DIGITIZING PRODUCTS:
CREATING DEMONSTRATORS
FOR FUTURE EDUCATION

digi demo

Smart Heating Application
IoT part

Demonstrator classification and documentation

Belfort, May 2022
ESTA Belfort

Co-funded by the Erasmus+ Programme of the European Union

Project consortium

UCN
Fagskolen i Viken
Universitatea Babeș-Bolyai Cluj-Napoca, Centrul Universitar UBB Reșița
FH Vorarlberg University of Applied Sciences
ésta school of business & technology Belfort

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)	

Legal Disclaimer

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

Table of Contents

Document authors

	First name Last name	Institution
Key author	Sylvain Sagot	ESTA Belfort
Further authors	Thomas Röhr	ESTA Belfort

Revision history

Version	Date	Author(s)	Description
1.0	24.05.2022	Sylvain Sagot, Thomas Röhr	Initial document version
1.1	28/03/2023	Thomas Röhr	Final version

Document status

Status description	
For Information	
Draft Version	
Final Version (Internal document)	
Final Version (public document)	x

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

List of figures

List of tables

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.

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 IoT/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	☒ 7 (Master)
Year of study	4
Domain	☒ IoT
Objective	☒ Development by students
Workload	2 ECTS
Keywords	IoT, Smart heating, Software specification; connectivity;

This IoT demonstrator aims at showing how to connect, interact, gather, and control data of a simple mechanical object through a centralized control system. The objective of the system is to manage temperature in an educational building. 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 mechanical valves receive instructions 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.

The "mechanical part" of the valve, presented in **Figure 1** (right side), includes a servomotor (MG90S), a power management component (current or voltage) and an effector. The hardware "IoT part" of the valve is presented in **Figure 1** (left side). The control command is carried out by an Arduino Uno Wifi Rev 2 and the temperature and humidity sensor by a DHT11 sensor.

During the DigiDemo project, a separate demonstrator (see demonstrator ESTA#1) was launched to build a smart heating valve by integrating this IoT part into the mechanical part.

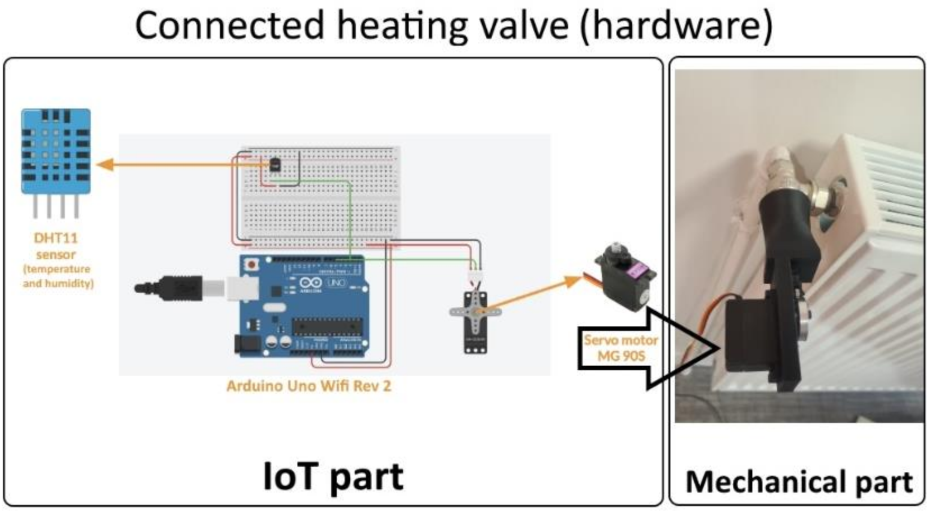


Figure 1: Image of the connected heating valve (hardware)

For the software part, **Figure 2**, a Raspberri Pi is used with Mosquitto, an MQTT open-source server, to communicate with the Arduino (emitter/receptor). Grafana, which is a multi-platform open-source analytics and interactive visualization web application, allows to display the temperature and humidity information through dynamical dashboards by using Influx-DB, an open-source time series database (TSDB). Node-Red, a programming tool for wiring together hardware devices, permitted to manage the links and data between all the electronic components, **Figure 3**.

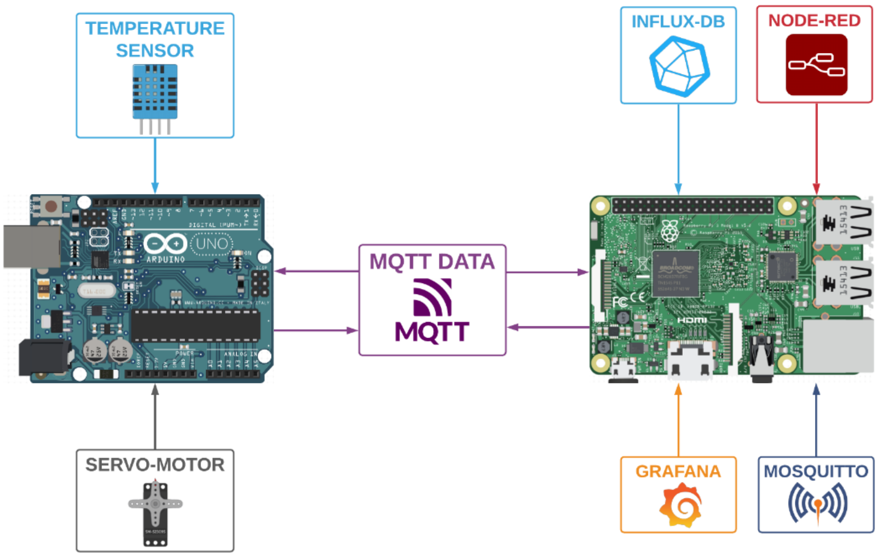
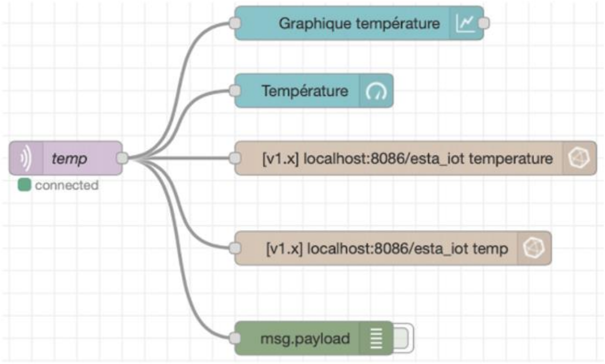


Figure 2: Hardware and software part of the connected valve




```
//###################################################
// Envoie MQTT
//###################################################
Serial.print("Envoie de la température: ");
Serial.println(temperature);
Serial.println(t);

Serial.print("Envoie de l'humidité: ");
Serial.println(humidity);
Serial.println(h);

// envoie de la temp & humidité en mqtt
mqttClient.beginMessage(temperature);
mqttClient.print(t);
mqttClient.endMessage();

mqttClient.beginMessage(humidity);
mqttClient.print(h);
mqttClient.endMessage();
```

Figure 3: Data gathering through MQTT and Node-Red (Ex. of code)

3 Description of fulfilment of demonstrator characteristics

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 connectivity constraints ❖ Knowledge / understanding of the different types of electronic components ❖ Knowledge / understanding of different API, web tools to manage connectivity and data ❖ Methods for determining adequate IoT hardware and software part choice to solve a simple problem
Sustainability awareness	❖ The electronic components can be reused thanks to the use of a breadboard ❖ Electronic components are selected according to their energy consumption
Replicability	The valves are at the European standards, the electronic components are available all over the planet: all the elements used are therefore replicable in any school in Europe. The source code is in open access.
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.)
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	100
Costs (operation)	EUR	5
Workload (implementation)	Hours – Teacher Hours - Students	24 30 each

Dimension	Property	Value
Workload (operation)	Hours	8
Size	m	50x100x50
Weight	kg	<1kg
Special requests	no/yes, if yes: which	no

The workload refers to the effort needed by the teacher for implementation and operation of the demonstrator. As for the workload of the students please refer to chapter 2**Erreur ! Source du renvoi introuvable.**.

5 Educational information

5.1 Educational information

<u>Prerequisites</u>

- Notions of electronic
- Notions of programming,
- Notions of networks
- Notions of data management
- Intensity and voltage of an electrical circuit

<u>Course content</u>

Introduction

- Internet of Things: Introduction, Evolution and Trends
- IoT Enabling and Building Blocks Technologies

Basic Hardware Elements for IoT

- Electronic Components, Sensors, Microcontrollers
- Development boards: Arduino, Raspberry Pi

Programming for IoT

- C/C++ programming with Arduino
- Python and JavaScript (NodeJS) programming with Raspberry Pi

Internet, networks, and communication protocols for IoT

- Internet protocols and protocols for IoT
- OSI Model, IP, TCP, UDP, HTTP, MQTT, CoAP, Lora, LoraWAN

Data Storage and Analysis for IoT

- Databases for IoT, SQL, NoSQL, APIs, REST
- Statistics and Data Analysis and Time Series

Applications for IoT

- Monitoring and Control Interfaces for IoT Systems
- Building blocks of an application for IoT
- Web of Things

<u>Learning outcomes</u>

Skills: the student will be able to apply his knowledge in a diversified context, allowing the aggregation and integration of the variety of technologies into a coherent system for IoT.

He/she will be able to:

(1) identify the elements of an IoT system,
(2) know the role of the constituent technologies of an IoT system, and
(3) use the specific and adapted tools allowing the design, development, and prototyping of systems for IoT.

Planned learning activities and teaching methods

The course lasts 45 hours in class and 15 hours of unsupervised work, for a total of 60 hours. The face-to-face part is organized in 5 full days and two half days (4h30 and 3h). The preferred teaching methods are learning by doing and project-based learning. Generally, each lecture (duration 30min) is followed by a TD session (duration 1h00+ depending on the complexity of the subject). The work on the individual project benefits from a personalized supervision of 6 hours (distributed according to the total number of students) and a complement of 15 hours THE (work without supervision).

Teaching methods are

- Composition of the course: CM: classroom - 12 hours
- TD: experiential - 27h
- Individual PROJECT (personalized supervision) - 6h
- THE PROJECT (work without supervision) - 15h

Assessment methods and criteria Evaluation by application to other cases

Evaluation is conducted as follows:

- Grade in written exam: key concepts, exercises (35%)
- Grade on class participation (exercises/code in TD) (15%)
- Grade on individual IoT project (50%):
  - Report (10%)
  - Presentation (15min + 5min demo + 10min questions - 20%)
  - Quality of the project (functionality, creativity, complexity, effort, demonstration during the presentation; 20%)

Expected Deliverables:

- Individual IoT project (the implementation, report, presentation, source code)
- Source code of the exercises evaluated in TD

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

- Does the making or use of the product create pollution?
- How can the energy consumption of the demonstrator be reduced?
- How can the transmitted data volume be optimized

Recycling

- Can the demonstrator, or parts of it be recycled?

Product integrity

- 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?

6 Organizational information

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.
- Implementation of assembly and installation.
- Monitoring data

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.

