Produtech II SIF 24541 T.6.3.3 - Development of a flexible and low-cost localization and navigation system for PPS6

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1 Initial Work Plan

The initial work plan consisted of three main stages: a comprehensive state of the art survey of flexible and low-cost localization and navigation systems, the development and further construction of a solution and, finally, the presentation of the results obtained by the final robotic system.

Regarding the state of the art, the studies were focused on two previous works also developed at LAR [4, 5]. These studies had already presented quite interesting but few results and with some limitations. Then, the aim would be to try to suppress some of the drawbacks presented and indeed to conceive the final intelligent robotic system. The overall system is shown in Figure 1, where Data Matrix targets are encoded with its own location, which through a further detection/decoding stage would provide the final robot positioning.

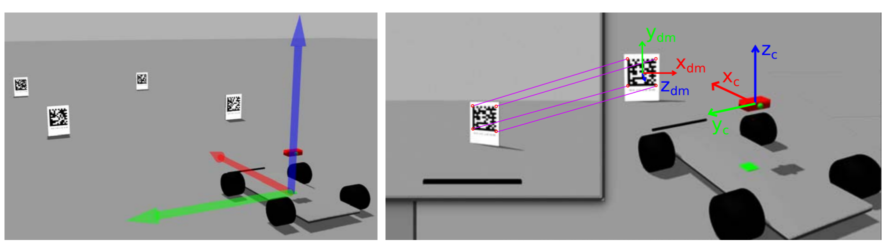

Figure 1: Navigation system through the detection of visual encoded landmarks using trilateration and related techniques [4].

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2 Development

This section lists and describes, chronologically, the entire work developed during this one year of research.

2.1 Sep - Oct: Retrofitting of AtlasMV robot

After the study of the state of the art, the construction of the prototype was initiated. Since the Atlas project[1] had already designed mobile robots a long time ago, I took advantage of one of these robots and removed everything that was outdated and put in newer devices such as: arduinos and a Nvidia AGX Xavier computer for real time processing. This prototype is composed of a small robot driven through a remote controller that emulates an industrial Automated Guided Vehicle (AGV). Therefore, the new hardware used is described in Table 1.

Table 1: Summary of the hardware deployed in the robotic system.

Name	**Description**	**Function**
DC/AC Inversor	In:48 V Out:AC	AGX Xavier power
DC/DC Inversor	In:12 V Out:5 V	Arduino power
Arduino	In:5 V	Steering controller
Jetson AGX Xavier	In: AC	DL computation
Four Cameras	Multi-Cam. Board	Data acquisition

Nvidia AGX Xavier board enables the creation of AI applications mainly based on Deep Learning by incorporating 512-core Volta GPU with Tensor Cores and (2x) NVDLA Engines. The NVIDIA Jetpack and the DeepStream latest versions were installed in this board to provide the SDK required for this project.

Regarding the software that allowed to control the mobile robotic system, several modules were developed and they are presented from the low-level up to the high-level:

- *maxon_des*: it is the library of functions to communicate with the Maxon DES 70/10 digital EC Servoamplifier. This library[2] includes functions that give feedback about the board status and errors, read and set some static and dynamic parameters such as: current, motor velocity, stop the motor motion, etc..

- *ros-maxon-driver*: it is the Robot Operating System (ROS) driver[3] to use those functions through the ROS-melodic framework. This driver translates the joystick inputs into the respective function call.

[1] http://atlas.web.ua.pt/
[2] https://github.com/lardemua/maxon_des
[3] https://github.com/lardemua/ros-maxon-driver

2.2 Oct - Dec: Research

Until all the equipment is available, [2] was conceived following a previous work related to road detection [3]. In this work, a novel system of combining simultaneous and different DL-based algorithms for road detection was developed. Thus, the focal point is the merging procedure of two DL algorithms: one segmenting the road lines and the other segmenting the road space.

2.3 Dec - April: Data Matrix Detection

Since one of the major bottlenecks of the current applications was the processing time, several DL approaches were exploited to perform the Data Matrix detection task. Hence, a dataset of Data Matrix spread out in different environments was prepared in the labelbox application[4] and trained Faster RCNN network through the Detectron2 platform [6]. This work[5] was a proof-of-concept in the sense that Deep Learning algorithms were validated as targets detector with higher accuracy and speed as the ones provided by the existing *libdmtx* classical approach. This study gave rise to [1], where the entire workflow is described and assessed.

2.4 April - Aug: Research

The previous work paved the way for the study of several different types of Deep Learning networks for the object detection task. These networks differ in the number of stages and, consecutively, in the inference time. Thus, the last contribution[6] in this project is the study and assessment of both single shot methods — YOLO and SSD (Single Shot Multibox Detector) — and two stage detectors — Faster RCNN. Here, the influence of different feature extractors (backbones) and some data augmentation techniques were studied. Finally, this last stage of the project provided the design of the final pipeline for the detection/decoding of Data Matrix including YOLOv4 model running on the Nvidia AGX Xavier. Furthermore, the same networks were also trained for the road objects detection task, yielding a final YOLOv4 model running in real-time at 18 fps in the same device.

3 Results

All results can be seen in the reference sections of the papers mentioned throughout this document. Moreover, visual results are presented through the playlist in `https://www.youtube.com/playlist?list=PL8k82WSQRJKzByR54XnHOGdiGJPPpE-0Y`. Finally, a GitHub repository[7] was documented in order to resume the project.

[4] https://labelbox.com/
[5] https://github.com/lardemua/faster-rcnn-data-matrix
[6] https://github.com/lardemua/data-matrix-detection-benchmark
[7] https://github.com/lardemua/agv-visual-localization

4 Conclusion

In summary the contributions for this project were:

- AtlasMV retrofitting and Nvidia AGX Xavier setup;
- Panorama image ROS package and drivers to interact with the robotic system;
- Published "Road detection based on simultaneous deep learning approaches." [2];
- Published "Detection of data matrix encoded landmarks in unstructured environments using deep learning." [1];
- Submitted "Comparative Analysis and Selection of Deep Learning Networks for the detection and decoding of Data Matrix Landmarks in Unstructured Environments";
- DeepStream and TensorRT apps on Nvidia AGX Xavier for road objects detection.

References

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[2] Tiago Almeida, Bernardo Lourenço, and Vitor Santos. Road detection based on simultaneous deep learning approaches. *Robotics and Autonomous Systems*, 133:103605, 2020.

[3] Tiago Almeida, Vitor Santos, and Bernardo Lourenço. Scalable ros-based architecture to merge multi-source lane detection algorithms. In Manuel F. Silva, José Luís Lima, Luís Paulo Reis, Alberto Sanfeliu, and Danilo Tardioli, editors, *Robot 2019: Fourth Iberian Robotics Conference*, pages 242–254, Cham, 2020. Springer International Publishing.

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[6] Yuxin Wu, Alexander Kirillov, Francisco Massa, Wan-Yen Lo, and Ross Girshick. Detectron2. https://github.com/facebookresearch/detectron2, 2019.