Vision-based assistance systems for road users

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***Abstract*—The paper presents vision-based assistance systems for road users. Analysis of statistical data indicates that solutions, which improve safety, regulate traffic flow, and assist road users are very desirable. Such systems, mainly implemented in mobile devices, are proposed for pedestrians, cyclists, motorcyclists, and car drivers. Three presented applications are video processing systems. The first one supports a driver by detecting the traffic lights change. The second one indicates turn signals of a vehicle from adjacent lane. The third one warns pedestrians about approaching vehicles at night. Results of performed experiments show high efficiency of the presented applications. Any of these systems may be a part of a subsystem for autonomous vehicles.**

Keywords*—*assistance systems; mobile devices; vision-based detection; traffic lights detection; vehicle headlights detection; turn signal detection;

I. INTRODUCTION

Traffic is understood as a phenomenon of using roads for travelling and carrying goods. It generates many issues related to safety and efficiency of transport.

In year 2013 in European Union were 25900 road fatalities, including 3357 in Poland and 3339 in Germany. It means that every year a population similar to a small city dies. For every death there are about 4 permanently disabling injuries, 8 serious injuries, and 50 minor injuries [1].

Heavy traffic congestion increases air and noise pollution, vehicle fuel consumption, wastes time and frustrates people [2]. As example, in Warsaw, mean travel time is 40% longer than in the uncongested traffic [3].

A worrying fact is that one in six people in the EU suffers with some kind of disability [4]. Increasing number of elderly people with a severe disability are expected in future, especially if people aged 65 or more are 17% share of population [2].

Thus, solutions for improvements in safety, traffic flow, and assistive devices for people with reduced efficiency are very important. On one hand, they relate to the physical infrastructure, and, on the other hand, support mobile systems. The authors focus on vision-based mobile assistance systems designed for various target groups of people (Fig. 1).

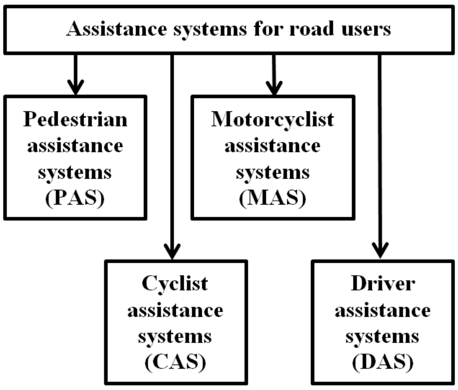

Fig. 1. Types of assistance systems for road users

The paper is composed as follows: after an introduction mobile and vision-based assistance systems are presented in Section 2 and Section 3, respectively. The proposed vision-based assistance systems, together with the results of experiments, are described in Section 4. In the last section, some concluding remarks are formulated.

II. MOBILE ASSISTANCE SYSTEMS

There are many mobile systems, which are available for main groups of the road users. Applications mainly use smartphones, wearable devices, or vehicle equipment. They acquire data from a bunch of sensors, e.g. accelerometers, gyroscopes, thermometers, heart rate monitors, and many others. We present some illustrative solutions, which are dedicated to a given group of the road users. In fact, some of them overlap the target group, so may be applied by various users.

Pedestrians are mainly assisted by navigation systems, which provide additional information about the destination. Some of them can operate even in indoor environment [5, 6, and 7]. Recognition of the current floor is performed using a barometric sensor [7]. Guide and healthcare applications use, e.g. pedestrian tracking, gait recognition and estimation of walking distance [8].

Applications for cyclists include: navigation, tracking, and recording a ride, providing distance, speed and other metrics, heart rate monitoring, first aid skills to combat the most common cyclists injuries, weather forecast, nearest bike and docking station search based on bicycle hire scheme, instructions for fixing of mechanical problems, and body measurement to choose the right size of a bike. Additional social functionalities allow to follow the progress of cycling friends, join clubs, and take part in challenges [9].

Motorcyclists are supported by applications, which can: calculate the quickest path to the destination by gathering speed information from other users, search for the nearest or cheapest gas station and reputable motorcycle shop, tracking and plotting parameters of riding. The weather forecasts are based on location and user-submitted ground level observations. A motorcycle crash may be automatically detected using gyroscopes and accelerometers [10].

The drivers are navigated by using GPS and locally they are supported by the parking assistant [5]. The eco-driving assistant assesses efficiency of the driving style in order to optimize the fuel consumption [11]. Diagnostic port of a vehicle and sensors of the mobile device are used for data acquisition. An application, which helps amateur drivers with gear changing based on car engine parameters from on board diagnostics is described in [12]. It also provides the assistance in case of vehicle breakdown. A system, which detects and alerts typical drunk driving maneuvers performed by the driver is presented in [13]. It is based on accelerometer and orientation sensor of a smartphone. Application for monitoring of the driver's health is typically based on sensors located in the vehicle and on the body [14].

Moreover, smartphones, wearable devices, and electronically supported vehicles, enable a large group of people to participate in experiments, simultaneously. Sensors, as cameras, microphones, accelerometers, and barometers, are built-in in the user mobile devices and are used for harvesting a large quantity of data in the urban environment. Then, these data are processed using signal processing techniques. This approach is called Mobile Crowd Sensing (MCS) and is presented in [15, 16]. Such technology may be used to collect data about threat events. Personal mobile devices may provide precise description of incidents to the database of the emergency notification system [17, 18]. As additional source of information it may increase efficiency of emergency services.

III. VISION-BASED ASSISTANCE SYSTEMS

Vision-based assistance systems record and process images or video frames. Data may be monocular or based on stereovision. In case of stereovision a difference between two stereo images may be used to calculate distances between the camera and interesting objects. Some examples of solutions based on the vision sensors are listed below.

In the so-called blind spot monitor vehicles can be detected in the area, which cannot be seen by the driver in the side mirror. Night vision technologies support visual perception of the driver in the night or under the limited visibility [19]. The system presented in [20] indicates presence and density of fog on a mobile platform. Another software is used for car detection and tracking [21] or detection of obstacles [22]. Collision and lane departure warning systems are other examples of driving assistants [23]. Detection of speed limits signs and warning the driver about exceeding are implemented in [24]. The reduction of fuel consumption may be supported by detection of traffic signs. It gives advices to the driver about the required deceleration [25].

Vision-based detection can be useful not only in the driver assistance but also as a source of information for automated driving of vehicles. A cooperative adaptive cruise control (CACC) system uses vehicle-to-vehicle (V2V) communication to access information about surrounding vehicles. In consequence, a platoon of vehicles is formed. The leader vehicle sends information about speed changes to the succeeding vehicle. Each vehicle in a stream receives information from preceding vehicle and optimally adjusts the speed. When failing to receive information from CACC, the system is downgrading to ACC (adaptive cruise control) mode without cooperation. In this case there is no information about vehicle stream and maintained space gaps are larger [26]. Generally, visual-based detection, e.g. detection of traffic lights, is important in for both, CACC and ACC mode.

It is a technology of traffic control, which can cause that physical traffic lights are unnecessary. This is the virtual traffic lights (VTL) system. It is based on V2V communications at intersections. Vehicles self-organize and decide about the priorities at the intersection. The drawback of this solution is that it requires routes exclusively reserved to the vehicles equipped with VTL with nullified traffic lights based on the infrastructure. Cars without such system must use traditional traffic lights. At intersections for cars of mixed types (with and without VTL) the functionality of physical traffic lights has to be maintained [27]. Thus, the detection of traffic lights is still reasonable.

IV. VISION-BASED ASSISTANCE SYSTEMS

The general idea of the proposed vision-based assistance systems is presented in Fig. 2.

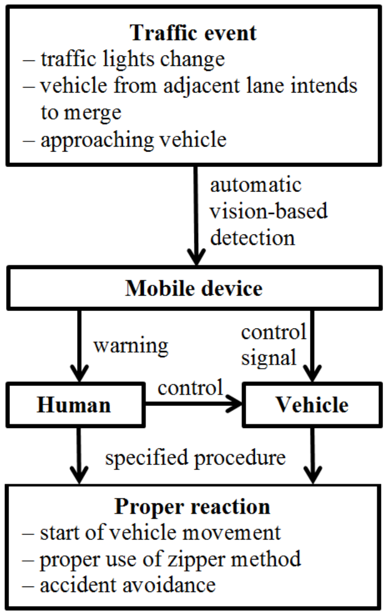

Fig. 2. Concept of proposed vision-based assistance systems

Each of the presented mobile systems automatically detects a given traffic event. These events are important for the proper traffic flow and urban safety. The road user is warned by the mobile device and a proper control signal is transmitted to the onboard vehicle equipment.

We proposed, implemented, and tested three mobile applications for detection of: traffic lights change, vehicle approaching to a pedestrian, and turn signal of a vehicle on the adjacent lane.

A. *Detection of traffic lights change*

First application detects traffic light changes from the red to green using a camera mounted in the area of the vehicle windscreen. It informs and reminds the driver about possibility of movement. A car equipment may be ready for start earlier than without the use of such system. In consequence, more cars may cross the intersection in one cycle or in other area controlled by the traffic lights.

The algorithm was initially implemented in Matlab programming environment [28]. The extended version was dedicated to smartphones equipped with Android OS (operating system) [29]. It works in the following steps. Firstly, the video frame is grabbed and loaded to memory. Then, the image is transformed from the RGB (red, green, and blue) color space to the HSV (hue, saturation, and value) color space. Then, the Gaussian filter is used in order to reduce the noise and unnecessary details. Next, a binarization, which thresholds the red and the green light, is performed [28]. Finally, circles are detected using the circle Hough transform (CHT). The algorithm checks if in the previous instance of the loop the red light was detected. If so, the program waits for the green light and indicates this detection. The algorithm determines whether the circle corresponding to the green light belongs to the same indicator that the red circle. In this step of the algorithm, conditions for searching the green light, as the second light, in the same indicator object are defined. Applied formulas and precise description of the algorithm and used functions are presented in [29]. The last step of the algorithm checks if the red circle, which was detected earlier, disappeared. If the lights have changed, the alert is automatically generated [29]. Illustrative frame with detected change from the red light to the green one is shown in Fig. 3a).

Experiments on the detection of traffic lights change were conducted using many real traffic videos. Detection rate for the initial version of the system was about 50% [28]. The mean detection rate for the improved version of the algorithm is about 78%. Improper recognition was affected mostly by poorly visible colors (low quality of a video sensor) or weak distinctness between colors [29].

B. *Detection of vehicle approaching to pedestrian*

Second application detects vehicles, which are approaching to pedestrians and warns about the threat. It recognizes even a silent car, which is going behind the pedestrian back. It is important especially in the case, when the walking person is blind, tired, or simply careless. A pedestrian alerted by sound or vibrations may change the movement trajectory in order to avoid an accident. The system uses a camera of a personal smart phone or is mounted directly in garment.

The algorithm, similar as in the previous system, was implemented in Matlab programming environment for testing of procedures [30] and then, an extended version for the Android OS was written [29]. The idea is to detect the car lights. This detection starts with an acquisition of image from a camera, e.g. built in the smartphone. Then, a color frame is converted to a grayscale picture. After that, the binarization specifies locations of the light sources corresponding to the vehicle headlights. The threshold used in this step was determined experimentally in order to detect light sources. Typically they are the brightest points in the image. Then, the small artifacts, unnecessary details, and noise are removed using filtering. After the extraction of light sources from the image, the circles corresponding to headlights are detected. For this purpose, again the CHT is used. Found circles are presented in the image. Headlights are detected if two circles are found and additional geometric conditions, described in [29] are met. At the end of the algorithm, the graphical and sound warning about the approaching vehicle is generated. Illustrative frame with the detected lights of the vehicle is shown in Fig. 3b.

The experimental results of the mobile application show that effectiveness of the detection is about 90%, while for Matlab programming environment it was about 88% [31]. Problems with the detection are caused mostly by low effectiveness in the full sun (mainly due to low contrast between traffic lights and surroundings) [29].

C. *Detection of turn signal of vehicle from adjacent lane*

The third application detects turn signal of a vehicle on the adjacent lane. It is helpful in a situation, when vehicles move in queue in two lanes in the same direction, while one lane ends and only the second lane is continued. The cars from the ended lane should change the lane and eventually all cars should move within the continued lane. The best (fastest) way to achieve this is the alternating order, i.e., one car from the continued lane and then one car from the ending lane, and so on. The system is used in the cars moving on the continued lane. We assume that the view range of the visual sensors of these cars cover the cars on the second lane, especially their turn signals. The maneuver of the first car, which is going to change the lane, should be permitted by one car from the continued lane. However, the same maneuver of the second and next cars should not be allowed by this same car. In case of permission the car should reduce the speed and prepare a space for the car from the left lane. In case of prohibition, the car should continue moving close to the vehicle ahead. The process of speed change may be performed automatically or manually by encouraging the driver using graphical, sound, or vibration warning [28]. In consequence of execution of the system procedure, the differences in speeds between two lanes and the total length of the queue should be reduced [32].

The recognition algorithm was implemented in Matlab programming environment. It works as follows: firstly, the video frame is loaded. Then, the RGB color model is transformed to the HSV representation. In the next stage the binarization for the rear position lamps is performed using the thresholds presented in [28]. Then, the morphological closing is performed using a disk-shaped structuring element. For turn signals, the binarization with threshold values presented in [28] and morphological closing are performed. As the result, there are two binary maps, a map of rear position lamps and a map of turn signal. Next, the area of position lamps is subtracted from the turn signal map if the common parts exist. Then, the connected components, which can constitute objects, are found in the binary map of position lamps. Properties of position lamps regions in a map, like the center of mass, the actual number of pixels and the diameter of a circle with the same area, are also measured. For founded connected components in position lamps map, the turn signal is searched in square area with centers in centers of mass of position lamps. Side lengths of squares equal to diameter of a circle multiplied by the constant value, which is a coefficient of distance between position lamp and turn signal. The connected components of turn signal are searched in selected area. Then, the center of mass property of turn signal region in map is measured. Finally, the result of turn signal detection is visualized on image [28]. Illustrative frame with detected turn signal is shown in Fig. 3c and the detected area of turn signals is enlarged in Fig. 3d. It should be noted that both indicator lamps have been properly detected.

a) b) c) d)

Fig. 3. Illustrative frames with detection of: a) traffic lights change from red to green, b) vehicle based on its headlights, c) turn signal of vehicle from adjacent lane, and d) enlarged detected area from (c)

The results of experimental tests of this application show the effectiveness about 83%. Problems with detection may be influenced by incorrect colors of lamp, for example too bright, and inadequate sizes of lamps for relatively long distances between a camera and a car [28].

D. Summary

Details of the described applications are summarized in Tab. 1. The best effectiveness has been experimentally proven for detection of approaching vehicles. In future the authors plan to implement the algorithm for turn signal recognition also for the Android platform.

TABLE I. SUMMARY OF PROPOSED VIDEO-BASED ASSISTANCE APPLICATIONS

Parameters	**Detection system**		
	Traffic lights change	***Approaching vehicle***	***Turn signal***
Version no. 1	Platform: Matlab		
- code lines (*)	124	32	112
- detection rate	50% [28]	88% [31]	83% [28]
Version no. 2	Platform: Android OS		
- code lines (*)	292	306	To be implemented
- detection rate	78% [29]	90% [29]	

(*) – without functions and libraries)

V. CONCLUDING REMARKS

Nowadays, there are plenty of mobile assistance systems for road users. Among them, solutions based on visual sensors are the most promising. Drivers can be supported by detection of traffic lights change and detection of turn signal of vehicle from the adjacent lane. Pedestrians are aided by detection of approaching vehicles.

The authors plan to expand the scope of applications for traffic lights changes detection for motorcyclists, cyclists, and pedestrians. Detection of approaching vehicles will also include estimation of trajectory of the vehicle based on changes of its position between frames. All experiments will be focused on increasing the systems efficiency for safety and quality of travel.

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