STEAMCITY CURRICULUM

ROAD SIGNS OF TOMORROW

thematic: sustainable mobility, transport and regulation

sub-theme: artificial intelligence and new technologies

Introduction

Road infrastructure is facing a transition as **autonomous vehicles** begin to share roadways with traditional human-operated vehicles. This educational protocol addresses a key challenge in this transition: **the design of unambiguous road signals that can be interpreted by both human drivers and autonomous systems**.

The protocol guides students through the process of **co-designing new road signals** tailored to autonomous vehicle requirements while ensuring they remain **distinct from existing signage**. This approach tackles the problem of **visual communication** across different interpretation systems—human perception versus computer vision—within a shared infrastructure environment.

Through this learning experience, students will explore the **intersection of transportation infrastructure, visual communication, and artificial intelligence**. They will develop an understanding of how autonomous vehicles "see" and interpret their surroundings, the limitations of current signage systems for machine interpretation, and the design principles that can bridge these gaps.

Students will learn to **analyze existing road signage from both human and machine perspectives**, identify potential **ambiguities** and **interpretation** challenges, and apply design thinking to create signals that are machine-readable yet distinguishable from human-targeted signs. They will **test and iterate designs using basic image recognition principles** while considering the practical implementation challenges of introducing new elements into established systems.

This protocol approaches several key questions: How can we create visual communication systems that serve both human and machine users without confusion? What design principles ensure effective recognition by computer vision systems? How should new technological requirements be integrated into existing infrastructure with minimal disruption? What balance must be struck between innovation and compatibility with established systems?

By engaging with these questions through hands-on design activities, students will contribute **potential solutions to real-world challenges** while developing **critical thinking skills** about the technological transitions reshaping our infrastructure. This protocol serves as a practical introduction to the considerations involved in adapting our physical environment for an increasingly autonomous future.

Interdisciplinary

Technology and engineering
Geography
Art & Design

Sustainable Development Goals

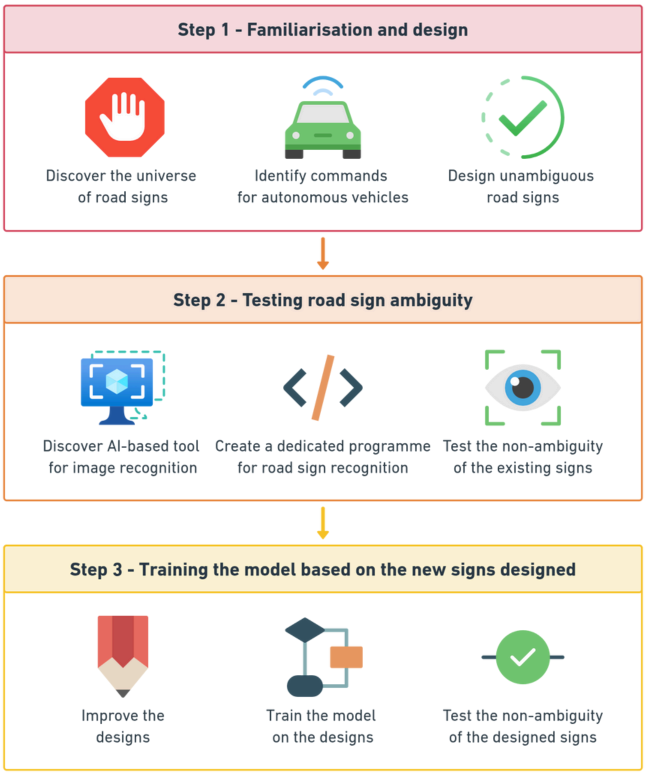
9 INDUSTRY, INNOVATION AND INFRASTRUCTURE

15 LIFE ON LAND

Overview

Protocol Structure

The protocol is divided into **three complementary phases** building upon each other to create a comprehensive understanding of signal design for autonomous vehicles. Each phase integrates specific learning objectives, presented hereunder:



Step 1 - Familiarisation and design: During this step, students are asked to familiarize themselves with the basic concepts behind this protocol. Based on this knowledge, they should engage in a creative process of developing new road signals. Students should identify needs and design solutions that meet specific criteria.

Step 2 - Testing road sign ambiguity: In the second step, students should organise the **testing** of the automatic image reading and classification tool, previously trained to recognize conventional road signs such as stop signs, directional signs, and speed limits. The aim is to verify whether a new sign design is not classified (or is classified with negligible probability) as one of the already known signs.

Step 3 - Training the model based on the new signs designed: The third step focuses on validating and refining the designed signals through **training** of the automatic image reading and classification tool by making it recognize and classify the different signs proposed by the learners using the signal objective modeled as classes.

Getting started

Duration: The total duration of the activities is **at least 2 hours per day for 3 days**, favoring in-person activities to maximize involvement.

Level of difficulty:

Material needed: The suggested tools are ***phygital (digital + physical)*** in nature, favoring physical components (also called tangible) in the ideation phase and using automatic image reading and classification tools based on digital artificial intelligence.

Some tips for organisation:

- The **familiarization** phase can be carried out as an individual or collaborative activity, using a traditional frontal lesson approach or encouraging interaction between participants. It aims to present the activity and terminology. It is required a digital or physical **list of road signs** recognized by the classifier used in the following stage. For instance : https://docs.google.com/document/d/1Sal0SarpjkAVluao1xucSsvPznF30WNT/edit?usp=drive_link&ouid=111043907319139362715&rtpof=true&sd=true

- The **ideation** phase can be completely physical, conducted as an individual or collaborative activity, encouraging the representation of the new road sign after having discussed in a collaborative way the commands that we must introduce to manage the traffic of self-driving vehicles that allows their coexistence and synchronization with traditional human- or assisted-driving vehicles. The testing and training phases require digital tools. Participants can use **15cmx15xm paper sheets**.

- The **testing** tool must have been previously trained with representations of road signs already adopted to regulate traffic. It is preferable that both tools have the possibility of inserting new inputs acquired through a camera to facilitate the input from students who are making the road signs on physical and tangible tools, such as sheets of paper. A collaborative approach is suggested to enable reflection and brainstorming. We suggest using **SignVisionAI** (https://drive.google.com/drive/folders/1gYf5JkDzg41ZbesaIQk72BvD7rWRo5EN?usp=sharing) And a **Vittascience tool** (https://it.vittascience.com/ia/images.php).

Glossary

Keywords & Concepts	Definitions
Ambiguity Testing	The process of verifying whether a proposed road sign is similar to existing road signs, potentially leading to confusion.
Artificial Intelligence (AI)	A branch of computer science focused on creating systems that can perform tasks typically requiring human intelligence, such as learning, decision-making, and image recognition.
Image Classification	The ability of AI tools to identify and categorize images based on their content, often used for testing the uniqueness of road signs.
Learning Phase	The stage during which an AI tool acquires knowledge by being exposed to labeled data, enabling it to recognize patterns or make predictions.
Road Sign Ambiguity	The potential for a road sign to be misinterpreted or confused with existing signs.
Self-Driving Vehicles	Autonomous vehicles capable of navigating without human intervention, require specialized road signs for effective communication.
Training Phase	A step where an AI tool is taught to recognize specific images or patterns, such as the representations of novel road signs.

Bibliography

Mauro D’Angelo and Maria Angela Pellegrino. 2021. Roobopoli: a project to learn robotics by a constructionism-based approach. In Methodologies and Intelligent Systems for Technology Enhanced Learning (MIS4TEL), Workshops.

Gennari, Rosella, Alessandra Melonio, and Mauro D'Angelo. 2023. Engaging Learners in the Collaborative Design of Sustainable Smart Cities. In Sustainable, Secure, and Smart Collaboration (S3C) Workshop @ *CHItaly*.

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Protocol

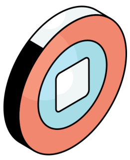
Step 1 - Familiarisation and design

Background and description of the problem to be solved in this step: During the first step, students will familiarize themselves with basic concepts related to the proposed activity, reflect on the types of signals to introduce, select one of the proposed types, and develop a preliminary design for their chosen type.

Learning Objectives: Familiarize with concepts concerning road signs and terminology and stages related to artificial intelligence-driven tools.

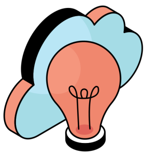
Conceptualisation

Before beginning the activities, teachers should collect information to evaluate the impact of the proposed activities including **students' perception and awareness of artificial intelligence tools, smart cities, and road signs, as well as their expectations.** Here are some questions to use for this pre-investigation phase:



Do you think?

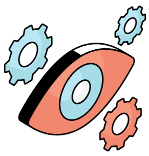
- Designing road signs is fun?
- Designing road signs is easy?
- It would be fun if we programmed them with artificial intelligence?
- It would be easy?
- Artificial intelligence is magic?
- There only one type of tool based on artificial intelligence?



Which of these are AI-based tools?

- Tools for grouping elements, also known as clustering [YES]
- Generative tools like ChatGPT [YES]
- Tools for classifying objects, known as classifiers [YES]
- Cloud-based tools, such as cloud native [NO]

Do you think an artificial intelligence tool needs a learning phase?



Which terms do you think are related to artificial intelligence phases?

- Training [YES]
- Regression phase [NO]
- Verification or testing phase [YES]

Do you think an artificial intelligence tool also knows what you hae not taught it?

If an artificial intelligence tool has learned to recognize and distinguish clothing items, will it also be able to classify movies?

Interactive methods can be used to perform this pre-assessment discussion:

- **Emoji Meter**
  This method creates a visual scale of opinions on the whiteboard. Teachers draw a horizontal line with emojis representing different levels of agreement, ranging from very negative (😡) to very positive (😄). After asking a question, each student writes their initials on a sticky note and places it on the scale at the position that matches their opinion. This allows for instant visualization of the distribution of opinions in the class and helps identify trends. It's particularly effective for Likert scale questions like "Do you think designing road signs is fun?"
- **Four Corners**
  This activity encourages physical movement. The teacher designates each corner of the classroom as a different response option (for example: "Strongly Agree," "Agree," "Disagree," "Strongly Disagree"). After asking a question, students move to the corner that represents their opinion. This method not only promotes active participation

but also allows students to visually see where their classmates stand. The teacher can then ask volunteers from each group to explain their choice.

- **Sticky Note Clusters**
  For open-ended or more complex questions, this method is very effective. Students write their responses on sticky notes (one idea per note), then attach them to the board. The teacher or students can then organize these sticky notes into thematic groups. For example, for the question "What road signs regulate traditional vehicle mobility?", the sticky notes could be grouped by categories (danger, prohibition, mandatory). This approach helps identify patterns of thinking and visually structure collective knowledge.
- **Digital Poll with QR Code**
  For technology-equipped classrooms, using online polling tools accessible via a QR code offers many advantages. The teacher creates a survey with the desired questions and generates a QR code that students can scan with their devices. Results are displayed in real time, allowing for immediate discussions on observed trends. This method works particularly well for series of questions and allows data to be saved for later analysis.

By using these varied methods throughout the questioning session, the teacher can maintain student engagement, collect different types of data, and adapt to diverse learning preferences. Alternating between these techniques also helps energize the session and encourages participation from all students, including those who might be reluctant to express themselves verbally in front of the entire class.

Students Investigation

<u>Familiarisation</u>
The first phase of the investigation is dedicated to acquire the terminology necessary to proceed with the ideation phase. Teachers are responsible for introducing the structure of the proposed activities in terms of duration, modalities, tools used, expectations.

Once done, they can then proceed with the road sign introduction phase by providing answers to questions such as:

"What are autonomous vehicles?" [open question]
⏩ They are vehicles capable of driving by themselves, without the need for a driver.

"What road signs regulate the mobility of traditional vehicles?"
⏩ Vertical road signs (the signs) are divided into:

DANGER. They are formed by a triangle with a red border and white field.

PROHIBITION. They are formed by a circle with a red border and white field.

PRIORITY. They decide who can go first. They are formed by a triangle with the point down (YIELD) and an octagon (STOP).

MANDATORY. They impose or prohibit certain behaviors. They are formed by a blue circle with white designs.

INFORMATION. They provide useful information to road users. They have a square or rectangular shape, with black or white writing and designs.

"Are there categories of signs designed to regulate the mobility of autonomous vehicles only?"
⏩ [Give students time to fantasize and brainstorm. If no spontaneous ideas emerge, suggest the categories of TRANSIT IN AUTONOMOUS/HUMAN DRIVING MODE]

"What do we mean by unambiguous signs?"
⏩ Signs that don't conflict with existing signs. Additionally, we should ensure they are easily interpreted by others (people or automated systems).

It is crucial to accompany definitions with **practical examples** to make the familiarization phase concrete and digestible. Teachers should encourage **interaction** to avoid de-activating emotional states.

This phase can be moderated through slides, favoring a traditional lesson, through unplugged tools, such as card games to associate names or characteristics with different signs, or by asking participants to respond using sticky notes or digital tools such as Mentimeter (https://www.mentimeter.com).

Ideation

Once satisfied that the students are familiar with the terminology and basic elements, teachers can proceed to the ideation phase:

> "Yesterday I received a call from the mayor of our town who asked if we could help him design new road signs dedicated to autonomous vehicles, that are not ambiguous, meaning they don't conflict with the road signs that currently regulate the mobility of vehicles in circulation. To design your road signs, you have paper and pen available."

Students will be tasked to:

- **Identify the road sign objective.** It is appropriate to have the students propose the road sign goal they want to ideate, dedicated to self-driving vehicles, which are not ambiguous, that is, do not conflict with the road signs that currently regulate the mobility of vehicles in circulation. An example might be to design a road sign to *move to autonomous/manual driving.*

- **Design the new road sign** (individually or collaboratively). Once agreed on the road sign objective, students can move to the ideation stage proposing a new road sign. It is a hands-on session, relying on paper and pencil toolkit. In particular, participants have to manually paint new road signs on sheets of 15cmx15cm. They can work individually or collaboratively.

Conclusion & Further Reflexion

At the end of the ideation phase, the teacher gathers the proposed ideas and encourages students to briefly share their suggestions with the group. This sharing phase enables immediate reflection through brainstorming, allowing for potential modifications, addressing ambiguities, and ensuring consistency in the design of proposed road signs.

Students learn about current road signs regulating traditional vehicles and explore the needs and opportunities for new signs adapted to self-driving vehicles. They are introduced to road sign design concepts through questionnaires, discussions, and teacher-led sessions.

Engaging in hands-on activities, they conceptualize and manually design new road signs that align with the regulatory needs of autonomous vehicles, fostering collaboration and creativity.

Through this process, they develop the ability to conceptualize, prototype, and critically evaluate road signs that address real-world challenges in autonomous vehicle regulation.

Step 2 - Testing road sign ambiguity

Background and description of the problem to be solved in this step: The second step is entirely dedicated to the testing phase aimed at verifying whether the proposed road signs are ambiguous, i.e. attributable to road signs already used to manage the mobility of human-driven vehicles, through a laboratory approach combining short presentation pills of the mechanisms underlying artificial intelligence tools through a frontal approach and allowing participants to immediately put into practice the principles introduced. Students can iteratively refine their proposal or propose a new sign by retracing the ideation phase.

Learning Objectives: Acquire or consolidate/refine knowledge of AI-based tools for image classification by demystifying AI-based tools. Use the tools presented in the recognition of ambiguity in the proposed signals compared to road signs already in circulation. Learn how to test an AI-driven tool.

Conceptualisation

The objective of this phase is to acquire, consolidate, or refine knowledge of AI-based tools for image classification while demystifying AI-powered systems. Students will use these tools to identify ambiguities in their proposed road signs by comparing them to existing traffic signs used for human-driven vehicles.

This step is entirely dedicated to testing, structured as a laboratory experience. It combines short theoretical insights on AI mechanisms with practical implementation, allowing students to apply learned concepts immediately. They may iteratively refine their proposed signs or create new ones by revisiting the ideation phase.

The investigation steps must be followed progressively to:

- **Facilitate** group reflection and review of designed road signs.
- **Iterate** road sign ambiguity testing using an AI-driven tool, such as SignVisionAI. Set up the computer camera under optimal conditions, preferring natural light, avoiding excessive brightness or darkness, and ensuring no obstacles interfere with image recognition. Conduct testing first with preloaded images from the tool before proceeding to student-created signs. Evaluate each design individually. Refine any proposed sign recognized as an existing one. Repeat the process until all signs are unambiguous.
- (Optional) - **Refine** the design if the road sign is identified as an existing signal.

Students Investigation

At this stage, it is crucial to use a workshop approach, allowing students to work autonomously to test the ambiguity of the proposed signal, and collaboratively discuss improvements to remove ambiguity, if any.

Cold Reflection

Students briefly share their road sign proposals with their peers, whether modified after the previous step or unchanged. This sharing session enables a structured brainstorming phase to assess potential modifications and discuss ambiguities.

Ambiguity Testing Using AI Tools

Students test their proposed signs for ambiguity using **SignVisionAI** (https://drive.google.com/drive/folders/1lwb4TkkNRnQ0K3j0s8kxeq7xg7a3pLak?usp=sharing). This AI model has been trained on a broad dataset of existing road signs, recognizing features such as warning signs, mandatory directions, pedestrian crossings, traffic restrictions, and other regulatory signals.

The teacher prepares the computer's camera for optimal image recognition, ensuring:

- Preference for natural light, avoiding overly bright or dark environments.
- Removal of obstacles that could interfere with classification.

Students then test AI recognition of example road signs provided in the manual. One by one, they submit their designs for classification. If a proposed sign is identified as an existing one, the student must refine or redesign it. The process continues iteratively until all proposals are deemed non-ambiguous.

Example - Non-ambiguous

Non-ambiguous proposal for a sign meaning "Forbidden in autonomous mode"

Example - Ambiguous

Ambiguous proposal for a sign meaning "Forbidden in autonomous mode"

Conclusion & Further Reflexion

To conclude, teachers categorize proposals into ambiguous and non-recognized by AI. A collective discussion follows, analyzing ambiguous designs, tracing the evolution of ideas, and documenting reasons for modifications. This phase ensures students understand the iterative nature of design and AI-based classification while refining their final proposals.

Thanks to this step, students have deepen their understanding of AI-based tools for image classification, focusing on their role in detecting ambiguities in road signs. Discussion emphasized how AI interprets visual inputs and how this knowledge applies to evaluating and refining the clarity of proposed signs.

Through a hands-on lab approach, students used an AI-driven tool, such as SignVisionAI, to test the ambiguity of their road signs compared to existing ones. Iterative refinement based on the tool's feedback ensured final designs are unique and unambiguous.

Practical experience with AI tools can strengthen students' ability to evaluate and improve their designs. Engagement in testing and refinement fosters critical thinking, teamwork, and iterative problem-solving skills, aligning their concepts with real-world standards.

Step 3 - Training the model based on the new signs designed

Background and description of the problem to be solved in this step: The third and last step is dedicated to the training phase aimed at enabling an AI-driven tool to recognize road signs achieving the same objective, e.g., move to autonomous driving, through a laboratory approach combining short presentation pills of the mechanisms underlying artificial intelligence tools through a frontal approach and allowing participants to immediately put into practice the principles introduced. Participants can iteratively refine their proposal or propose a new sign by retracing the ideation phase.

Learning Objectives: Acquire or consolidate/refine knowledge of AI-based tools for image classification by demystifying AI-based tools. Use the presented tools for the proposal of unique road signs to manage the mobility of autonomous vehicles.

Conceptualisation

The training process follows a structured sequence of steps to ensure uniformity in design and effective AI recognition.

Students first **review and refine their proposed road signs**, ensuring they are consistent and easily interpretable. A **voting process** determines the most effective representation when multiple variations exist.

Next, students create **standardized versions of their final design** using different artistic techniques to generate diverse training data.

Finally, **the AI model is trained and tested using these images**, reinforcing the principles of AI-based classification.

Students Investigation

Reflection and Review

Teachers present all non-ambiguous road signs developed in the previous session. A discussion follows to assess the uniformity and coherence of the proposals.

If multiple similar versions of the same sign exist, a vote determines the most easily interpretable representation. The majority selects the final reference sign, defining its shape, color, and symbol.

Representation of the Final Road Sign

Students individually create a standardized version of their selected road sign.

Multiple versions should be produced with variations in color intensity and artistic techniques, including colored pencils, markers, finger painting, collages, wax colors, and watercolors. This diversity enhances AI training effectiveness.

AI Training

As designs are completed, teachers ensure optimal conditions for image capture using the Vittascience tool.

Approximately 80% of the images are used to train the AI. The remaining 20% serve as validation data, testing whether the AI consistently classifies all representations under the same road sign category. A higher number of authored images increases the likelihood of successful AI training.

Reflection and Evaluation

Teachers collect and analyze the final designs. A discussion follows on the AI's recognition performance and the effectiveness of training data.

Feedback on the AI process is gathered through a questionnaire similar to the one used in the initial phase.

Conclusion & Further Reflexion

At the end of the training phase, teachers collect the ideas developed and the results. It is suggested to collect feedback and opinions on AI through questionning students using the similar questions from the step 1, to compare how learning has evolved.

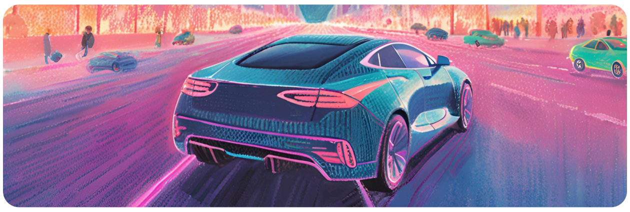
By completing this step, students have gained practical experience in training AI models to classify road signs for autonomous vehicles. They have developed critical thinking, collaboration, and iterative design skills while applying AI principles to real-world mobility challenges. Group discussions led to a final representation, which has then been used to train an AI-based tool, such as the Vittascience platform. The process involves capturing varied images to ensure robust AI recognition.

Thanks to the whole protocol, students have enhanced their understanding of AI-based tools, particularly how they are trained to recognize specific visual inputs. They have explored fundamental AI training principles, such as data diversity and consistency in classification.

Printables of road signs

Exploring further

Here are two engaging initiatives designed for secondary school students to explore associated technologies and issues linked to the protocol: **LiDAR technology and autonomous vehicle communication**.



LiDAR Technology

Students can explore LiDAR by using simple tools such as laser pointers and measuring devices to simulate how light detection and ranging work. They can also analyze real-world LiDAR data sets, compare 3D mapping results, and discuss how self-driving cars use this technology for navigation. A classroom project could involve building a basic LiDAR-like sensor system using Arduino or Raspberry Pi to detect distances and obstacles, reinforcing the importance of LiDAR in autonomous driving.

The Basics of LiDAR - Light Detection and Ranging by NEON Science: https://www.neonscience.org/resources/learning-hub/tutorials/lidar-basics

Can You Fool A Self-Driving Car? - A video by Mark Rober that explores the limitations of Tesla's camera-based Autopilot system versus a LiDAR-equipped vehicle, illustrating how LiDAR enhances autonomous vehicle perception and safety: https://www.youtube.com/watch?v=IQJL3htsDyQ

Collaborative Autonomous Vehicle Programming Challenge

Students can work in teams to build and program small autonomous vehicles capable of communicating with each other and reacting to their surroundings using microcontrollers like Arduino or Raspberry Pi. The challenge involves programming the vehicles to exchange data (such as speed, direction, and obstacles) and make collaborative driving decisions. This can include a simulated intersection where cars must coordinate right-of-way or a cooperative obstacle avoidance system. Through this activity, students learn about vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) communication, key principles in smart mobility.

High School Autonomous Vehicle Competition by Argonne National Laboratory: https://www.anl.gov/education/high-school-autonomous-vehicle-competition?utm_source=chatgpt.com

MIT Research on Human Reasoning in AI for Self-Driving Car Navigation - Insights on how AI-driven vehicles can learn from human behavior for safer and more efficient decision-making: MIT News