CAFA RAM robot computer vision based positioning CAFA-RAM-CV

Fed4FIRE+ Experiments in IMEC GPULab

Report Sep 2020

CAFA

Computer Vision and Robotics Company
ESTONIA

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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

3. 3D maps and 3D Analyzer for analysing positions of sensors and cameras

FED4FIRE

CAFA Tech

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Designing and training Convolutional Neural Networks

1. Objectives, requirements and tasks
2. Generation/ renewing samples databases for AI
3. AI training and optimization for radar or camera
4. Hardware+ software setup
5. Testing the CVS
6. Continuous cooperation between CVS and human operators

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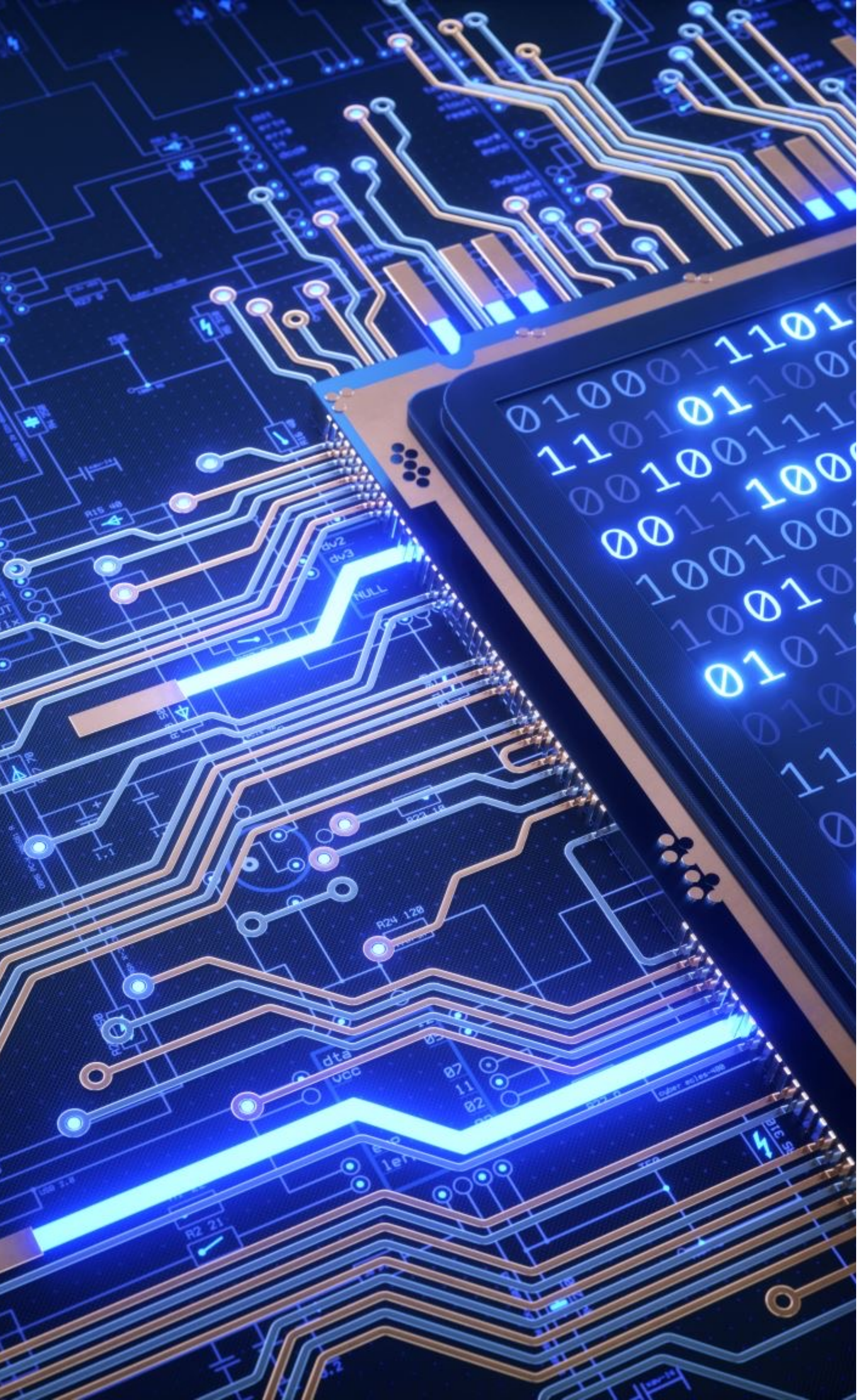
Deep Learning based Convolutional Neural Networks

- Computer Vision solutions can be used on UAVs, UGVs, as well as data analysis of cameras and SAR, UWB radars.
- Computer Vision has a great deal of work with samples and the ability to build such neural networks so that the system can learn more and more on its own.
- However, today's state of the art computer vision is such that human help is needed. It's like teaching a child in grades 1-12 and also at university.

CAFA RAM-20 robot

- Self-driving robot
- Max payload 140kg and speed up to 30km/h) for Logistics, Construction and Agriculture companies
- Uses Computer Vision System for near-real-time (under 1 seconds) markers detection and obstacle avoidance

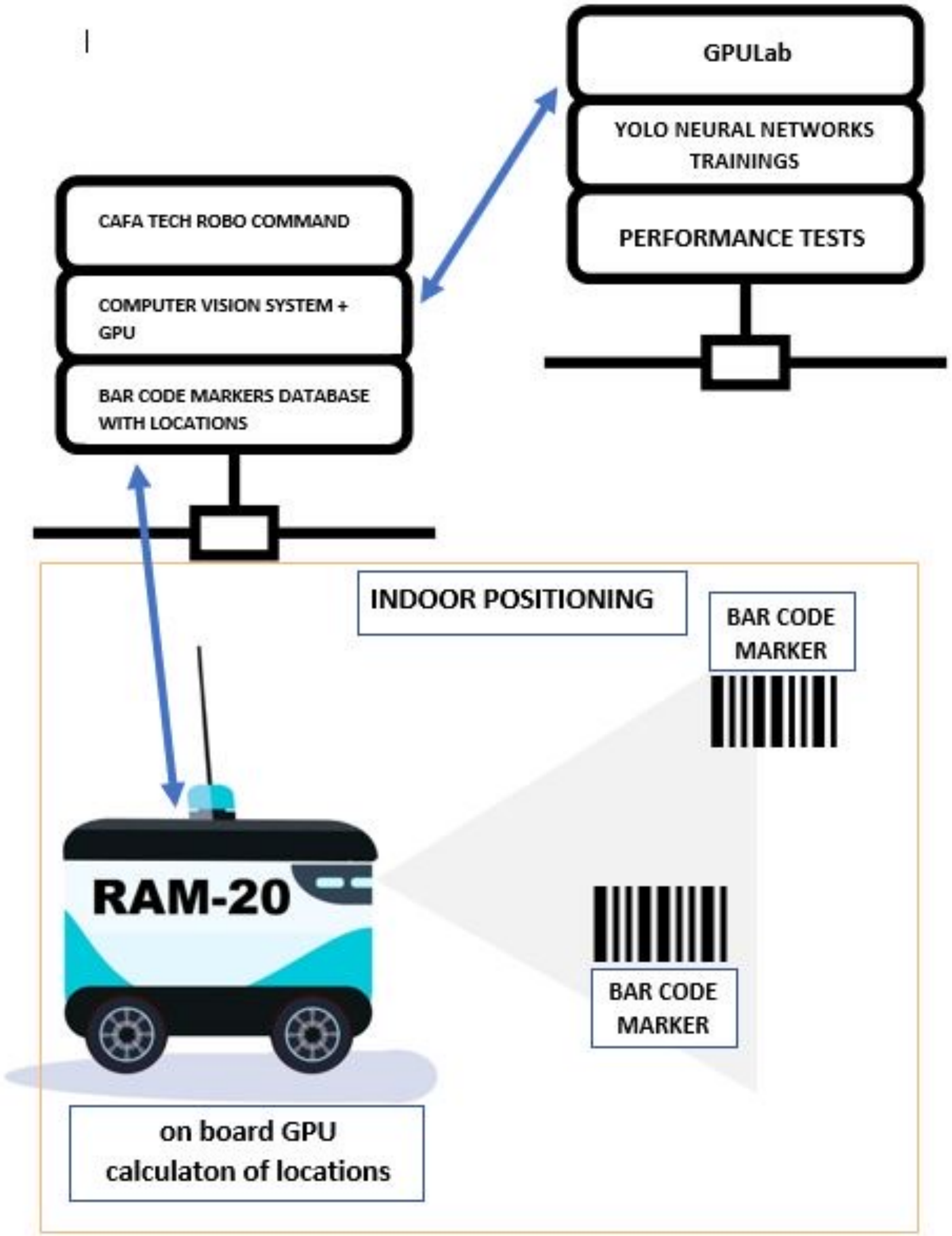


RAM-20 robot self-driving function

For autonomous driving and working RAM robot must know the exact location and information about humans and activities around a robot. To use the robot in automatic tasks, it is necessary to know the location of the robot in near real time. The GNSS signal does not propagate indoors and therefore another method must be used.

One of the best ways is to use it Computer Vision solution for analysing sensors data with using GPU based high performance computing in near real time.

The alternatives (UWB based beacons, RFID-s etc.) does not provide information about humans and activities around a robot. Therefore, Computer Vision technology is more promising, because it allows to develop analytics of surrounding activities in addition to identifying markers.



Overall architecture of RAM-20 CV based positioning

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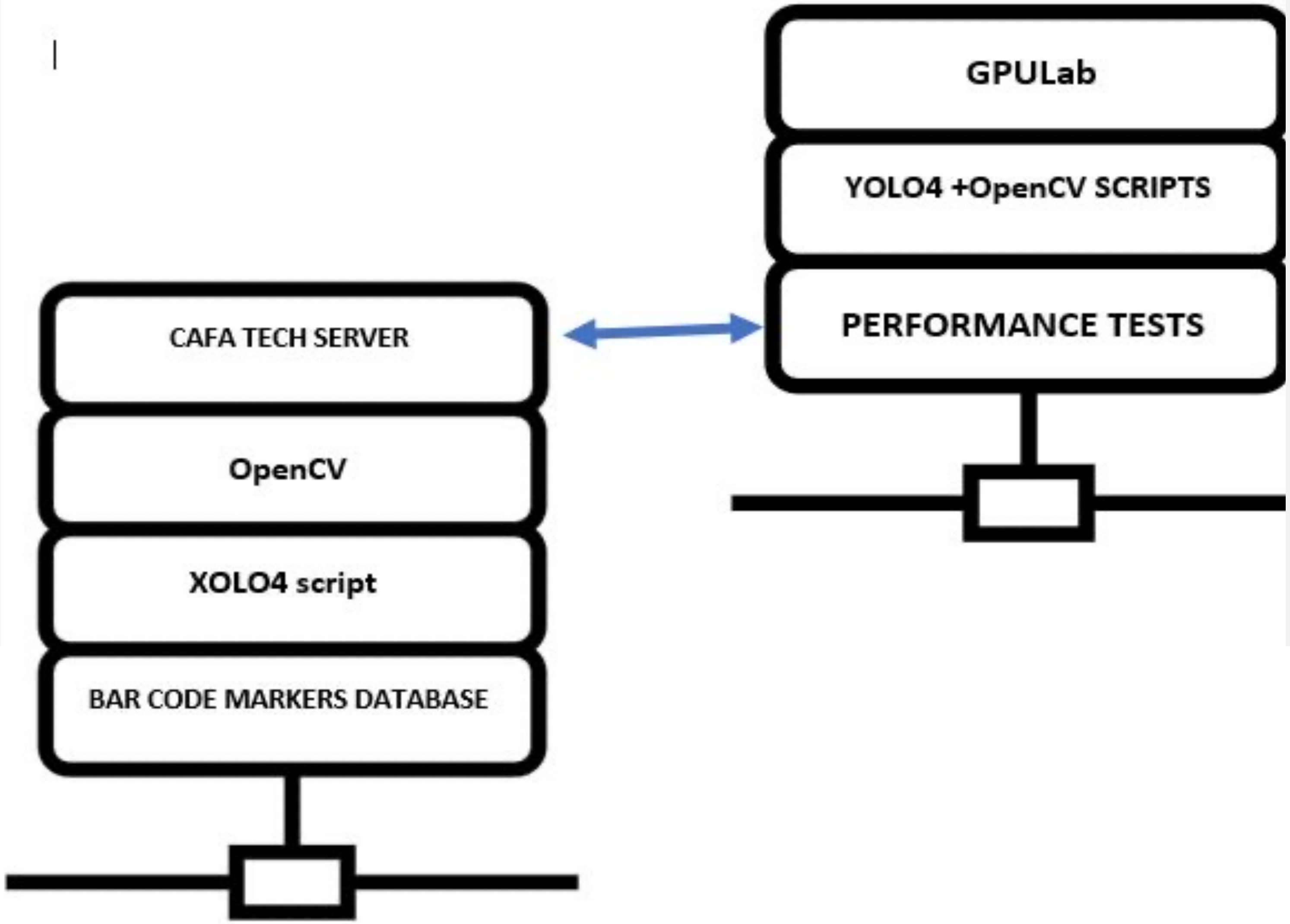
The experiment consisted of 4 stages

- 1. GPULab documentation and instructions and technical requirements were analyzed and accesses were set up and resources reserved for experiments.
- 2. Bar code markers and suitable photos for their identification were selected and added to the CAFA Tech database.
- 3. OpenCV and Yolo4 scripts were selected and compiled for use on GPULab GPUs to identify markers.
- 4. The performance of scripts on GPUs with different capacities was tested in GPULab.

Overview of set-up of the CAFA RAM-20 Stage 1 experiments



Goals of experiments

- In a computer vision system, it is important to conduct experiments to determine how different GPU units can handle real-time close computing. Based on this, it is possible to decide which computing power GPU unit should be placed on the robot's board and what its computing power is, and what are the more complex CV tasks that require the use of a GPU unit running on an edge server. There must be sufficient data communication between the GPU unit running on the Edge server and the robot.
- It is commercially necessary to find a cost-effective solution for the following systems:
- a) GPU unit on board the robot,
- b) High performance computing (HPC) center GPU unit for Edge server calculations; and
- c) Learning center (where Deep Learning and Convolutional Neural Networks are developed) GPU unit.
- The GPU unit planned on board the robot (for example, Nvidia Jetson AGX Xavier) is similar in its technical characteristics to the NVidia GeForce GTX 1080Ti GPU card in the GPU Lab.
- However, the NVidia Tesla V100 GPU in the GPU Lab is suitable for HPC edge server and Learning center solutions.
- Therefore, experiments were performed with IMEC GPULab GPU units NVidia GeForce GTX 1080Ti and NVidia Tesla V100 GPU.

Benefits from experiments

- The experiments helped to map the ability of different GPU devices for CAFA Tech to identify markers, which contributes to the development of a cost-effective Computer Vision solution.
- Stage 1 experiments gave necessary information which GPU units to plan for the robot board and which for Edge computing (incl. 5G MEC).
- It helped to find cost-effective solutions for planning GPU-based computing power locations.

Experiments technical description Part I

- 1. GPUlab-cli tool was installed under Ubuntu 20.04 LTS and set up by the instructions in https://doc.ilabt.imec.be/ilabt/gpulab/cli.html for convenient repetitive use and evaluated
- 2. jFed was installed under Windows 10 and tested with PEM key and password with various tests for evaluation
- 3. Jupyterhub.ilabt.imec.be was evaluated
- Evaluation of the three development platforms showed that the the most convenient and modern was Jupyterlab as there was very convenient access to /projects folder and terminal (not always seen in other Jupyterlab implementations).
- 3. Having alternatives in running and using Docker images helped a bit with debugging. For example running out of container space halted the job in Jupyterhub and GPULab-cli very similarly.

Experiments technical description Part II

- 4. Other types of YOLO darknet implementations were studied. Generally other implementations claimed to have lesser performance or they were just Python-bindings for underlying YOLO darknet.
- 5. There are CAFA Tech solution to install CUDA toolbox, CUDNN, OpenCV (compiled from source with CUDA) and darknet YOLOv4 (Compiled from source with OpenCV and CUDA) for maximum performance for real-time object detection for a mobile robot navigation (and later obstacle avoidance).
- 6. CAFA Tech estimates that training new models would be the best to be completed with V100 (cluster 6 machine) and normal operation of robot would require GTX 1080Ti (cluster 4 machine). Installation process would require more than 10 GB of container space at the point of compilation. Provided the OpenCV and darknet have been specifically compiled for the hardware, the requirements for the bare run-time would likely fit inside current container limits. However, in an early stage of development the OpenCV and darknet both may need frequent recompilations.
- 7. CAFA Tech compiled “prepare_all.sh” shell script which file contains the commands for the installation, git cloning, compilation and installation of the aforementioned software components. With successful build those commands would make up most of the Docker file.
- 8. CAFA Tech found a workable solution for GPUlab to install the newest driver, toolkit, cudnn and compile matching GPU accelerated OpenCV along with darknet YOLOv4. The following Nvidia-smi tool screenshot shows the most descriptive results of the work:

GPU Lab experiment screenshot

```
mhiiemaa@cafayolo:/groups/ilabt-imec-be/cafa-robot-cv-location$ nvidia-smi
Wed Sep 23 17:39:20 2020
+-----------------------------------------------------------------------------+
| NVIDIA-SMI 450.51.06    Driver Version: 450.51.06    CUDA Version: 11.0     |
|-------------------------------+----------------------+----------------------+
| GPU  Name        Persistence-M| Bus-Id        Disp.A | Volatile Uncorr. ECC |
| Fan  Temp  Perf  Pwr:Usage/Cap|         Memory-Usage | GPU-Util  Compute M. |
|                               |                      |               MIG M. |
|===============================+======================+======================|
|   0  GeForce GTX 108...  Off  | 00000000:01:00.0 Off |                  N/A |
|  0%   43C    P5    37W / 250W |      0MiB / 11178MiB |      3%      Default |
|                               |                      |                  N/A |
+-------------------------------+----------------------+----------------------+

+-----------------------------------------------------------------------------+
| Processes:                                                                  |
|  GPU   GI   CI        PID   Type   Process name                  GPU Memory |
|        ID   ID                                                   Usage      |
|=============================================================================|
|  No running processes found                                                 |
+-----------------------------------------------------------------------------+
```

Main conclusion

- 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).

Business impacts

- CAFA Tech perceived from these experiments:

1. Gained knowledge how to work with testbeds outside CAFA Tech.
2. Acquired new competences about Yolov4, OpenCV and Nvidia solutions.
3. Practical implementation solutions for CAFA RAM-20 robot computer vision solution.
4. Inputs for next experiments with GPULab and Smart Highway.

The direct value for CAFA Tech

- We tested and found working solution for using Yolov4, OpenCV and Nvidia scripts for different GPU-s which is very useful for CAFA RAM-20 robot positioning.
- It helped to find a cost-effective solution for the following systems:
- a) GPU unit on board the robot,
- b) High performance computing (HPC) center GPU unit for Edge server calculations; and
- c) Learning center (where Deep Learning and Convolutional Neural Networks are developed) GPU unit.
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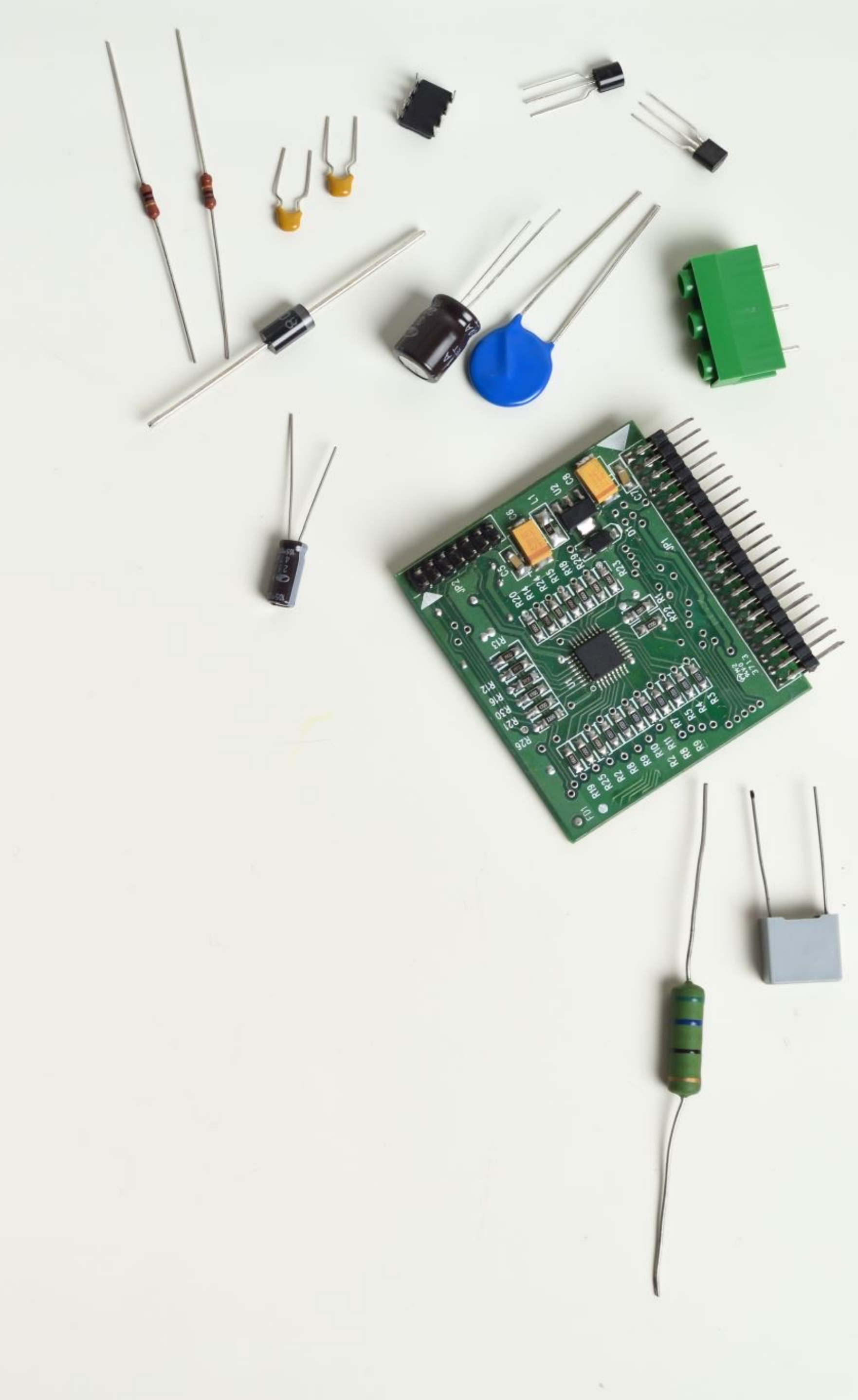
The indirect value for CAFA Tech:

- 1st Stage Experiment gave experience in how remotely control experiments with a testbed abroad.
- New ideas for experiments with GPULab and Smart Highway.



Quota for Fed4Fire

Thanks to an experiment we conducted under Fed4FIRE +, we found out what GPUs we should use on the robot onboard and what can be placed on the Edge server.

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

Environmental and Green technology aspects

- CAFA Tech solutions help to reduce environmental emissions, as automation and robots ensures that tasks are performed with less energy.
- Digitized 3D information is an important factor for Industry 4.0 solutions. More efficient production helps to reduce the environmental impact.
- Reduces the Ecological footprint as fewer cameras can achieve better results