DIGITIZING PRODUCTS:
CREATING DEMONSTRATORS
FOR FUTURE EDUCATION

digi demo

Distance measurement

Demonstrator documentation

Belfort, July 2023
ESTA Belfort

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

Project consortium

UCN

Fagskolen i Viken

Universitatea Babeş-Bolyai Centrul Universitar UBB Reşiţa Cluj-Napoca

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	Daniel Schlegel	ESTA Belfort
Further authors	Thomas Röhr	ESTA Belfort

Revision history

Version	Date	Author(s)	Description
1.0	02/12/2022	D. Schlegel	V1
2.0	10/07/2023	D. Schlegel	V2

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

Despite ongoing digitalisation of the European industry, many companies and especially SMEs still dispose of manual machines they purchased in the past. These machines are often very performant, but using them needs competences that are no longer available or not used on a daily basis. Thus, using the machines becomes more and more unusual, with a risk of throwing them at one moment despite their potential use.

Digitalisation manual machines to continue using them or even integrating them in more digital/automatised workflows contributes to minimising costs for the company as well as reducing environmental impacts.

This demonstrator shows a smart measurement system that can be added to manual machines, such as, e.g., a milling machine.

2 Key properties

The key properties of the demonstrator are:

Table 2.1: Specification of key properties

Key Property	Value
EQF level	☒ 5 (Technician) ☒ 6 (Bachelor) ☐ 7 (Master) ☐ 8 (PhD)
Year of study	2 - 4
Domain	☒ Mechatronics ☐ IoT
Objective	☒ Demonstrate a functioning ☐ Development by students
Workload	3 to 20 hours
Keywords	Kinematics, pulley and belt transmission, rotating coder, 4 digit display

3 Demonstrator description

The demonstrator uses a manual milling machine to demonstrate options for digitalisation enabling it for further use with enhanced performance through a digital measurement system.

Students discover how to convert a linear to a rotational movement, the working principle of a rotational encoder, how to read a rotational encoder signal and to convert it into a meaningful physical value that is displayed on an interface.

4 Description of fulfilment of demonstrator characteristics

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

Table 4.1: Description of fulfilment of demonstrator characteristics

Characteristic	Description
Teaching improvement	Through this demonstrator, the following improvements can be carried out in the lessons ❖ conversion of a linear to a rotational movement ❖ working principle of a rotational encoder ❖ reading of a rotational encoder signal. ❖ converting a signal into a meaningful physical value ❖ displaying this value
Sustainability awareness	This system shows how to retrofit a machine that seems initially complicated to use and not up to date at all. This allows to save old materials and avoids investing into new material that fulfill quite the same requirements.
Replicability	As all components respect standard sizes and connection, and as all the components can be obtained everywhere, the system is fully replicable.
Industry needs	This system could be easily applied to many industrial machines that are still used in the industry. There are many cases where machines are still well working, and their only flaw is the lack of feedback for some parameters. This demonstrator is a way to show that some parameters can easily be extracted with the mean of simple acquisition chains.
Interdisciplinarity	The system allows understanding mechanical, electronical, and informatics principles

5 Classification according to the dimensions

Table 5.1: Classification according to the dimensions

Dimension	Property	Value
Value chain	development	☒
	production	☐
	sales	☐
	after-sales-support	☐
	use	☒
	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	80 – 150
Costs (operation)	EUR	N/A
Workload (implementation)	Hours	30

Dimension	Property	Value
Workload (operation)	Hours	1
Size	mm	300*200*100
Weight	kg	1
Special requests	no/yes, if Yes:	availability of an oscilloscope

5.1 Additional information

5.1.1 Chain of technology

This demonstrator covers all the measurement chain, from mechanical components that converts linear to rotational displacement, to digital displays, as well as data transmission to a smart phone.

5.1.2 Sustainability

The idea is to convert old mechanical machines to more easy-to use systems. Experience shows that the measurement is the main problem encountered by the students while learning machining, and this is sometimes so prohibitive that the equipment is changed to a new one. With this system, it is possible to keep older systems in use.

5.1.3 Physicality

This demonstrator is a physical setup

5.1.4 Degree of student freedom

This demonstrator will be used as a support of a guided activity. The students will have to make measurements of the displacement ratios (linear/rotation), and they will have to read the shape of the signal to understand the way of working of the encoder. After that, they will be able to work more autonomously for the development of the code.

5.1.5 Transportability

This demonstrator has originally put in place for a lathe and a mill, that are not designed to be transportable.

But it is possible to design a transportable version of this demonstrator with a linear displacement guide.

5.1.6 Costs

The cost of the elements used is of 80 €. If a linear translation unit is to be used, the cost is of 150 €.

5.1.7 Workload

Mounting the elements on a translation unit can be done by the students during the course, to help them understand the technological chain; this only takes 1 hour. The development of the code can need up to 20 hours if the students must code the taking into account the rising edges and the phase shift.

6 Educational information

6.1 Prerequisites

- Intensity and voltage of an electrical circuit
- coding fundamentals (parameters, loops, etc.)

6.2 Course content

- Different linear/rotational conversion systems: belts, gear, screws. Link between the geometrical parameters and the conversion rates.
- Rotational encoder principle: shape of the generated signal, precision of the encoder.
- Precision and sensitivity of the whole system.
- Different display technologies: segments, matrix.

6.3 Course result

Knowledge of electronical components and different mechanical transformation systems:

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

6.4 Planned learning activities

- E-learning courses (reading and evaluation activities)
- Mounting of the system: assembly of the whole measuring chain: fixation of the belt on the guide, fixation of the encoder on the translating carrier, solidarisation of the pulley and the coder, analogical outputs of the encoder, digital inputs of the display. Measuring the primitive diameter of the pulley
- Analysis of the behavior of the encoder with simple code, reading the phase angle and the rising edges
- Calculation of the ratio between the sensitivity of the coder and the carrier's displacement
- Implementation of the code for the 7-segments (or else) display.

6.5 Teaching methods

Preliminary e-learning, then guided practical work, with sufficient photographs and description of the results that should be obtained.

6.6 Evaluation methods and criteria

Evaluation by application to other cases

- Criterion 1: understanding of the conversion ratio
- Criterion 2: being able to choose a {mechanical converter + encoder} for a specific purpose, regarding the expected measurement precision
- Criterion 3: being able to transform the output of a sensor into a readable information

7 Organizational information

- Project duration. The project can be organized into a week: part of one first course for the mounting of the system, then the rest of the course for the understanding of the signals and the different conversion ratios. Then the rest of the week for the coding.
- Team size: the project should work with groups of 3-4 students. All activities are integrated into the planning described above

8 Description of the technology and the setup

8.1 Description

The system is based on the relative displacement of a belt or the associated pulley. Following the configuration, either the belt or the pulley and the encoder are united with the mobile part. The belt should be put in place to ensure a free displacement of the pulley on the whole stroke of the machine, with some blocking ends that are specific to the machine. The belt then is then wrapped around the pulley with some auxiliary pulley or due to some particular surfaces of the encoder support, allowing a good link between the rotation of the pulley and the linear movement of the belt. This last part is also specific to the machine.

8.1.1 Bill of Materials

Référence	Name	Origine	Source / name of the file
1.	Encoder housing	3D Printed	
2.	Incremental Photoelectric Rotary Encoder	Gotronic	https://www.gotronic.fr/art-encodeur-rotatif-6-mm-sen0230-26819.htm
3.	T2.5 20 teeth Pulley	HPC Europe	https://shop.hpceurope.com/fr/produit.asp?prid=3935&produit=Poulie%20dent%C3%A9e%20de%20positionnement%20type%20T
4.	T2.5 Belt	HPC Europe	https://shop.hpceurope.com/fr/produit.asp?prid=91&produit=Courroie%20ferm%C3%A9e%20type%20T
5.	Belt tensionner	3D Printed	
6.	Ø 32 Magnet	Hpc Europe	https://shop.hpceurope.com/fr/produit.asp?prid=3925&produit=Aimant%20plat
	M3x16 Screws (2 parts)	Bricovis	TCHC M3x16 Acier 12.9 Noir EF DIN 912
	M5x20 Screw (2 parts)	Bricovis	TCHC M5x20 Acier 12.9 Noir EF DIN 912
	M5x10 Screw (1 part)	Bricovis	TFHC M5x10 Acier 10.9 Noir EF DIN 7991
	ESP32 Board	Gotronic	https://www.gotronic.fr/art-module-nodemcu-esp32-28407.htm
	4 Digits display	Gotronic	

Catalogues consulted in September 2022

8.1.2 Context of the system

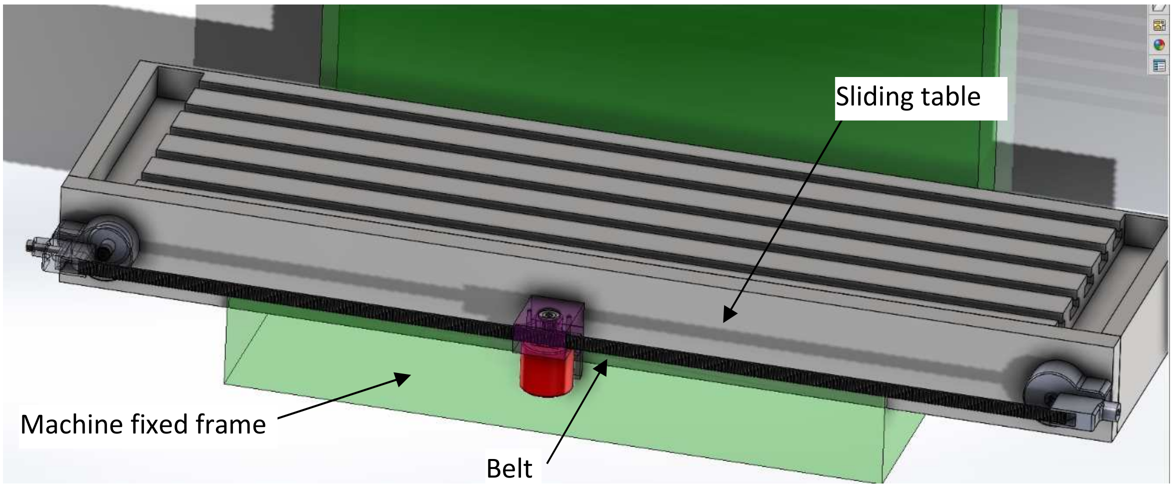

Figure 1: System context

8.2 Setup

8.2.1 Assembly

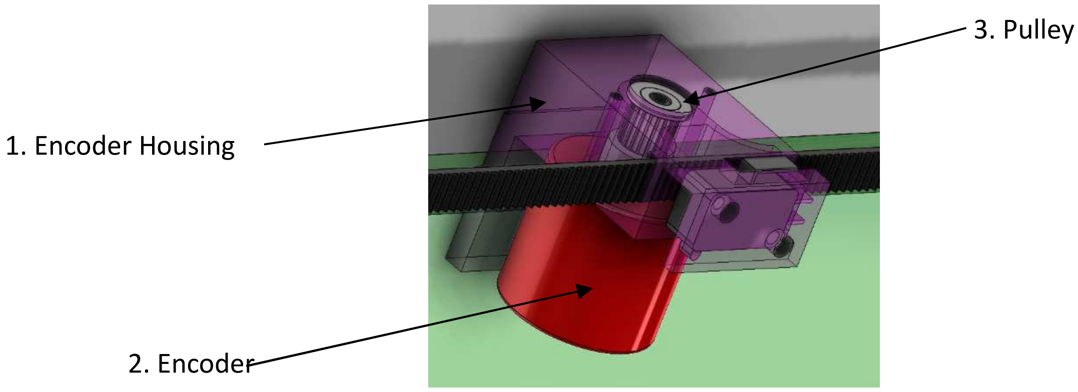

Figure 2: Assembly of the movement system (1)

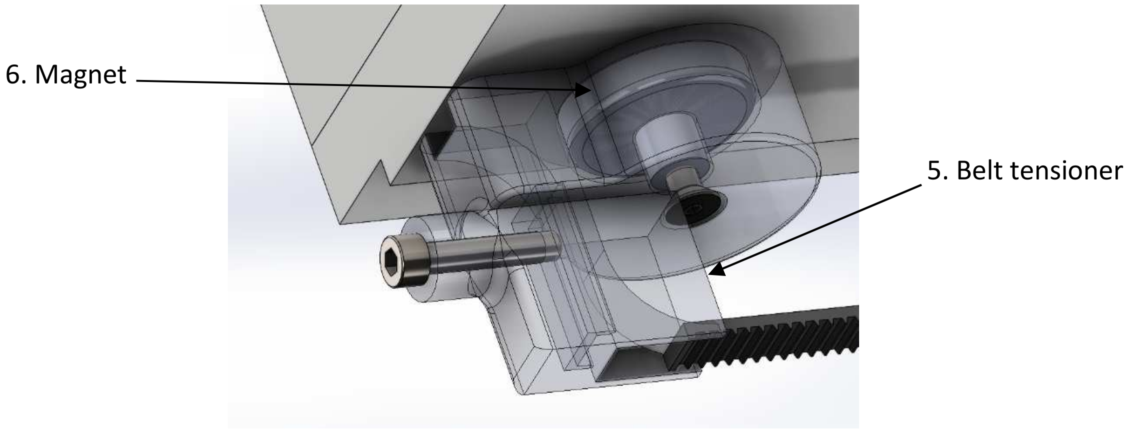

Figure 3: Assembly of the movement system (2)

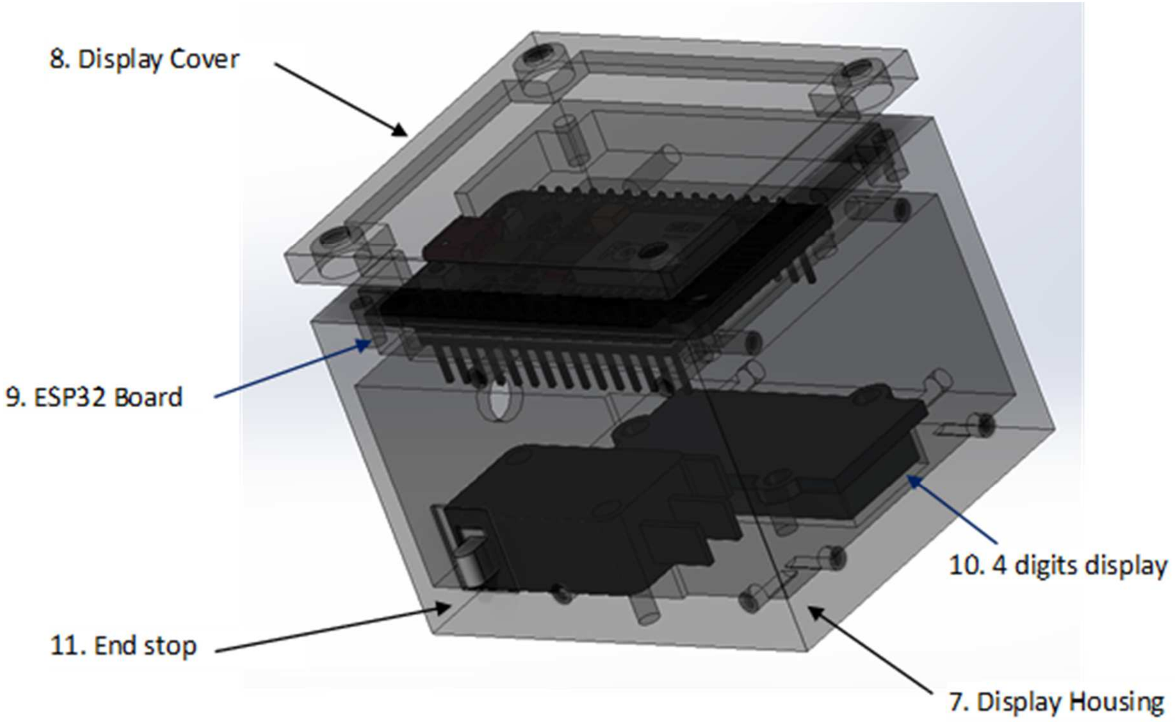

Figure 4: Assembly of the movement system (3)

8.2.2 Schematics of the connections

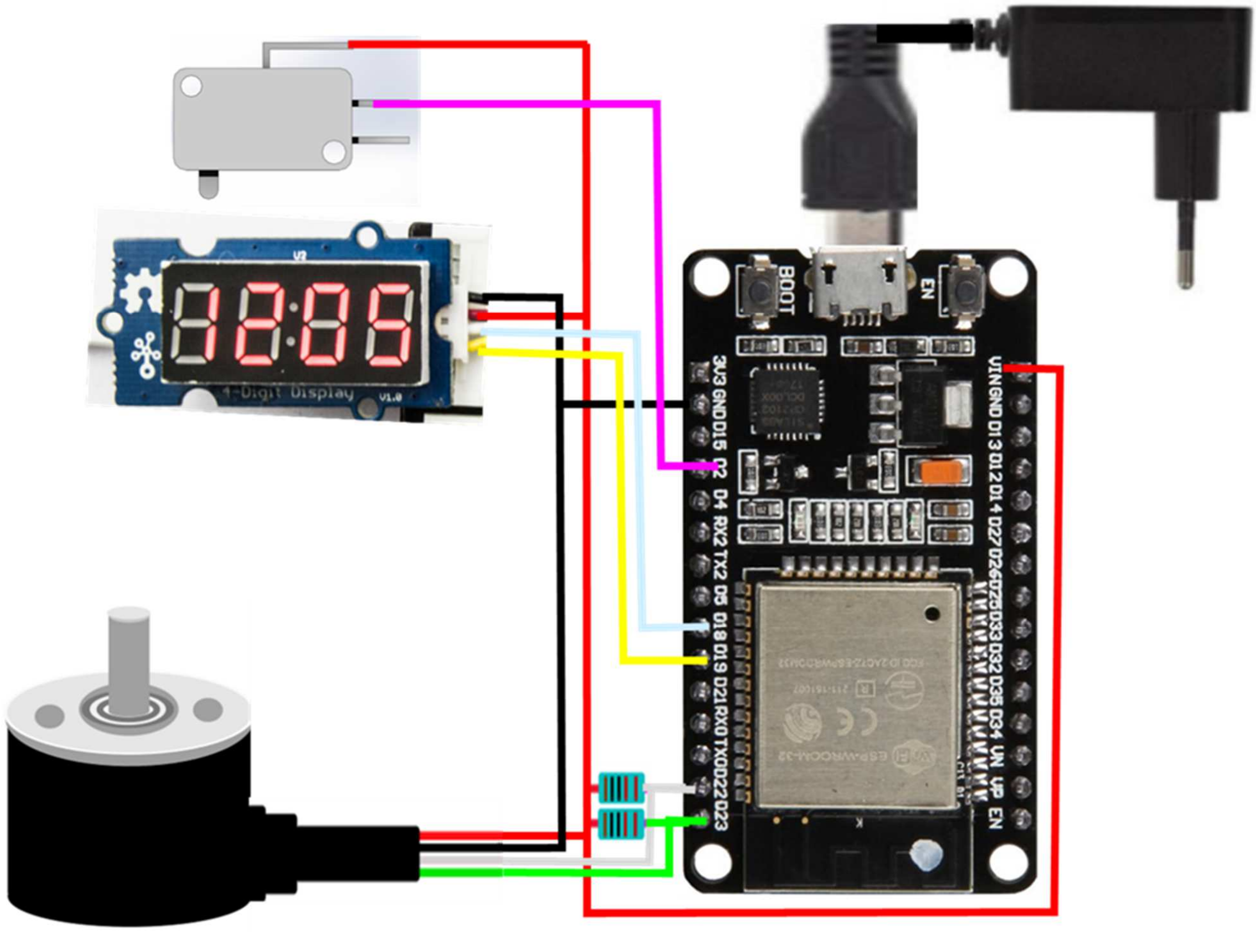

Figure 5: Schematics of the connections

8.2.3 Commented Source Code

Table 8.1 Commented source code

```
#include "TM1637.h"

// Pins definitions for TM1637 and can be changed to other ports
const int CLK = 19;   //Yellow Cable (CLK)
const int DIO = 18;  //White cable (DIO)
TM1637 tm1637(CLK, DIO);
#define ENCODER_A 22 // Pin for Encoder A
#define ENCODER_B 23 // Pin for Encoder B
#define RESET 2 // Pin for the reset entry


// Global variable for storing the encoder position
```

```
volatile int encoder_value = 0;
 volatile int PA = LOW ;
  volatile int PB = LOW ;
  volatile int INCA = 0;
volatile float mesure = 0 ;


void setup() {
  Serial.begin(115200); // Initialize serial communication
  pinMode(ENCODER_A, INPUT_PULLUP);
  pinMode(ENCODER_B, INPUT_PULLUP);
  pinMode(RESET, INPUT_PULLDOWN);
tm1637.init();
tm1637.set(BRIGHT_TYPICAL);//BRIGHT_TYPICAL = 2,BRIGHT_DARKEST = 0,BRIGHTEST = 7;


// Attaching the ISR to encoder A
attachInterrupt(digitalPinToInterrupt(ENCODER_A), encoder_isr, CHANGE);
 }

void encoder_isr() {
  // Reading the current state of encoder A and B
int A = digitalRead(ENCODER_A);
int B = digitalRead(ENCODER_B);
if ((A==HIGH)&(PA ==LOW)){
  if (B == LOW) {
    encoder_value++;
  }
  else if (B==HIGH) {
    encoder_value--;
  }
  PA = HIGH;
}
if ((A==LOW)&(PA ==HIGH)) {
  if (B == HIGH) {
    encoder_value++;
  }
  else if (B==LOW) {
    encoder_value--;
  }
    PA = LOW;
}
}
```

```
void loop() {


// Takes into account the RESET Button
  int R = digitalRead(RESET);
if (R == HIGH) {
  encoder_value = 0 ; //Sets the Value to 0 if the reset button is pressed
 Serial.println(" Reset Pressed ");
}


if (R == LOW) {
 Serial.println(" Reset pressed ");
}
mesure = encoder_value*0.038  ; // Calculates the displacement of the belt. The 0.038 value is the ratio between the pully diameter and the encoder step
   Serial.println("Encoder value: " + String(mesure));
   tm1637.displayNum(mesure);
 delay(250);
}
```

https://shop.hpceurope.com/fr/produit.asp?prid=3935&produit=Poulie%20dent%C3%A9e%20de%20positionnement%20type%20T