Robotics and Autonomous Systems 121 (2019) 103266

Contents lists available at ScienceDirect

Robotics and Autonomous Systems

journal homepage: www.elsevier.com/locate/robot

Editorial: Special issue on autonomous driving and driver assistance systems

The research on Autonomous Driving and Driver Assistance Systems (ADDAS) has been increasing continuously for several decades, but the last years have exhibited unprecedented attention, both by the many dedicate books published in this field, but especially for the numerous papers in several conferences, workshops and special sessions worldwide. The contexts of these events cover a large spectrum of communities, ranging from robotics up to intelligent transportation, intelligent vehicles or vehicular technology, among others.

The scope and potential of the technological applications in ADDAS is so huge that it can serve as test bed for an almost unbounded set of sciences and technologies that go from the classic navigation issues and system control, up to the more recent and daunting challenges in deep learning contexts.

This special issue is not an exception to this scenario, and its 19 peer reviewed papers cover a wide range of problems that can be categorized into the following topics:

1. Scene Perception [1–5]
2. Localization, Visual Odometry and SLAM [6–8]
3. Cabin Concerns with Drivers and Passengers [9–11]
4. Vehicle Systems Control [12–15]
5. High Level Navigation [16–18]
6. Deep Learning [2,10,17,19]

The previous categorization is however not very strict, since it is natural for a single paper to cover both a known specific problem along with some more generic tool applied to solve that particular problem. So, some times there is a fusion of focus and interest on the specific problem and the tool used to solve it, where the now ubiquitous Deep Learning paradigm is a clear example, or also the usage of Robot Operating System (ROS) as the supporting architecture for many implementations. The main contents of the papers published in the special issue are described next with more details in the following lines.

Scene Perception

Perception of vehicle's surrounding is a topic of interest and a key component for both autonomous driving and driver assistance systems. Several papers have been focused on this topic covering problems that go from traffic lights recognition, scene awareness till obstacle detection and distance estimation. In [1] the authors propose an innovative reliable method to recognize the state of traffic lights in images using accurate 3D maps and a self-localization technique in it. Quantitative evaluations indicate that the method achieved over 97% average precision for each state and approximately 90% recall as far as 90 meters under preferable condition. In a more general way, [4] proposes a robust method for generic obstacle detection and collision warning. The proposed approach is able to detect all obstacles without prior knowledge and detect partially occluded obstacles. The approach is robust to variations in illumination and to a wide variety of vehicles and obstacles. Improvements on true positive detection in comparison with state of the art are shown. On the contrary to previous approaches, the usage of a stereovision based scene perception is proposed in [5] and [2]. In [5] the authors propose a novel framework for vehicle detection and localization with partial appearance using stereo vision and geometry. The proposed approach is based on the widely used v-disparity map representation to detect candidates vehicles. Then, a deep learning-based verification completes vehicle detection. A more general approach is presented in [2], where an efficient method to perform recognition and 3D localization of dynamic objects on images from a stereo camera is described. The proposed approach relies on a deep learning framework able to simultaneously identify a broad range of entities, such as vehicles, pedestrians or cyclists, with a frame rate compatible with the strict requirements of onboard automotive applications. The results presented in the paper show the capabilities of the perception system for a wide variety of traffic situations. Finally, and also related with scene perception, the authors in [3] tackle the challenging problem of extrinsic calibration of a radar-LiDAR-camera sensor system. The authors propose a novel calibration method that involves a special target design and a two-step optimization procedure. The proposed calibration method has been tested on a variety of sensor configuration showing that it is able to reliably estimate all the six parameters of the extrinsic calibration.

Localization, Visual Odometry and SLAM

The ability of autonomous vehicles to obtain their position and orientation within the environment where they are driving in is crucial to several tasks as planning and piloting. Several sensors are available for this, the GPS (Global Positioning System) and IMU (Inertial Measurement Unit) being two of the most used. Both have many advantages but have also several shortcomings for autonomous vehicles applications due to accuracy or their limitations in urban scenarios. That is why in [6] the authors propose sensor fusion for the localization (both translation and attitude) of a mobile wheeled robot. Several sensors are used: odometers, gyroscope, accelerometer, magnetometer and a camera for visual landmark localization. The algorithm is able to deal with the asynchronous nature of the sensors and the failures of many of them and runs in real-time. SLAM

https://doi.org/10.1016/j.robot.2019.103266

(Simultaneous Localization And Mapping) algorithm has been applied to robotics for some years and in [7] the authors proposed a system able to maintain the fast performance of a direct method and the high precision and loop closure capability of a feature-based method. A key-frame is used for global or local optimization and loop closure, whereas a non-key-frame is used for fast tracking and localization. Besides that, the system fuses the computer vision data with inertial measurements. Thanks to this an equilibrium between speed and accuracy is achieved. The public availability of data-sets is crucial for research teams do not have the needed sensors for start developing new ideas and for testing and comparing different approaches. In the last article of this subsection [8], the authors propose a benchmark of visual odometry and SLAM techniques. The Urban@CRAS data-set shows several scenarios presenting different conditions and urban situations: vehicle-to-vehicle and vehicle-to-human interactions, cross-sides, turn-around, roundabouts and different traffic conditions. The sensor data comes from a 3D LIDAR, color cameras, a high-precision IMU and a GPS navigation system. Besides the data, the authors propose a bench marking process for visual odometry and SLAM where qualitative and quantitative performance indicators are obtained so different approaches can be compared.

Cabin Concerns with Drivers and Passengers

Attention to car occupants, be it the driver or a passenger, is of course a central topic in Driving Assistance. Driver monitoring, namely the posture, can give indication of the driver focus and attention level. Paper [10] proposes a method to estimate head pose after a monocular camera performed by a deep neural network using a small gray scale image. Additionally, the authors released a new dataset of head poses for further studies, despite the fact that the solutions presented outperform current state-of-the-art techniques. Predicting human-driver reactions is a concern addressed by paper [9]. The authors perform a survey on several algorithms to predict the lateral control actions of human drivers. A comparison of the algorithms is made in terms of their suitability to develop haptic-shared ADAS, which share the control force with the human driver. The driver steering torque is considered a central point to establish a proper model, but as low-cost driver simulators only monitor steering angle and not steering torque, the authors propose a methodology to estimate the steering-wheel torque. Using the estimated steering torque, they train several machine learning driver control models and compare the performance using both simulated and real human-driving data sets. Paper [11] focuses on detecting and counting the passengers of nearby vehicles as seen from the ego-vehicle using monocular vision. The on-road Vehicle PassengEr Detection (ViPED) system is proposed and is based on the human perception model in terms of spatio-temporal reasoning, namely the slight movements of passenger shape silhouettes inside the cabin of the preceding car seen through the windshield. A Convolutional Neural Network is used to infer the number and position of passengers.

Vehicle Systems Control

Some of the proposed works have focused on specific systems of the vehicle control, be it the low level control or the fusion of data from multiple sensors: in [12], a dynamic test model used for the design and tuning of low level PID and LQR controllers are presented; in [15], the sidesliping of vehicles is estimated using a self-calibrating architecture which fuses several sensors such as an inertial measurement unit and a global positioning system; in [14], a nonlinear model predictive controller is proposed to produce an online estimate for a cost-effective cruising velocity; in [13], a study on the effect of medium access control protocol and the unreliable measurements on acceleration information for the cooperative control of vehicle platoons is presented.

High Level Navigation

The planning and execution of the movement of intelligent vehicles continues to be a relevant topic of research, in particular in complex, dynamic environments. As such, this special issue contains several works on the topics of navigation and trajectory planning: in [17], an approach is proposed that models the interaction between the autonomous vehicle and the environment, with the goal of determining the optimal driving strategy for the autonomous vehicle; in [18], an anticipatory kinodynamic motion planner that considers dynamic complex environments containing both static and dynamic obstacles is proposed. Finally, in [16], a novel software architecture for intelligent vehicles is proposed, focusing on the flexibility and scalability as a means to effectively evaluate novel algorithms. The implementation of the architecture is shown for two real platforms, the iCab (Intelligent Campus Automobile) and IvvI 1.0 vehicle (Intelligent Vehicle based on Visual Information).

Deep Learning

Deep learning based approaches are becoming the dominant paradigm in almost every basic and applied research topics. In the current special issue several works were based on the usage of such a framework. In this section just the most representatives are summarized. In [2] the authors propose an efficient approach to perform recognition and 3D localization of dynamic objects on images from a stereo camera, with the goal of gaining insight into traffic scenes in urban and road environments. The usage of a deep learning framework allows to identify a broad range of entities, at a frame rate compatible with the strict requirements of onboard automotive applications. Stereo information is later introduced to enrich the knowledge about the objects with geometrical information. A deep learning based framework has been also used in [17], but in this case it is intended to target the planning problem of autonomous vehicles. The system learns the driving style of an expert driver using reinforcement learning strategies. Simulated results demonstrate the system is able to reach the desired driving behaviors for an autonomous vehicle. Focusing also on the driving behavior, in [19] a deep learning based technique is proposed to accurately predict driving manoeuvres in a few seconds in advance. The authors propose a domain adaptation based technique, which is able to adapt a learned model to new drivers and different vehicles. The proposed approach has been evaluated in several datasets yielding an average increase in performance of 30% and 114% respectively compared to no adaptation based techniques. Finally, focusing on driver monitoring, [10] proposes a novel method to estimate a head pose from a monocular camera. The proposed algorithm is based on multi-task learning deep neural network that uses a small grayscale image. The network jointly detects multi-view faces and estimates head pose even under poor environment conditions such as illumination change, vibration, large pose change, and occlusion. The authors also release a new dataset for head pose estimation. The proposed framework outperforms state-of-the-art approaches quantitatively and qualitatively with an average head pose mean error of less than 4° in real-time.

Conclusions

Autonomous Driving and Driving Assistance Systems are now highly versatile and broad contexts which support the test and usage of both classic and modern techniques in domains ranging from perception, planning, control until classification and deep learning. Being a concern of daily routines for humans, and now also machines, it is becoming irrefutable that many quests can be tried and experimented in this attractive field of technology and science. This special issue clearly corroborates that with its wide range of topics and techniques as described in the earlier sections. But, what is now striking fiercely is the almost unavoidable imposition of the soft computation tool of the moment: deep learning.

For example, we still see classic oriented trends such as Model Predictive Control (MPC) to predict and control machine motion, but often there are also works which tackle similar problems with deep learning approaches. Many authors are surrendering to this almost sinful and irresistible framework; more and more are migrating, and right now we can only guess what future editions of this special issue will bring to the community.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgments

This work has been supported by: the Spanish Government, Spain under Project TIN2017-89723-P, the "CERCA Programme / Generalitat de Catalunya", Spain, the ESPOL project PRAIM (FIEC-09-2015), Ecuador and FCT — Foundation for Science and Technology, Portugal, in the context of project UID/CEC/00127/2019. The authors gratefully acknowledge the support of the CYTED, Spain, Network: "Ibero-American Thematic Network on ICT Applications for Smart Cities" (REF-518RT0559).

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Available online 22 August 2019

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