The system recognizes automatically the license plate of a teacher's vehicle, by means of artificial intelligence and opens the school parking gate accordingly.

Automatic Number Plate Recognition

Written by
4H/5H & Maurizio Galli

Designed by
Maurizio Galli

Version 2.0

2020-2021


STOP

Goals

1

The goal of the ANPR (**A**utomatic **N**umber **P**late **R**ecognition) project had two sides.

- Increase the soft and technology skills of our students.
- Establish a best practice to be spread among European peer schools.

1.1

Main Educational Goals

Main Educational Goals

1

AI and Computer Vision

Use machine learning to train a Neural Network. Learn how to use openCV library.

2

Hardware

Implement a software solution on a Raspberry PI/PC.

3

Software

Design a software supervisor with python.

4

Design

Design a complex system, implementing a robust solution.

5

Marketing

Write a basic marketing plan. Prepare a video and a communication document. Learn public speaking techniques.

6

Management

Manage a complex project using Trello.

1.2

Knowledge & Skills

Warehouse

GROWTH

ABILITIES

SUCCESS

FESSIONAL

PROGRESS

ADVANCED

Knowledge & skills

Knowledge and skills that have been promoted during the project, divided by area of expertise.

Area	Skills	Knowledge
Artificial intelligence and computer vision	Train a Neural Network Use openCV Library	CNN, SVM, papers, opencv, virtualenv
Hardware	Implement software on Raspberry PI Interface with a camera Use of a wireless relay switch	Raspberry PI, Shelly 1, Router, Camera
Software	Software development	Python, Django, Bootstrap, Tkinter, Restful, Vscode, C#, Access, ADO, RTSP protocol, Linux VM
Design	Know UX design techniques	Learn UX design
Marketing	Know basic marketing elements	Learn basic marketing plan and competitive analysis
Management	Use of a project management software	Trello
European project	How to disseminate a project	Dissemination

and how we reached them...

4 extra hours every Tuesday afternoon

Activities assigned singularly

Teacher's check of activities every Monday

1.3

European Project


EU
BARENTS SEA
SEA OF NORWAY
SWEDEN
FINLAND
GULF OF BOTHNIA
Helsinki
Tallinn
ESTONIA
Stockholm
BALTIC SEA
Riga
LATVIA
LITHUANIA
Vilnius
NORTH SEA
UNITED KINGDOM
IRELAND
Dublin
DENMARK
Copenhagen
CELTIC SEA
THE NETHERLANDS
Amsterdam
London
Berlin
Warsaw
ENGLISH CHANNEL
Bruxelles
BELGIUM
GERMANY
POLAND
Luxembourg
Paris
Prague
CZECH REPUBLIC
SLOVAKIA
Vienna
Bratislava
FRANCE
AUSTRIA
Budapest
HUNGARY
BAY OF BISCAY
SLOVENIA
Ljubljana
Zagreb
CROATIA
ROMANIA
Bucharest
GULF OF LIONS
PORTUGAL
Lisbon
Madrid
SPAIN
ITALY
Rome
BULGARIA
Sofia
BLACK SEA
ADRIATIC SEA
TYRRHENIAN SEA
M E D I T E R R A N E A N
GREECE
AEGEAN SEA
Athens
IONIAN SEA
CYPRUS
MALTA
Valletta
S E A
Belgium
Bulgaria
Czech Republic
Denmark
Germany
Estonia
Ireland
Greece
Spain
France
Croatia
Italy
Cyprus
Latvia
Lithuania
Luxembourg
Hungary
Malta
Netherlands
Austria
Poland
Portugal
Romania
Slovenia
Slovakia
Finland
Sweden
United Kingd
The protocol order of the Member States is based on the alphabetical order of their geographical names in the original language.

Dissemination and exploitation

Project type: Erasmus+ KA229.
One of the main goals of the project was to establish a best practice to be spread among European peer schools.

What are the aims and objectives of the dissemination and the exploitation?
The first goal of dissemination and exploitation is to spread projects' results.

Why is it important to share project results? What are the wider benefits?
Dissemination and exploitation activities can often create new opportunities to extend the project and its results or develop new partnerships for the future.
Dissemination and exploitation goals may be to:

- raise awareness;
- extend the impact;
- engage stakeholders and target groups;
- share solutions and know how;
- influence policy and practice;
- develop new partnerships.

How to disseminate and exploit results?

- the Erasmus+ Project Results Platform;
- project or organisational websites;
- meetings and visits to key stakeholders;
- workshops, seminars, training courses, exhibitions, demonstrations, or peer reviews;
- reports, articles in specialised press, newsletters, press releases, leaflets or brochures;
- radio, TV, YouTube, Flickr, video clips, podcasts or apps;
- social media;
- public events;
- project branding and logos;
- existing contacts and networks.

Who is the target audience?

- end-users of the project activities and deliverables;
- stakeholders, experts or practitioners in the field and other interested parties;
- decision-makers at local, regional, national and European level;
- press and media;
- general public.

What can be disseminated and exploited?
Tangible results may include:

- an approach or a model to solve a problem;
- a practical tool or product, such as handbooks, curricula, e-learning tools;
- research reports or studies;
- good practice guides or case studies;
- evaluation reports;
- recognition certificates;
- newsletters or information leaflets.

Intangible results may include:

- knowledge and experience gained by participants, learners or staff;
- increased skills or achievements;
- improved cultural awareness;
- better language skills.

European Commission

HOW TO COMMUNICATE YOUR PROJECT

Think, Plan, Act strategically
- What do you want to achieve?
- Communicate from day one

Be creative
- Vamp up the visual, reduce the writing
- Use social media

You can't reach everyone
- Define your target audience
- Use consortium resources, expertise and ideas

Get into the media mindset
- Identify relevant media people
- Understand media language and needs

Think Issue, not project
- What issue is the project addressing?
- Link communication to hot topics in society

Think global, act local
- Local and regional media are effective targets
- Use the project's local connections

Make it relevant to daily life
- Show the impact on society
- Avoid technical language and jargon

Build your brand
- Become a trusted source and voice
- Contribute where and when you can

Design

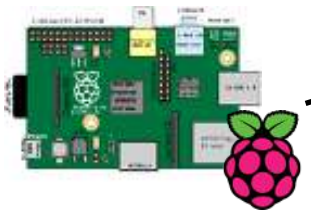

PARKING
P

2

Technology design started with specific assumptions:

- Complete process automation
- No time overhead nor workflow changes for school staff
- Project division in subsystems

System Design



Raspberry PI or PC
recognizes the teachers' plates and sends an opening command to the gate.

Router

Camera
sends a video stream to the Raspberry PI.

School parking gate

wifi relay

LAN

System Design 2

School LAN

POE switch

POE

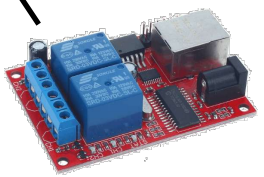
Camera

PC (Intel NUC i7)

recognizes the teachers' plates and sends an opening command to the gate.

School parking gate

(clean contact)



Ethernet Relè

Ethernet

COMPONENTS

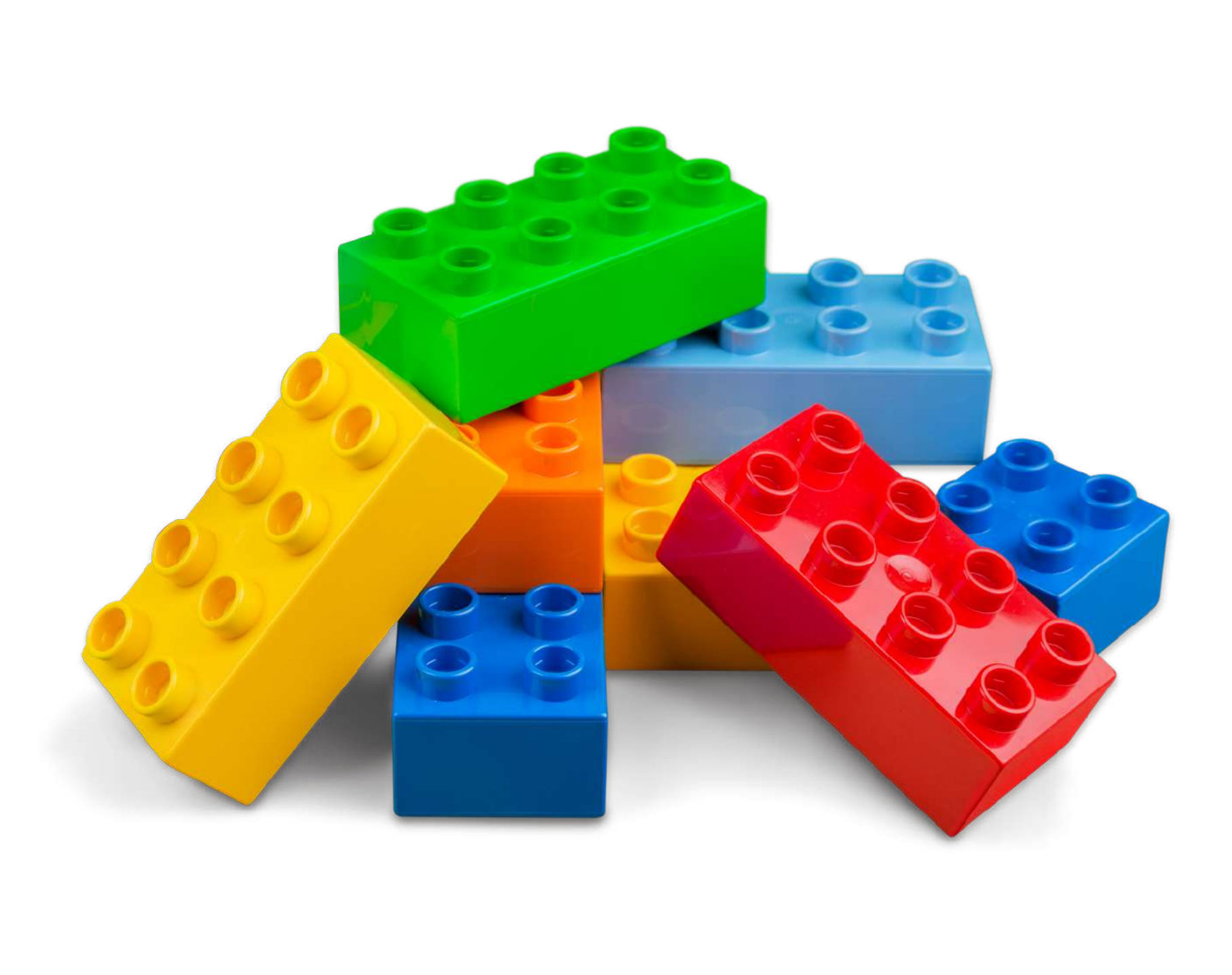
Camera: compatible with Open CV, IP type, CMOS sensor, global shutter technology.
Raspberry PI: it recognizes authorised license plates.
Router/Switch: it connects all system's elements.
Wifi switch: It is used to open the gate and it is connected via cable to the gate and via Wi-Fi to the router.
PC: backup solution in case the Raspberry's performance is not good.

HOW IT WORKS

1. The Raspberry PI receives the video stream from the camera and recognizes the license plate.
2. Then the license plate is compared with the teacher's database, if there's a match, the Raspberry will send a signal to the Shelly 1 relay switch to open the gate.

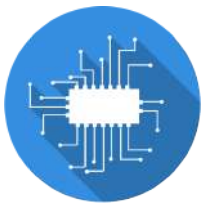
2.1

Subsystems



Six Subsystems

During the project the class was divided into groups and each group was allocated a subsystem. Individual activities were assigned to the students during all project steps. The subsystems have been divided into hardware and software components and have been prioritised based on system workflow.



1

Deep Learning. (CNN)
The ANPR core. AI techniques for acquiring and recognizing a car license plate.

2

Supervisor (SUP)
All software around the ANPR core. UX design was applied.

3

Raspberry PI / PC (BERRY)
Where all software resides. It is connected by LAN to the camera and the school gate.

4

Camera (CAM)

Frame acquisition through OpenCV library. Camera placement.

5

School Parking Gate (SPG)

Parallelise wireless relay switch to the current gate opening system.

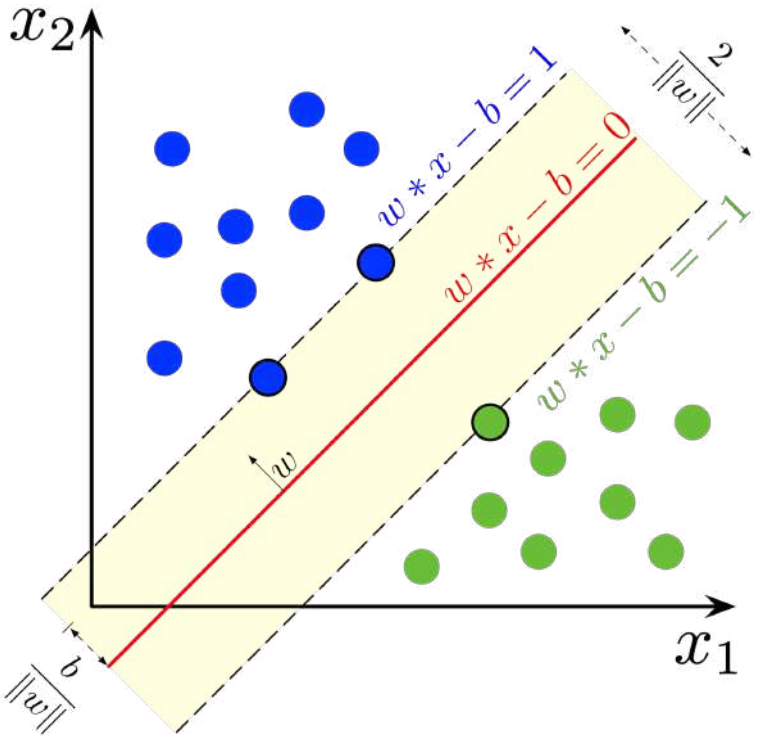
6

System Integration (SYS)

Project management, quality assurance and privacy aspects.

1. Deep Learning (CNN)

To develop the ANPR core system we decided to use at least two different Machine Learning techniques: SVM (Support Vector Machine) and CNN (Convolutional Neural Network). "Core" is referred to the software necessary to grab the frames from the camera and recognizes the licence plate numbers of the teachers entering the school parking.



SVM Support Vector Machine

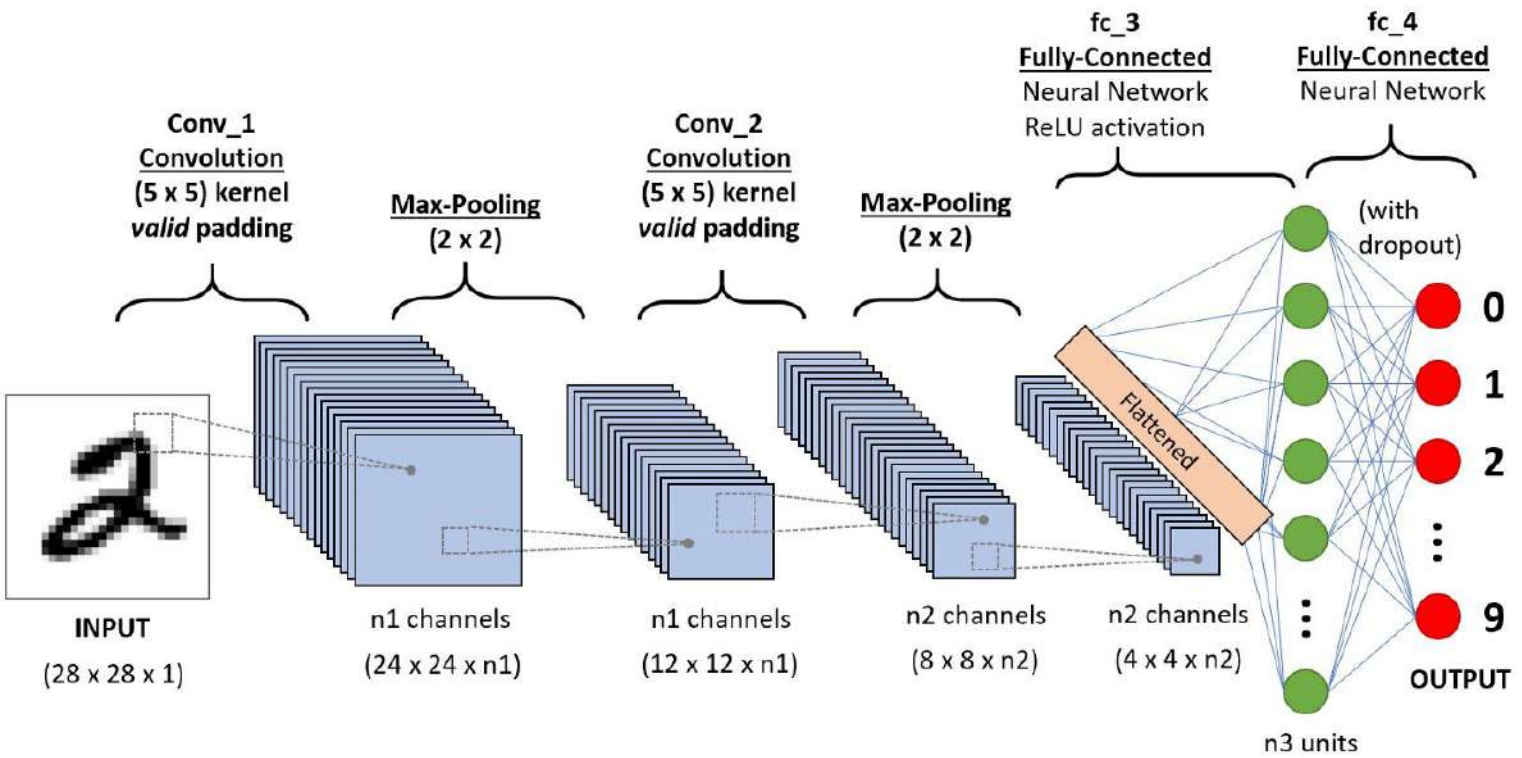
During the first implementation we planned to use SVM because it offers, with respect to CNN, a good recognizing performance of the number plates and, at the same time, a faster implementation.

Support vector machines are supervised learning models with associated learning algorithms that analyse the data used for classification and regression analysis.

CNN Convolutional Neural Network

In deep learning, a convolutional neural network (CNN, or ConvNet) is a class of deep neural networks, most commonly applied to analysing visual imagery.

CNNs have applications in image and video recognition, recommender systems, image classification, medical image analysis, natural language processing, and financial time series



Academic papers

We collected more than 80 academic papers on ANPR to research the subject and some of those were suitable to form our knowledge base. Go to academia.edu and search for: ANPR or ALPR.

main source: academia.edu

Some useful web links

opencv.org
python.org
microsoft.com
visual studio code
ubuntu
raspberrypi.org
pyimagesearch.com
kaggle.com
github.com
tensorflow.org

keras.io
academia.edu
opencv.org
trello.com
amazon.com
selea.com
shelly 1
axis.com
hikvision.com

openCV-Python

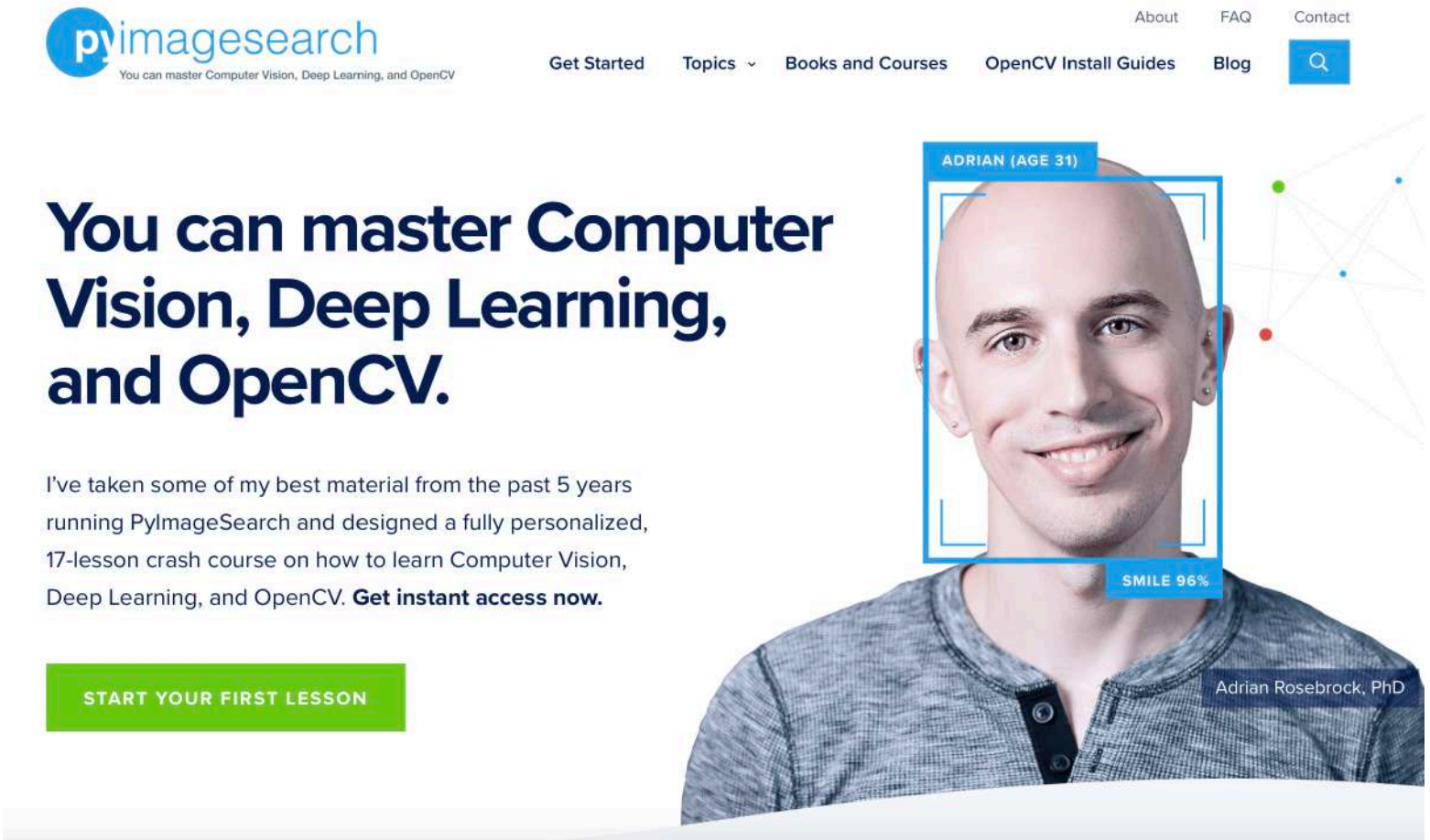
OpenCV-Python is a computer vision library written in C/C++ and wrapped with Python. We used it for grabbing and processing camera frames in the core ANPR system.

we use it for ...

- Grabbing frames
- Changing colour spaces
- Geometric transformations
- Images thresholding
- Smoothing
- Morphological transformations
- Image gradients
- Canny edge detection
- Contours

pyimagesearch

In order to start with an ANPR "core" we purchased the "gurus course" from pyimagesearch. During the project we tested and modified this core in several ways.



Environment

To develop the ANPR core, a Linux VM, an IDE and many AI libraries were needed.

Ubuntu VM
A Linux machine is necessary to install all software for core development.

Virtualenv
Installing the virtual environment Virtualenv is very useful due to very fast changing in all the necessary libraries.

Visual Studio Code
The Microsoft "light" developing IDE with python extensions.

Libraries
We used a lot of AI libraries were necessary or required.

ANPR core flow

Software steps for number plate recognition

1. Stream acquisition

video input to system (rtsp protocol)

2. Localisation

number plate localisation (openCV)

3. Segmentation

extraction of chars/ numbers (openCV)

4. Recognition

Classification of chars/ numbers (CNN or SVM)

2. Supervisor (SUP)

Software supervisor is the application that includes the ANPR AI core. We decided to develop two software solutions: a web application and a desktop one.

Web Application
The application server runs on a Raspberry PI or a PC and it was developed with **Django** and **Bootstrap**.

Stand alone desktop application
The application runs on a single device a Raspberry or a PC. The Raspberry solution could be unattended while PC solution will be positioned in the school reception.

UX design

In our project we applied UX design criteria

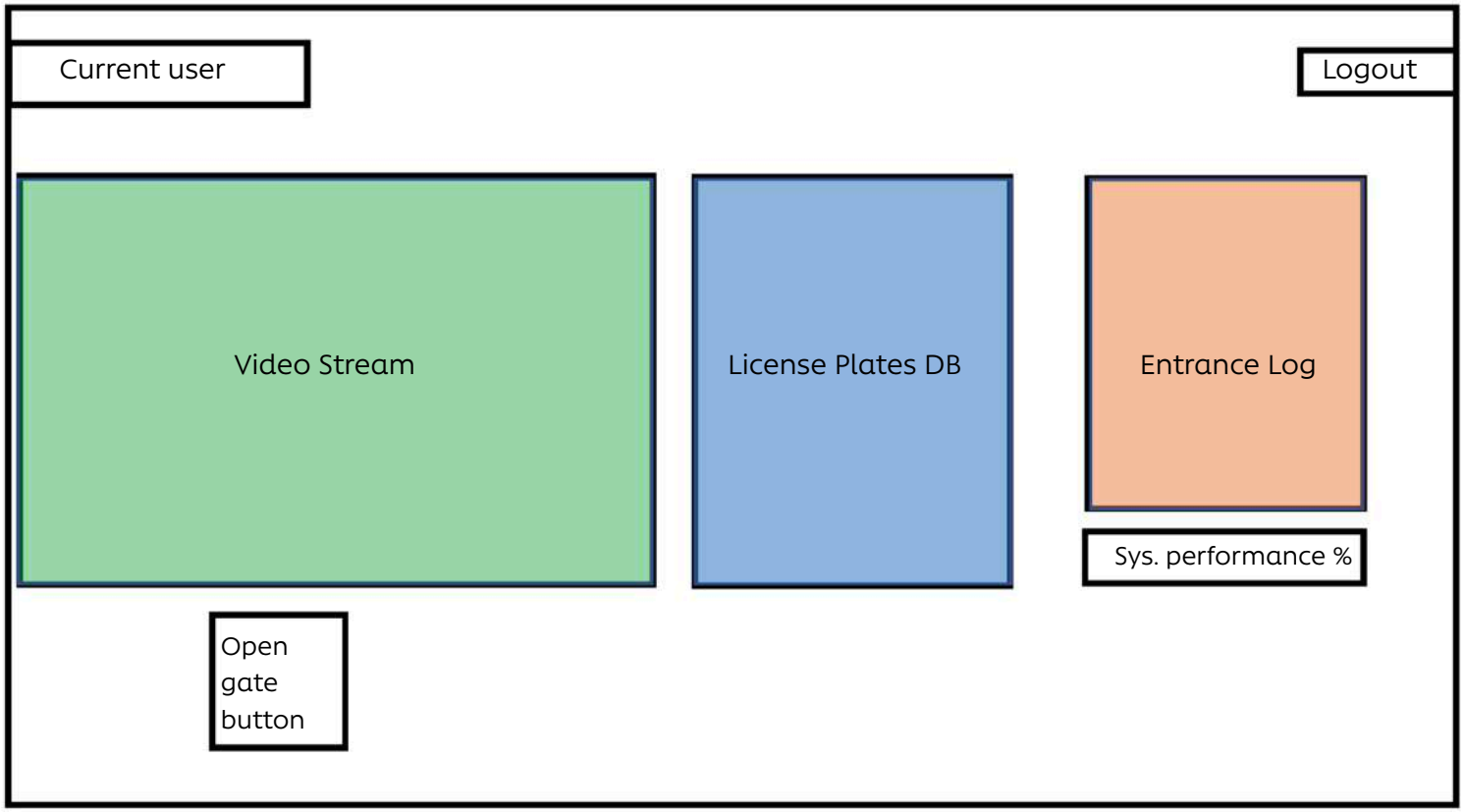
What is User Experience Design?

"User experience" encompasses all aspects of the end-user's interaction with the company, its services, and its products. It includes the practical, experiential, affective, meaningful and valuable aspect of human-computer interaction.
The first requirement for an exemplary user experience is to meet the **exact needs of the customer,** without fuss or bother. Next comes **simplicity and elegance** that produce products that are a **joy to own, a joy to use**.
In order to achieve high-quality user experience in a company's offerings there must be a merging of the services of multiple disciplines, including engineering, marketing, graphical and industrial design, and interface design.
The UXD involves the design of the entire process of acquiring and integrating the product, including **aspects of branding, design, usability and function**.

Characteristics of a product

If you want to create a good product and have an advantage on the market, the user experience must have this 7 characteristics.
Useful: provides a purpose for its target customers. If the product has no purpose, it's unlikely to be able to compete for attention on a market full of useful products.
Usable: enable users to effectively and efficiently achieve their end objective. Cars are a good example of a high level of usability, you can focus on driving while you are changing station on the radio.
Findable: ensures the product and its contents are easy to find.
Credible: ability to trust in the product. It's nearly impossible to deliver a good UX if the user thinks the product creator is lying or has bad intentions.
Desirable: conveyed through branding, image, aesthetics and emotional design.
Accessible: provides a ux which can be accessed by users of a full range of abilities.
Valuable: delivers value to the business and to the customer. The value factor is the sum of all the different factors of user experience combined.

A user interface mockup



Technical Office data exchange

Data exchange to and from the technical office. Transfer will be automated so technical staff don't need to modify their workflow in any way.

Technical Office

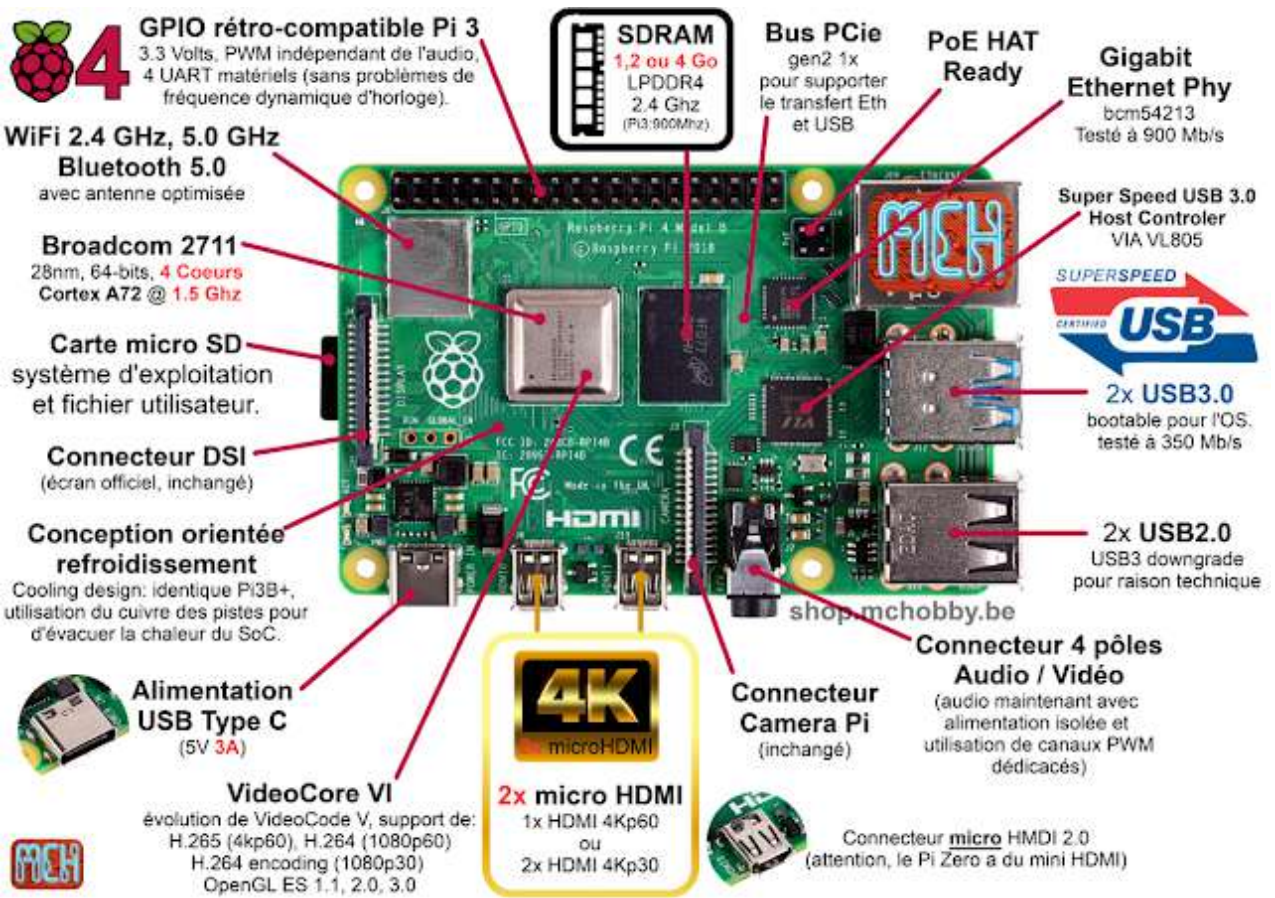
parking entrance log

teacher's plates DB

Intel NUC

3. Raspberry PI/PC (BERRY)

We decided to use Raspberry PI in case the system was unattended and the performance of the number plate recognition are good, otherwise we would use a PC with a desktop application.



The Raspberry Pi is a small single-board computer developed in the United Kingdom by the Raspberry Pi Foundation to promote teaching of basic computer science in schools and in developing countries. The board was designed to host operating systems based on the Linux kernel or RISC OS. Raspberry can do everything you'd expect a desktop computer to do, from browsing the internet and playing high-definition video, to making spreadsheets, word-processing, and playing games.

Raspberry Pi is contained on a single circuit board and features ports for:

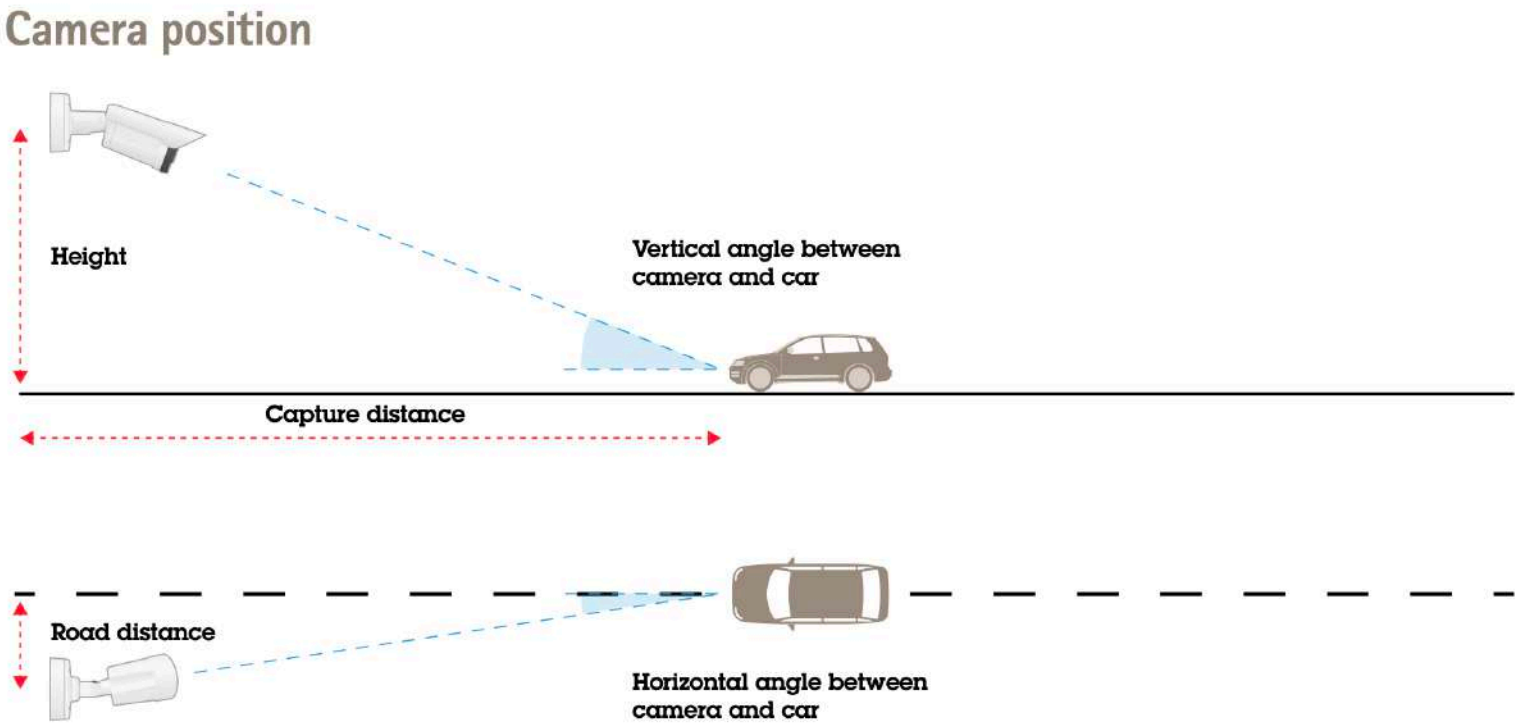
- HDMI
- USB 2.0/3.0
- Composite video
- Analog audio
- Power
- Internet
- SD Card

The computer runs entirely on open-source software and gives students the ability to mix and match software according to the work they wish to do.

The components vary depending on the model. The first Raspberry Pi, Raspberry Pi 1, was released in February 2012, followed by other models, again with an extremely affordable starting price of 35 dollars. The Raspberry Pi 3 was distributed starting from February 2012. It has a 64-bit CPU and, for the first time, has already integrated Wi-Fi and Bluetooth (Low Energy).

The computer name is a play on words. The first part refers to the name of a fruit, as is traditional in computer companies, such as Apple, Blackberry or Acorn, while "Pi" is the abbreviation of "python interpreter" (python interpreter), since Python is the language of main programming used by developers in the Raspberry Pi.

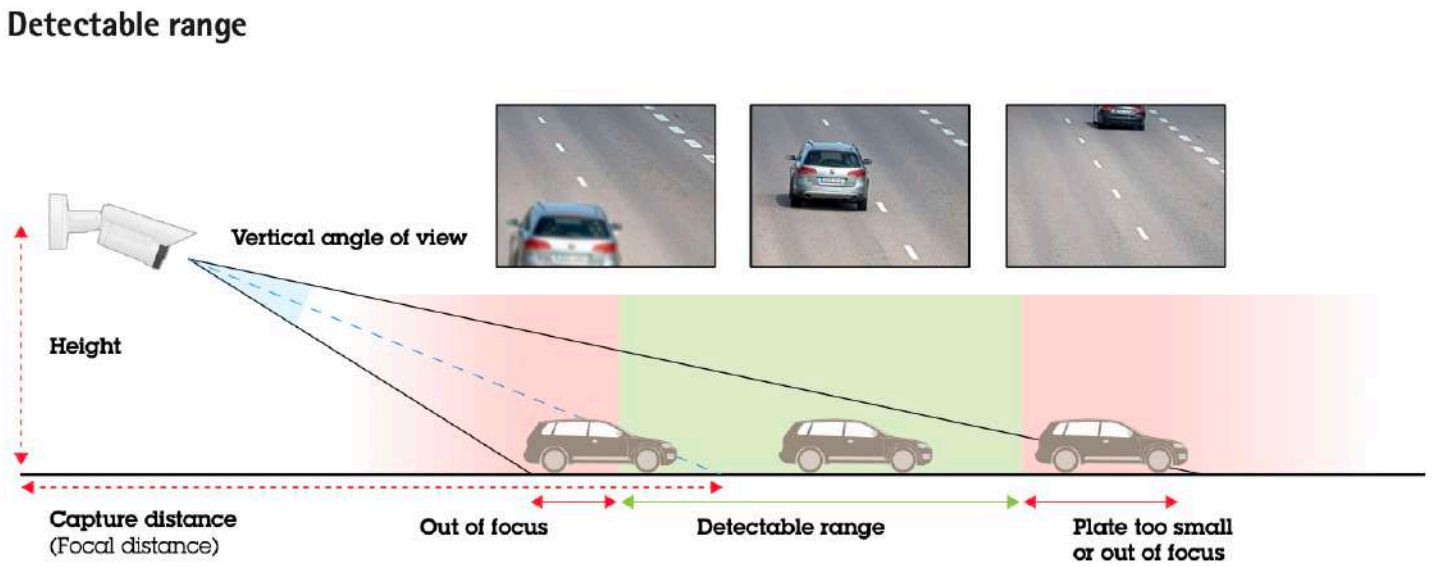
4. Camera (CAM)



Vertical angle must be < 30° and road distance < 2mt.

Depth of field

Detectable range is defined by depth of field. We needed to calculate for how many second the plate was clear based on car speed



National licence plates

Here is some national license plates examples and chars that are excluded.
What to do?? Retrain the SVM and modify in the code the method “loopOverDetectedPlates” accordingly.

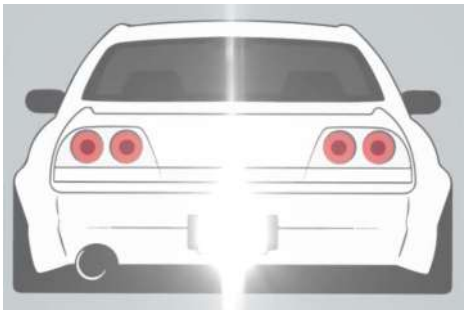
I, Q, V, Å, Ä and Ö

all vowels and Q

I, O,Q,V

Q, W, X, Y

Factors affecting vision

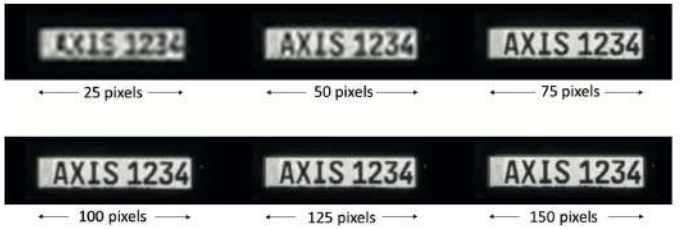


Smearing/Blooming

Deterioration

Sun and lighting

Net shadows



Pixel Density

Lights trail

Orientation

Camera choice

For a good performance it is better to use a camera with a monochromatic global shutter cmos sensor with high frame rate. Here are two possible choices.

Telecamera Sricam Italia Camera Lettura Targhe LPR, 2 Megapixel Sony, Varifocal Lens 6-22 mm, IP66

Hikvision

4 Mega Pixel Fotocamera IP Bullet con POE, scheda SD fino a 128 GB, zoom ottico 4 X

Camera choice 2

First cameras wasn't reliable so we bought a new one camera from DSE ITALIA (dseitalia.it)

5. School Parking Gate (SPG)

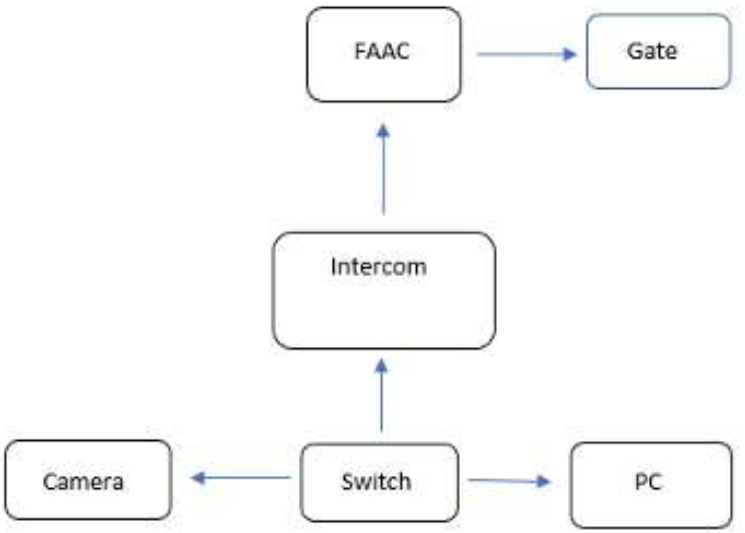
The current gate system is composed of: a gate, a camera, a supervising software and 2 PCs.

The gate opening command is sent manually when someone rings the intercom.

Intercom receives the opening command and sends it to the **FAAC** gate automation.

The current camera frames the gate but is not suitable for number plate recognition .

The current gate system



Gate

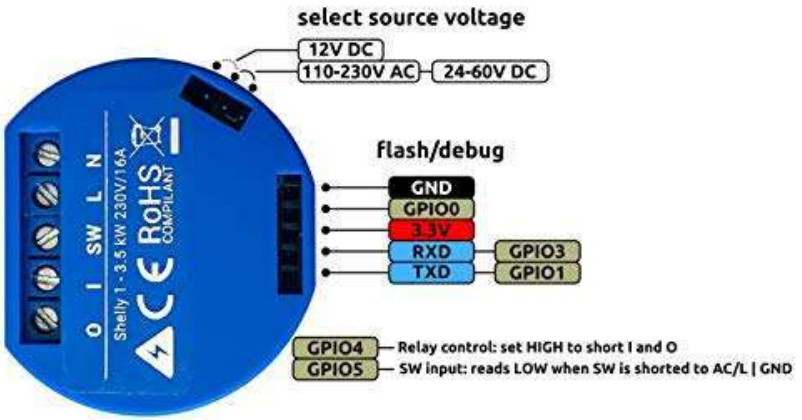
Camera

Intercom

RELE' WIFI- Shelly 1

This is the device we have chosen to open the school parking gate, it is a wifi relay switch. The opening command will be sent from the Raspberry PI. Shelly 1 will work in parallel with the current opening system.

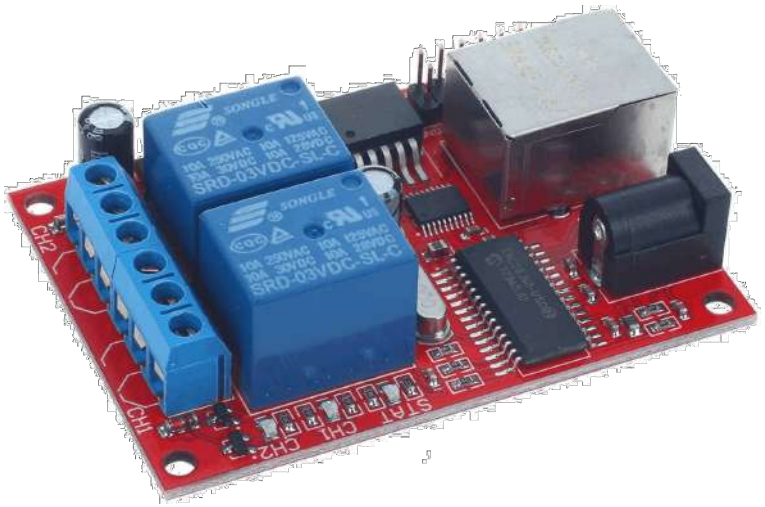
Shelly 1 Open Source WiFi, Smart WiFi Relay Switch, WiFi Alexa, Google Home



- HIGH COMPATIBILITY - Control all your home appliances with your voice. The Shelly 1 OS are Google home and Amazon Echo Compatible.
- WEEKLY SCHEDULING - Create custom daily schedules for your devices.
- OPEN SOURCE - Use the power of Mongoose OS to make your own application. Make your Arduino project live and usable in your automation project. Also, you can share your experience with developers all over the world.
- CONTROL APPLIANCES WITH PRE-SET ON-OFF FUNCTION -
  Control wide range of home appliances with the help of the free Shelly Cloud application. Check your home appliances status anytime and anywhere and control them on and off.
- 24/7 APPLICATION SUPPORT - Free iOS/ Android Shelly Cloud application. You can check your devices status anywhere and anytime. Remotely turn on or off the connected devices.

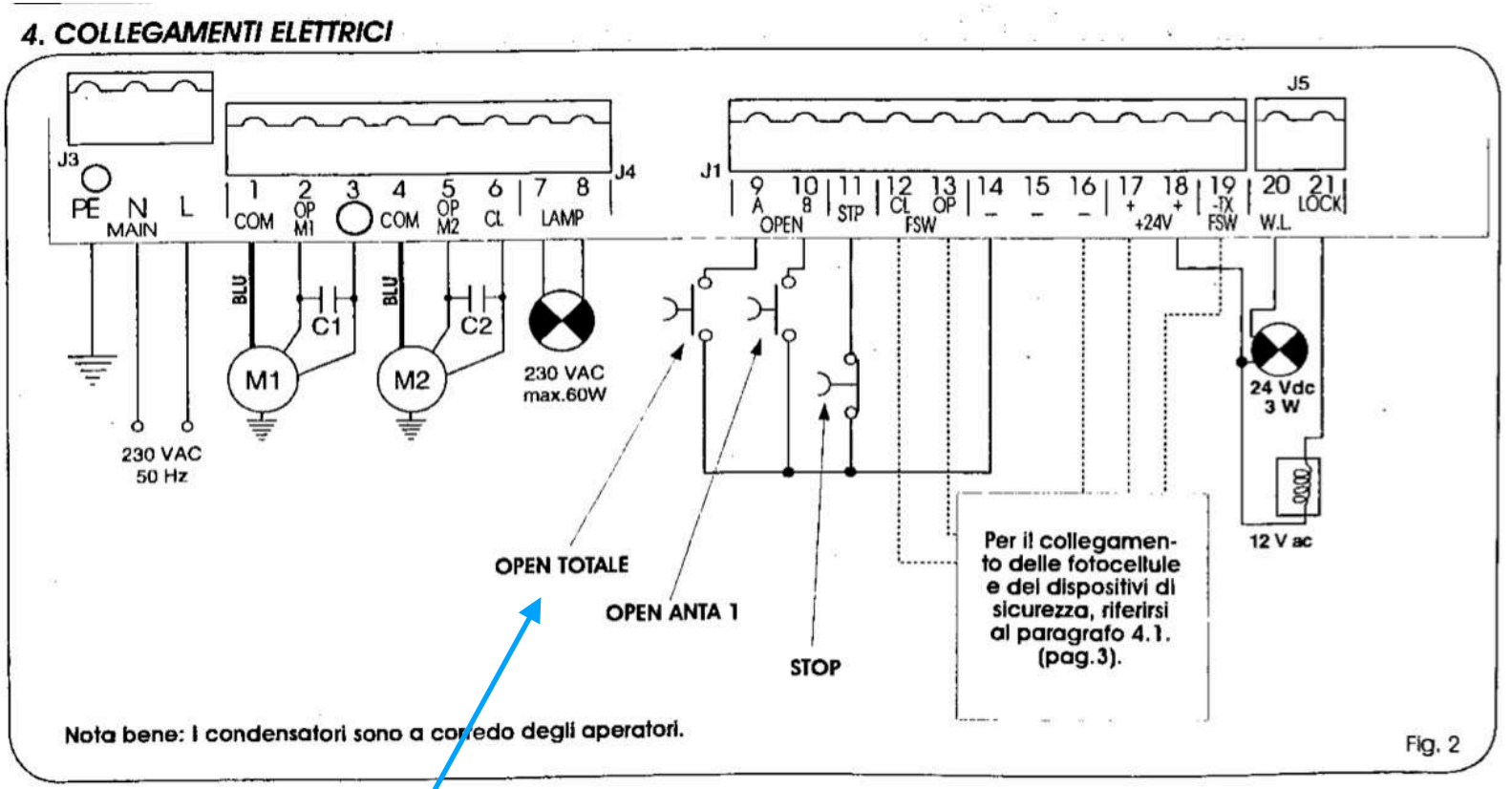
RELE' Ethernet

This kind of relè is more reliable than that with wifi technology



LAN Ethernet Controller Module, TCP/UDP Controller Module with 2-Way Relay Board Delay Switch DC(5-24V) for Replacement of Web Server Electronic Kit Circuit Board

- Industrial grade STC microcontroller as the main control chip
- Onboard 2-way high quality relay with relay with absorbing diode circuit
- With 1 power indicator, each relay has a state indicator, the light is on and the relay is closed.
- The relay module can be extended to reach 8 outputs. Note: The relay module should be active high.
- Module parameters such as module IP address, can be configured through the network



Gate schema

Relè will be paralleled to this switch

Selecting camera pole position

the first possible place

Blue: outside the school
Purple: inside the school

the second possible place

the third possible place

Best suitable place for the camera pole

final position for the camera pole (~3 meter out of ground)

6. System Integration (SYS)

System Integrators' activities: project coordination, software integration, technical office integration, quality control, privacy, performance test.

Project management
Meeting planning and reporting. Use of TRELLO for the project planning. The project was divided in five steps. This communication document summarises all the activities.

Software Integration
Connecting all software together and in particular core ANPR with user interface (UI). We developed two solutions: a web application and a desktop standalone.

Technical Office
Integrating data of the technical office.

Quality control
Testing the quality of software. Not yet done due to the project stop.

Privacy
Study of privacy compliance and request for all necessary permissions. In our case the video capture is made by framing outside the gate in a short public road.

Performance Test
To be done in the fourth and fifth project step

Workflow


Trello

3

To manage the project we used the agile method SCRUM and the  tool.

Scrum

For the project we used a simplified SCRUM method. Scrum is one of various "AGILE" methods. The scrum workflow is detailed in the next page. In SCRUM there are three different key roles: Product owner, Scrum Master, the Scrum Team.

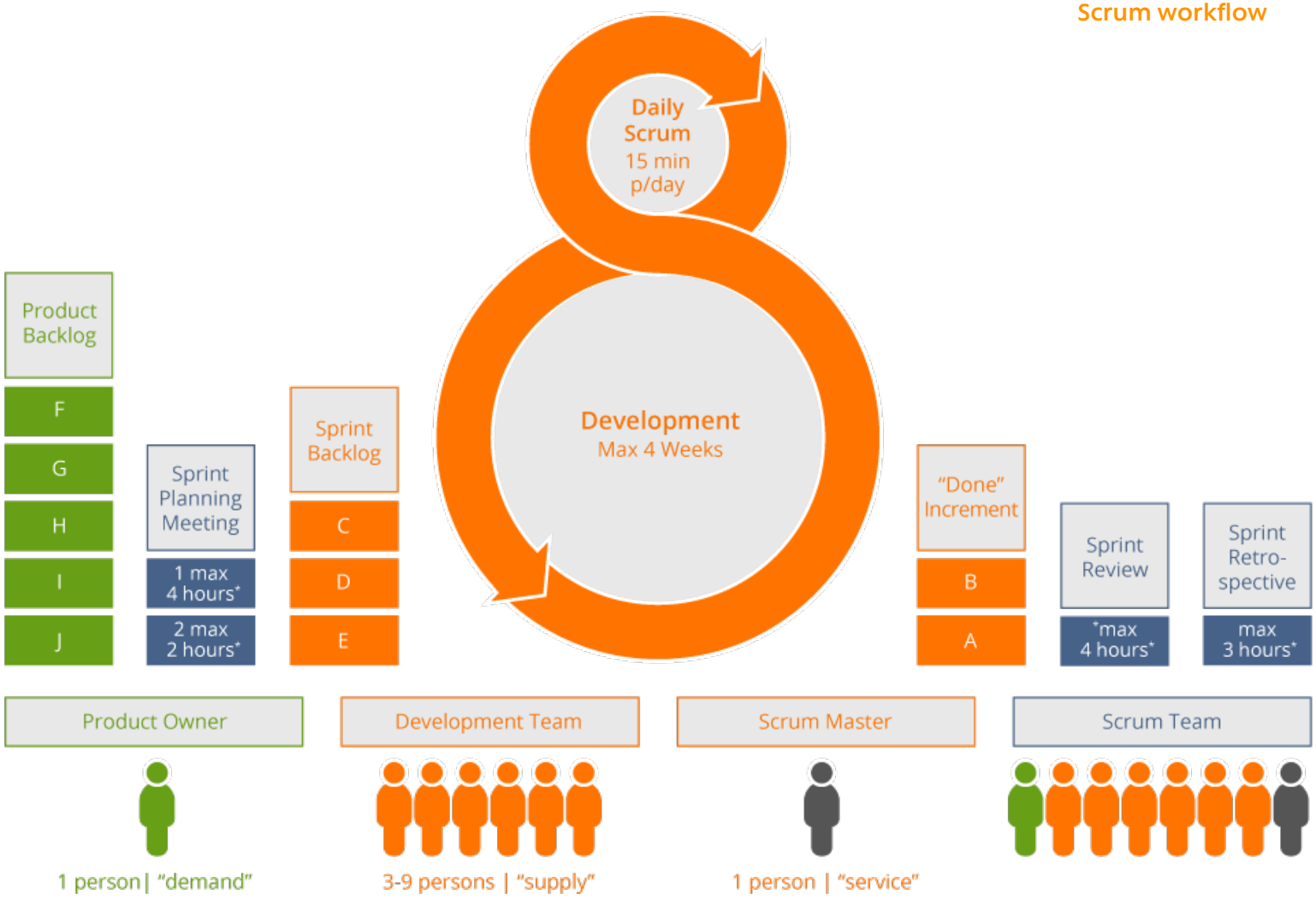
Product Owner
Activities: management of backlog, coordination with scrum master, product vision and modulation of the development team

the Scrum Team Development team

Scrum Master
helps the **Scrum** Team adopt **Scrum** in a way that continuously improves the team's capability to maximise the generated business value.

PAY ATTENTION
Scrum Master is a new profession

Scrum workflow

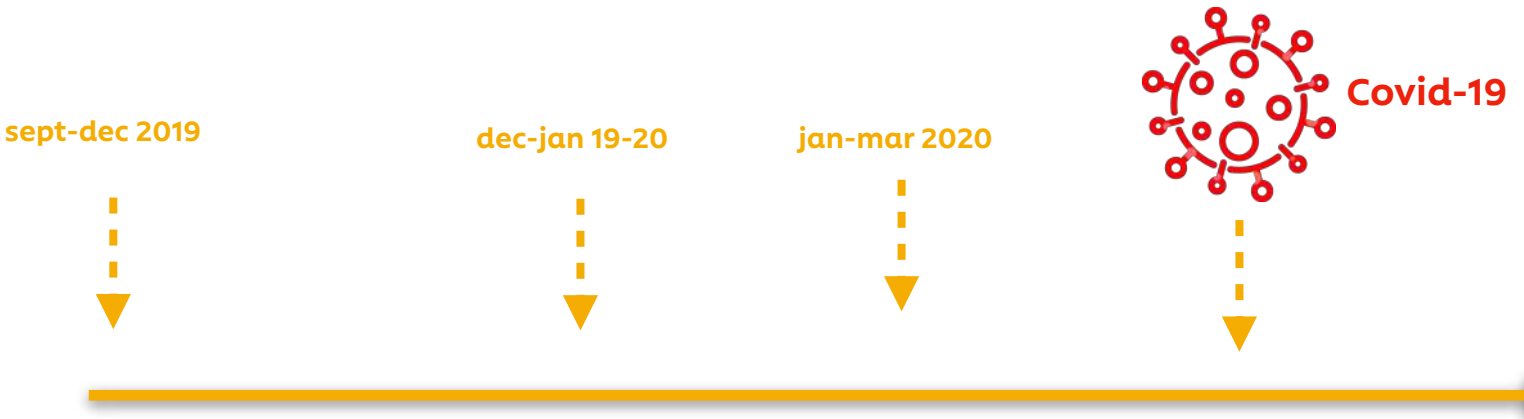


*Duration of this event depends on the duration of the sprint.

Trello

For project management we used a custom Trello board, to implement a Scrumban (Scrum+Kanban) method. All activities, assigned to students, were negotiated for each “sprint” and inserted in the project backlog, as this method was used for the first time all activities were planned by a supervisor (the teacher)

Project steps (1)



1

Knowledge acquisition
Time for acquiring the necessary knowledge

2

Design
Design of all subsystems

3

SW implementation
Core and UI implementation

Project steps (2)

4

Product and field test

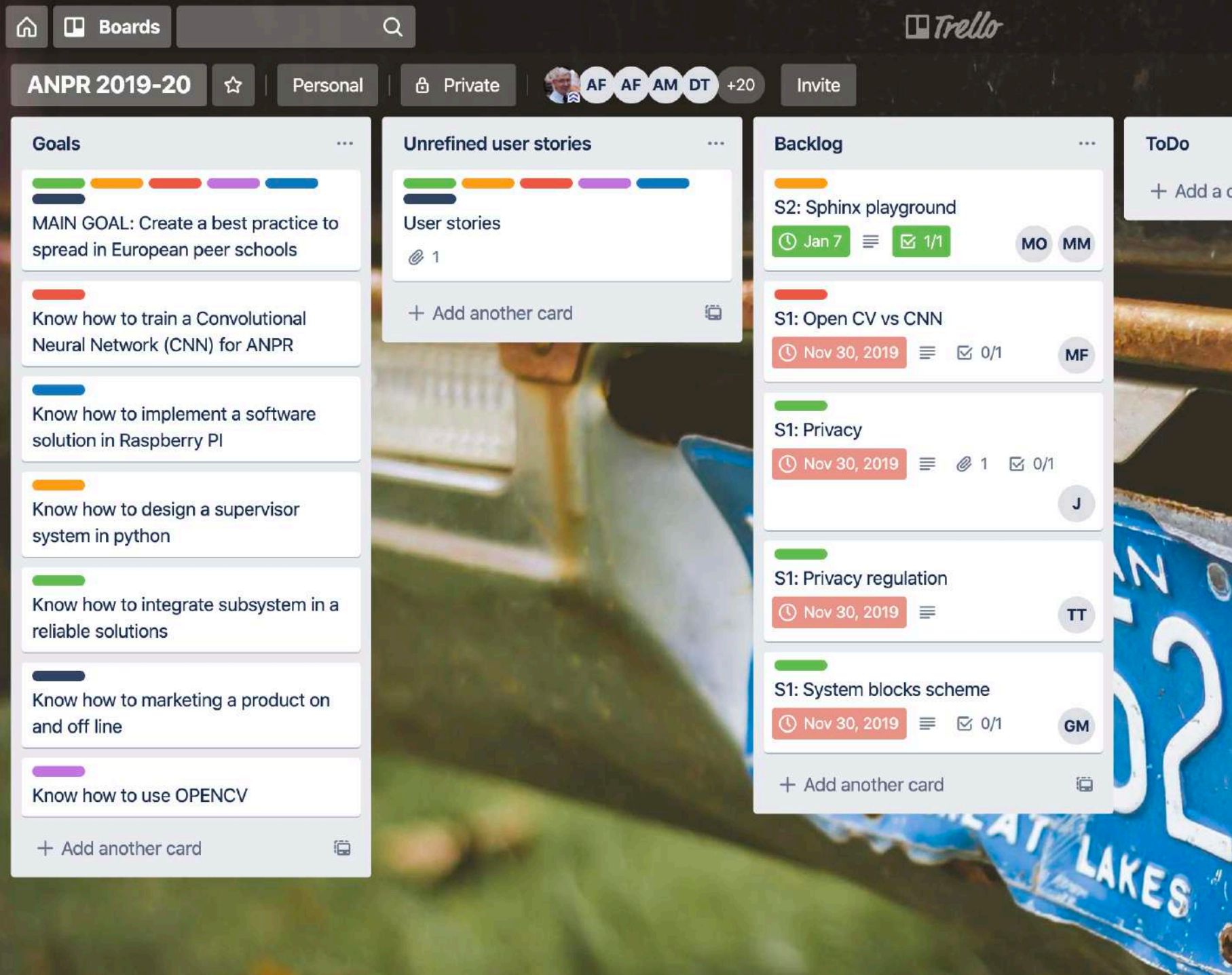
5

Preliminary field test

6

Final test and optimisation

To be done


Boards
Trello
ANPR 2019-20
Personal
Private
AF AF AM DT +20
Invite
Goals
MAIN GOAL: Create a best practice to spread in European peer schools
Know how to train a Convolutional Neural Network (CNN) for ANPR
Know how to implement a software solution in Raspberry PI
Know how to design a supervisor system in python
Know how to integrate subsystem in a reliable solutions
Know how to marketing a product on and off line
Know how to use OPENCV
Add another card
Unrefined user stories
User stories
1
Add another card
Backlog
S2: Sphinx playground
Jan 7
1/1
MO MM
S1: Open CV vs CNN
Nov 30, 2019
0/1
MF
S1: Privacy
Nov 30, 2019
1
0/1
J
S1: Privacy regulation
Nov 30, 2019
TT
S1: System blocks scheme
Nov 30, 2019
0/1
GM
Add another card
ToDo
Add a
LAKES


Trello
Private
AF AF AM DT +20
Invite
Butler
Show Menu
Doing
Add a card
Approval
Add a card
Done
S3: Stand-alone application 2
Mar 1
0/2
LL S
S3: ANPR Cloud solution
Mar 1
0/1
ER
S3: Stand alone application 1
Mar 1
0/2
LP MO
S3: Web interface
Mar 1
0/1
FM
S3: Web application 1
Mar 1
3/3
GA MM
S3: Web application 2
Mar 1
3/3
AF MC
S3: Linux Deamon
Mar 1
J
S3: JSON data exchange by socket
Add another card
Add another list
MICHIGAN
MG 452
GREAT LAKES

Test

4

Hardware test

- Cameras
- Relè
- Wifi
- Raspberry

Software test

- Morphological transformation
- Contour performance on license plate detection
- Different CNN performance analisys
- SVM performance (no tesseract)
- Test on performance of all

CODE

5

anpr.py

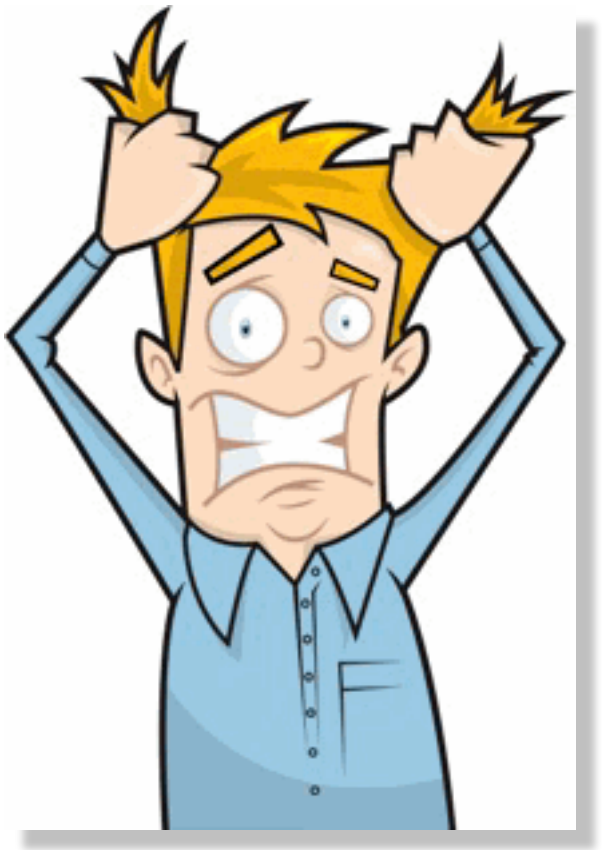
rele.py

licence_plate.py

config.py

Student	Algorithm
Battecca	Relè class
Ferrari	Deskew
Miserotti	Check number plate
Ragalli	Yagmail
Soprani	Whitelist

Credits



Our **Principal** at project start

Just for kidding!

Our Principal has always
supported us in a wonderful way

The stakeholders: The Principal, Teachers, Technical Office, Computer Science Dept., European Project Team, Administration, School Staff

Team

Atija Geri
Bergonzi Simone
Bozzini Jacopo
Cordani Francesco
Costa Mattia
Croci Mattia
Fedele Alessandro
Ferrari Alessandro
Kacka Zuzanna
Losi Lorenzo
Maggi Filippo
Malaj Migel
Marina Alessandro
Mazzetta Giulio
Minei Francesco
Mirza Toader
Ouadi Marouan
Pedegani Lorenzo
Rossi Edoardo
Tosca Tommaso
Vitanov Slave

Alberici Giovanni
Battecca Mattia
Capellini Elisabetta
Cicala Alessandro
Comite Gabriele
Favari Cristian
Ferrari Maria
Foppiani Lorenzo
Guarnieri Luca
Illica Andrea
Komisarjevsky Luca
Miserotti Matteo
Pighi Marco
Ragalli Manuel
Soprani Valerio
Tanchev Marko
Trabucchi Nicolò
Vieru Roxana Maria
Ziliani Maia
Znaidi Mohamed Anas

Other credits

Adrian Rosebrock (pyimagesearch.com) for software backbone

Design Inspiration for this document: **Osterwalder** (https://www.strategyzer.com) & Trish **Papadakos** - Value Proposition Design - Wiley

Danilo Rebecchi (adyda.it) for: current control of parking system

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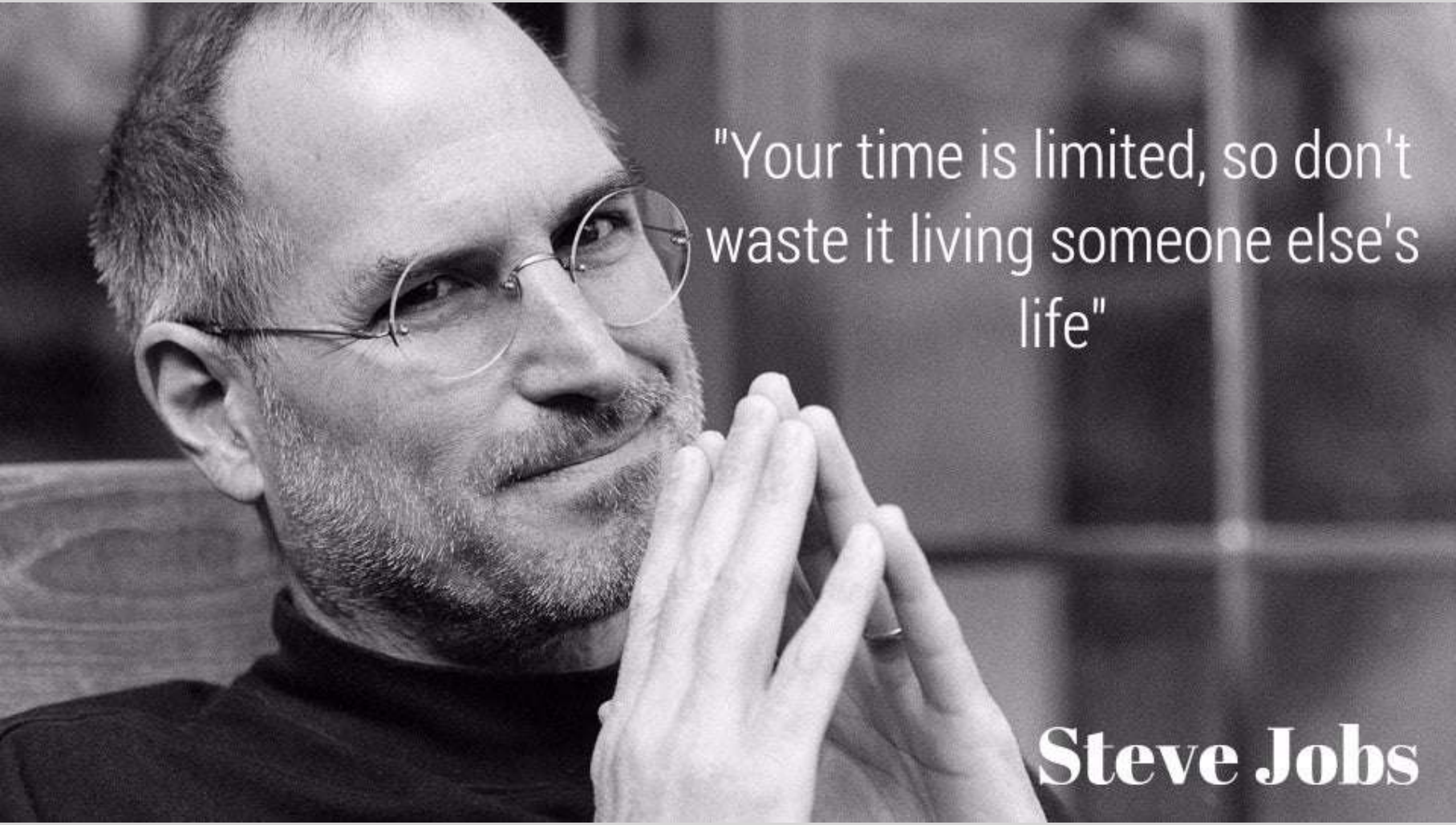
Academic papers from: academia.edu

Special support from: **Claudio Rebecchi**

and...special thanks to

- **Gian Guido Pizzelli**
- **Maria Luisa Sesenna**
- **all teachers of computer science dept.**
- **technical office**


"Your time is limited, so don't waste it living someone else's life"
Steve Jobs