RoadEye: Road Condition Monitoring using Computer Vision and Deep Learning Techniques

Christos Theoharatos, Andreas Makedonas, Dimitris Kastaniotis, Demetris Anastassiou and Vaggelis Vassalos

IRIDA Labs S.A., Patras InnoHub – Kastritsiou 4, 26504 Magoula Patras, Greece
htheohar@iridalabs.gr

Abstract. The RoadEye project proposes the development and demonstration of an integrated application (or system) for real-time road condition monitoring, using a camera and an embedded system, which can be integrated in complete ADAS systems that provide a full range of functions. This application will be able to track and detect the condition of the road surface in real-time, within a distance of 5-to-25 meters from the vehicle, based on computer vision and machine/deep learning techniques. The techniques that are being developed within the project will be able to classify the state of the road into some preselected categories such as normal road and slippery road (e.g. wet, snow etc.), and even detect surface anomalies within the road such as potholes and speed bumps / humps.

Keywords: Road condition monitoring system, Computer vision, Deep learning, Embedded systems, Heterogeneous computing.

1 Introduction

In recent years, the ADAS (Advanced Driver-Assistance Systems) market has been growing rapidly with systems and applications that are focusing towards autonomous driving vehicles. A recent study by McKinsey[1] predicts an impressive increase rate in this market, in the years to come.

ADAS systems usually combine different functionalities that may vary among manufacturers such as traffic sign recognition, lane departure warning, collision avoidance etc. These systems are mainly based on radar sensors, however the use of a camera is considered to be cost-effective. The camera is usually located on the front of the car, along with an embedded system that can run, in real-time, computer vision algorithms.

The RoadEye project[2] proposes the development and demonstration of an integrated application (or system) for real-time road condition monitoring, using a camera

[1] https://www.mckinsey.com/industries/semiconductors/our-insights/advanced-driver-assistance-systems-challenges-and-opportunities-ahead

[2] Project website: www.roadeye.gr

and an embedded system, which can be integrated in complete ADAS systems that provide a full range of functions. This application will be able to track and detect the condition of the road surface in real-time, within a distance of 5-to-25 meters from the vehicle, based on computer vision and machine/deep learning techniques. The techniques that will be developed within the project will be able to classify the state of the road into some preselected categories such as normal road and slippery road (e.g. wet, snow etc.), and even detect surface anomalies within the road such as potholes and speed bumps / humps, as shown in Fig.1.

(a) Plane road (b) Slippery road (c) Pothole (d) Speed bumps

Fig. 1. Road condition scenarios.

2 Project Description

2.1 Goals and Objectives

To achieve the objectives, the RoadEye project has set the following goals:

1. Creation of a complete road image dataset from cars driving on different roads and with different, real-life conditions.
2. Development of a computer vision technology based on artificial intelligence and deep learning techniques, which will be trained on real-life data as well as on existing road datasets.
3. Exploitation of Irida's skills on implementing real-time deep learning architectures based on commercial collaborations with big companies such as Qualcomm, Cadence and Xilinx, and adaptation of suchlike architectures within the RoadEye project.
4. Pilot implementation on an embedded system using heterogeneous computing techniques, in order to optimally exploit available computing resources such as CPU, GPU and DSP.

By achieving the above goals, the project coordinator (Irida Labs) foresees the exploitation of the following useful results:

1. A complete road image dataset gathered on a National level, to be used in ADAS applications.
2. Intellectual Property (IP) technology for the detection and identification of different road conditions. Irida Labs is particularly active in the protection of IPs, with applications such as video stabilization and deep learning technology, and related USPTO patents.
3. Development of embedded software, in the form of an API/SDK, which can be integrated into different computing platforms such as Qualcomm,

NVIDIA or Xilinx. Irida Labs is already collaborating with market-dominating companies such as Qualcomm and Xilinx.

2.2 Phases of the project

The RoadEye project is based on a relatively simple methodology that Irida Labs has successfully followed in the past to develop commercial applications in the field of computer vision using deep learning networks. This methodology includes three distinct and interconnected phases, as shown in the PERT diagram below.

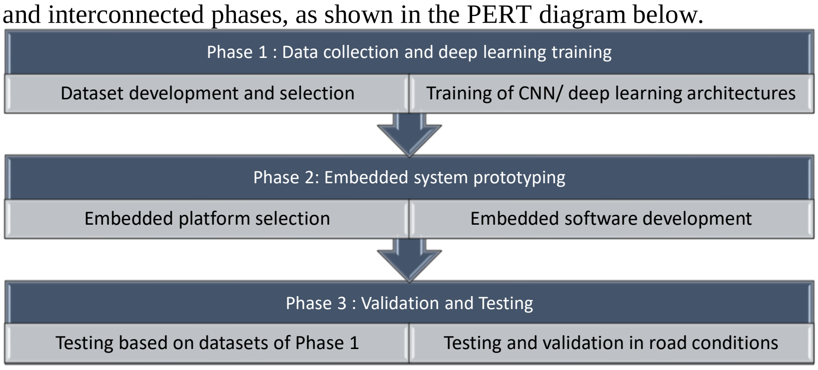


Fig. 2. Phases of the RoadEye project – Pert diagram.

2.3 Tasks and description

In general, the project is comprised of the following tasks:

Task1 – Technical management. This task includes the administrative and technical management of the project, as well as the Preparation of interim and final progress reports. The duration is M1-M18.

Task2 – RoadEye development database. This task includes:

- Data collection (M1-M12): Collection and organization of data with different road conditions, by searching for existing bases and on-site data collection. In the first case, bases such as Kitti [1], Mapillary [2] and others will be evaluated. Data collection campaigns will also be run.
- Data Preprocessing (M4-M12): Ensure that images / videos taken with different cameras and under different conditions are appropriate material for the development of the RoadEye application. The goal is to ensure maximum application scalability in different conditions. For this purpose, pre-processing and data augmentation techniques will be used.

Task3 – RoadEye Artificial Intelligence Training. This task includes:

- Selection of Artificial Intelligence Networks (M4-M9): Different CNN-based classification and detection networks will be examined for their complexity and suitability for embedded systems implementation.
- Training of Artificial Intelligence Networks (M7-M15): Networks will be trained with deep learning methods and using frameworks such as Caffe-2[3] or Tensorflow[4]. Variations of networks such as VGG [3] that have shown significant scalability will also be used. Throughout the course of training, emphasis will be placed on the subsequent implementation in real time.

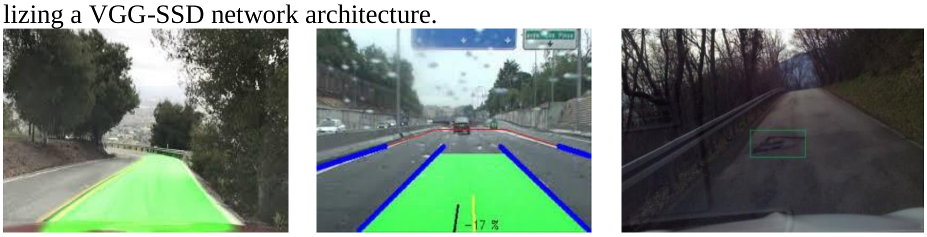
Task4 – Development of Embedded RoadEye Software. This task includes:

- Embedded system selection (M10-M12): Embedded platforms and SoCs where pilot RoadEye can be implemented with a) Time / consumption performance criteria and b) Commercial exploitation aiming at widely accepted platforms and low cost. Irida Labs has developed commercial applications on platforms such as Qualcomm Snapdragon and NVIDIA Tegra that will be the main choices.
- Development of embedded software for RoadEye (M10-M18): The chosen platform will use heterogeneous computing techniques to maximize the use of available computing resources. The aim is the accuracy of the system in a ~ 5m radius. to be> 90%, while the system can process real-time HD video - 1080p30.

Task5 – Control and validation of the RoadEye prototype. This task will check and evaluate RoadEye prototype performance with:

- Detection rate for different road conditions and in particular for detecting irregularities (puddles)
- Error rate for wrong alerts for RoadEye
- Computational complexity and real-time consumption
- Error detection rates in different conditions than the algorithm training, using different data from the training system

Fig. 3 shows some indicative road condition classification and detection results utilizing a VGG-SSD network architecture.



(a) Plain road (b) Slippery road (c) Pothole detection

Fig. 3. Road condition classification and detection results.

[3] https://caffe2.ai/

[4] https://www.tensorflow.org/

Task6 – Dissemination and commercial exploitation of project results. This task includes:

- Dissemination (M6-M18): Publicity actions to disseminate project results.
- Commercial exploitation of results (M6-M18): Participation in international exhibitions in Europe, Asia and USA to promote and promote the project's results.
- B2B meetings (M6-M18): Bilateral promotion of project results (B2B meetings) with companies and organizations mainly abroad.

Acknowledgments

This research has been co-financed by the European Union and Greek national funds through the Operational Program Competitiveness, Entrepreneurship and Innovation, under the call RESEARCH – CREATE – INNOVATE (project code: T1EDK-05231).

References

1. Geiger, A., Lenz, P., Stiller, C., Urtasun, R.: Vision meets Robotics: The KITTI Dataset. The International Journal of Robotics Research, 32(11), 1231–1237 (2013).
2. Neuhold, G., Ollmann, T., Bulò, S. R., Kontschieder, P.: The Mapillary Vistas Dataset for Semantic Understanding of Street Scenes. In: IEEE International Conference on Computer Vision (ICCV), pp. 5000-5009, Venice (2017).
3. Simonyan, K., Zisserman, A.: Very deep convolutional networks for large-scale image recognition. In: ICLR 2015.