FFI

Verification Methods for Active Safety Functions

Project within FFI - Vehicle and Traffic Safety

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FFI

Content

FFI in short

FFI is a partnership between the Swedish government and automotive industry for joint funding of research, innovation and development concentrating on Climate & Environment and Safety. FFI has R&D activities worth approx. €100 million per year, of which half is governmental funding. The background to the investment is that development within road transportation and Swedish automotive industry has big impact for growth. FFI will contribute to the following main goals: Reducing the environmental impact of transport, reducing the number killed and injured in traffic and Strengthening international competitiveness. Currently there are five collaboration programs: **Vehicle Development, Transport Efficiency, Vehicle and Traffic Safety, Energy & Environment and Sustainable Production Technology.**

For more information: www.vinnova.se/ffi

1. Executive summary

Novel methods and tools have been developed to determine active safety system performance using computers within the project “Verification Methods for Active Safety Functions”. Special attention has been given to include the non-ideal behavior of sensors, to deal with the large variation within the traffic environment where the system operates, and to develop methods to determine system robustness and performance.

The project has delivered:

- Method and tool to determine the sensor errors of camera based active safety system
- Method to determine the worst case performance of collision avoidance and mitigation systems and the corresponding traffic scenario as well as system robustness
- Method for formal verification of collision avoidance systems, and system robustness to measurement errors
- Method to predict the benefit of active safety functions applied to Volvo Cars’ “Full Auto-brake with Pedestrian Detection” based on real world fatal pedestrian accidents
- Method for sensitivity analysis and tuning of active safety system
- Method for reliable vehicle pose estimation using vision and single-track model
- Method to develop pedestrian detection algorithms using augmented training data
- One PhD with scientific publications
- Presentations at SAFER, Chalmers and international conferences

2. Background

Active safety systems have the potential to reduce fatality and traffic related injuries significantly. New technologies emerge rapidly to enable new active safety function concepts which can save lives. The Volvo Car Corporation is at the frontier of this development with a vision that nobody should be killed or seriously injured in a Volvo vehicle year 2020.

In order for the vehicle to autonomously take decisions to intervene to avoid the approaching accident when the driver fails to do so requires advanced sensing technologies of the environment as well as smart algorithms.

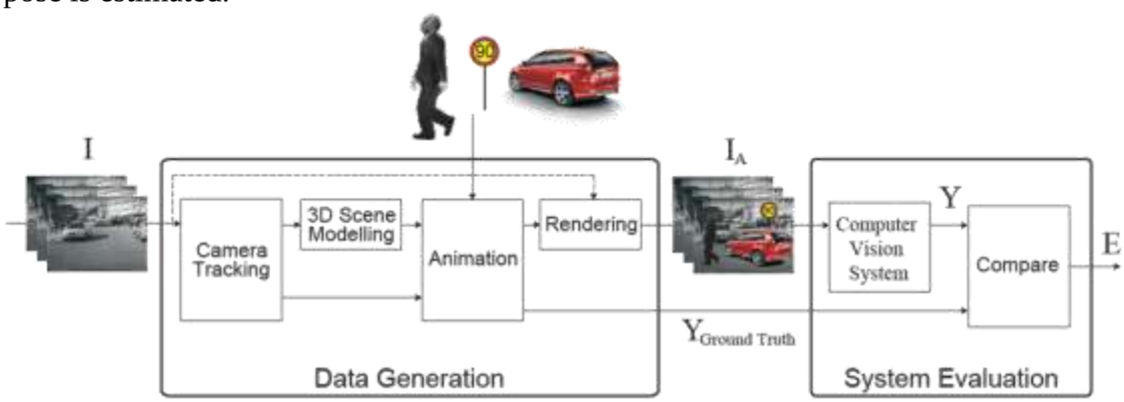
These new safety technologies require innovation within analysis and verification in order to secure product quality. We need to show that the system works as intended when needed, and does not disturb the customer otherwise. Both parts are very challenging since we are dealing with collision avoidance systems where the safety of the testing personnel has to be guaranteed. At the same time we have to gather sufficient amount of relevant data to verify the system meets function requirements.

3. Objective

The project objective is to develop novel analysis and verification methods within active safety to meet upcoming function requirements of new systems. In particular, we need to address: 1) the non-ideal behavior of sensors, 2) the large variation in traffic environment, and 3) to develop methods for performance evaluation which also quantifies the robustness of the system.

4. Project realization

Particular emphasis has been given to use computer based techniques to predict the detection performance and non-ideal behaviour of camera based active safety systems. We have developed a method and tool using augmented reality based techniques to create new traffic situations in which the camera performance can be determined even in collision scenarios. Moreover, we have developed a framework for performance evaluation of mobile computer vision systems. It uses the fact that the 3D world can be reconstructed from an image sequence and vehicle models at the same time as the camera pose is estimated.



Furthermore, we have also developed a new method to determine the worst case performance of a collision avoidance system and the corresponding traffic scenario. The analytical method has been applied to a model system for longitudinal and lateral scenarios.

Next we proceeded to develop a formal approach to verify a collision avoidance system using reachability analysis. The inherent strength of this method is that we do not have to analyse each scenario separately since it allows us to investigate an entire spectrum of traffic situations simultaneously.

A method to predict the benefit of active safety systems has also been developed. By reconstructing real world accident scenarios in our traffic simulator, and resimulate them with active safety system enabled, we can determine the effectiveness of the system. For Volvo Cars collision avoidance system with full auto-brake and pedestrian detection we show that 25% of all pedestrian fatalities would have been avoided if all cars had been equipped with the Volvo system.

5. Results and deliverables

5.1 Delivery to FFI-goals

Active safety technologies combined with passive systems exhibit an exceptional potential to achieve a safer traffic environment. For example, we have in this project shown that the Volvo Cars auto-brake system with pedestrian detection could save the life of every fourth pedestrian that is being killed in traffic accidents today. This system is already in production. If the driver in addition would react on the warning system an even larger benefit could be achieved.

Within the project we have developed novel concepts to analyse and verify active safety systems. These methods and tool gives us the opportunity to launch new active safety systems to the market at a higher pace. That increases our competitiveness and enables growth.

We have also developed the collaboration between industry and university by performing research within verification methods relevant to the industry. As a spin-off we have also found new ways to design the detection systems that might lead to growth in Sweden.

6. Dissemination and publications

6.1 Knowledge and results dissemination

The active safety area evolves rapidly to find countermeasures for more accident scenarios. There is also a trend towards self-driven cars which demands significant innovation within verification methods. At the same time, rating of active safety systems calls for further development within analysis and verification methods and tools. The industry is also trying to shorten lead times and reduce costs by transitioning to computer based development and verification.

The FFI funded project Next Generation Test Methods for Active Safety Functions (NG-TEST) addresses development of physical and virtual test methods.

6.2 Publications

A) J. Nilsson, A.C.E. Ödblom, J. Fredriksson, A. Zafar and F.Ahmed, Performance Evaluation Method for Mobile Computer Vision Systems using Augmented Reality, In Proceedings of the IEEE Virtual Reality Conference, 2010, pages 19-22, Waltham, Massachusetts, USA.

B) J. Nilsson and A.C.E. Ödblom, On Worst Case Performance of Collision Avoidance Systems, In Proceedings of the IEEE Intelligent Vehicles Symposium, 2010, pages 1084-1091, San Diego, California, USA.

C) J. Nilsson and M. Ali, ´Sensitivity Analysis and Tuning for Active Safety Systems,´ In Proceedings of the IEEE Intelligent Transportation Systems Conference, 2010, pages 161-167, Madeira Island, Portugal.

D) J. Nilsson, ´On Performance Evaluation of Automotive Active Safety Systems,´ Licentiate Thesis, No 014/2010, ISSN 1403-266X, Chalmers University of Technology, Göteborg, Sweden, 2010.

E) M Lindman, A Ödblom, E Bergvall, A Eidehall, B Svanberg and T Lukaszewicz, ´Benefit Estimation Model for Pedestrian Auto Brake Functionality´, In Proceedings of the ESAR Conference, no. 300961, September 2010

F) J. Nilsson, A. C. E. Ödblom, J. Fredriksson, and A. Zafar, ´Using Augmentation Techniques for Performance Evaluation in Automotive Safety,´ in Handbook of Augmented Reality, 1st ed., B. Furht, Ed. Springer, 2011, pp. 631649.

G) J. Nilsson, J. Fredriksson, and A. Ödblom, ´Bundle Adjustment using Single-Track Vehicle Model´, in Proceedings of the IEEE International Conference on Robotics and Automation, 2013, pp. 2888-2893.

H) J. Nilsson, A. Ödblom and J. Fredriksson, ´Worst Case Analysis of Automotive Collision Avoidance Systems´, submitted for possible journal publication.

I) J. Nilsson, J. Fredriksson and A. Ödblom, ´Verification of Collision Avoidance Systems using Reachability Analysis´, accepted for publication at the 19th IFAC World Congress, Cape Town, South Africa, 2014.

J) J. Nilsson, J. Fredriksson and A. Ödblom, Reliable Vehicle Pose Estimation using Vision and Single-Track Model, submitted for possible journal publication.

K) J. Nilsson, P. Andersson, I. Gu and J. Fredriksson, Pedestrian Detection using Augmented Training Data, accepted for publication at the 22nd International Conference on Pattern Recognition, Stockholm, Sweden, 2014.

L) J. Nilsson, ´Computational Verification Methods for Automotive Safety Systems´, PhD thesis at Chalmers University of Technology, ISBN 978-91-7385-973-8, 2014.

7. Conclusions and future research

Active safety has the potential to eliminate a number of severe traffic accidents to create a safer traffic environment. In order to achieve this, the development of methods and tools for verification and analysis is needed.

Several important contributions have been taken within this project to develop innovative computer based verification methods. Particular emphasis has been given to mobile computer vision based systems which uses a camera to interpret the surrounding environment. We can now analyze its performance, also prior to collisions with various traffic objects, in a computer. Furthermore, we have shown that it is possible to accelerate the development of computer vision systems using augmented training data sets.

We have also investigated the robustness of collision avoidance system in many traffic scenarios. In addition, we have developed a method to find the worst case performance, along with the corresponding scenario, as well as methods to formally verify the function.

We also have developed a method to predict the benefit and risk of active safety systems applied to real world fatal pedestrian accidents.

There is a large need for additional research and method development within verification methods since the area of active safety grows rapidly and goes towards increased automation with self-driven cars.

8. Participating parties and contact person

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