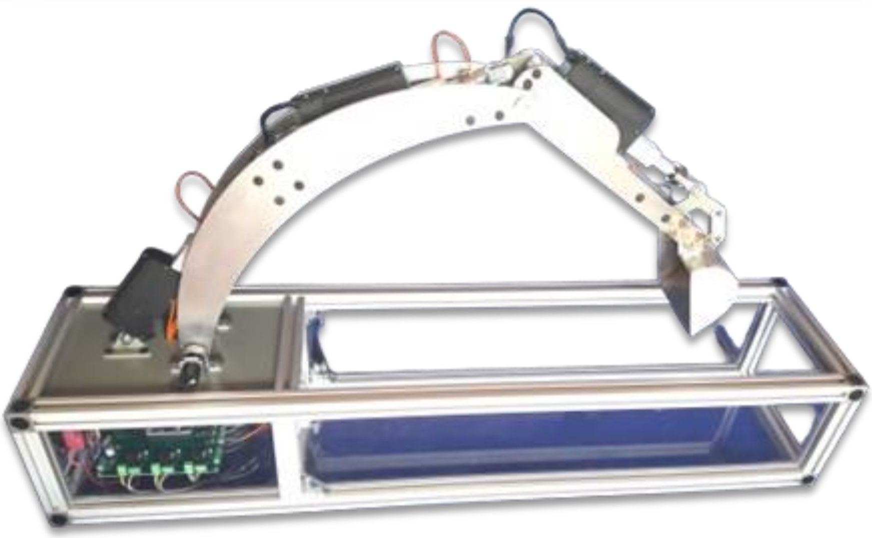
Electric Excavator Arm with integrated AI

Based on a real system for teaching industrial engineering sciences

From an real Electric excavator (Volvo for example)

To a didactic system :

Electric excavator arm with integrated AI



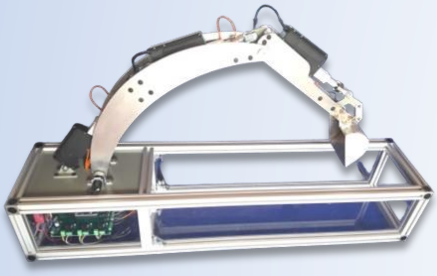
The training bench includes :

- ✓ An Electric excavator arm with integrated AI (LxWxH 120 x 32 x 58 cm, weight 25 kg) on a frame
- ✓ A control/command unit and a control and acquisition software package
- ✓ A virtual model (digital twin)
- ✓ A technical file (industrial and didactic)
- ✓ A training file with hands-on activities

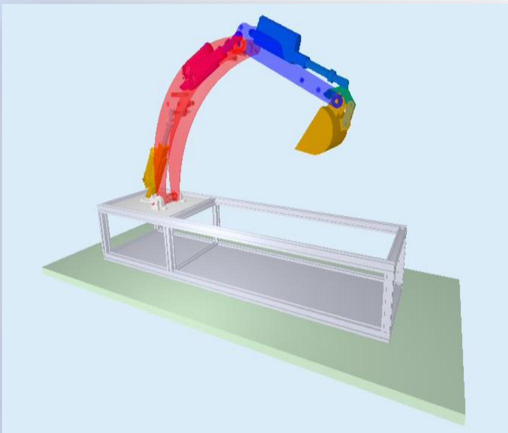
Reference : S2I//1200

The **Articulated arm**, inspired by that of an electric excavator, has **3 position-servo axes (with speed loop) to make excavation work autonomous**.

Each axis is controlled by an **electric cylinder** and is equipped with an **incremental encoder** and a **force sensor**, enabling the following program :

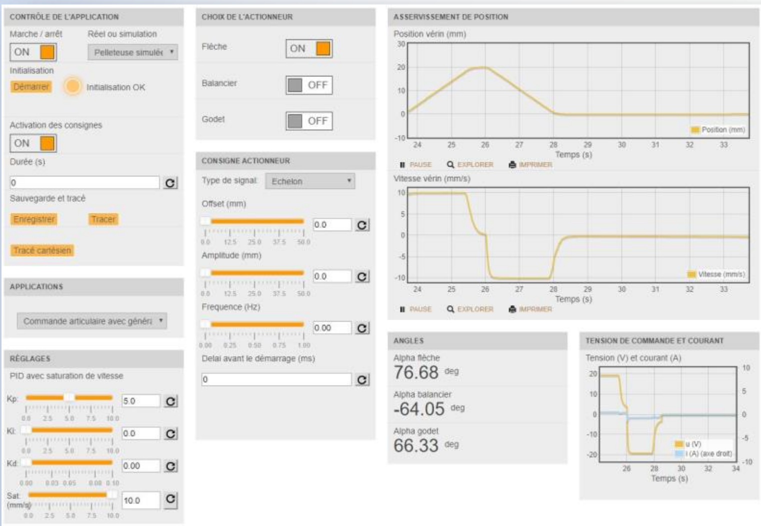


- **Control** (characterization, identification, modeling, correction)
- **Closed- and open-loop geometric/kinematic law** (system with 4 bars <-> **computer**)
- **Static**
- **Dynamics/Energetics/Power**



The control software MyViz integrates:

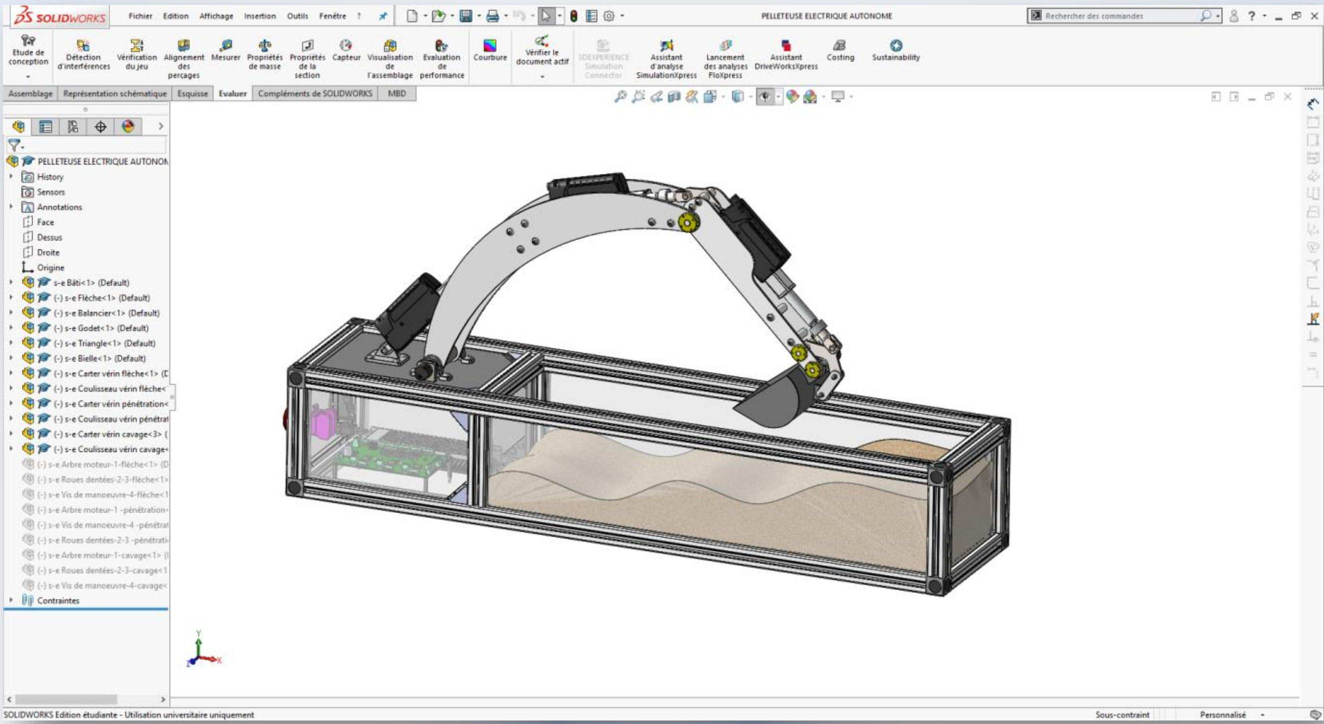
- A 3D model, controlled in real time, with the real dynamics of the system (**digital twin**).
  All students can work simultaneously on this digital twin, enabling group activities
- A model-based control with **SysML**

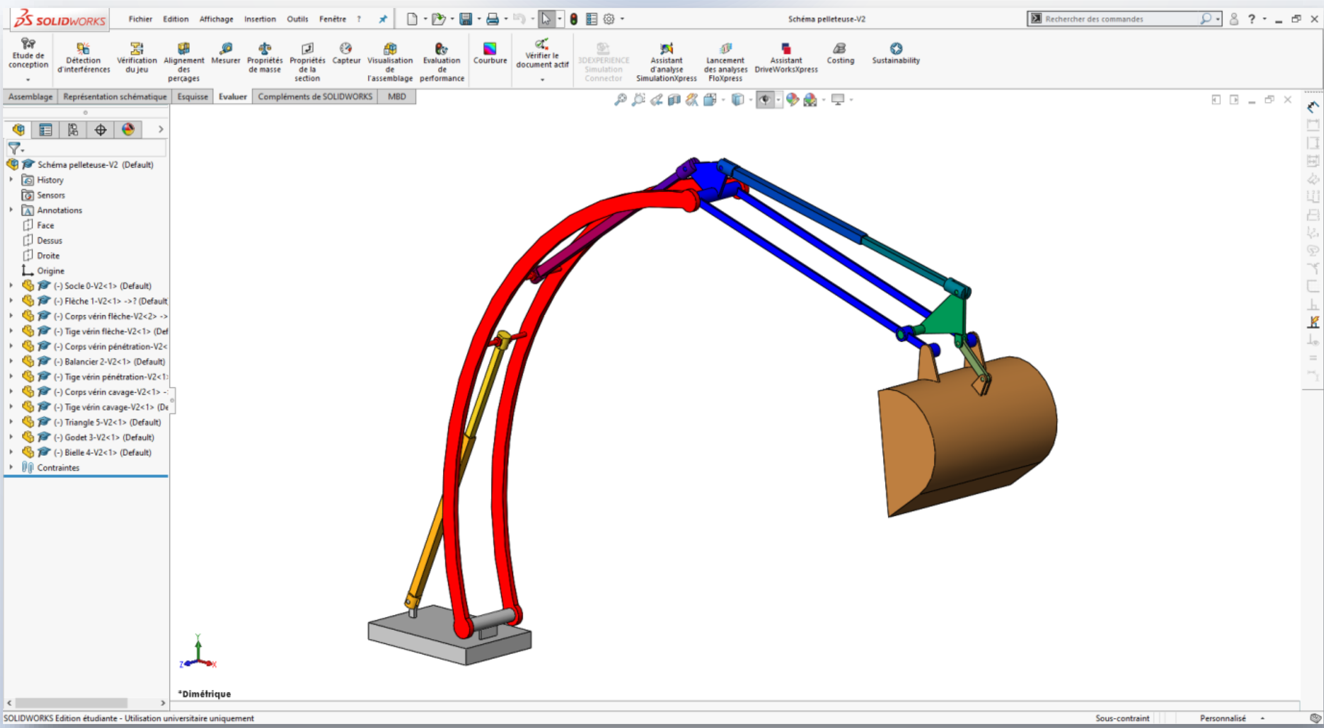


- A **Python** control mode (via high-level commands)
- An autonomous piloting by **Artificial Intelligence**, with safety by obstacle recognition (**supervised learning**), trajectory optimization (**reinforcement learning**).

The **trainer** is delivered with :

- A technical file
- A pedagogical file with hands-on activities
- A **Solidworks volume model** that can be used directly for **simulations in Meca3D**
- **2 kinematic diagrams**





Training activities

Activity 1 : System overview

Identify the components of an excavator arm

Identify the system's components (name and function) and complete the associated functional sequences based on analysis of the real system and the technical documentation provided (SysML diagrams etc.).

Activity 2 : CILS performance and modelling

Handle the arm as closely as possible to the operator's instructions

Model the system in a block diagram to be completed with the component transfer functions identified from experimental results or technical documentation.

Activity 3 : ÉTUDE DES SYSTÈMES SOLIDES

Link operator actions (cylinder control) to arm movements (articulations)

Identify part movements from measured trajectories, identify links between solids, complete a kinematic diagram and set up an I/O law to be validated using experimental results.

Activity 4 : Static study

Relate the forces to be supplied by the cylinders to the configuration of the arm and the force to be supplied by the bucket.

Identify the variation in force supplied by the actuator as a function of the arm configuration. Knowing the position of the center of mass for a system of solids will enable you to determine, for a given configuration of the arm, the relationship between the force supplied by the actuator and the action of gravity applied to the arm. This relationship can then be validated experimentally.

Activity 5 : Sequential behaviour of the system

Automate arm movement on a loading/unloading cycle

Impose the movement of the excavator arm via a state diagram (graphical programming in the HMI) or a Python algorithm (via high-level commands allowing different arm components to be moved under different options (arm speed, direction of movement, etc.).

Activity 6 : Dynamic study

Take into consideration the dynamics of the arm in the forces to be supplied by the cylinders

Demonstrate the influence of the arm's inertia on the mechanical actions to be provided by the actuator. By applying the theorem and/or principle of dynamics, knowledge of the mass properties of the parts and of the movement will enable you to establish a law linking the force supplied by the actuator to the angular parameter of the associated element (boom orientation in the case of the boom actuator, pendulum orientation in the case of the penetration actuator, etc.). This law can be validated experimentally.

Activity 7 : Choice of a corrector

Enable optimal behavior of the excavator arm (safety, productivity)

Visualize the influence of corrector types on system behavior (simulated or real). Corrector parameters can be modified in the HMI or in the associated Python program. The choice of the type of corrector and its characteristic parameters should lead to compliance with the imposed specifications.

Activity 8 : AI – Safety in autonomous mode

Enable the excavator to identify the presence of an unwanted object/individual in the work area

Supervised learning to set up a stop condition by recognizing an unwanted object (chosen by the student) in the excavator's working area. This condition can be integrated into the state diagrams that manage the autonomous operation of the excavator.

Activity 9 : AI – Autonomous excavator

Make the excavator autonomous in its operation, taking its environment into account

Autonomous operation of the excavator in its environment (imposed by a ground profile, for example, in the form of an image to be integrated into the learning program and "pasted" onto the system's chassis): make a round trip (loading/unloading) while avoiding obstacles. The AI calculation of the arm movement will be based on reinforcement learning. The trajectory can also be optimized in terms of energy consumption.