DIGITIZING PRODUCTS:
CREATING DEMONSTRATORS
FOR FUTURE EDUCATION

Connected Heating thermostat

Demonstrator classification and documentation

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ESTA Belfort

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Project consortium

Dissemination level

Code	Access granted to	
PU	Public	X
PP	Restricted to other programme participants (including the Commission Services)	
CO	Confidential, only for members of the consortium (including the Commission Services)	

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About the DigiDemo project

Environmental challenges and digital transformation are two of the main drivers changing the world and the way business will be is done in the future. Therefore, it is essential to enable future employees to address these drivers. The skills and competences needed to develop digitalized products and awareness of the environmental challenges are therefore crucial for the European workforce and industry to continue being competitive in a future green economy and to maintain jobs across Europe.

The DigiDemo project addresses these challenges by developing demonstrators especially for higher education allowing to improve mainly mechanical engineering studies by integrating skills and competences allowing them to understand, develop and commercialise connected products. The results will be publicly available and can be used by every institution interested in integrating this type of training in their cursus.

www.digidemo-project.eu

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Abbreviations

ESTA	ESTA Belfort (France)
FHV	Fachhochschule Vorarlberg (Austria)
FSV	Fagskolen I Vinius (Norway)
UCN	University College Nordjylland (Denmark)
UBB	Centrul Universitar UBB din Resita (Romania)
IoT	Internet of Things
SME	Small and Medium Enterprises

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1 Introduction

The present demonstrator is part of a larger project consisting in developing a smart heating system to be used in the school building of ESTA Belfort in France. This system must make it possible to control the temperatures online in the various classrooms and work rooms of the school (or any other building in which the rooms are used intermittently).

To do this, we have chosen to control the thermostatic radiator valves remotely, replacing the existing manual valves with connected electric valves. The final objective of these works is to have an affordable connected heating thermostat that can substitute standard valves, and that can be steered using an application (on a computer or smartphone) as part of the facility management. Once a temperature selected through the application, the different valves of a room are steered to reach and maintain the selected temperature. This solution, once operational, will help ESTA Belfort reducing massively energy consumption for heating as classrooms are often overheated or heated during periods when no classes are held (e.g., during the night). The overall project is split into two demonstrators, the valve including the integration of the connectivity and a functional description for an IT management tool, and specific lectures and practical works on how to connect and steer devices with an application.

During the Autumn term 2021/22 and spring term 2022, two groups of students contributed to the development of the first mechanical prototype for a connected heating thermostat, the described project. The demonstrator can be used individually but it is, as described above, integrated into a wider approach at ESTA. All student groups had members both from the Industry 4.0 and from the Digital Transformation specialisations.

This prototype is the basis for further projects in the next terms to improve and realise the planned smart heating system.

This topic has been chosen for the following reasons:

- It is a real case with direct use to the students' environment that allows to apply mechanical design, prototyping, connectivity, and software design.
- The overall project can be divided in subprojects that can be used as demonstrators and will form a bigger system once combined
- Even if smart connected valves exist, their purchase is expensive
- The demonstrator highlights how technology can contribute to reduce environmental impacts of daily live.

2 Overview

The key properties of the demonstrator are:

Table 1: Specification of key properties

Key Property	Value
EQF level	6 (Bachelor)
Year of study	2 – 4
Domain	Mechatronics
Objective	Development by students
Workload	2 ECTS
Keywords	Smart home, connected heating valve, WiFi connection, kinematics, motorization, autonomy, ESP32, temperature sensor

This demonstrator aims at showing how a simple mechanical object can be connected and interact with a centralized control system. The one we will describe is part of an overall system to manage temperature in an educational building. Depending on the differences between the setpoint and the actual value, they close or open the heating circuits to a greater or lesser extent and thus make it possible to adjust the temperature to requirements. This system must make it possible to control the temperatures online in the various classrooms and work rooms or in any other building in which rooms are used intermittently.

To do this, we have chosen to control the thermostatic radiator valves remotely, replacing the existing manual valves with connected electric valves. The valves described below receive an instruction from the control system; they also receive the temperature in the room to which they belong. Depending on the differences between the setpoint and the actual value, they close or open the heating circuits to a greater or lesser extent and thus make it possible to adjust the temperature to requirements. This valve therefore includes all the elements of a classic servo chain: sensors (possibly remote), control/command, power management component (current or voltage) and effector. The sensor can be centralized (one sensor per room) or specific to the valve; the control command is carried out by a Wifi module of the ESP32 type. The effector and its driver circuit depend on the technology used: DC motor, stepper motor. A big constraint comes from energy management, which must be optimized to limit battery consumption. To this end, the number of accesses to the network and to the temperature setpoint will have a very low frequency (every half hour or every hour).

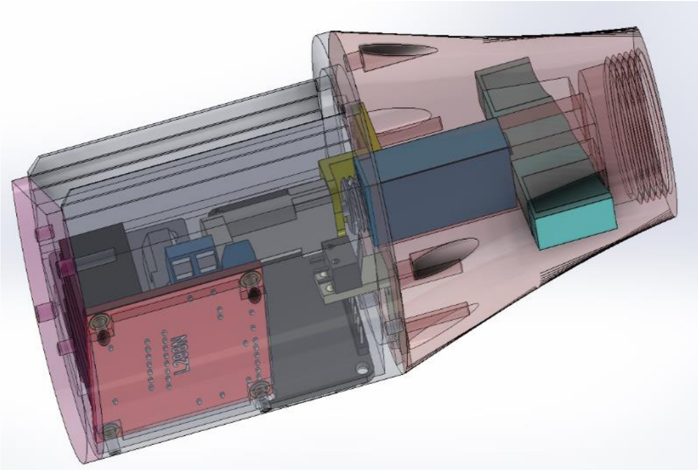

Figure 1: Image of the thermostatic valve

The documents “Bill of Material.docx” and “Assembly instructions.docx” list the elements needed and describe the assembly instructions.

3 Description of fulfilment of demonstrator characteristics

This description shall be included as a table as shown below:

Table 2: Description of fulfilment of demonstrator characteristics

Characteristic	Description
Teaching improvement	Through this demonstrator, the following improvements can be carried out in the teaching: ❖ Analysis of the continuity of the digital / physical chain ❖ Illustration of energy consumption constraints ❖ Knowledge / understanding of the different types of motorizations for low power ❖ Knowledge / understanding of different rotation - translation motion transformation systems: screw, cam, connecting rod ❖ Methods for determining force and torque values on a simple problem
Sustainability awareness	❖ On the valve itself: To be able to operate for a long time without having to change batteries, this system must not consume too much energy. To this end, it raises awareness of the yields and efficiency of different technological solutions: a servo will consume more energy than a DC motor. Time ranges considered and response times are of the order of an hour. It therefore raises awareness of the link between time constant and control circuit: no need to have a control circuit under permanent voltage ❖ The purpose of this system is also to optimize the overall consumption of the whole school. It will be possible thanks to him to show everyone how much energy is saved compared to an uncontrolled situation. It will also allow those who wish to reactivate the heating in a room to know the energy cost of their action.
Replicability	The valves are at the European standards, the components are available all over the planet: all the elements used are therefore replicable in any school in Europe. The plans of the parts to be produced are provided with standardized functional dimensions, their assembly should therefore be done without difficulty. However, some parts can be made with a 3D printer, so a calibration process must be defined to assess the manufacturing dispersions and define the compensations applied to the different components.
Industry needs	This product was imagined because no industrial valve could meet the double constraint autonomy / centralized control. Autonomous valves are difficult to control centrally, and it is difficult to access their code, whereas centralized control systems are mainly intended for industrial control devices (3-way valves, etc.)

Characteristic	Description
Interdisciplinarity	The system was made by students of mechanics, electronics, and computer science. They were brought to work together, to present their work to each other, to define the data to be exchanged, the physical values to be measured and controlled. The fact of having involved the students throughout the digital --> physical chain therefore required sharing and understanding of their respective disciplines, thus encouraging interdisciplinarity. This is all the simpler as all the elements making up the chain are simple and therefore easily accessible to the different students.

4 Classification according to the dimensions

Table 3: Classification according to the dimensions

Dimension	Property	Value
Value chain	development	☒
	production	☒
	sales	☐
	after-sales-support	☐
	end-of-life	☐
Chain of technology	mechanical structure	☒
	sensors	☒
	electronic circuits	☒
	edge device	☐
	data transmission	☒
	cloud	☐
Sustainability	energy reduction	☒
	material reduction	☒
	better materials	☐
	better production	☐
	reparability	☒
	recycling	☐
Physicality	physical setup	☒
	simulation	☐
Degree of student freedom	demonstrated	☐
	guided	☐
	coached	☒
	autonomous	☐
Transportability	fixed	☐
	transportable	☐
	portable	☒
Costs (implementation)	EUR (for one demonstrator including all the technologies)	300 €
Costs (operation)	EUR	10 €/year

Dimension	Property	Value
Workload (implementation)	Hours	30
Workload (operation)	Hours	3
Size	mm	70x70x200
Weight	kg	0,5
Special requests	no/yes, if yes: which	no

5 Educational information

5.1 Connected Heating thermostat

Prerequisites

- Notions of forces and moments,
- Modeling in a plane
- Balance of forces of a solid
- Intensity and voltage of an electrical circuit
- Link between force, moment, displacement, power, energy

Course content

- Different types of motorizations, their characteristics of torque, speed, precision, etc.
  - DC motors
  - Stepper motor
  - Servomotors
- Control of these different engines:
  - physical quantities at input/output: power supply, connection
  - data used for piloting
- Different types of rotation translation kinematic transformation:
  - wheel and worm
  - screw-nut system
  - crank rod / slider
  - rack/pinion
- Characteristics of these transformations:
  - gear transformation ratio
  - effort transformation ratio
  - performance and efficiency factors
- Geometry of these transformations:
  - part shapes
  - guidance of the different movements

Learning outcome

Knowledge of electrical components and different mechanical transformation systems:

- The various most frequent configurations: basic components, connections, usual configurations
- Limits and advantages of these different configurations

Planned learning activities

1. E-learning courses (reading and evaluation activities) Context: needs assessment (measurement of valve closing forces, link between battery capacity and average / instantaneous consumption x operating timeAssembly and test of different electrical then mechanical configurations: Connection between components (according to an assembly manual describing the flows within these connections) Modification of the control program according to the components tested Measurement of associated physical quantities (intensity, voltage, torque, rotation/translation speeds Identification of the parameters of each of the components on the system: speed curve, reduction

ratio Identification of the limits of the proposed models, possibility of transposition to industrial systems Search for the motor/transformer configuration allowing the control of the valve to be carried out **Teaching methods**

Preliminary e-learning, then guided practical work (especially on connections). Statement of values, plotting of curves, tests of different configurations by varying certain parameters for induction of the laws of behaviour of each of the systems. **Assessment methods and criteria**

Evaluation by application to other cases Criterion 1: understanding of the electrical forces and quantities involved

- Criterion 2: choice of components
- Criterion 3: pre-sizing of components
- Criterion 4: organization and connection between components **Recommended / required readings**E-learning courses set up by students

Mode of delivery (face-to-face, distance learning)Remote for e-learning courses, then **face to face** in practical work

5.2 Sustainability – questions for reflection

The questions below are meant as inspiration for the teacher using the demonstrator. The aim is to strengthen the student's awareness regarding sustainability through reflecting upon questions related to the demonstrator. The questions can be used during the lecture or as the starting point for individual or group work, connected to the lecture. It is suggested that the students in groups answer the questions and then present the result of the discussion on class.

The questions below are divided into three main categories, general considerations, recycling, and product integrity, where the last two categories are addressing this specific demonstrator.

General considerations

- What can be the contribution of connected heating thermostats to the energy reduction of a building?
- How does the construction scheme influence the energy consumption of the thermostat and the autonomy with one set of batteries?
- Does the making or use of the product create pollution?
- How can the energy consumption of the demonstrator be reduced?
- How can the material consumption needed for the demonstrator be reduced?

Recycling

- Can the demonstrator, or parts of it be recycled? How can this be changed to increase the part of recycling?
- Can all the materials be recycled – are they "pure" or do they need special treatment?
- How can the recycling of the demonstrator or its parts be improved?

Product integrity

- What are the key aspects to obtain a durable product, in terms of construction and material?
- Which parts of the demonstrator need maintenance?
- Can parts which should be maintained be easily disassembled from the demonstrator?
- Can an update of components (which?) be foreseen to enlengthen its lifespan?
- Is the software of the demonstrator easy to update?

- How can the autonomy of the demonstrator be improved?
- Can the demonstrator be repaired?

6 Organizational information

6.1 Project duration

The project can be organized over a semester; five key weeks can be identified:

- Understanding the problem and identifying the different technological solutions: personal research of components, research of similar systems fulfilling the same functions, etc.
- Measurement of the need: force of closing / opening of the valves. Finding simple measurement setups with simple components (lever arm, weight).
- Qualification of components: measurement of torques, forces of transformation systems, and different motorization systems. Measurement of electrical consumption. Calculation of returns.
- Implementation of assembly and installation.
- Monitoring of behaviour and battery charge

6.2 Team size

Interdisciplinary groups can be set up. The project worked well with groups of 3-4 students. All activities are integrated into the planning described above

7 Description of the technology and the setup

7.1 Demonstrator Documentation

There is no manual or background information on the rationale of the demonstrator.

The overview of the files supplied together with this description of the demonstrator is given below. It includes all files needed to replicate the demonstrator.