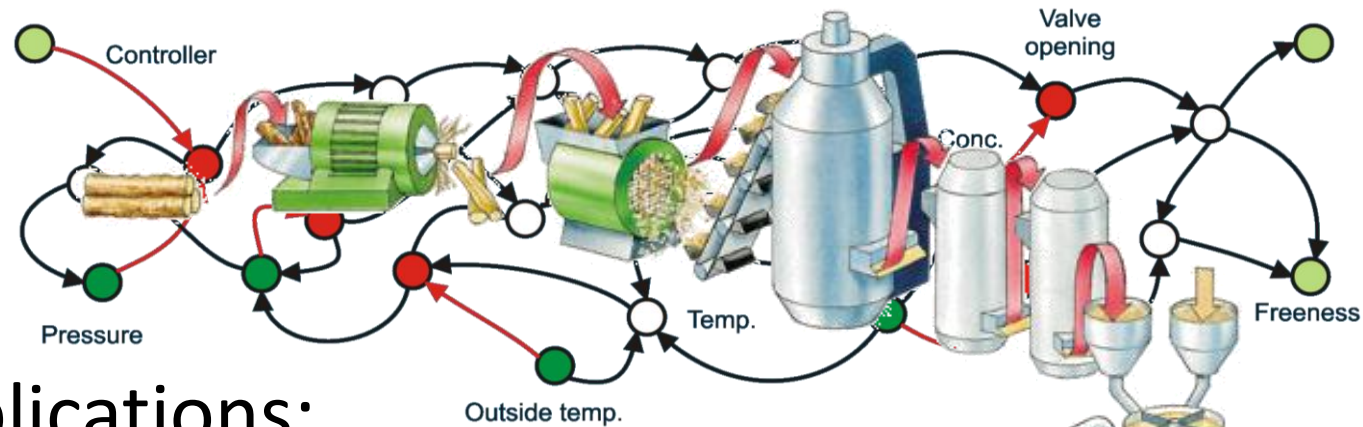
- Some complications:
  - Creating models is difficult and tedious
  - The connections can come and go
  - Fewer people have to achiev
  - The population is gro

- Needed: Trustwo   adapting systems
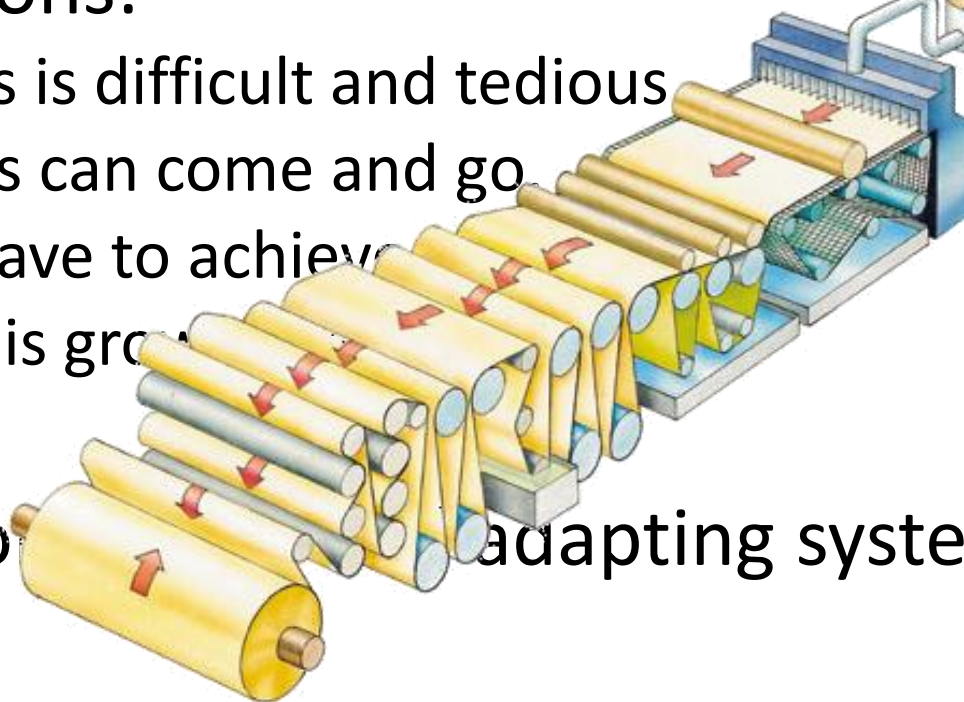
Efficient design of control strategies

- Reconfiguration of control systems.

- Data-driven decision making on control structures.

- Robustness of control structure selection.
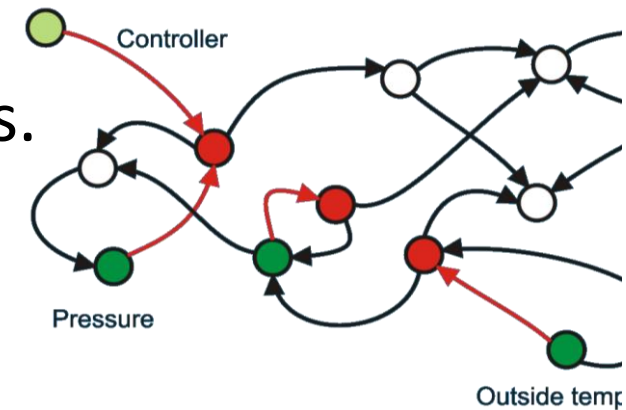
- Towards system autonomy: Digital twins.
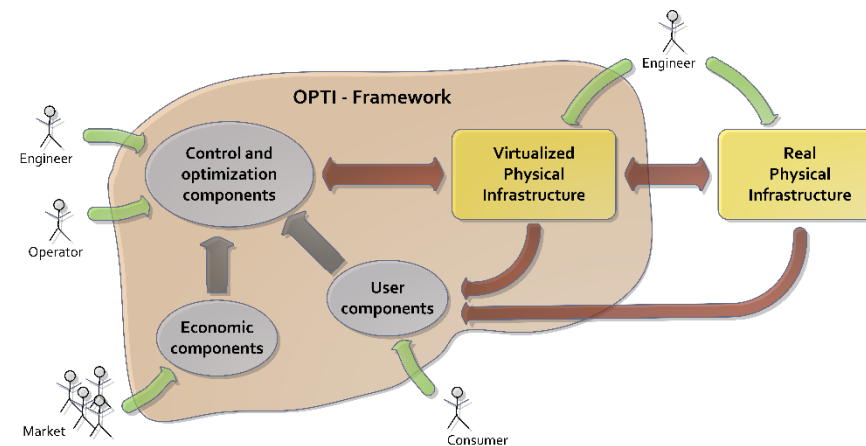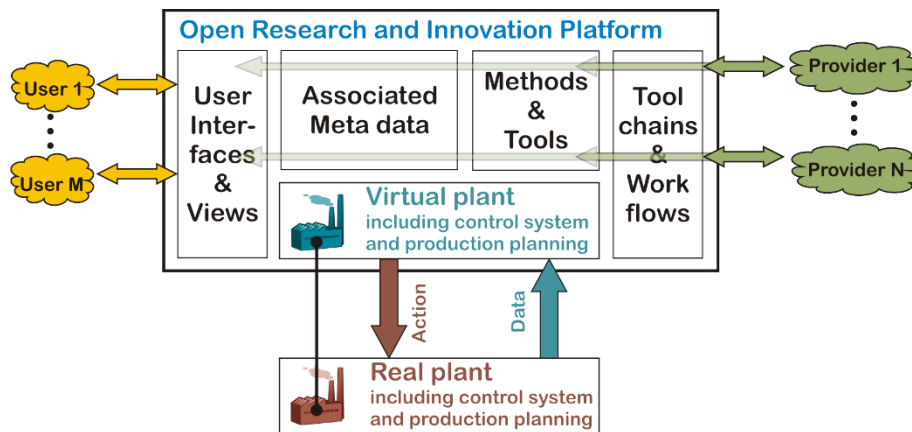
Past projects in pulp and paper

- **SCOPE**
  Collaboration of major pulp & paper industries in the north. Both long term and short term activities

- **MeSTA – Methods for structural analysis**
  Project that created methods to determine control strategies for processes. Open Source tool ProMoVis.

- **EQoRef – Energy efficiency of pulp refiners**
  Model based approach to understand and improve refiner operation. Mainly together with Mondi Dynäs

On-going Activities

- **OPTi project**
  Optimisation of district heating and cooling systems. Treated as a process industry plant.

- **PiiA-WARP** (VINNOVA PiiA)
  Reconfiguration of processes using wireless components

- **AutoMod-Pre** (VINNOVA PiiA)
  Automated model geneation of process industry plant. At the moment together with SSAB.

Open Source tool ProMoVis

Tested on several cases in P&P:

- Stock preparation plant at SCA Obbola

- Bark boiler at SCA Obbola

- Secondary heating at Billerud Karlsborg
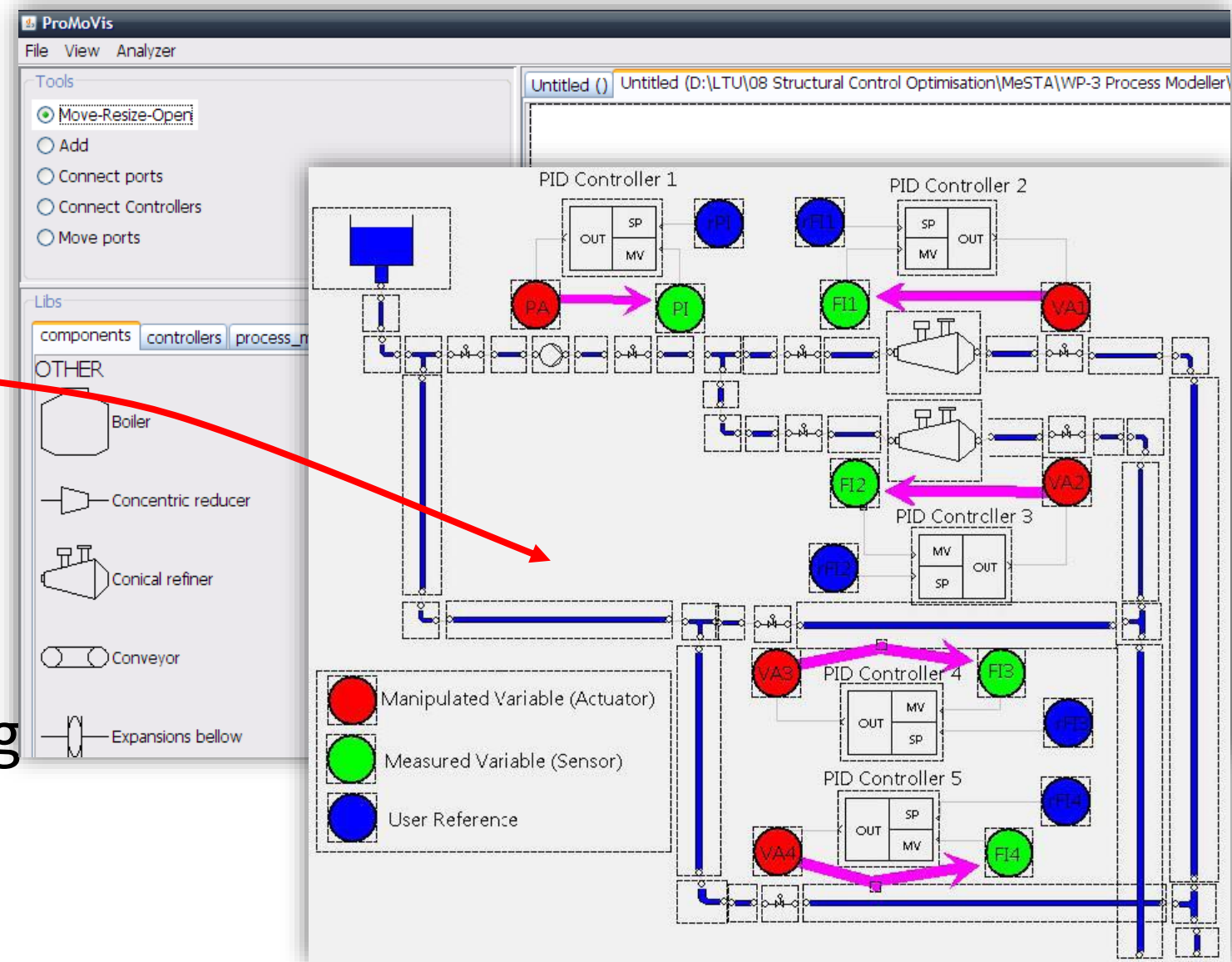
Open Source tool ProMoVis

District heating in Luleå:

- 46000 pipes
- 800km in length
- 4 production units
- Large number of valves, pumps, HEX.
- Ongoing!
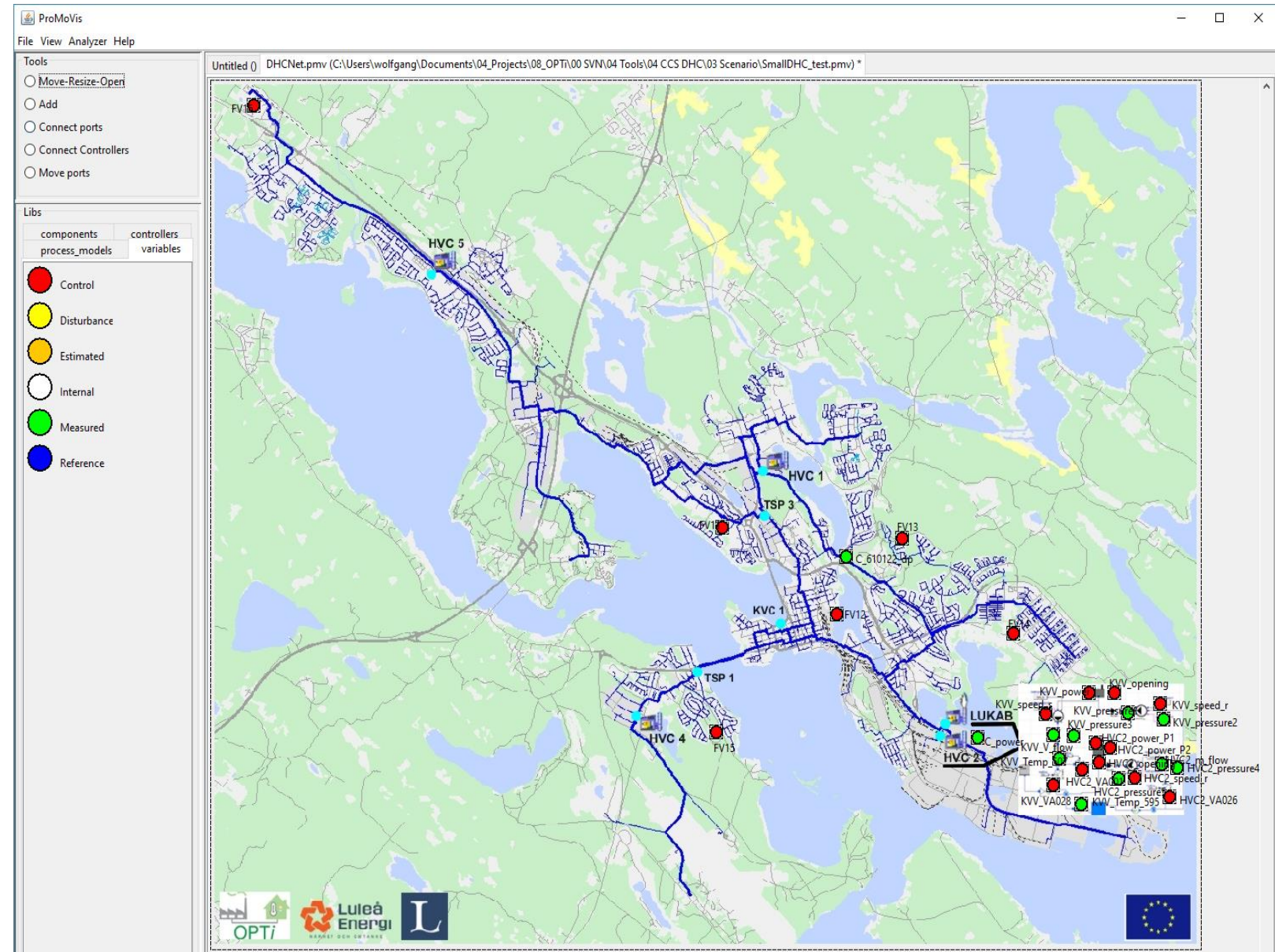
Modeling and simulation of Large scale systems

- Models are the basis for advanced control and monitoring solutions

- In OPTi the complete grid was modelled in an automated fashion.

- A digital twin was build where building models were created using machine learning methods
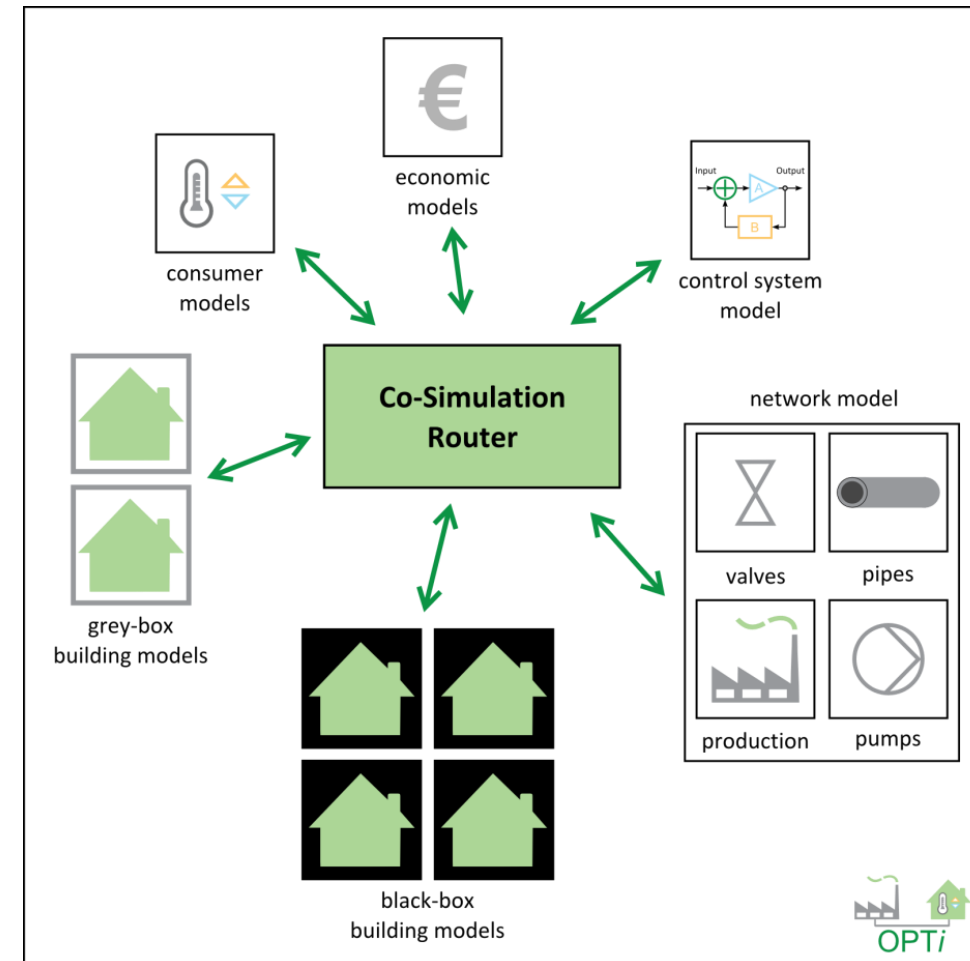
Automated model generation

- Models need to be generated and re-generated automatically!

- Use-cases:
  - Simulation study for better operation
  - Training simulation
  - Control (re-)design
  - Condition base monitoring
  - Predictable refurbishment
  - etc.
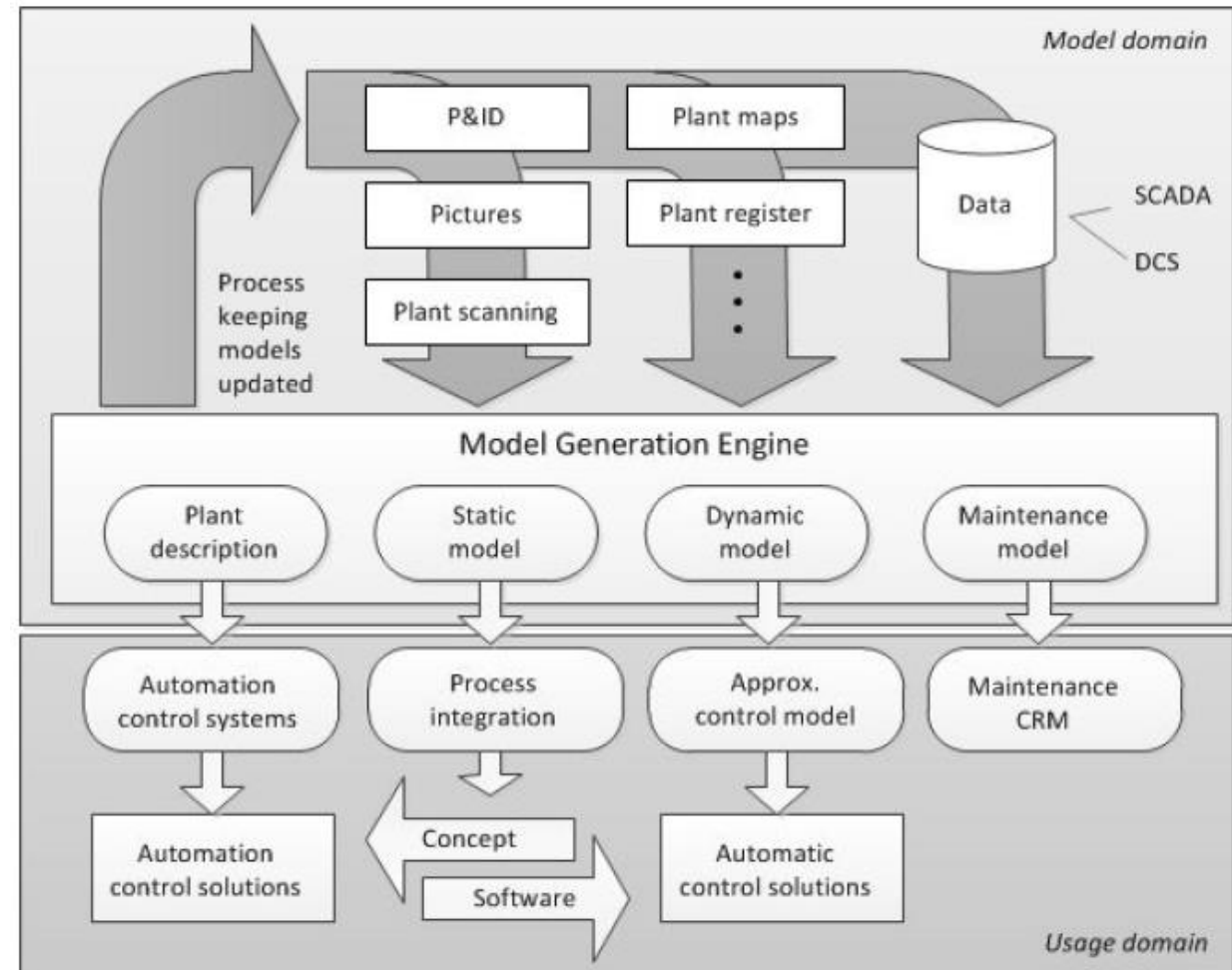
Condition based maintenance methods

- Joint effort with
  - LKAB
  - LTU – Operation and Maintenance
  - LTU – Control Engineering Group

- Topic: Combine condition monitoring and eMaintenance methodologies for mining processes

- Goal: Make maintenance more effective and increase availability and productiveness of processes

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Application cases:

- Vertical plate pressure filter
- Grate-Kiln

A principle sketch

Maintenance actions

Control actions

Measurements

Process Model

estimated Measurements + Predictions and non-measurable information
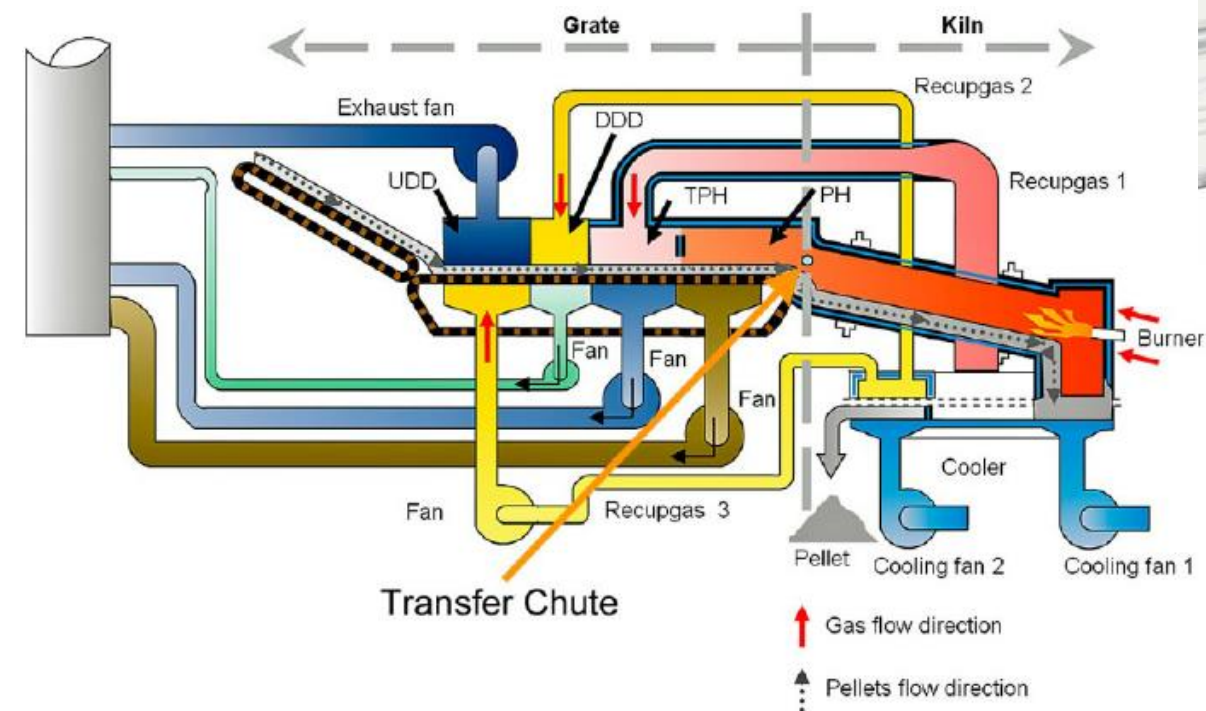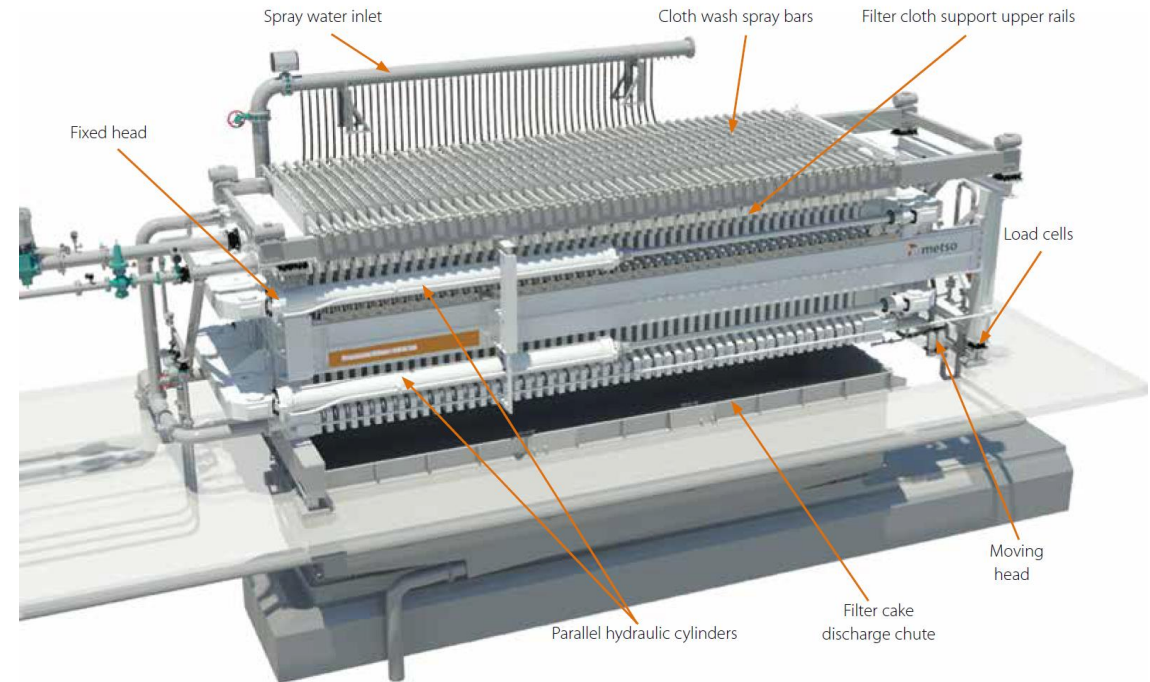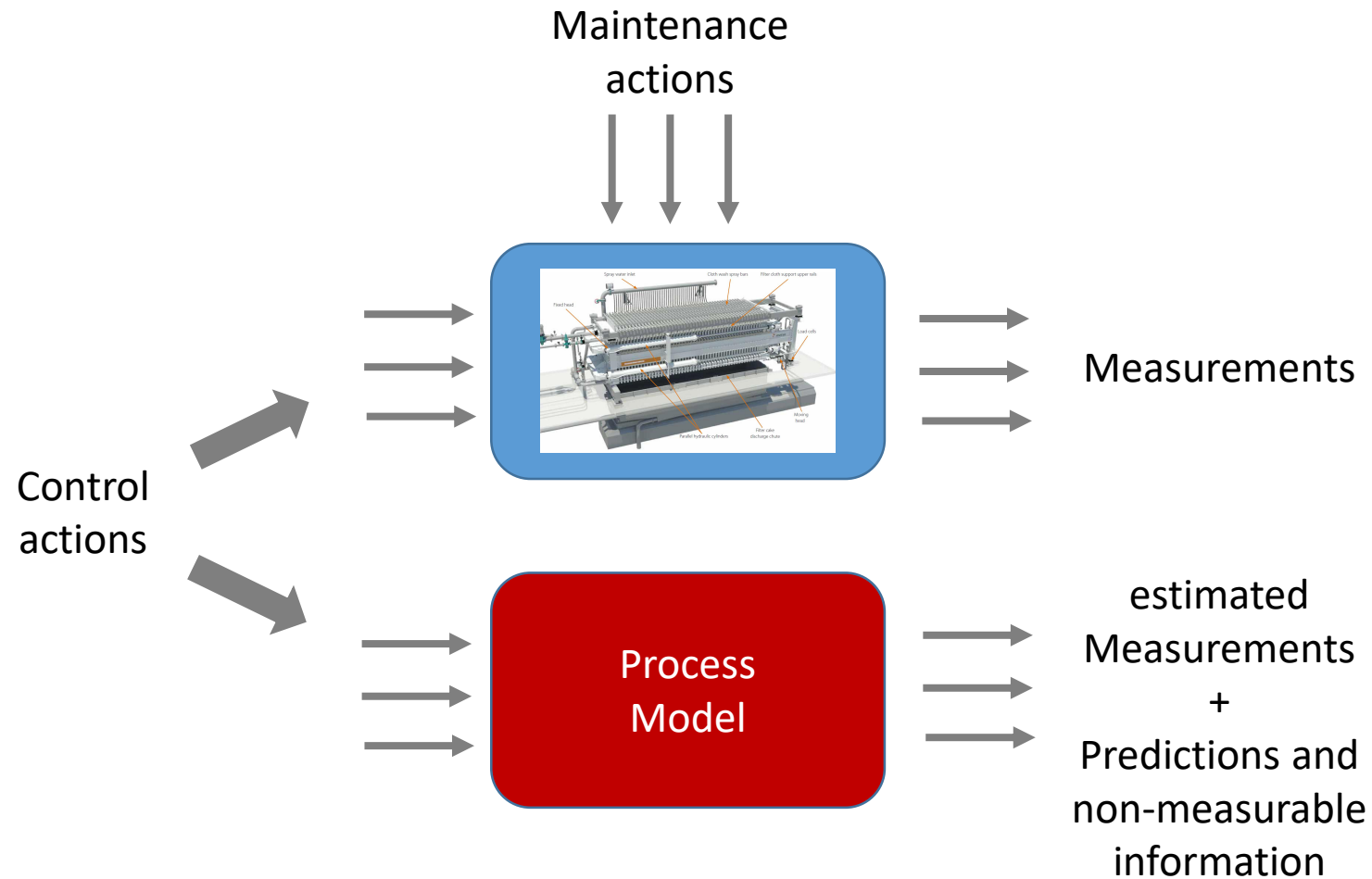
Principle sketch (2/2)
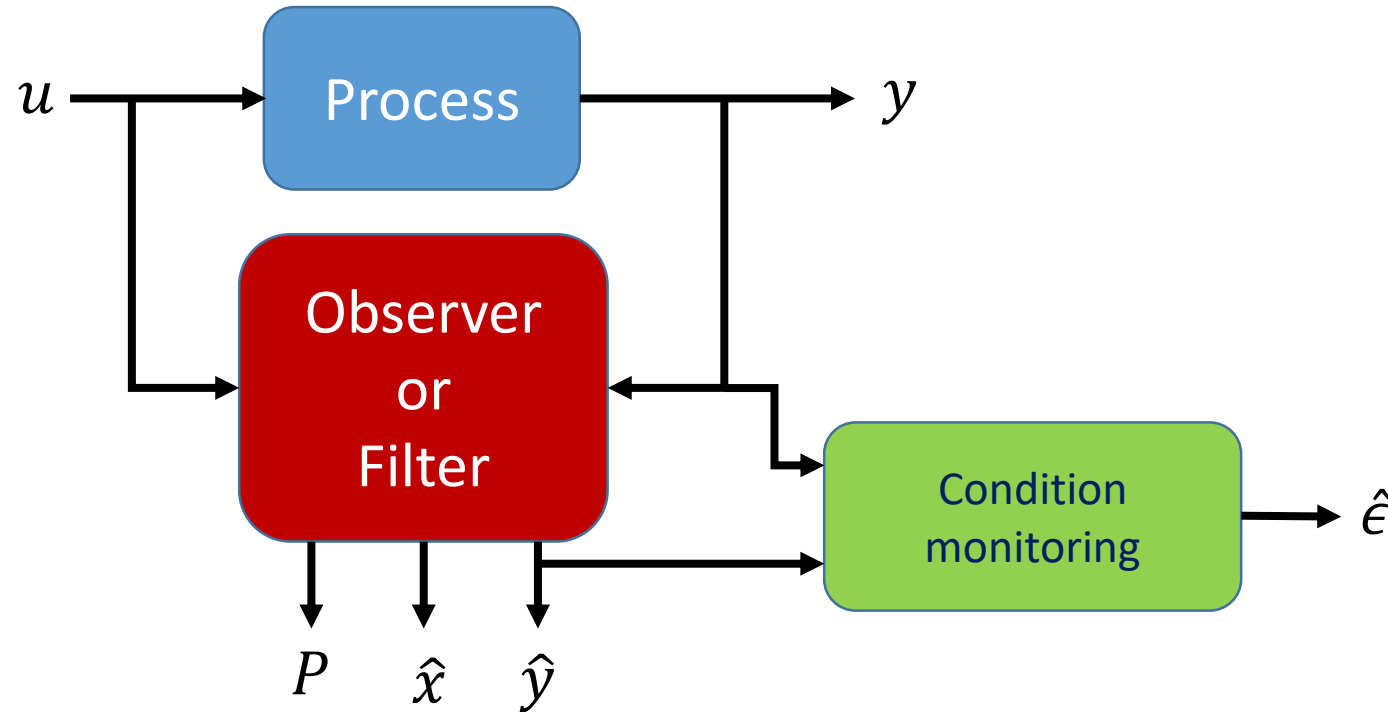
- Needed:
  - Prognostics for maintenance
  - Presciptive maintenance

Collaborating Autonomous Aerial Vehicles

The AEROWORKS robotic team will consist of multiple heterogeneous "collaborative Aerial Robotic Workers", a new class of Unmanned Aerial Vehicles equipped with dexterous manipulators, novel physical interaction and co-manipulation control strategies, perception systems, and planning intelligence.

Collaborating Autonomous Aerial Vehicles

- **Exploration, localization** and **navigation** in unknown environment
- **Sensor fusion**: Vison, IMU, Accelerometers, ultrasound, **UWB 3D Localization**, Lidar, ….
- **Optimal control** for path following, obstacle avoidance, coordination and battery life

Widefind kom med i nationell rymdsatsning

LULEÅ Widefind från Luleå är ett av åtta bolag i Sverige som har blivit utvalda att delta i den nationella rymdsatsningen, ESA BIC Sweden.
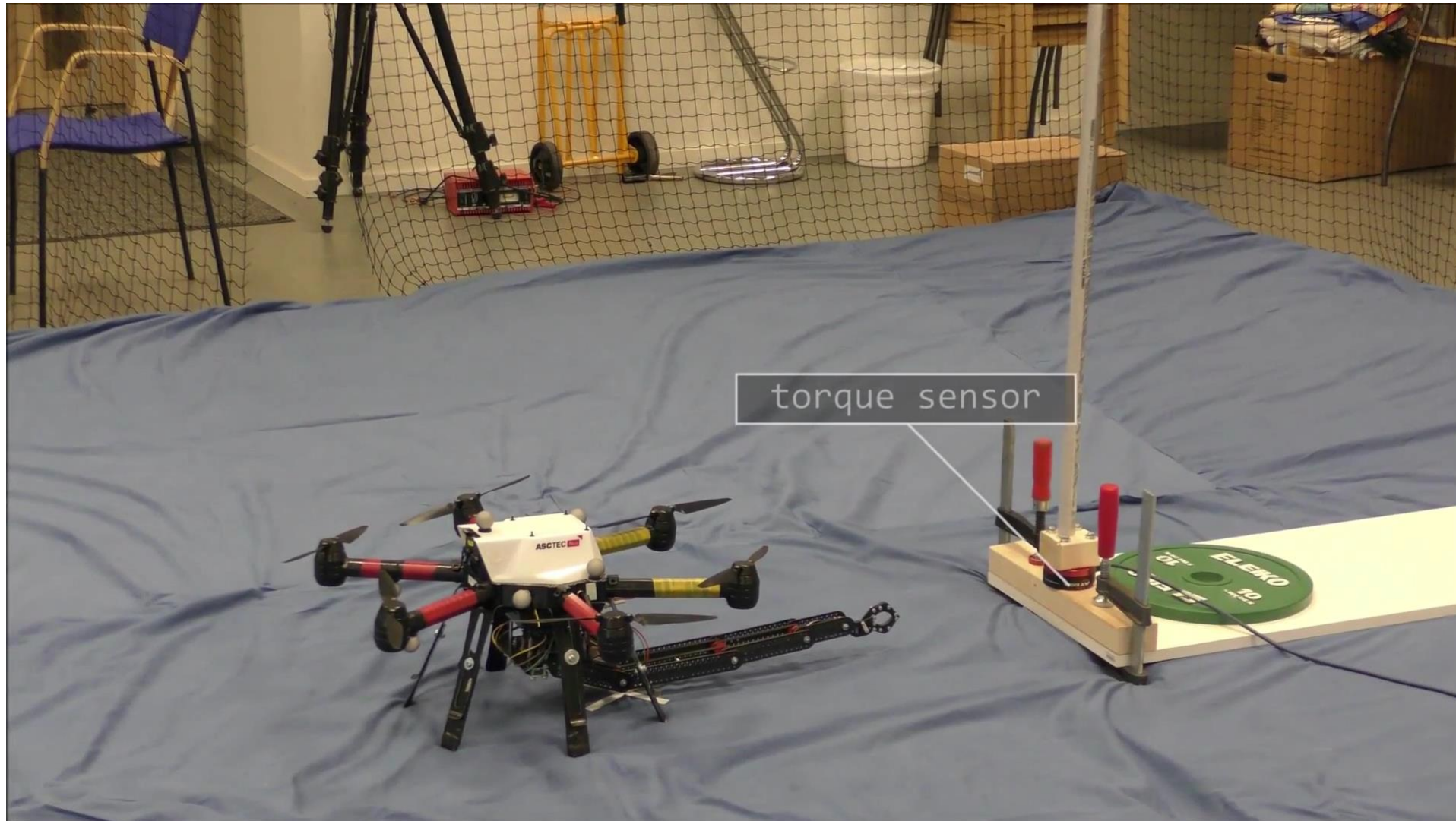
Autonomous Aerial vehicles

Framsteg inom Forskning och Teknik 2017

https://www.svt.se/nyheter/lokalt/vasterbotten/sjalvkorande-dronare-ska-hjalpa-vindkraften
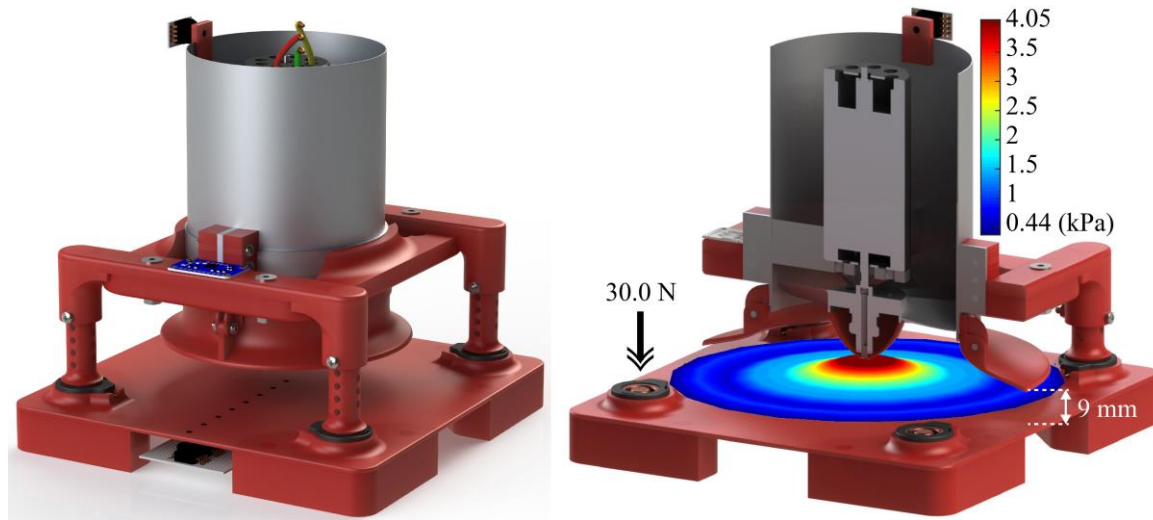
Autonomous Aerial Workers

torque sensor

Automation in mining

CompInnova

An Advanced Methodology for the Inspection and Quantification of Damage on Aerospace Composites and Metals using an INNovative Approach

Vortex propulsion and suction

- H2020-FETOPEN-2014
- 2.5 M€
- 5 Partners
- Coordinator: Cranfield University

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BART

Falls and **fear of falling** pose major threats to health and independence among elderly people. Our objective is to gain further knowledge regarding **balance control** aspects on fall risk and fear of falling by
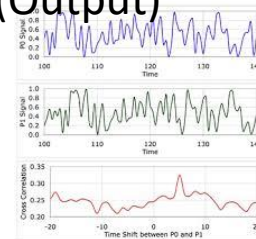
- assessing **postural sway** and **control mechanisms** in static and dynamic tests,
- creating a robotic humanoid with artificial muscles and electronic control systems
- establishing a mathematical formulation of balance control and experimentally evaluate it on the **robotic humanoid**.
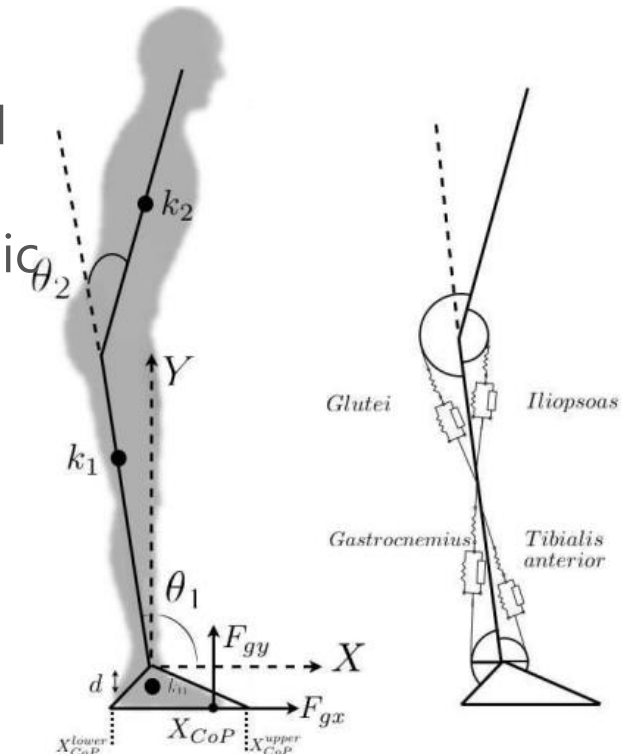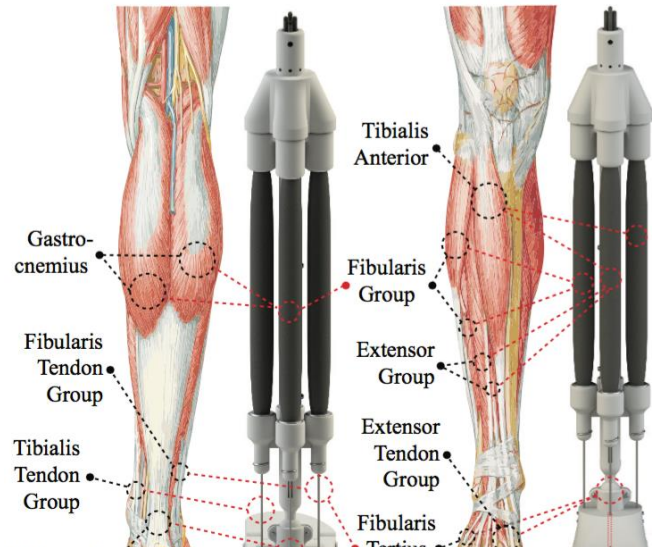
EMGs (Input)
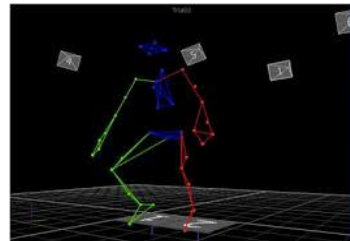
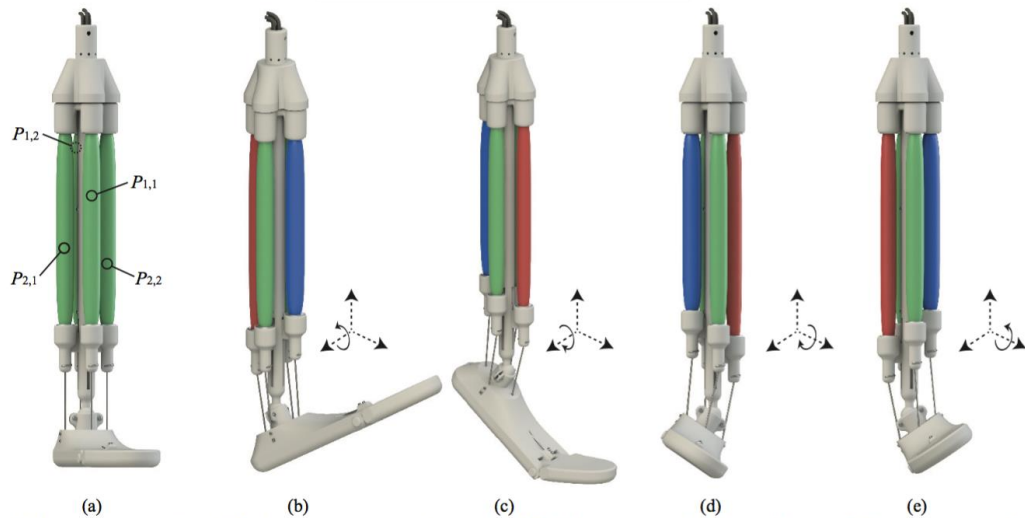Real Motion (Output)

Musculoskeletal Model

Bio-inspired robotics

Graphical representation of the HURL movement strategy during: (a) Idle, (b) Dorsiflexion, (c) Plantar Flexion, (d) Eversion, and (e) Inversion.