Introduction to the Special Section on In-Vehicle Computer Vision Systems

ROAD accidents are the main cause of death of people under 45 years of age in Europe and they number about 1 300 000/year, causing over 40 000 deaths and more than 1 700 000 injuries each year. The direct and indirect costs have been estimated at $160 billion [1]. In the United States, more than 42 000 people died on the nation's roadways in one year, equal to one person dying every 13 min [2]. In Japan, the number of road accidents exceeded 940 000 in 2001, causing nearly 9000 deaths [3].

With these premises, it should be obvious that any effort in reducing the cause of accidents and/or reducing the effects of accidents on people is welcomed. For this reason, in the last decades, many research projects have investigated solutions in the field of intelligent transportation systems (ITS). Possible research topics can be classified by means of their area of applicability: traffic control (e.g., intelligent traffic-light management, traffic-sign recognition, and accident detection and management) and intelligent vehicles (e.g., autonomous vehicles, platooning, route planning, and driver assistance). The current availability of low-cost vision devices and the full development of computer vision techniques make vision an interesting solution for these classes of problems. In particular, the papers included in this Section address the problem of computer vision systems mounted on vehicles.

The two main purposes of automatic systems for intelligent vehicles are to provide the vehicle with autonomous guidance and to increase the safety of the vehicle and its occupants. To this aim, the main requirements are

- landmark detection (for road following purposes);
- traffic-sign detection and recognition (for route planning and alerts to the driver);
- obstacle detection (for computing time-to-impact and for automatic obstacle avoidance);
- monitoring and improvement of safety inside the vehicle (for intelligent airbag deployment or monitoring of the driver's distraction level).

This Special Section brings together the expertise of outstanding researchers in different topics related to in-vehicle computer vision systems. We received 19 submissions for this Section and, after a rigorous reviewing process, we selected six papers to illustrate the relevant topics and techniques at the forefront of in-vehicle computer vision research.

Independent of the final objective of the application, vision systems mounted on running vehicles present two main problems: the first is that the camera is moving and the second is that processing suffers from image instability due to bumpings and vibrations. Liang *et al.* introduce a solution to the latter problem. Their video-stabilization approach is based on the extraction of global features, such as lane lines and the road vanishing point. These features are matched in consecutive frames to compute the global motion of the scene. Expected and unexpected motions are separated by keeping track of expected motion parameters with a Kalman filter. The expected camera motion is used to stabilize the input image through image warping.

Most road accidents are due to distraction or high speeds that make it impossible to react to obstacles. Thus, automatic (and early) obstacle detection is a key feature for safety in-vehicle systems. Demonceaux *et al.* propose to exploit motion information to detect obstacles from a normal camera mounted on the vehicle. Wavelet analysis is employed to extract road motion and hierarchical Bayesian modeling is used to classify as potential obstacles the sets of pixels that are not in accordance with the road motion.

Very significant obstacles, whose avoidance can really save lives, are pedestrians. More than 200 000 pedestrians are injured and about 9000 are killed in road accidents in the European Union each year. For this reason, three of the six papers included in this Section are related to pedestrian detection. In particular, since human vision is weaker at night, three or four times as many deaths occur at night than during the day. Therefore, all three of these papers use infrared vision, both to work at night and to simplify pedestrian detection (due to the heat-sensitive nature of the sensor, humans appear brighter than the rest of the scene).

Liu and Fujimura present a stereo night-vision system based on a two-stage method for stereo correspondence and motion detection without egomotion calculation. Hotspots are extracted as potential pedestrians and scene disparity is used to discard false positives. This method works well when the camera motion has a dominant translational motion with a small amount of rotational motion, which is likely to happen for cameras mounted on vehicles.

Bertozzi *et al.* instead propose to use a single infrared camera for pedestrian detection. This approach is based on a multiresolution localization of warm symmetrical objects with specific size and aspect ratio. A set of matched filters are used to reduce false detections due to other road participants. For real-time purposes, the processing is based on the analysis of single frames only.

Fang *et al.* define a new shape-independent approach to pedestrian detection in infrared images. The first step is a projection-based horizontal segmentation, followed by a brightness-based segmentation to determine the vertical position of potential pedestrians. Then, a classification method based on multidimensional histograms, inertial moments, and contrast is used to detect actual pedestrians by comparison with a single pose-independent pedestrian template.

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The complement to safety on the roads is the provision for the driver's safety inside the vehicle. For instance, automatic alarm generation in case the driver is distracted (e.g., systems for yawn detection have been proposed) or if the driver answers a cell phone are two examples of this type of applications.

Another interesting topic for in-vehicle safety is that of "smart airbag" systems, reported in the last paper of this special section by Trivedi *et al.* The incorrect and nontimely deployment of airbags can cause serious problems to the vehicle's occupants. This system employs stereo vision and a thermal infrared camera to dynamically analyze the posture of vehicle occupants. Head pose and size are estimated by means of skin detection (exploiting the thermal information) and stereo vision (using the disparity image to compute the background model and, then, obtaining the foreground point by suppressing the background). Head pose and size are used to infer the posture of the occupants and decide the exact time for the airbag deployment.

In conclusion, we feel that this Special Section has highlighted several interesting issues on the topic of in-vehicle computer vision systems. We would like to thank all of the authors for contributing to this Section and all of the reviewers for their valuable help in selecting the more representative papers for this section.

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Dr. Trivedi is a Fellow of the International Society for Optical Engineering (SPIE). He served as Chairman of the Robotics Technical Committee, IEEE Computer Society. He was elected to serve on the Administrative committee (BoG) of the IEEE Systems, Man and Cybernetics Society and has received the Distinguished Alumnus Award from Utah State University, Pioneer Award (Technical Activities), and Meritorious Service Award from the IEEE Computer Society.