DIGITIZING PRODUCTS:
CREATING DEMONSTRATORS
FOR FUTURE EDUCATION

2-axis solar tracker

FI UBB

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Project consortium

Dissemination level

Code	Access granted to
PU	Public
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.

Content

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Abbreviations

ESTA	ESTA Belfort (France)
FHV	Fachhochschule Vorarlberg (Austria)
FTO	Fagskolen Tinius Olsen (Norway)
UCN	University College Nordjylland (Danmark)
BBU	Babes Bolyai University (Romania)

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1 Introduction

A 2-axis solar tracker using four light sensors is a device that tracks the position of the sun and adjusts the orientation of a solar panel to maximize the amount of energy that can be harvested. The tracker consists of a mechanical structure that holds the solar panel and two servo motors, an electronic circuit that includes four light sensors, an Arduino microcontroller, and programming code that runs on the microcontroller.

The key properties of the project are:

Table 1: Specification of key properties of the project

Key Property	Value
EQF level	6 (Bachelor)
Year of study	3
Domain	Mechatronics
Workload	6 ECTS
Keywords	3D printer, servo motor, Arduino, energy efficiency, PV panel

The project is proposed as a part of the *Renewable Energy* course in the 3rd year of the undergraduate program at the Engineering Faculty at UBB University. The typical class size is 15-20. Students will be split into teams of 4-5 people. The teams will be formed to include students from different specializations such as Electrical Engineering or Industrial Informatics. The task of the students that use the 2-axis solar tracker, controlled by a microcontroller, will be to design, develop and test to maximize the output of photovoltaic (PV) panels.

The student's task is not only to implement and test the solar tracker, but also to optimize its performance by selecting the appropriate sensors and motor driver, and by calibrating the tracker to ensure maximum energy efficiency. The students will also be required to document their design process, present their findings, and submit a final report on their project. Through this project, the students will gain hands-on experience in renewable energy systems as well as mechatronics, and develop skills in the design, implementation, and testing of complex systems.

2 Stand description

A 2-axis solar tracker Arduino project involves designing and building a device that can track the position of the sun using two servo motors controlled by an Arduino microcontroller. The solar tracker will adjust the orientation of a solar panel to ensure that it is always aligned with the sun, maximizing the energy yield that can be harvested.

The solar tracker will use four light sensors to determine the position of the sun, two for the horizontal axis and two for the vertical axis. The Arduino microcontroller will use this information to control the two servo motors, which will adjust the position of the solar panel accordingly.

The design of the solar tracker will involve mechanical engineering to create a structure that can hold the solar panel and the two servo motors. It will also involve electrical engineering to design the circuitry for the light sensors, servo motors, and Arduino microcontroller.

Overall, the demonstrator requires skills in both mechanical and electrical engineering, as well as programming skills for the Arduino microcontroller. The end result will be a solar tracker that can significantly improve the energy efficiency of a solar panel, making it an ideal project for those interested in renewable energy and sustainability.

A brief overview of the experimental prototype is given in Figure 1.

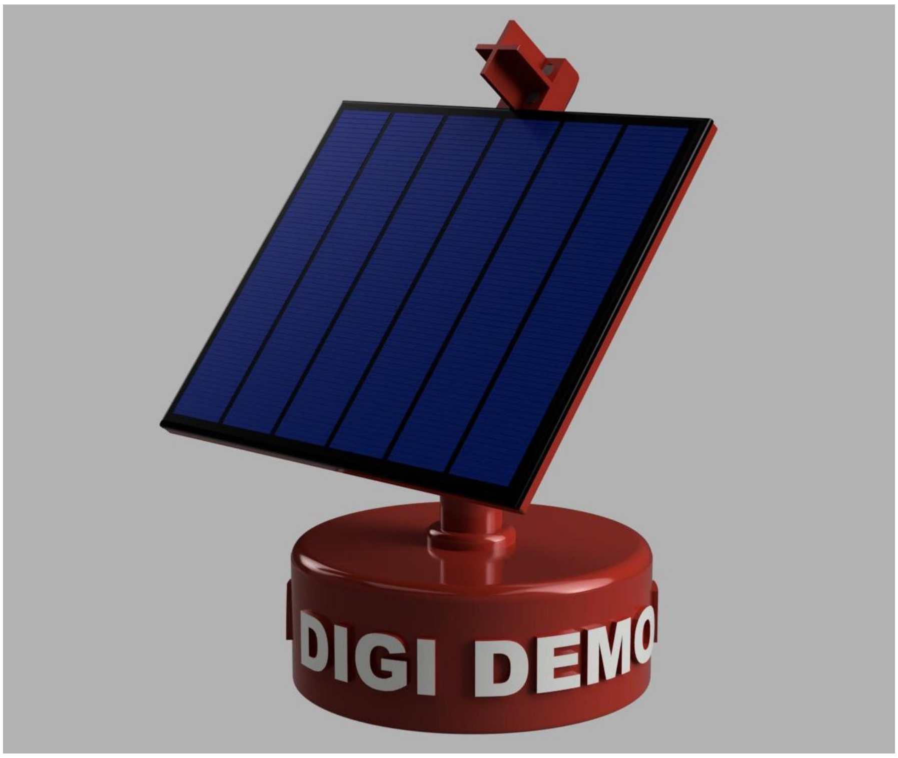

Figure 1: Brief overview of the experimental prototype

2.1 Mechanical parts

The mechanical structure of the dual axis solar tracker is a critical component that holds the solar panel and two servo motors responsible for controlling its orientation. To ensure the stability and resilience of the structure, it is necessary to design it with sturdy materials that can withstand various elements such as wind, rain, and dust. The two servo motors must be positioned correctly to ensure that they have the necessary range of motion to adjust the position of the solar panel in both axes. Moreover, the structure must allow for easy adjustment of the position of the light sensors to maximize solar energy absorption. To achieve these requirements, a 3D printer is used to print all the mechanical parts with precision and accuracy, figure 2.

1. Angle support left 35.0, 20.0, 27.5 mm
2. Angle support right 35.0, 20.0, 27.5 mm
3. Base 122.2, 121.3, 47.0 mm
4. Bottom cover 116.0, 116.0 20.2
5. Cover axis 38.0, 38.0 2.0 mm
6. Holder for vertical bar 30.0, 30.0, 6.0 mm
7. Holder for horizontal servo 20.8, 21.8, 8.5 mm
8. LDR Shade 19.0, 22.0, 20.0
9. Solar panel frame 165.0, 157.0, 5.0 mm
10. Spacer 7mm 20.0, 20.0, 5.5 mm
11. Spacer right 3mm 20.0, 20.0 3.0 mm
12. Top base 41.0, 43.0, 40.0 mm
13. Top cover 19.0, 65.0, 14.4 mm
14. Vertical axis 30.0 30.0, 57.0 mm

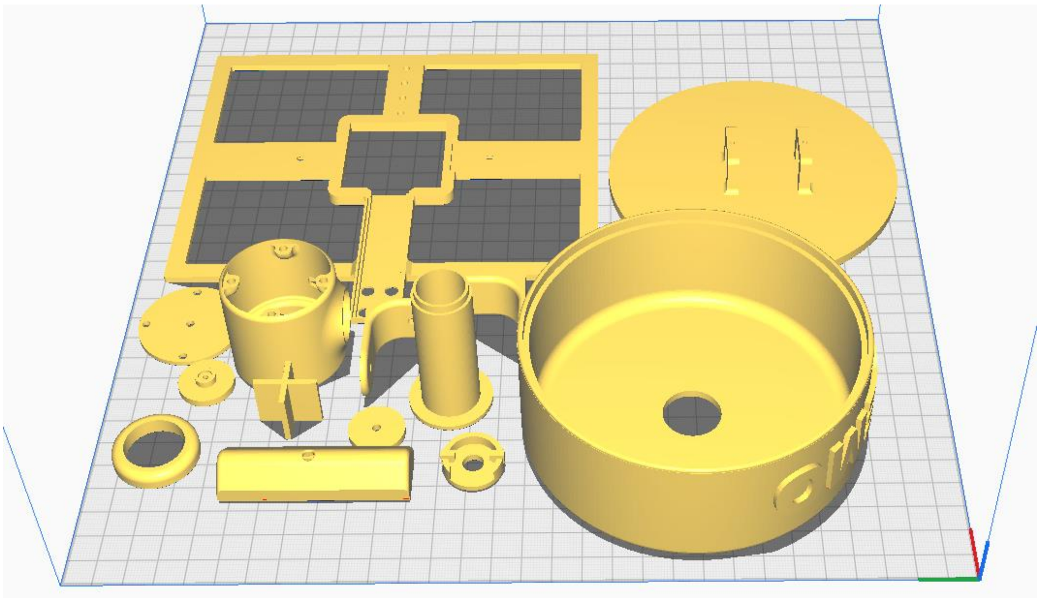

Figure 2: Brief overview of all the parts in 3D slicer

All of these files can be printed using a 3D printer, and they should fit together seamlessly to create a functional solar tracker.

2.2 Electronic Engineering

The electronic circuit consists of four light sensors, an Arduino microcontroller, and other electronic components necessary for the sensors and microcontroller to function properly, figure 3. The four light sensors are positioned at strategic locations on the solar tracker structure to measure the intensity of the sun's rays at different positions. The light sensors provide input to the Arduino microcontroller, which uses the data to calculate the optimal position of the solar panel.

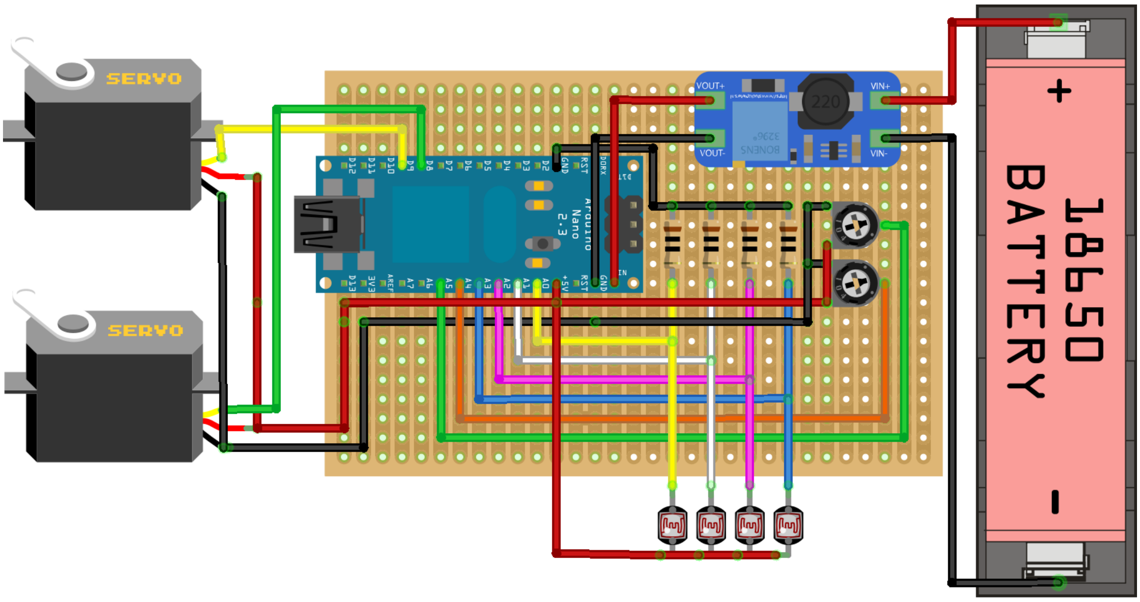

Figure 3: Brief overview of the wiring diagram

The components needed for a two-axis solar tracker:

1. 1x Arduino nano v3

2. 4xLight sensors (LDRs)

3. 2x sg90 or sg90s servo motors

4. 2x potentiometers (10K Ohm)

5. Set off Jumper wires

6. 1x 18650 battery

6. 1x Battery holder for 18650 batteries

7. PCB board (optional, for a more professional look and to solder the circuit)

8. Breadboard (if you don’t use the PCB board)

9. 4x 1K Ohm resistors

10. 1x MT3608 DC-DC Step Up Converter

11. 1x 165x135 Solar panel

2.3 Programming

The programming code for the Arduino microcontroller is responsible for reading the input from the four light sensors and controlling the two servo motors to adjust the orientation of the solar panel. The code must be written to ensure that the solar panel moves smoothly and quickly to track the sun's movement in the sky. The code must also be able to respond to changes in lighting conditions, such as clouds or shadows, and adjust the position of the solar panel accordingly.

```
#include <Servo.h>  // Include the Servo library

Servo servoX;  // Create a Servo object for the horizontal servo
Servo servoY;  // Create a Servo object for the vertical servo

int sensorPin1 = A0;  // Define analog pin A0 as the input pin for light sensor 1
int sensorPin2 = A1;  // Define analog pin A1 as the input pin for light sensor 2
int sensorPin3 = A2;  // Define analog pin A2 as the input pin for light sensor 3
int sensorPin4 = A3;  // Define analog pin A3 as the input pin for light sensor 4

int sensor1Value = 0;  // Variable to store the reading from light sensor 1
int sensor2Value = 0;  // Variable to store the reading from light sensor 2
int sensor3Value = 0;  // Variable to store the reading from light sensor 3
int sensor4Value = 0;  // Variable to store the reading from light sensor 4

int threshold = 30;  // Set the threshold value for the light sensors (adjustable via
potentiometers)

int xPin = A4;  // Define analog pin A4 as the input pin for the horizontal sensitivity
potentiometer
int yPin = A5;  // Define analog pin A5 as the input pin for the vertical sensitivity potentiometer

int xSensitivity = 1;  // Variable to store the horizontal sensitivity value (adjustable via
potentiometer)
int ySensitivity = 1;  // Variable to store the vertical sensitivity value (adjustable via
potentiometer)

void setup() {
  servoX.attach(9);  // Attach the horizontal servo to pin 9
  servoY.attach(10);  // Attach the vertical servo to pin 10
}

void loop() {
  sensor1Value = analogRead(sensorPin1);  // Read the value from light sensor 1
```

```
  sensor2Value = analogRead(sensorPin2);  // Read the value from light sensor 2
  sensor3Value = analogRead(sensorPin3);  // Read the value from light sensor 3
  sensor4Value = analogRead(sensorPin4);  // Read the value from light sensor 4

  int xError = (sensor1Value + sensor2Value) - (sensor3Value + sensor4Value);  // Calculate the horizontal error
  int yError = (sensor1Value + sensor4Value) - (sensor2Value + sensor3Value);  // Calculate the vertical error

  int xCorrection = xError * xSensitivity;  // Calculate the horizontal correction value
  int yCorrection = yError * ySensitivity;  // Calculate the vertical correction value

  if (xCorrection > threshold) {  // If the horizontal correction is above the threshold, move the servo to the right
    servoX.write(servoX.read() - 1);  // Decrease the horizontal servo angle by 1 degree
  } else if (xCorrection < -threshold) {  // If the horizontal correction is below the threshold, move the servo to the left
    servoX.write(servoX.read() + 1);  // Increase the horizontal servo angle by 1 degree
  }

  if (yCorrection > threshold) {  // If the vertical correction is above the threshold, move the servo up
    servoY.write(servoY.read() + 1);  // Increase the vertical servo angle
} else if (yCorrection < -threshold) { // If the vertical correction is below the threshold, move the servo down
servoY.write(servoY.read() - 1); // Decrease the vertical servo angle by 1 degree
}

delay(10); // Delay to allow the servos to reach their new positions
}
```

2.4 Description of the fulfillment of demonstrator characteristics

Table 2: Description of the fulfillment of demonstrator characteristics for the focus project

Characteristic	Description
Teaching improvement	The project can be used as an educational tool to teach students about solar tracking and its potential applications in various fields. The use of Arduino and other electronics can also help in teaching basic programming and circuit design concepts.

Characteristic	Description
Sustainability awareness	By using solar energy to power the solar tracker, the project can raise awareness about the importance of renewable energy sources and their potential to reduce carbon emissions. Additionally, the project can also promote environmental conservation and the importance of increasing energy yield of renewable sources to mitigate climate change.
Replicability	The project can be easily replicated using readily available components and open-source software. The use of 3D printing for mechanical construction can also facilitate easy replication and customization.
Industry needs	The project can be adapted to meet the specific needs of different industries, such as agriculture or forestry, where solar tracking can be used to optimize plant growth and maximize yield.
Interdisciplinarity	The project combines concepts from various disciplines, such as electronics, mechanical engineering, and environmental science, making it a great example of interdisciplinary collaboration. This can also help in fostering innovation and creativity by bringing together different perspectives and approaches.

2.5 Classification of the demonstrator according to the dimensions

This is given in the table below.

Table 3: Classification of the focus project 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	☐

Dimension	Property	Value
Sustainability	energy reduction	☐
	material reduction	☐
	better materials	☐
	better production	☑
	repairability	☐
	recycling	☑
Physicality	physical setup	☑
	simulation	☐
Degree of student freedom	guided	☐
	coached	☑
	autonomous	☐
Transportability	fixed	☐
	transportable	☐
	portable	☑
Costs (implementation)	EUR	200
Costs (operation)	EUR	0
Workload (implementation)	Hours	50
Workload (operation)	Hours	8h
Size	m	0.3 x 3 x 0.2
Weight	kg	1
Special requests	no/yes, if yes: which	no

2.6 Educational information

Planned learning activities and teaching methods

Lectures: In-class lectures will be given on the fundamentals of electronic engineering, as well as on the specific topics related to the design and implementation of the dual-axis solar tracker. These lectures will include both theoretical and practical components and will be designed to provide students with a solid understanding of the concepts and techniques involved.

Project work: The majority of the course will be spent working on a hands-on project to design, build, and test a dual-axis solar tracker. Students will work in teams to complete various aspects of the project, including circuit design, programming, and mechanical construction. This project work will provide students with valuable experience working in a team and applying their theoretical knowledge to a real-world problem.

Coaching sessions: Regular coaching sessions will be held to provide students with feedback on their progress, help them troubleshoot any issues they encounter, and offer guidance and support throughout the project. These coaching sessions will be led by experienced instructors with expertise in electronic engineering and PV energy and will be designed to help students succeed in their project work.

Assessment methods and criteria

Written examination, technical documentation, project result.

Mode of delivery (face-to-face, distance learning)

The mode of delivery for the course can be argued based on various factors such as the availability of resources, student preferences, and the course objectives.

If the course involves hands-on activities and practical sessions, face-to-face delivery may be more suitable as it allows for better interaction and engagement with the materials and equipment. However, if the course content can be delivered effectively through online platforms, then distance learning can be a viable option.

Another factor to consider is the accessibility of the course to students. If students are spread across different geographical locations, distance learning can be more convenient and accessible to them. On the other hand, if the majority of the students are in close proximity to the institution, face-to-face is preferred.

Ultimately, the decision on the mode of delivery should be based on a thorough analysis of the course objectives, student needs and preferences, and the availability of resources.

Course content Requirements analysis: Introduction to solar energy

The principles of solar energy

Types of solar panels

Efficiency of solar panels

2. Basic electronics

Analog and digital electronics

Ohm's law

Resistors, capacitors, and inductors

Diodes and transistors

Operational amplifiers

Microcontrollers

3. Solar tracking

Advantages of solar tracking

Types of solar tracking

Theoretical background of solar tracking

Types of sensors for solar tracking

4. Mechanical design and 3D printing

Basic design principles

Solid modeling

3D printing technologies

Mechanical components for solar tracker

5. Arduino programming

Introduction to Arduino IDE

Arduino syntax and coding

Interfacing sensors with Arduino

Motor control with Arduino

6. System integration and testing

System architecture

Integration of electronic and mechanical components

Testing and validation of the system

7. Sustainability and environmental considerations

Energy efficiency and reduction

Materials and production processes

Life cycle assessment and environmental impact

Assessment methods and criteria:

- Practical project work and demonstrations
- Technical report and documentation
- Oral presentations and discussions
- Peer and self-assessment
- Final project evaluation based on the demonstration of the solar tracking system.
-

Learning outcomes

1. Students will be able to design and build a functional dual-axis solar tracker using an Arduino microcontroller, light sensors, and 3D printed mechanical components.
2. Students will gain a deep understanding of the principles of solar energy, including how to optimize energy generation through tracking the sun's position.
3. Students will acquire proficiency in the use of various electronic components, including light sensors, potentiometers, and servo motors.
4. Students will develop skills in troubleshooting and problem-solving, as they work through challenges and unexpected issues during the design and building process.
5. Students will be able to apply principles of sustainability and energy efficiency, as they incorporate energy reduction strategies and consider the life cycle of the project.
6. Students will improve their skills in project management, as they plan and execute the various stages of the project, including design, construction, and testing.
7. Students will develop teamwork and collaboration skills, as they work in groups to complete the project and present their findings to the class.
8. Students will gain experience in effective communication, both oral and written, as they document their progress and present their findings to the class.

2.7 Organizational information

For the organization of the project, the following details apply:

- Project Duration: The project will span half a semester, starting in the first days of October and concluding in mid-December with the final presentations. This timeline allows for sufficient time to plan, design, build, and test the 2-axis solar tracker project.
- Team Size: The project teams will consist of a mix of students with interests in both electronics and mechanical engineering. The optimal team size for this project is between 4 and 6 members. This team composition ensures a diverse skill set and allows for effective collaboration and division of tasks.
- Preparatory and follow-up activities. No special activities are needed. Prior to the start of the project, the demonstrators must be set up and checked by a lab technician.

2.8 Description of the technology and the setup

File Structure:	**Focus-Setup**	
	Filename/Folder	Comment
00_Notes		
	FileStructure.xlsx	Description of the files = this document
	Price_Calculation.xlsx	Approximate Cost means
01_Pictures		
10_Documents		
	Course-Information.pdf	General information about the course for the students
20_ExportImport		
30_AdditionalEquipment		
	Component-Overview.docx	File with an overview of all additional components needed
40_Simulation		
50_CAD	2-axis_solar_tracker.zip	The files that need to pe 3D printed
60_ElectricalLayouts	Electrical wiring.png	Explanation of the electrical connections
70_Programming		
	Solar_Traker.ino	The Arduino code

Details of the price calculation can be found here:

No.	Component	Quantity	Unit Price (€)	Total Price (€)	Link
1	Arduino Nano v3	1	20	20	https://rb.gy/n9myp
2	Light sensors (LDRs)	4	1.5	6	https://rb.gy/ms3gx
3	SG90 or SG90S Servo motors	2	4	8	https://rb.gy/r8ttv
4	Potentiometers (10K Ohm)	2	2	4	https://rb.gy/e6w08
5	Set of Jumper wires	1	10	10	https://rb.gy/1mhr8
6	18650 battery	1	5	5	https://rb.gy/g1tlm
7	Battery holder for 18650 batteries	1	2.5	2.5	https://rb.gy/1aek5
8	PCB board	1	2	2	https://rb.gy/vbi07
9	Breadboard	1	3	4	https://rb.gy/l7ma1

10	1K Ohm resistors	4	0.1	1	https://rb.gy/5t0g6
11	MT3608 DC-DC Step Up Converter	1	5	5	https://rb.gy/ussg6
12	M3*8 screws	20	0.1	2	https://rb.gy/dacip
13	3D printer filament (PLA)	1	30	30	https://rb.gy/zjooi
14	Solar panel (165x135)	1	100	100	https://rb.gy/m6g1i
	Total:			197.5	

Annex A. References

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