CAFA self-driving-robot experiments in Smart Highway CityLab and GPU Lab

CAFA-RAM-Robot

9th Fed4FIRE+ Competitive Call Experiments (Stage 2 SME) Category "Medium Experiments"

Report May 2022

CAFA

Computer Vision and Robotics Company
ESTONIA

www.cafatech.com

Tanel Järvet

1. Autonomous Multi-robot systems with ground robots and drones

2. Computer Vision Systems for analysing sensors and cameras data feeds in near real time

FED4FIRE

CAFA Tech

Robotics Company (SME)

Legal name: CAFA Tech OÜ

Reg. code: 12923164

ESTONIA, 106112 Tallinn, Madara 29

www.cafatech.com

Tanel Järvet, CEO

tanel.jarvet@cafatech.com

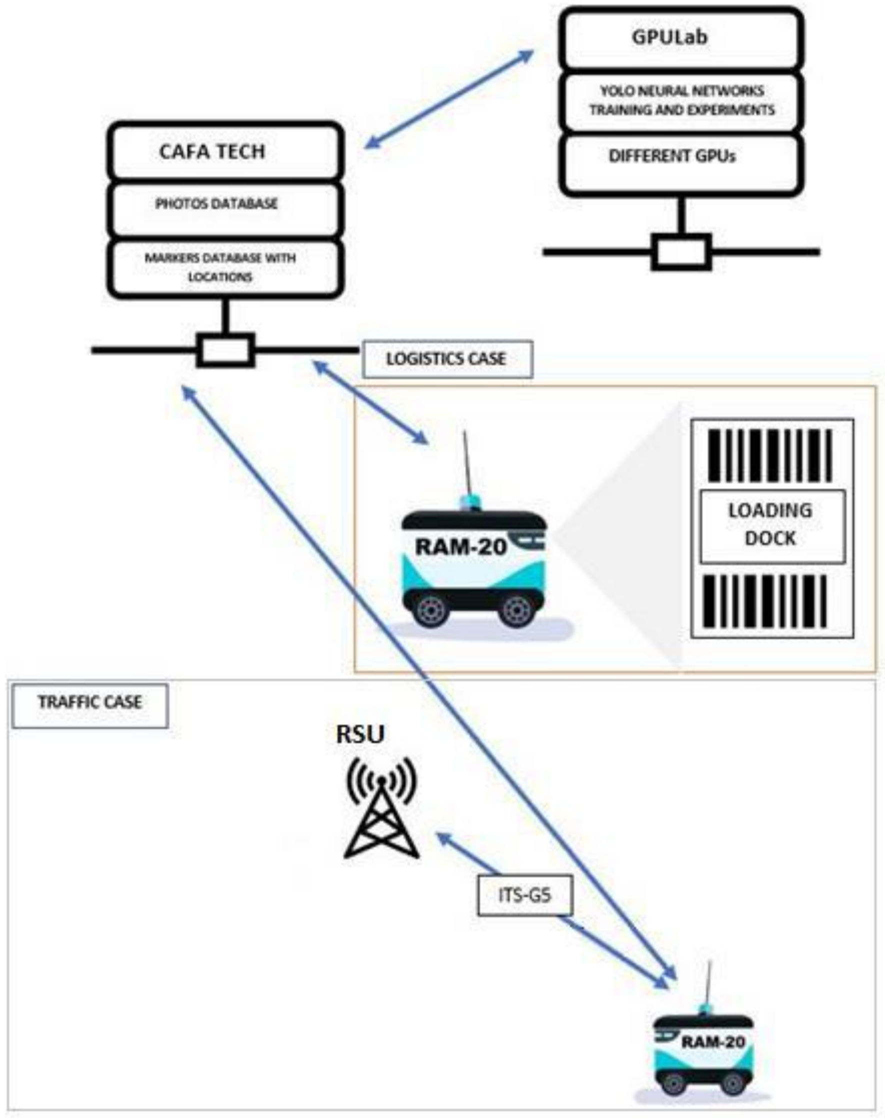
Tel. +372 56 911 732

CAFA-RAM-Robot Medium experiments: 2021-2022

ITS-G5 (Cohda Wireless MK5 OBU) experiments in Smart Highway V2X testbed to transfer information from the CAFA RAM-20 robot to other vehicles (experiments in CityLab).

Computer Vision solution experiments to identify outdoor markers for location and detection of people and vehicles close to the robot in near real time (experiments in GPU Lab).

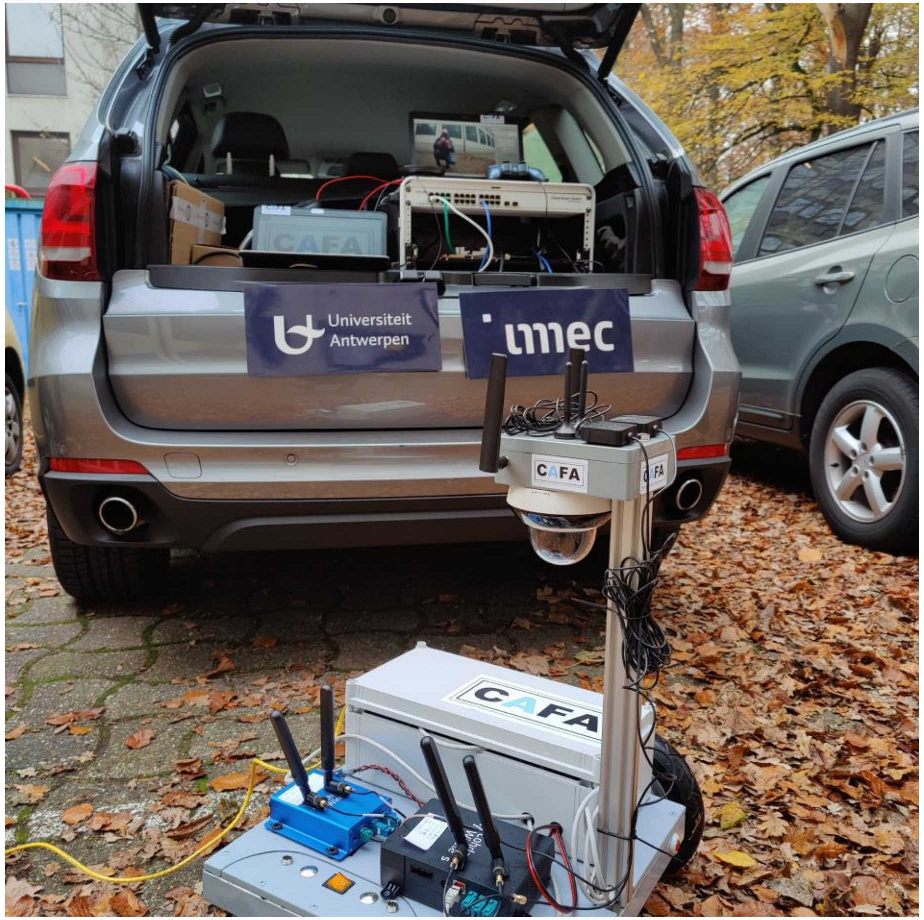
CAFA RAM Robot experiments initial architecture



Main idea of Smart Highway tests in CityLab in Antwerp 2021-Nov

- When driving on the streets, it is important to identify other vehicles and transmit the location and direction of the CAFA RAM-20 robot to other vehicles and to receive information from other (e.g. from self-driving cars) about their trajectory and location in near real time. In EU there are two main solutions for V2X (Vehicle to everything) communication at 5.9GHz:
- ITS-G5 (based on 802.11p wifi technology for Intelligence Transportation System) and
- C-V2X (Cellular-Vehicle-to-everything) based on 3G / 4G / 5G mobile communications.
- These standards are also relevant for self-driving robots involved in traffic. Since both standards are used equally, the experiments must be performed with both technologies.
- CAFA Tech tested in Smart Highway (CityLab) testbed ITS-G5 set up with Cohda MK5 OBU

Preparations and technical set up in City Lab in Antwerp 22.-23.Nov 2021

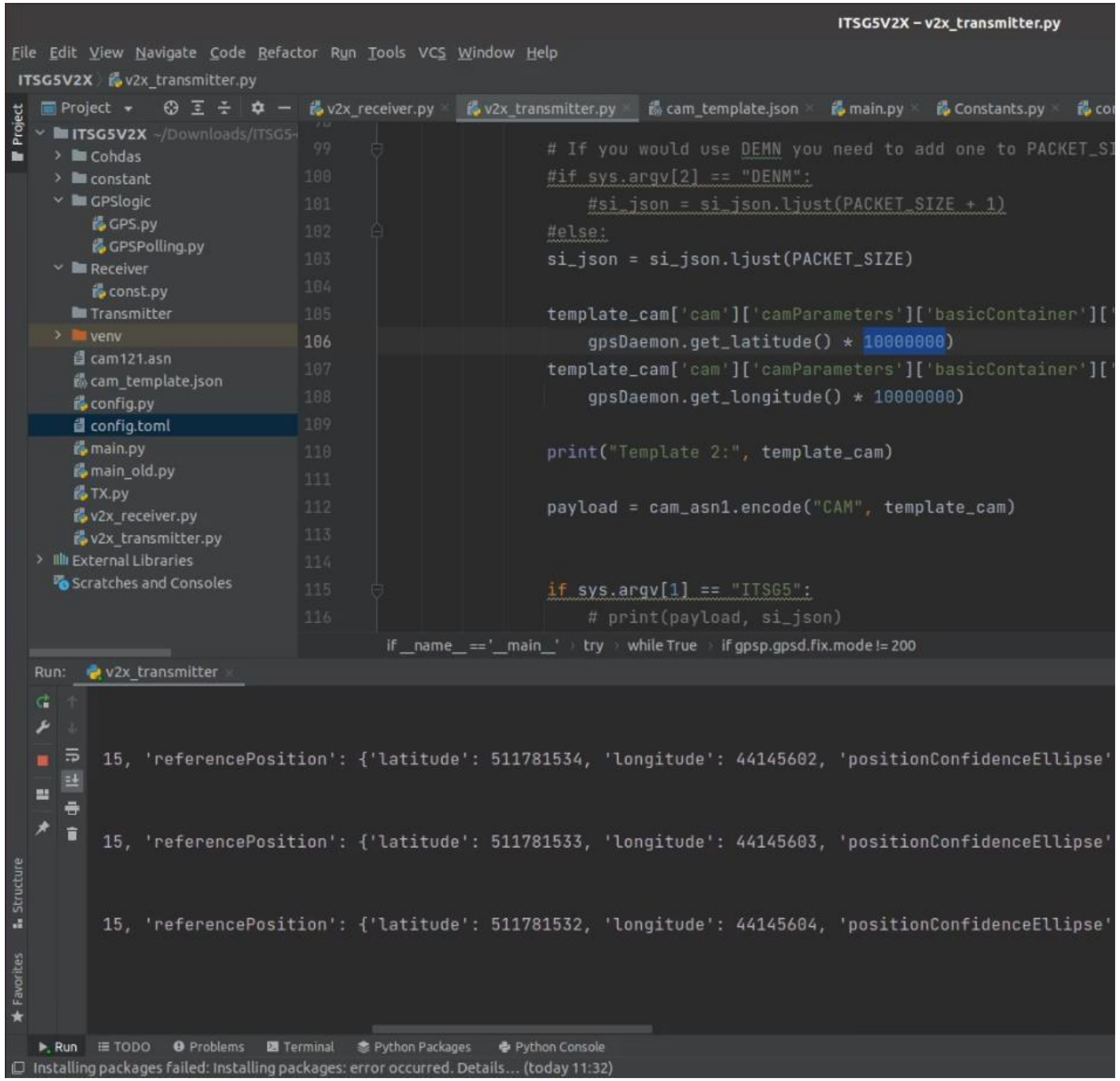


CAFA RAM Robot sending location information to Smart Highway testbed 22.-23.Nov 2021 (video)

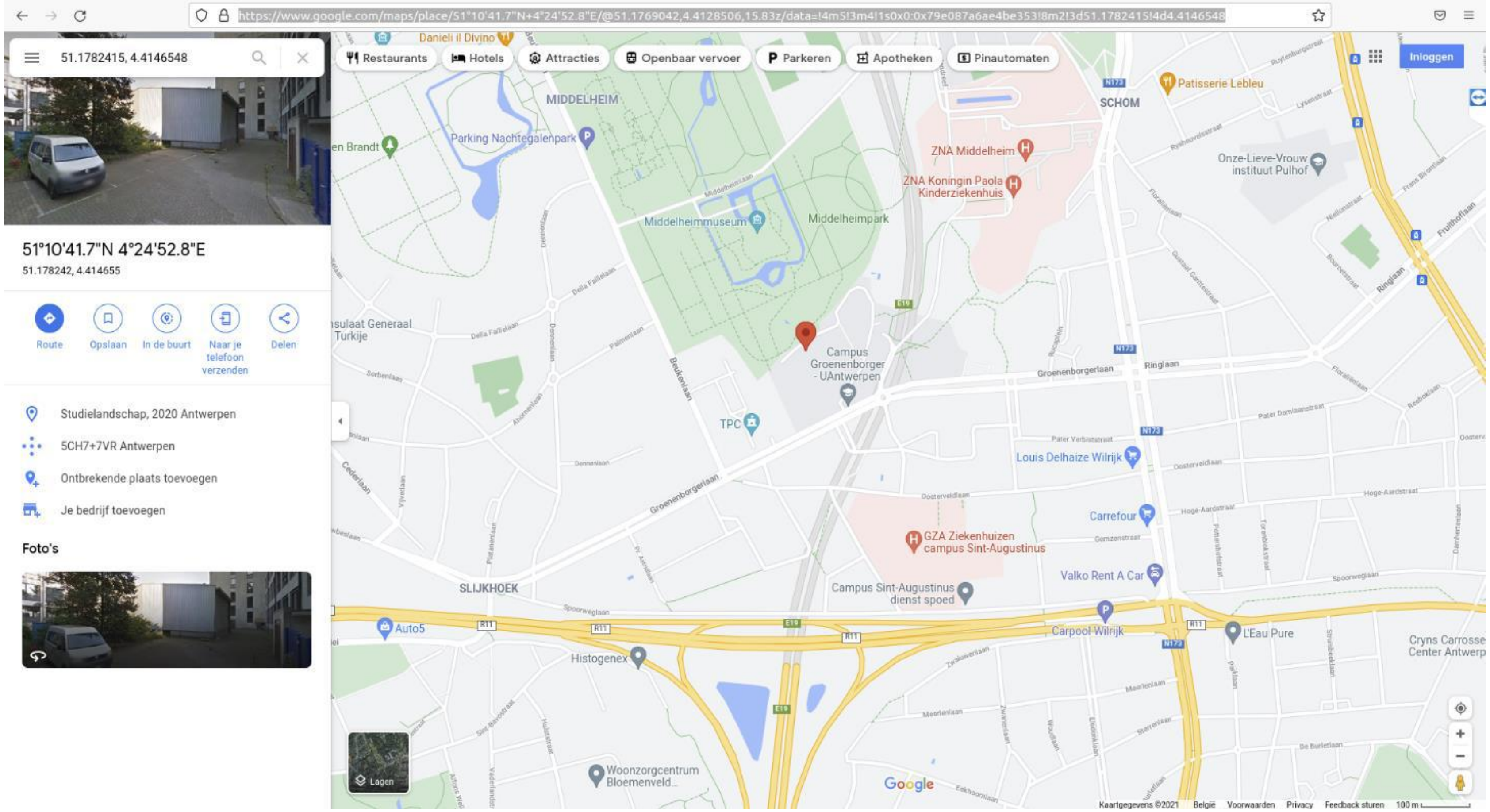
Pycharm IDE showing v2x_transmitter.py being run on CAFA RAM robot-s on-board PC

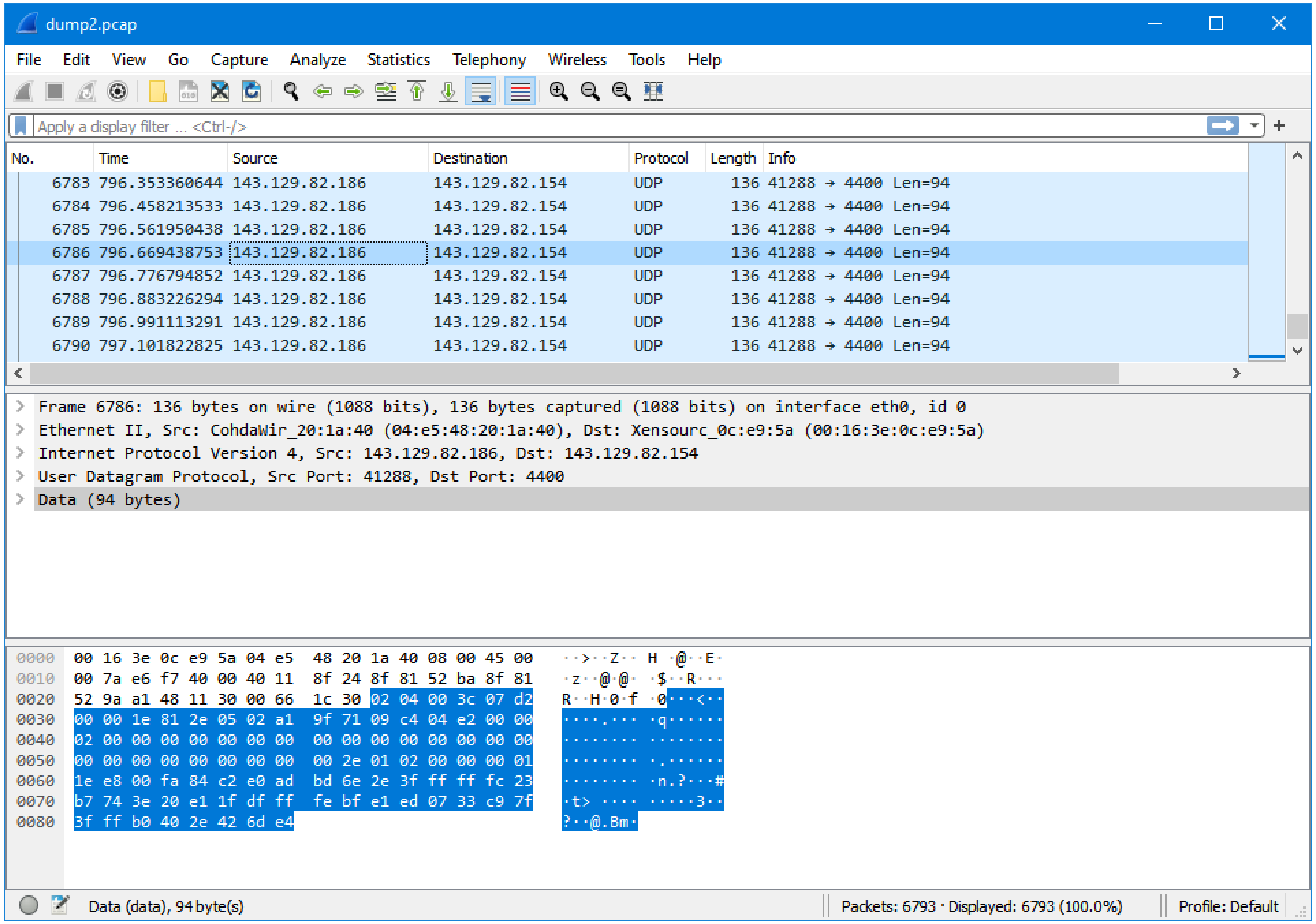
Figure 1. (used and captured over TeamViewer). *template_cam* object's latitude and longitude information update (to match actual robot's coordinates as received from on-board MK5) instructions can be seen in the code section.

Also, some GPS drift can be observed on text output below. Human readable JSON format messages printed out on Python console before conversion to binary CAM format as the program is in running state.



Coordinates of the CAFA RAM robot (taken from Python console output) on Google Maps.





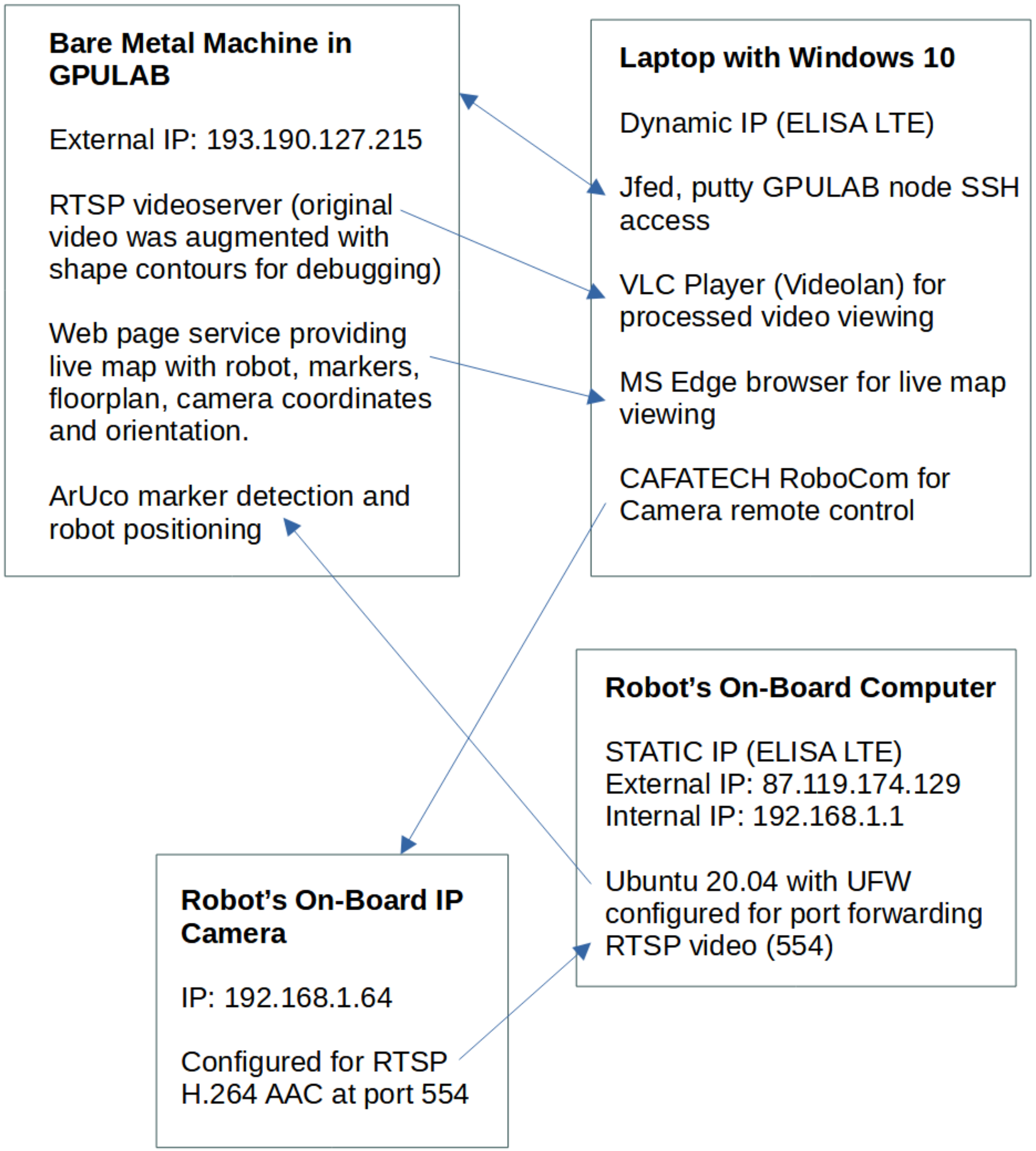
Packets captured with Wireshark (by CityLab team) showing CAM messages being sent to 143.129.82.154 (port 4400) which is IP address of LXC container "mhiiemaa-receiver" – Standard CAM ASN.1 (binary only) packets.

Smart Highway experiments completed! 23-Nov-2021

Conclusions of Smart Highway experiments

- **For the first time in Europe, CAFA Tech team tested the mobile robot's location sharing with other vehicles over the ITS-G5 protocol!**
- CAFA Tech`s team learned the Smart Highway testbed technologies and planned a computationally lightweight software/hardware solution for the CAFA RAM robot's on-board PC.
- Additionally, 2 full working days on-site were spent for software development and hardware troubleshooting with the Antwerp University team to implement the functionality of broadcasting its position to the Smart Highway wireless network using proper ASN.1 CAM messages. **Various tests and observations verified that this goal was achieved.**
- There was an attempt to send data over Mk6c (to the second Mk6c via C-V2X protocol) but on-site testing proved this to be too incompatible with the currently used python code and libraries.

Architecture of GPU Lab final experiments in May 2022

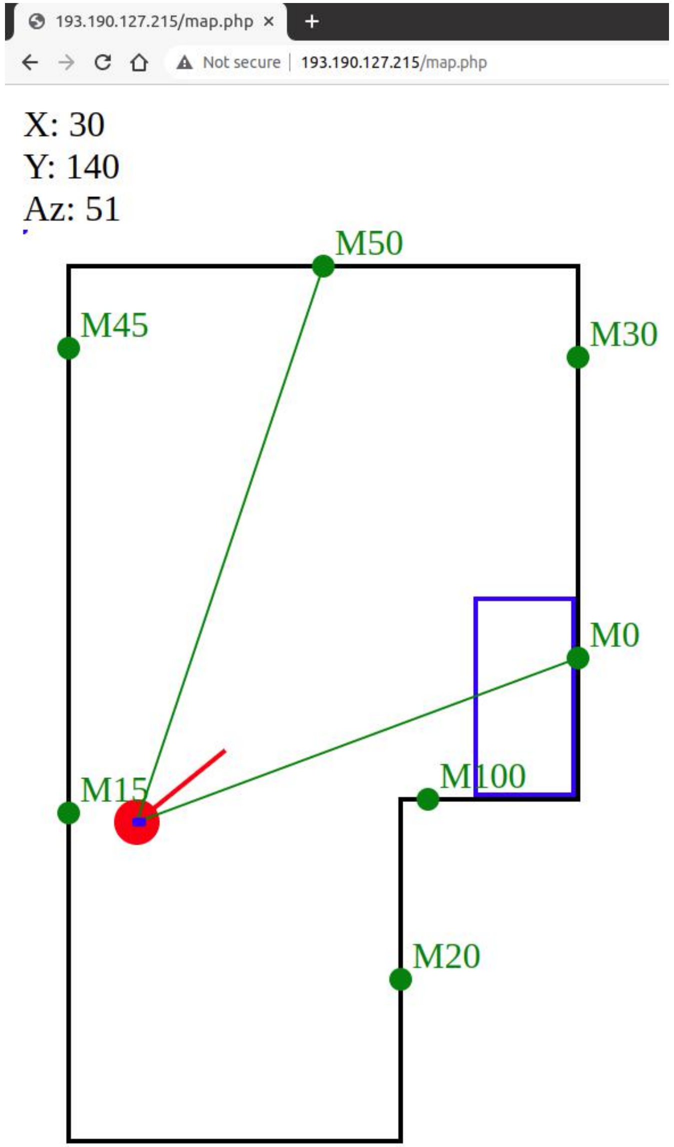


GPU Lab experiments
Outdoor markers detection with CUDA GPUs

- The goal of the experiments was to run Nvidia CUDA enabled OpenCV computer vision program in the www.wall2.ilabt.iminds.be Virtual Wall 2 testbed server.
- To achieve that, the opencv-contrib-python wrapper package with OpenCV bindings were compiled with Nvidia CUDA support.
- The opencv-contrib-python also supports detection of ArUco rectangular markers. The developed Python program detects the markers, calculates the distances from detecting camera to the markers and uses that info to calculate the local coordinates of the camera in the test site.

Screenshot from the CAFA Robot C2 map view

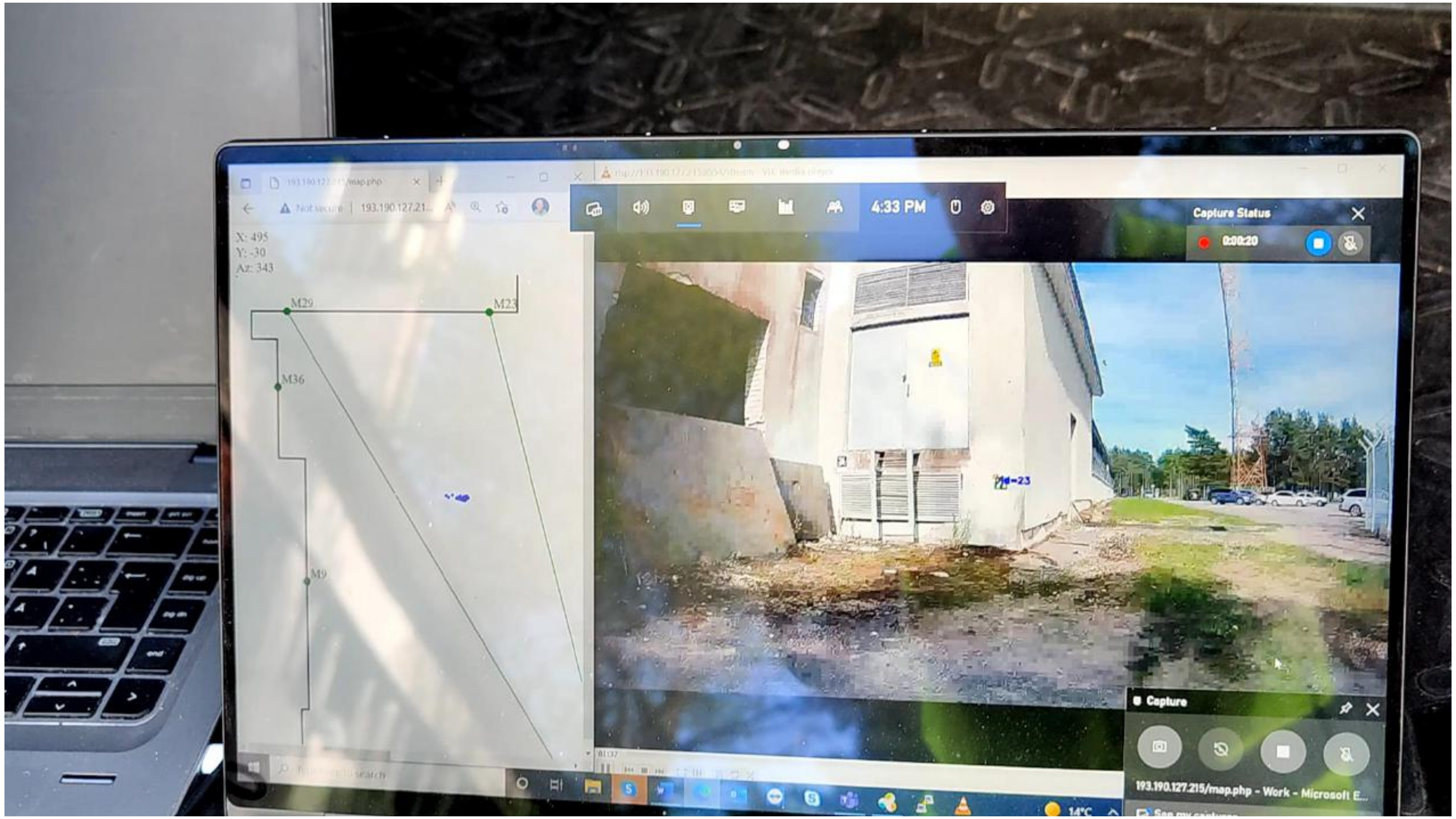
- The location of the markers are taken from markers.csv and displayed on the map as green dots with their respective id numbers.
- As can be seen from the demo video, small blue dots track the camera movement in region.



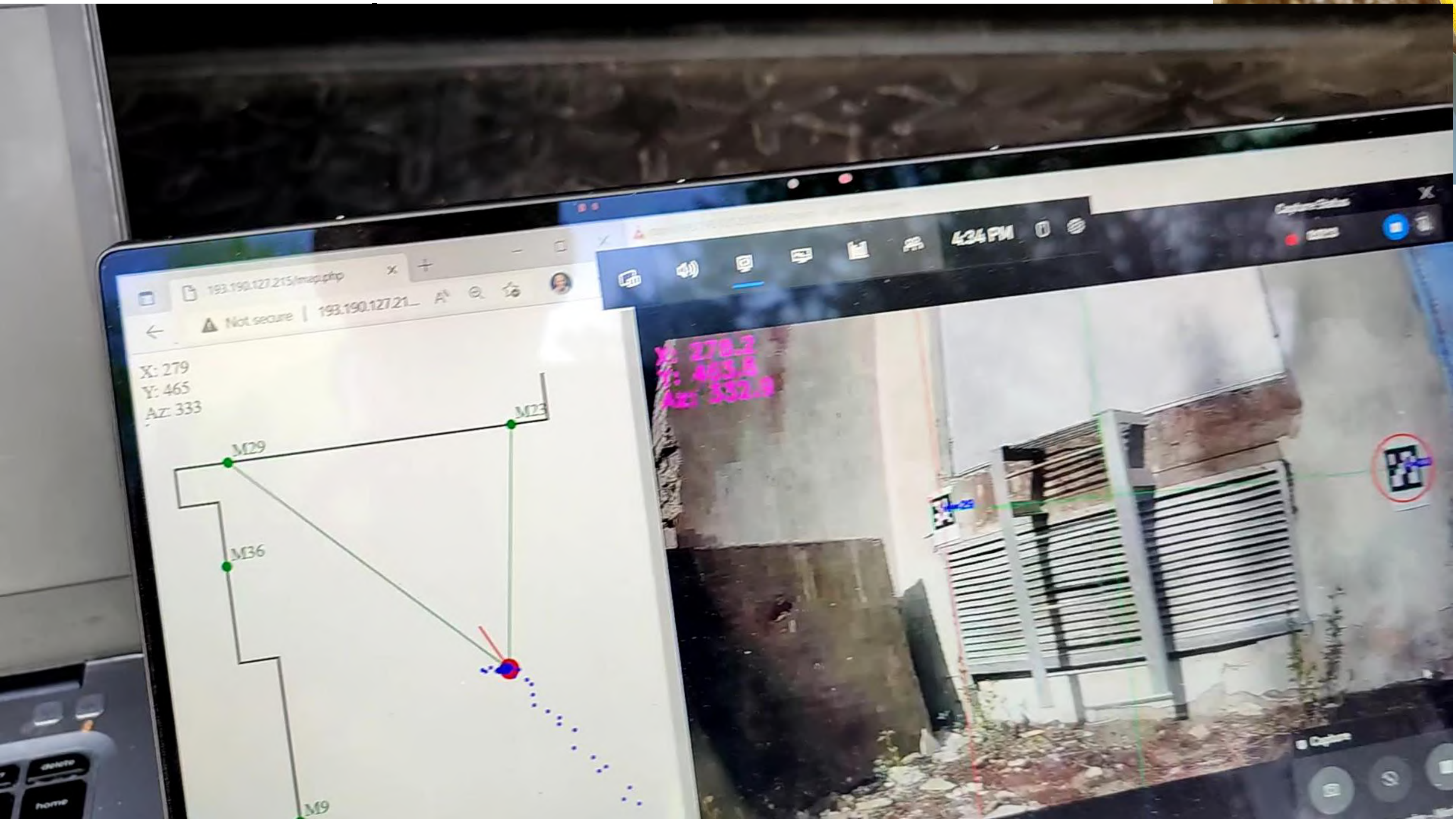
Experiments with outdoor markers to determine the location of a CAFA RAM robot in May 2022

CAFA Tech successfully compiled OpenCV with Python3 with Nvidia CUDA support and deployed and tested outdoor marker detection software in the iMec iLab.t server.

Positioning CAFA RAM robot outdoor location



CAFA RAM robot outdoor location



Person and vehicles detection final tests 2022-May (video)

Person and vehicle detection by CAFA RAM robot from a distance of more than 20m

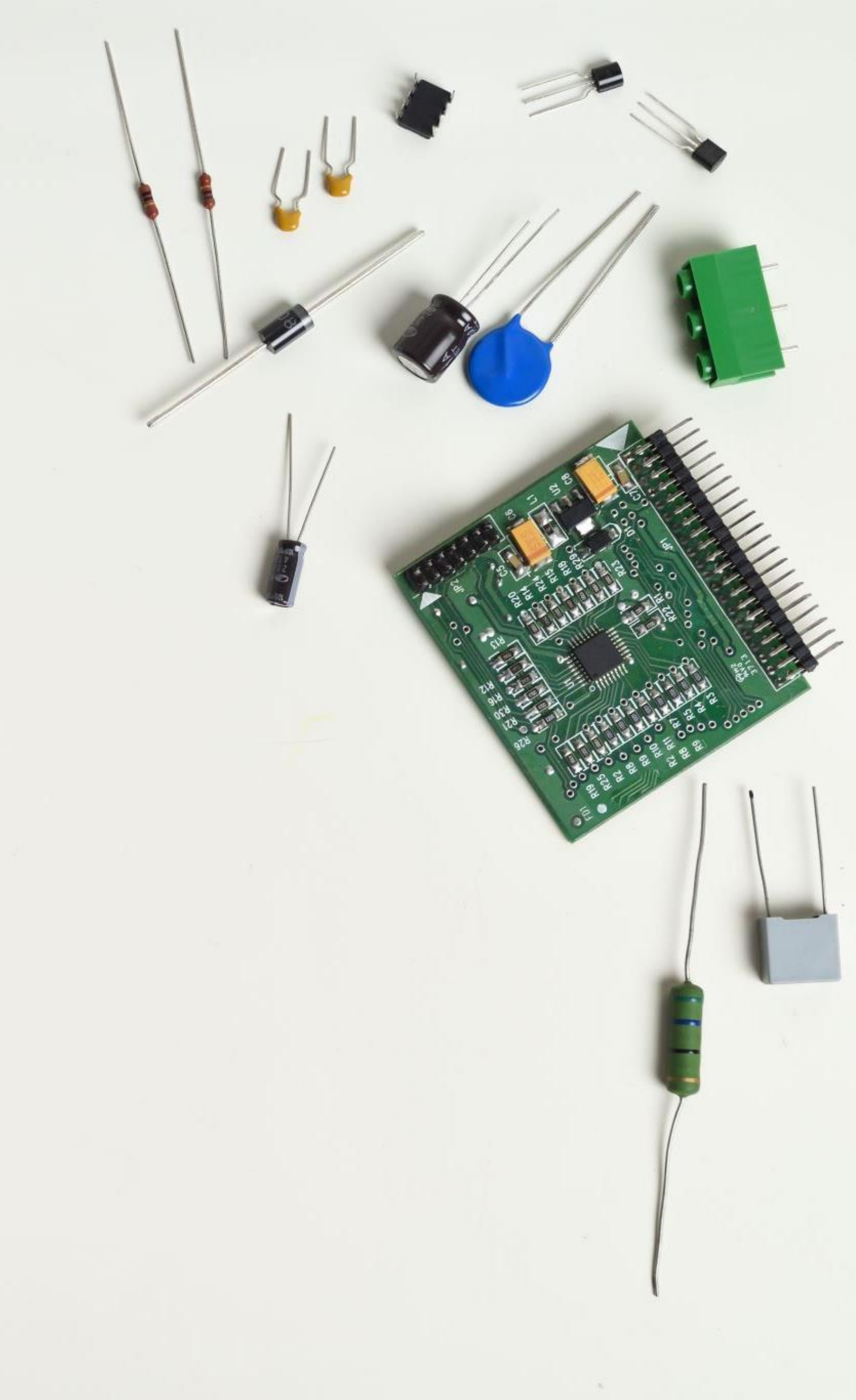
The results of the personal identification algorithm are displayed on the laptop´s screen (left side). The UI is on the right side of the screen.

GPU Lab experiments conclusions

- Considering the results, it is safe to say that the GPULab hardware and software in it`s current configuration fit perfectly for the project.
- GPU compilation for CAFA RAM CV has the newest version of the driver, toolkit and code. Presented compilation should have the highest performance as much as running YOLOv4 algorithms is concerned.
- CAFA Tech created scripts that can be used to run an OpenCV and darknet YOLOv4 solution with the latest drivers and GPU support when running the corresponding script (prepare_all.sh).

Objectives and results of CAFA RAM robot Stage 2 Medium experiments

Objective	Proposed action	KPI	Results
Obj1. The robot can identify outdoor markers for precise operations.	Experiments with Computer Vision algorithms for identifying outdoor markers.	The robot detects the marker and its data in 0.9 seconds	Achieved. See details below in section B.2.1.
Obj2. The robot can identify its outdoor precise location.	Experiments with location software which uses identified outdoor markers and these pre-defined locations and GPU for near real time location computing.	The robot can locate it with accuracy +/- 10cm	Achieved. See details below in section B.2.1
Obj3. Obstacle detection - the robot can identify humans and vehicles around the robot, within a radius of 20m	Experiments with Computer Vision software using YOLO convolutional neural networks (CNN) for identifying humans and other moving objects around the robot.	The robot detects humans and vehicles within minimum 20m radius under normal visibility conditions and in daylight	Achieved. See details below in section B.2.2
Obj4. The robot transmits its location, speed and direction to other vehicles and receives information from other vehicles via C-V2X communication protocol	Experiments with the robot´s communication device and software to send out the robot location, speed and direction using C-V2X protocol.	The robot sends its location, speed and direction and receive same data over C-V2X protocol	Achieved. See details below in section B.2.3.
Obj5. To identify appropriate GPU units for robot onboard (for location calculation and computer vision tasks) and on edge (for neural networks training)	Experiment with different GPU-s for Obj 1-4 actions to evaluate computing performance for Computer vision and locating tasks onboard and in the edge.	Identified relevant and cost-effective GPU onboard and GPU in the edge for supporting RAM-20 robot self-driving function.	Achieved. See details below in section B.2.1 and B2.2.



Quotas for Fed4Fire

The Smart Highway testbed offers unique opportunities in Europe to test how to share real-time information between robots and vehicles using both the ITS-G5 and C-V2X protocols!

GPU Lab enables experiments with state-of-the-art GPU technologies and has world-class documentation and support team to help you prepare and run tests!

Benefits from experiments

- For the first time in Europe, CAFA Tech team tested the mobile robot's location sharing with other vehicles over the ITS-G5 protocol.
- CAFA Tech`s team learned the Smart Highway testbed technologies and planned a computationally lightweight software/hardware solution for the CAFA RAM robot’s on-board PC.
- The experiments helped to map the capacity of different GPU devices for CAFA Tech to identify markers and personas and vehicles, which contributes to the development of a cost-effective Computer Vision solution.

Business impacts –
CAFA Tech perceived from these experiments

1. For the first time in Europe, CAFA Tech team tested the mobile robot's location sharing with other vehicles! (over the ITS-G5 protocol)
2. Gained knowledge how to use testbeds outside CAFA Tech.
3. Acquired new competences about Cohda Wireless MK5 and MK6 devices, Yolov4 and OpenCV algorithms.
4. Practical implementation solutions for CAFA RAM-20 robot Computer Vision solution.