Intelligent Sensors for Real-Time Hazard Detection and Visual Indication on Highways

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***Abstract*— In this work we present an intelligent modular system that monitors traffic in highways and alerts drivers of sudden stops, in poor visual conditions. The system is composed of several identical modules, to be placed in the middle of a highway's lane, that sense the lights and communicate their presence and velocity to the neighbor modules via RF. With such information, the nearby modules estimate the velocity of the passing cars. When the module ahead detects a car passing at a much slower speed than what was previously estimated, it alerts the other modules, so they produce a visual indication for the oncoming drivers. The system operates autonomously by harvesting solar energy and storing it a battery.**

Keywords: Intelligent Transportation Systems, Auto Traffic Monitoring, Low-Power Embedded System, Ad-hoc Wireless Communication, Sensor Network.

I. Introduction

This paper presents an autonomous embedded system that tries to improve safety in highways in poor visibility conditions due to the road profile, or adverse meteorological conditions. It acts as an active alert signal to other drivers.

Some previous works [1], [2] automatically detect traffic accidents using image processing techniques. The proposed system is to be installed on the road, and is composed of several modules that work together to perform real-time traffic monitoring and detection of hazardous situations. Each module measures the time elapsed between the communication of a preceding module and the detection of the vehicle by the sensor. Therefor, knowing the distance between each device it is possible to determine a vehicle's speed, and if it reduced drastically the velocity, or even if it stopped.

The main contributions of this work are: definition of the architecture of the system and its requirements; definition of hardware and software for the embedded system; communication protocol; characterization and modeling of the light pattern produced by vehicles; simulation of the operation of the modules.

II. Proposed System

The proposed system is composed of several identical modules that acquire information about traffic from sensors, detecting vehicles, estimating its velocity and reacting to hazard situations.

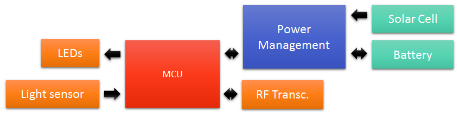

Fig. 1. Organization of the blocks in the module.

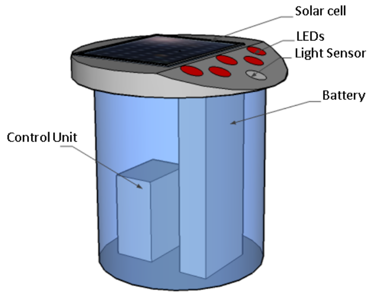

Fig. 2. 3D rendering of the case for the modules, including its components.

The automatic decision about the existence of an accident is based on a message passing algorithm between modules, through an wireless ad-hoc network. Each message informs the neighbor modules about each vehicle detection. If a module doesn't detect a passing vehicle during an expected period, either too slow or stopped, then it alerts its neighborhood until de regular traffic flow is normalized.

A. Hardware

Due to the system's operating environment, and its implement restrictions, each module is comprised of a solar cell, a battery, a power management unit, a micro-controller (MCU),an RF transceiver, a light-sensor and LEDs, as illustrated in figure 1. The battery is charged via the solar cell. The MCU provides all the control logic of the module and its peripherals, e.g. LED, RF module, and light sensor. Figure 2 shows a 3D rendering of the system in its case. The solar cell is on the top, and the LEDs positioned to guarantee that drivers can see them.

B. Software Intelligence

The system is meant to react to 2 inputs: the light sensor, and reception of a message from the RF module; and actuate

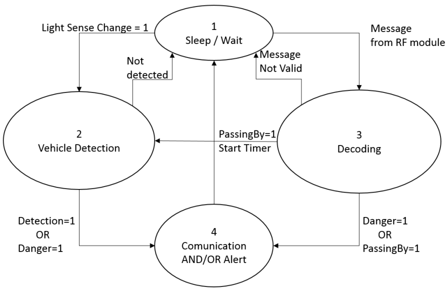

Fig. 3. Controller state machine.

2 outputs: visual indication via LEDs, and transmission of message to the RF module. To support such functionality, an FSM was thought to be programmed on the MCU to control the system using 4 states: Sleep, Detection, Decoding, and Communication. Change of states are described in figure 3.

After reset, the system is in the initial state (State 1: Sleep), waiting for a message from another module (State 3: Decoding) or detection of a vehicle (State 2: Vehicle detection). In state 3, the received status can be: a) Vehicle detection, b) Send a warning, and c) Reception acknowledgement. If the message received is a warning, then it goes to state 4 ("Communication / Alert") and activates the light signaling during a period of time and the message is retransmitted. At the end of transmission the FSM goes back to the initial state. In the the second state ("Vehicle detection") it starts to count the time after receiving the message. The time stops when a vehicle is detected, and since the physical distance between modules is known an estimate of speed can be calculated. After the vehicle is detected, a corresponding message is sent to the neighbor modules. The system waits for acknowledgement messages. If the time waiting is greater than a threshold, it changes to state 4, and turn on the LED light and send a warning message to be received by all nearby modules. The device then returns to state 1.

C. Communication

The modules communicate with each other via RF broadcast messages, so that other modules within coverage range can bypass a faulty module in the system and continue its operation. There are 3 types of messages exchanged by the modules are:

1) Detection: After vehicle detection with is velocity estimate.
2) Warning: When a vehicle doesn't pass on the expected time interval, due to abrupt speed decrease, or did not pass at all, due to an accident.
3) Acknowledgement: Indication of the information received by the module.

III. Experimental Validation

The first step taken for the implementation of the system consisted on a simulation in Matlab environment. It simulated the FSM, the detection algorithm, and the message passing scheme. Moreover, it allowed to study the behavior of the modules to the passage of the light intensity profile of each vehicle, and check the transmitted messages.

Fig. 4. Example of a photograph used to create the models for the different light patterns.

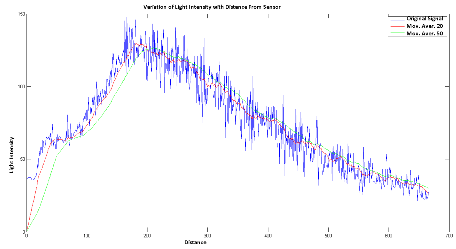

Fig. 5. Example of the data extracted from the light footprints to create the models for different vehicles.

The light intensity profile is based on real data, which were obtained by filming part of a highway to collect several light patterns from different vehicles. From several video-recordings several frames with light footprints of vehicles' headlights were extracted. They were then cropped and converted to grayscale, as illustrated on figure 4. To simulate the light sensor analysis, only the intensity values of the footprint were considered, shown in blue in figure 5, and low frequency signal in red.

IV. Conclusion

We have proposed and demonstrate a novel system to detect hazardous situations on highways due to sudden stops, or abrupt velocity reductions of vehicles, which are usually associated with accidents. The system is to be used in poor visibility conditions, due to adverse weather conditions, or highway's profile.

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