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SafeWay

Intelligent Street Monitoring System

CSIDC 2004 - Interim Report

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1. Introduction

Road traffic safety is a problem that has been given a lot of attention in the last decades and many attempts, social oriented or automatic systems as well, have been proposed in order to reduce the number of injuries by increasing the road security level. We address the same problem in this project, the possibility of reducing traffic accidents by the means of a vision-based driver assistance system, designed to automatically detect dangerous traffic situations involving pedestrians and auto vehicles as well. By intelligently monitoring the road activity using pedestrian and vehicle detection algorithms, the system allows the possibility of warning the driver of possible dangerous situations.

If we take a look at the statistics (Table 1), in 2000 around of 160,000 persons were killed on the roads. An estimation of 6,000,000 persons was seriously injured. Out of the approximately 150,000 people killed in road accidents in the Europe every year, an estimation of 30 per cent, approximately 45,000 are pedestrians.

The amount of all types of injuries is projected to rise from 5.1 million in 1990 to 8.4 million in 2020 with road traffic injuries being the major cause of this increase.

	Killed	Injured	Accidents
USA	41,967	3,400,000	2,222,000
EUROPE	164,677	6,118,844	6,283,521
ROMANIA	2,863	7,451	8,801

Table 1. Road traffic accidents statistics (Source UN-ECE)

The economical costs of road traffic cannot be neglected when estimations around USD500 billion have to be considered. In developing countries, the costs are even greater than USD100 billion, which can be as much as twice the annual amount of development aid.

2. Objectives

- Reduce the average number of injured pedestrians and drivers
- Increase the traffic fluency
- Increase the driving safety

The system will provide drivers with a road warning system, indicating possible accident situations, especially when the driver cannot realize the danger by himself. Reducing the speed translates in this case in reducing the gravity of injuries.

In small cities, where the number of pedestrians is usually low and there are no pedestrians at all in the night, the information provided by our system will increase the traffic fluency. Based on information displayed on the "Road displays" the drivers will have the opportunity to drive with the allowed speed.

An indication of car or pedestrians presence will have an impact on increasing the driving safety. A small number of accidents involving cars at lower speeds will have a result in decreasing the costs of damages for cars and injuries gravity for drivers and pedestrians.

3. Benefits of project

Several attempts of automated systems designed for increasing the road safety level have been proposed. A brief description of each of them is given in Table 2 along with their most important characteristics together with the impact they had on the problem being addressed. The very first statement that could derive from analyzing these systems is that they all attempt to solve the problem by focusing on particular aspects, e.g. devices, intelligent or not, to be installed in vehicles and providing mostly audio warning functions or automated traffic lights switchers. The disadvantages that come with these approaches consist in the fact that there is no warning whatsoever for pedestrians, the focus being mainly oriented on driver, or a bad management of the traffic lights that are not adapting dynamically to the real situations.

From the above, it becomes very clear the necessity of an external and autonomous system with the main task to intelligently evaluate the current road situation and launch the appropriate actions (warnings for both drivers and pedestrians, traffic light changes, signals to a control command center such as the local police department). Our version of such a system is a vision based oriented approach, which takes into consideration both the car and pedestrian information in a given scenario and takes actions in order to protect the two traffic participants in an equally manner. The main characteristics of the system together with the benefits brought to society, may be summarized as follows:

- Automated system no need for human presence or intervention.
- 24-hours a day road activity monitoring, including both pedestrians and drivers.
- The system may be installed on both usually crowded streets, in very large or even small cities, where the number of pedestrians is very low. In both cases, the advantages that come along.
- During the night, the number of pedestrians being low, the system will display "Clear road status" message, allowing higher driving speed.
- Live broadcasting of the current situation together with an on-line status report.

4. Innovation

Table 2 presents three examples of commercially available traffic analysis and monitoring systems. Most of the systems are based only on video monitoring the traffic and

System	Characteristics	Shortfalls
Traficon VIP/P Presence monitor	- Presence detection - Vehicle counter - Queue length measurement	- Lack of pedestrian detection - Only 24 static detection zones
COMETS Traffic surveillance	- Monitoring traffic situation - Identifying and tracking individual vehicles - Identifying episodically behavior of individual or vehicles groups	- Lack of pedestrian detection - Lack of immediate warning possibilities - Non-stationary surveillance system
INO Automated Road Traffic Analysis System	- Estimation of traffic speed and density - Individual tracking of vehicles - Diagnosing the traffic status	- Lack of pedestrian detection - The need of an human operator

Table 2. Commercially available automated road traffic systems

The following innovations emerge (also discussed in much detail in the System organization chapter below):

- Pedestrian presence detection in the traffic lane
- Car presence detection
- Full scene analyzing capabilities based on machine learning algorithms
- Computer vision and image understandings techniques applied to road safety
- No need for human operator or intervention
- Real time dangerous traffic situation warnings
- Live broadcasting feature with on-line status reports

5. System organization

The system organization is given in a structured manner in Figure 1:

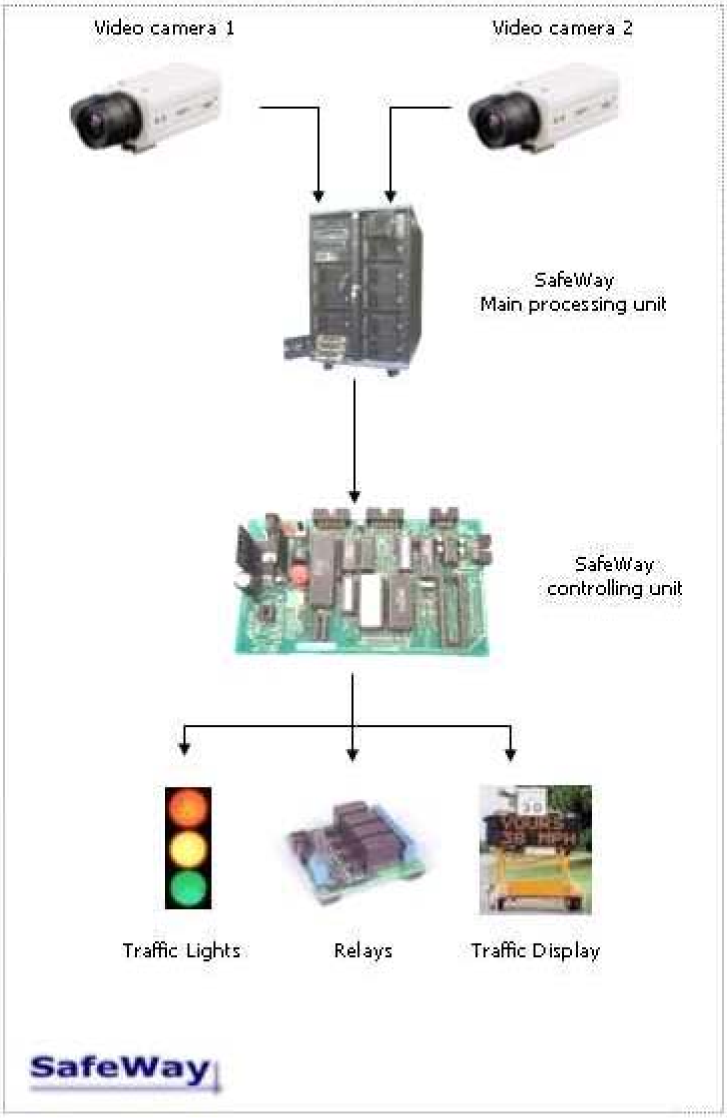

Figure 1. System organization

The hardware component consists of two video cameras connected with a standard Intel processor computer with Microsoft Windows 2000 Operating System. We built an interface microcontroller application board (PIC16F876), which receives commands from the SafeWay main processing unit, via RS-232 or Ethernet connection and activates the corresponding output warning signals. The SafeWay controlling unit can be connected in various ways to the road signaling equipments, such as traffic lights or character-based roads displays. Interfacing is achieved by using the following connection types: open collector outputs, free potential relay outputs or RS-232/RS-485 serial interfaces.

The software component of the system can be organized in a sequential manner, including 4 layers:

- **Data acquisition layer** (relates to video capture only);
- **Object detection layer**, the most important layer, includes car and pedestrian detectors;
- **Decision layer** aggregates the object detection results and, given a known scenario, decides the appropriate actions;
- **Action layer** takes care of handling the adequate actions, respectively: warns drivers and/or pedestrians of possible dangerous situations, signals to the SafeWay centers together with a live broadcast image and scene analysis, controls the traffic lights and warnings road displays.

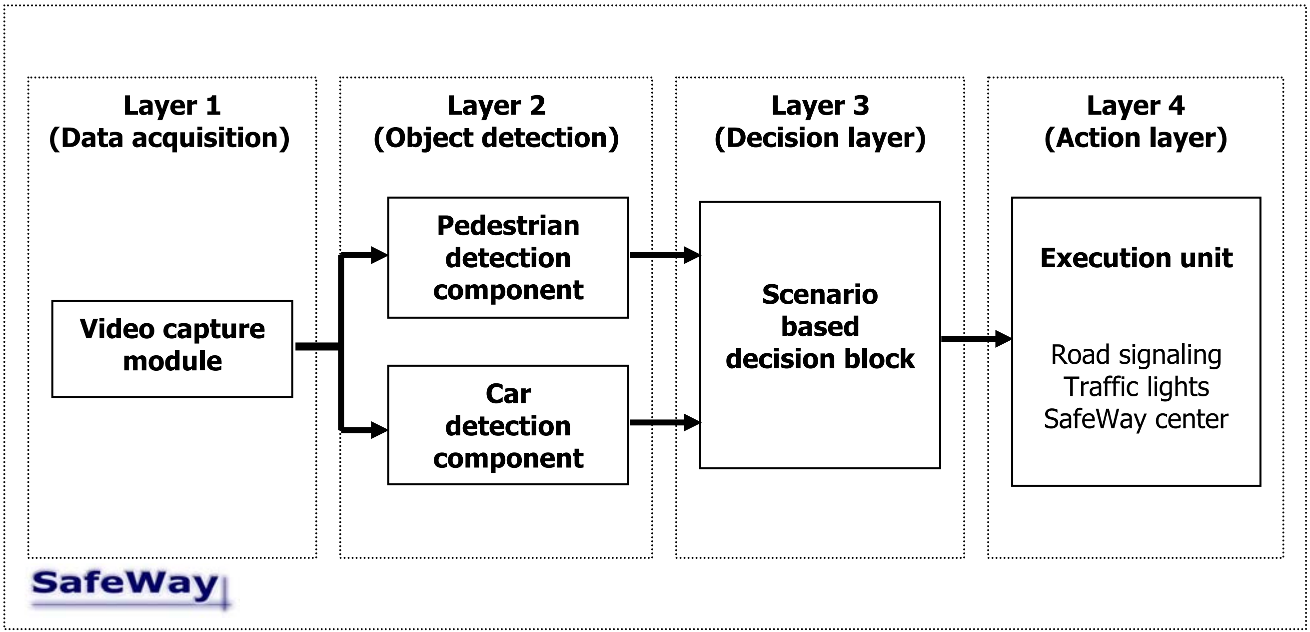

Figure 2. Software component organization

Being by far the most complex of all, the object detection layer can be considered the main component of the project, as it is its classifying results that determine the entire system's behavior and actions. Each of the 2 components, the pedestrian and car detectors, represent trainable machine learning modules, hence there is a clear separation in the layer 2 development process: the training and the testing phase (Figure 4).

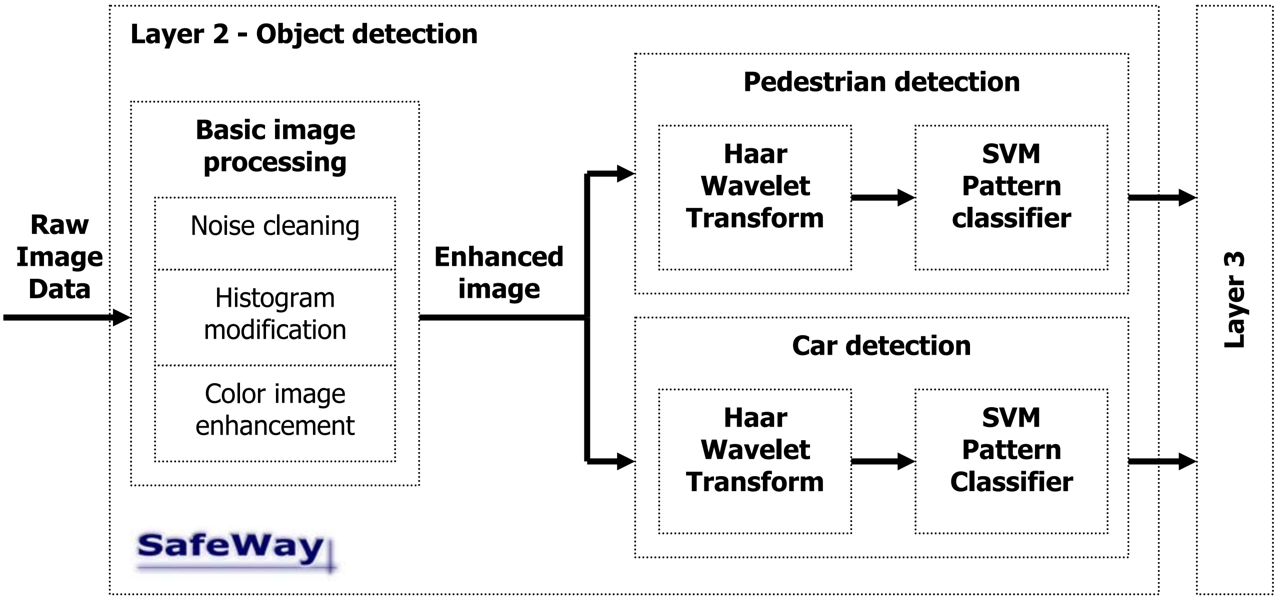

Figure 3. Object detection layer details

Either case, building a pedestrian or a car classifier, the process is basically the same: in the training phase, the system takes as input:

1) A set of images of the object class (pedestrian/car) scaled to the same dimensions and properly aligned so that the focus object is approximately in the center of the image

2) A set of non-object images, i.e. patterns that are not in the desired object class. Based on these sample images that constitute the training set (in the supervised learning approach), an implicit model of the data is constructed and hence, a classifier is built.

In the testing phase, the focus changes on applying the new built classifier to out of training set image samples (the testing set). The principle of detecting target object consists in sliding a fixed size window over the entire image and decide for each location whether the corresponding pattern represents an object or not.

At each position, the same set of features as the ones in the training phase are being extracted and the resulted pattern classified by the previously data built model. In order to achieve multi scale detection, the image is iteratively resized and processed again with the same fixed size window (the algorithm just presented can be quite expensive, however these shortfalls can be eliminated by using wavelet transformation on the initial image and hence, the extension to real-time systems is straightforward).

The key issues are obviously, the model chosen for object representation and the classifier type. Although the object types can be perceived as simplistic (pedestrian or cars), there is a great variability that accompanies the data, variability that gets translated into color, texture, pose and lack of a consistent background (a simple look at the image in Figure 5 will reveal all these aspects). Hence, the object representation must handle all these shortfalls of the search space and that will achieve a high interclass variability with a low intra-class one.

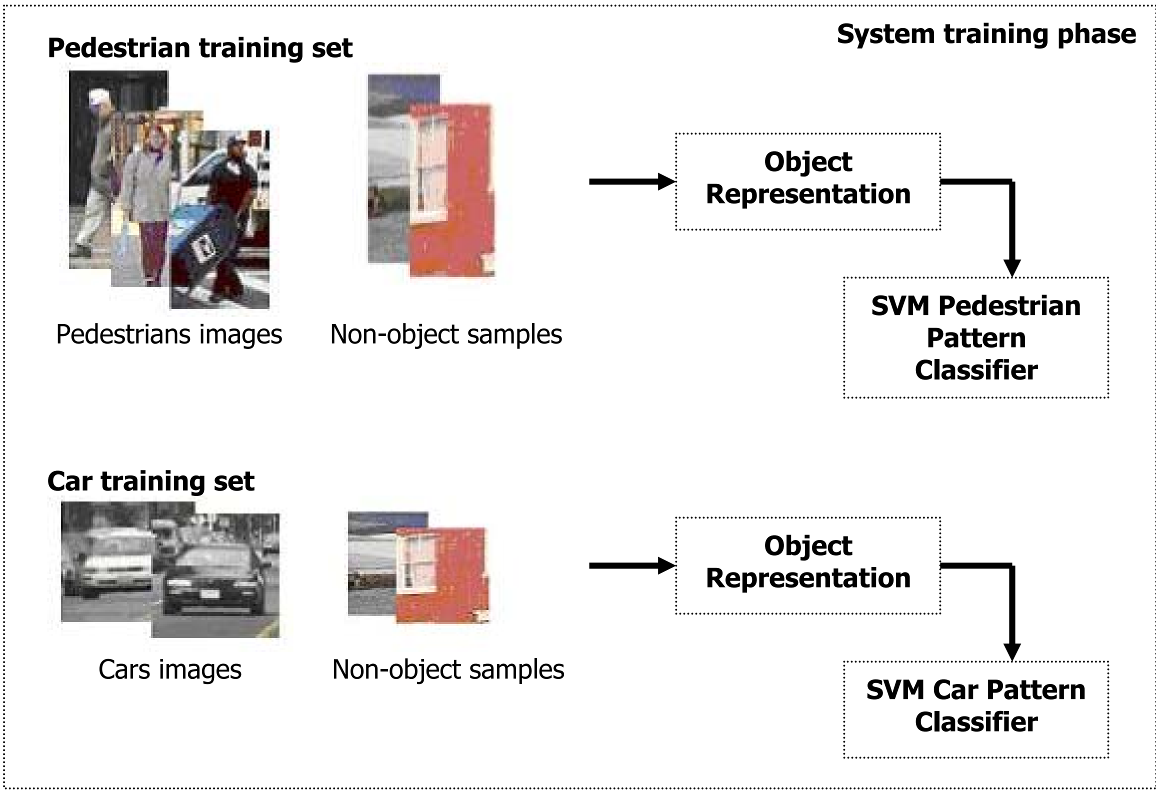

Figure 4. Training phase principles

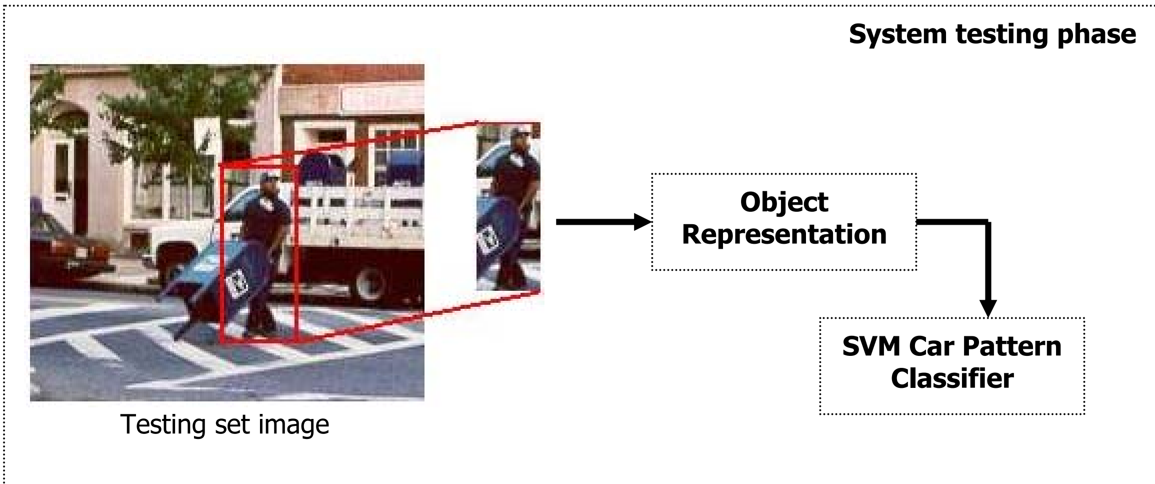

Figure 5. Testing phase principles

Traditional approaches, as pixel based representations or region based ones are very likely to fail if one would consider the permanent changing in color and texture. A possible relying approach to the problem is to use the set of Haar wavelets, which provide very good responses to local intensity differences in the image and to orientation variations as well. The wavelet transform will compute the image response to the wavelet filters (oriented wavelets – horizontal, vertical and diagonal) leading to fine coarse scale features embedded in the representation.

The approach taken to pattern classification is based on Support Vector Machines that proved to best achieve two important aspects needed in the system: precisely identify the factors that need to be taken into account in order to learn successfully (coming from statistical learning theory) and handling the complexity of real-world applications that often require advanced models and algorithms (much harder to analyze theoretically).

6. Principles of operation

SafeWay is an automated system designed to intelligently monitor the current road traffic, watching for both cars and pedestrians and taking the appropriate actions when dangerous situation conditions are met. Its general functionality and organization make possible adapting the system in many real world situations such as: crossroads with or without traffic lights control, highways, roadways or streets with low visibility points, suburban districts roads, etc. A few possible implementations are presented below, with focus on both drivers and pedestrians.

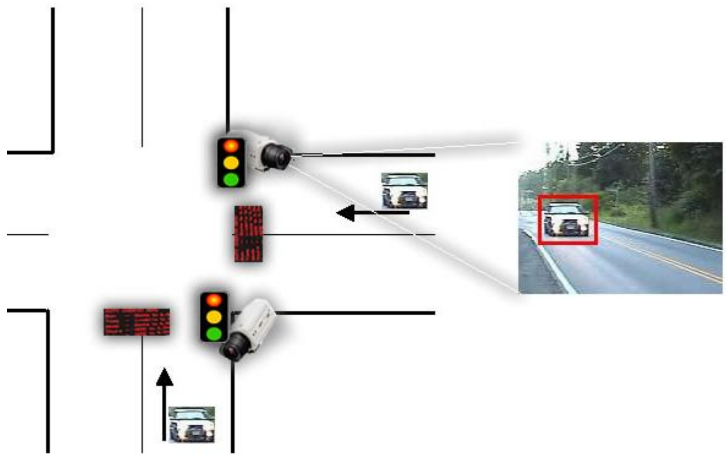

Figure 6. Crossroads scenario

The first scenario attempts to resolve the problem of car crashing. The only component used is vehicle detection combined with the road warning display. If a car is detected on one street, the system follows the pre-built scenario and automatically takes the proper action for the other.

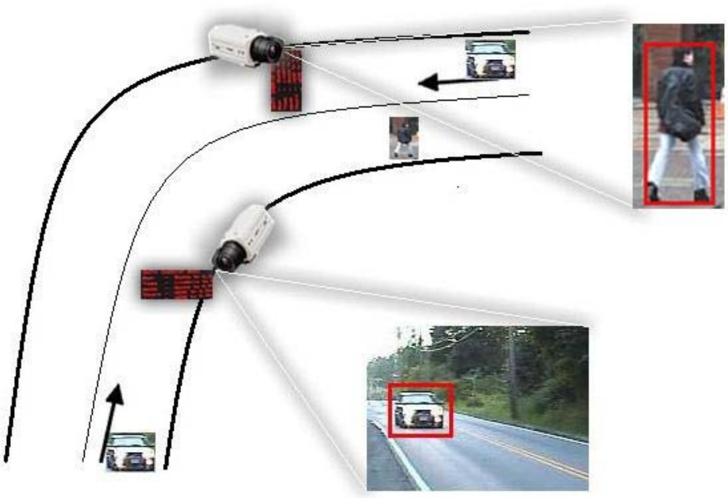

Figure 7. Low road visibility points

Moving a bit further, we can address the problem of low road visibility scenario. The SafeWay system is placed on a low visibility turn. One video camera is oriented into each entry of the curve. When a car enters the area covered by the either one of the cameras, the car driving from the opposite direction is warned by the road display. Also, if a pedestrian is detected on the road, the appropriate warning signal is activated.

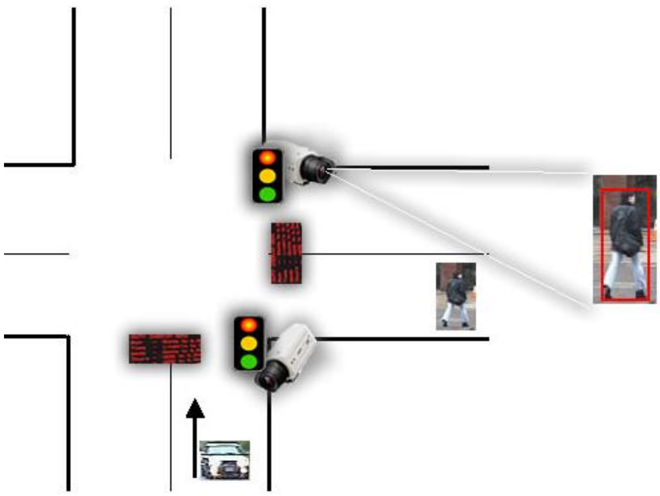

Figure 8. Pedestrian safety in suburban districts

In a similar manner to the first scenario, the system proves utility in suburban districts, in this case the focus being on pedestrians. Both the vehicles and pedestrians detection algorithms are being used and the warning systems addresses to all traffic participants.

7. Development plan

Time period	Activities	Tools
October	Project definition	
November	Addressing the problem: statistics, existing systems, benefits and possible innovations	
December	Video capture subsystem Hardware design and tests Basing image processing techniques	Visual C++ Microsoft DirectShow
January	Training image database building Hardware building Support Vector Machine Classifier implementation - phase 1 Haar wavelet transform	Visual C++ MPLAB Image database
February	Hardware interface testing Support Vector Machine Classifier implementation - phase 2 SVM Classifier tests (static images) Interim Report	Visual C++ MPLAB Image database
March	SVM Classifier tests (video) Hardware testing Video streaming component Software component integration	DirectShow Visual C++ MPLAB
April	System integration Field testing Final project analysis Final Report	Image database Video database

8. Cost

Component	Quantity	Price ($)	Cost ($)
Video camera	2	75	150.00
Video capture card	1	100	100.00
Microcontroller PIC1F876	1	10	10.00
SitePlayer web-server microcontroller	1	30	30.00
Connectors, resistors, capacitors, printed circuit board	-	15	15.00
		Total (USD):	305.00

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