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1. Introduction

1.1 Presentation

This project was developed through an international collaboration between six students representing diverse European academic backgrounds. By integrating technical engineering with creative design, the project seeks to bridge the gap between digital arts and human interaction. As detailed in Table 1, this multidisciplinary approach is foundational to ensuring the resulting solution is sustainable, inclusive, and optimized for public engagement.

Table 1: Project Contributors

Name	Studies	Location
Anna Bentzen	Applied Computer Technology	Norway
Giulia Vaneekhout	Product Development	Belgium
Julian Bednarek	Computer Science	Poland
Leon Gunsilius	Interactive Media	Germany
Paula Macias	Industrial Organization Engineering	Spain
Rui Mendes	System's Engineering	Portugal

1.2 Motivation

The selection of digital art as the project’s primary theme resulted from an evaluation of various sectors, including healthcare and general well-being. While these initial areas were considered, digital art was ultimately identified as the optimal intersection for the group's diverse expertise. This theme provided a unique synergy between the creative methodologies of the design-oriented members and the technical competencies of the computer science enthusiasts. By leveraging the convergence of artistic expression and digital innovation, the project transitioned from a theoretical concept to the development of an interactive installation designed to foster meaningful public engagement.

1.3 Problem

Although modern public transit systems (particularly metropolitan rail networks) are characterized by high physical density, they frequently function as spaces of significant social isolation. This phenomenon of collective detachment is driven by two primary factors:

Passive Digital Consumption: Passengers often utilize mobile devices as a primary strategy to mitigate the environmental stressors of crowded transit. This reliance on personal screens facilitates a transition from a shared public journey into a repetitive, solitary experience, a process often described as “digital escapism”.

The Anonymity of the “Non-Place”: Following Marc Augé’s theory of “Non-Places” , the metro is frequently perceived as a purely functional void, a transitional space to be endured rather than experienced. Current transit architectures lack the sensory stimuli required to encourage environmental presence or spontaneous interpersonal interaction. Consequently, these environments represent missed opportunities for community engagement and the promotion of collective mental

well-being [1].

This project addresses the deficit of meaningful physical engagement by proposing an immersive, shared environment that challenges the habitual over-reliance on personal technology.

1.4 Objectives

The primary objective of this project is to redefine the metropolitan transit environment by transitioning it from a purely functional corridor into a participatory space. To achieve this, the project focuses on the following four goals:

Mitigate Digital Isolation: To provide tangible, real-world stimuli that incentivize passengers to decrease reliance on mobile devices during transit.

Humanize the Transit Environment: To transform passive, anonymous commutes into human-centered experiences through the integration of interactive sensory design.

Facilitate Collective Agency: To utilize synchronized light and sharing of life lessons via anonymous messages to demonstrate how individual physical presence contributes to a larger, collaborative environmental state.

Promote Environmental Presence: To encourage mindfulness and spatial awareness, ensuring that the commute results in a unique user narrative rather than a standard, repetitive transit cycle.

1.5 Requirements

To ensure compliance with European industrial standards and safety protocols, the project must adhere to the following regulatory framework:

1.5.1 Regulatory and Standard Requirements

The system shall be designed and documented in accordance with the following European Union (EU) Directives:

- **Electromagnetic Compatibility Directive (2014/30/EU):** Ensuring the system does not interfere with metro signaling or communication.
- **Low Voltage Directive (2014/35/EU):** Governing electrical safety for components operating within specific voltage ranges.
- **Machinery Directive (2006/42/EC):** Applied to the mechanical integration of interactive handrails.
- **Radio Equipment Directive (2014/53/EU):** For any wireless data transmission components.
- **RoHS Directive (2011/65/EU):** Restricting the use of hazardous substances in electronic hardware.
- **Technical Standards:** Mandatory use of the International System of Units (SI) and a preference for open-source software architectures to ensure transparency and scalability.

1.5.2 Functional and Experiential Requirements

- **Universal Accessibility:** The interface shall require no prior instruction or specific language proficiency, ensuring inclusivity for all demographic groups.
- **Interpersonal Connectivity:** The system must utilize shared sensory feedback to actively mitigate digital isolation and promote social interaction among passengers.
- **Asynchronous Narrative (Digital Storytelling):** The installation shall include a Quick Response (QR)-based platform near exit points to facilitate the possibility for users to send and read messages anonymously, creating a temporal link between passengers.
- **Environmental Sustainability:** Material selection and power consumption must prioritize ecological impact and long-term durability in high-traffic environments.

1.5.3 Technical and Hardware Requirements

- **System Architecture:** The hardware stack shall consist of a centralized power supply, a microcontroller unit (MCU), distributed input sensors, and synchronized output modules.
- **Sensor Integration:** The system shall utilize tactile inputs (pressure, heart rate) integrated directly into the metro's physical infrastructure.
- **Real-time Feedback:** Visual (Light-Emitting Diode (LED)) and auditory (sound) outputs must respond with sub-perceptual latency to user interaction.
- **Structural Integration:** Existing metro handrails shall be replaced or modified with translucent housings containing embedded sensor-LED arrays.
- **Visual Logic:** The system must support multi-user light propagation, where individual touchpoints generate unique color pulses that travel vertically and blend on the ceiling to represent collective interaction.

1.6 Tests

The goal of this project is to create a working prototype of a Distributed Smart Lighting System for public transportation. This system enhances the passenger experience by providing interactive visual feedback through addressable LEDs, triggered by touch-sensitive poles equipped with Velostat sensors. By utilizing a Controller Area Network (CAN) Bus network, the system ensures high-reliability communication across the metro car, even in environments with high electromagnetic interference (EMI).

The primary objective of this project is to deliver a functional and robust prototype. To guarantee its performance and safety in a railway-simulated environment, several tests must be conducted. Each test is outlined below, including the specific Evaluation Methodology used to verify the results.

Functionality Tests:

(FT-01) Velostat Touch Detection: Connect the sensor node to a PC and monitor the Analog-to-Digital Converter (ADC) output via the Serial Plotter. Apply varying hand pressures to ensure the signal changes linearly and triggers the intended software threshold.

(FT-02) CAN Bus Communication: Implement a packet-counter script where the Pole Node sends 1000 sequential messages. The Ceiling Node will log received IDs to calculate the Packet Delivery Ratio (PDR), with a target of > 99.9 %.

(FT-03) LED Visual Response: Trigger the sensor and visually inspect the LED strip for color accuracy (Red, Green, Blue (RGB) values), ensuring no “dead pixels” or flickering occur during the animation cycle.

(FT-04) Sensitivity Calibration: Manually rotate the onboard potentiometer while applying a constant light touch. The test is successful if the trigger threshold can be adjusted to ignore vibrations while still detecting a deliberate touch.

(FT-05) Power Management: Use a high-voltage laboratory power supply set to 72 V and 110 V Direct Current (DC). Use a multimeter to verify that the Buck Converter output remains at a stable 5.0 V (± 0.1 V) under full LED load.

Performance Tests:

(PT-01) System Response Time: Record the interaction using a high-speed camera (240 Frames Per Second (FPS)). Count the frames between the initial hand-to-sensor contact and the first LED illumination to calculate total latency (Target: < 100 ms).

(PT-02) EMI Noise Resistance: Operate a brushed DC motor (simulating metro traction noise) within 10 cm of the CAN wiring and Velostat sensor. Monitor the system for “ghost triggers” or communication resets.

(PT-03) Thermal Performance Methodology: Activate the LEDs at 80 % brightness for 4 h in a non-ventilated environment. Use an infrared thermometer to measure the enclosure surface temperature every 30 min (Target: < 50 °C).

(PT-04) Voltage Drop Methodology: With the strip at full white brightness, measure the voltage at the Voltage at the Common Collector (VCC) pin of the very last LED using a multimeter. Ensure it remains above 4.7 V to prevent color distortion.

(PT-05) Long-term Durability: Use an automated mechanical actuator (or repeated manual cycles) to trigger the sensor 1000 times. Inspect the Velostat “sandwich” for delamination or loss of electrical sensitivity.

Software & Simulation Tests:

(ST-01) Components Integration Simulation: Import 3D models of the Printed Circuit Boards (PCBs) and converters into a Computer-Aided Design (CAD) environment (e.g., Fusion 360). Check for mechanical interferences and ensure a minimum 5 mm clearance between high-voltage and low-voltage traces.

(ST-02) CAN Bus Logic Simulation: Use a network simulator or a dual-MCU breadboard setup to force “data collisions” by sending messages from two nodes simultaneously. Verify that hardware arbitration correctly prioritizes the higher-priority ID.

(ST-03) Animation Algorithm: Run the LED code in a simulator (e.g., Wokwi) for 24 h to check for memory leaks or buffer overflows that could lead to software hanging.

(ST-04) Fault Detection: Physically disconnect the CAN High (CANH) wire during operation. The software must detect a “Heartbeat Timeout” within 500 ms and switch the LEDs to a static “Safety White” mode.

Safety Tests:

- (SF-01) Electrical Safety: Perform a continuity test between the aluminum enclosure and the system Ground (GND) using a multimeter. Resistance must be $< 0.1 \Omega$ to ensure proper earthing.
- (SF-02) Mechanical Safety: Conduct a tactile sweep test. Run a gloved hand over all surfaces and seams of the enclosure to ensure no sharp edges or protruding screws are present.
- (SF-03) Fire Safety: Review the manufacturer datasheets for all cables and 3D filaments used. Verify they carry a V-0 (UL94) flammability rating or Low Smoke Halogen Free (LSHF) certification.
- (SF-04) Vandalism Resistance: Attempt to peel the sensor off the pole using fingers. Apply a 5 kg impact to the sensor area and verify that the electrical housing remains intact and functional.
- (SF-05) Ingress Protection (IP): Lightly spray the enclosure with a fine mist of water (simulating cleaning fluids). Open the box after 5 min to inspect for any moisture ingress near the electronic components.

User Acceptance Testing (UAT):

- (UAT-01) Trigger Intuitiveness: Observe 5 non-technical users. Ask them to “activate the interaction” without explaining where the sensor is. More than $> 80 \%$ of users need to identify the pole sensor as the interaction point within 5 s.
- (UAT-02) Visual Comfort (Glare Test): Users sit in a “metro seat” 1 m away from the LEDs. Cycle through all colors at max brightness. Users report no eye strain or “dazzle” effect (blinding light).
- (UAT-03) Feedback Clarity: Ask users what the light animations signify (e.g., “What does the pulsing blue mean to you?”). Users correctly associate the animation with “System Active” or “Input Received”.
- (UAT-04) Ergonomics (Touch Height/Force): Test with users of different heights and hand strengths. All users can comfortably trigger the system regardless of their physical stature.

The testing framework defined in this chapter ensures the transition of the System from a concept to a robust prototype. By addressing EMI, thermal management, and passenger safety, these protocols guarantee that the CAN Bus architecture and Velostat sensing are reliable, scalable, and ready for real-world deployment in public transportation.

1.7 Report Structure

Below we can find in Table 2 the main structure of the report and a short description of every chapter.

Table 2: Report Structure

Chapter	Title	Description
1	Introduction	A comprehensive look at the team’s vision, the core problem we are solving, and the specific technical goals and success criteria for this iteration.
2	Background and Related Work	An evaluative review of current market solutions, identifying gaps in existing research and how our approach differentiates itself.

Chapter	Title	Description
3	Project management	A breakdown of the operational framework, including the selected development methodology, team roles, and resource allocation.
4	Marketing plan	A targeted plan for market positioning and user engagement, derived from an updated analysis of current industry trends.
5	Eco-efficiency measures for sustainability	Strategies for reducing the project's ecological footprint and an evaluation of the solution's long-term environmental viability.
6	Ethical and Deontological concerns	A critical examination of the ethical dimensions of our work, focusing on societal impact and deontological standards.
7	Project Development	An in-depth technical walkthrough of the prototype's architecture, hardware/software components, and the integration process.
8	Conclusions	A final assessment of the project's outcomes against our initial goals, including a roadmap for future iterations.
9	Bibliography	A curated list of academic, technical, and industry sources that informed the project's development.

1.8 Summary

Chapter 1 has shown us what CONNECT and share is about. The places where people wait are not really places where people connect with each other. We want to make sure that people can have a shared experience with eachother when they are using the Porto Metro.

We are going to use technology to create digital art to make this happen.

Now that we knoww what we want to do with CONNECT and share we need to look at similar projects and products that already exist offers. The next chapter will provide background research for the loneliness issue, similar projects and research about the planned components for the final product. We will look at what already exists and what we can learn from it to make CONNECT and share.

[1] Marc Auge, 1995. *Non-places: Introduction to an Anthropology of Supermodernity*. London: Verso, ISBN 9781859840511.

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