WATCH-OVER – THE CONCEPT OF A COOPERATIVE SYSTEM FOR VEHICLE TO VULNERABLE ROAD USERS COMMUNICATION

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ABSTRACT

WATCH-OVER is a European Specific Targeted project co-funded by the European Commission Information Society and Media within the initiatives of the cooperative systems for traffic safety and efficiency based on communication and sensor technologies. The project, supported by EUCAR and coordinated by Centro Ricerche Fiat, includes in its consortium vehicle and motorcycle makers, technology, automotive suppliers and research centres for the design, development and testing phase.

The main goal of the WATCH-OVER project is to avoid road accidents that involve vulnerable road users such as pedestrians, cyclists and motorcyclists. The innovative system concept, presented in this paper, will be represented by the cooperation of an on-board platform and a vulnerable user module. It is based on the interaction between an in-vehicle unit and users' devices that will allow all road users to take an active part in traffic in urban and extra-urban areas. For that reason the WATCH-OVER project carries out research and development activities in order to design and develop an efficient system for accident prevention.

INTRODUCTION

The WATCH-OVER project aims at avoiding traffic accidents that involve vulnerable road users, namely pedestrians, bicyclists and motorcyclists, in urban and extra-urban areas. This objective is in line with the European Policies and the ambitious goal of halving the road fatalities in 2010. The project is co-funded by the European Commission Information Society Technology (IST) in the strategic objective "eSafety Co-operative Systems for Road Transport" and started its activity in January 2006.

In 2002 around one third of the total road accident fatalities have been vulnerable road users. This is still an unacceptable high number and needs to be reduced. WATCH-OVER will contribute to increase the safety for pedestrians, bicyclists and powered two wheeler riders. Therefore the WATCH-OVER project is carrying out research and development activities for the design and development of a cooperative system that is aiming at the circumvention of accidents involving vulnerable road users in urban and extra-urban environments. As stated in the 2005-6 Work Programme of the IST, the main objective of the WATCH-OVER project is "to develop and demonstrate cooperative systems for road transport that will make transport more efficient and effective, safer and more environmentally friendly." According to this objective, the system concept is based on the interaction of an in-vehicle module and vulnerable road user's devices. These devices will be directly integrated in powered two wheelers or in wearable objects like helmets, watches or consumer electronics. Such systems will notedly enhance the support obtainable to drivers and other traffic participants.

The European funded projects PROTECTOR and SAVE-U had already been investigating accident prevention involving vulnerable road users. Both initiatives had as main objective the analysis of systems that are based on in-vehicle sensors. Different sensor technologies, such as microwave radar, near and far infrared, laser-radar and mono and stereo vision had been evaluated. The final outcome however shows that the extent to which these technologies are applicable is limited to those scenarios in which the vulnerable road users are not hidden by obstacles or located in a "blind area" of the sensors.

Thus the main difficulty in the detection of vulnerable road users in complex traffic is the limited “visibility” of car drivers and of in-vehicle sensor based systems. Additionally, the complexity of the traffic scenario presents a number of cases in which vulnerable road users are suddenly getting out from an area that was covered by other vehicles or by the infrastructure and therefore could not be seen by the driver in advance.

- The cooperative system of WATCH-OVER aims at enhancing these soft spots by focussing on advanced short range communication technologies in combination with the most promising video sensing technologies. By this combination of technologies the detection of vulnerable road users in complex traffic shall be enabled and therewith the most critical road scenarios shall be covered.

The technological challenge will be the development of a cooperative system for real time detection and relative localisation of vulnerable road users that includes innovative short range communication and video sensing technologies. The implementation challenge will be the deployment of a reliable system that is versatile for different vehicles and vulnerable road users.

The system will be limited to urban and extra-urban areas only, so traffic situations on motorways or speeds higher than a certain threshold find no consideration in this project. To ensure an expedient design and development and the technical feasibility of the co-operative vehicle-user system, the WATCH-OVER consortium consists of vehicle and PTW manufacturers, technology, automotive suppliers and research centres for its development and testing phase.

In this paper the results of the first project activities are presented. The most relevant information needed for the development of the WATCH-OVER system is given as well as an overview on the defined traffic scenarios and use cases.

OVERALL PROJECT ORGANISATION

To succeed in developing an efficient cooperative system for accident prevention, the work in the WATCH-OVER project is divided into seven different work packages (WPs). In these work packages the tasks for the involved partners in the project are defined as follows:

WP1 Project management and exploitation
WP1 deals with the management of all financial, administrative, technical and non-technical aspects of the project. Key activities of this work package are the exploitation of project results, the association to other related R&D projects and the standardisation bodies.

WP2 User requirements and scenarios
The goal of WP2 is to identify the needs and requirements of the target users as well as to analyse the most relevant scenarios of application.

WP3 Overall system specification
In WP3 the functional architecture specifications of the WATCH-OVER system is defined. Furthermore, all communication and sensor technologies as well as the warning and intervention strategy will be specified.

WP4 Communication and Sensing Technologies
WP4 deals with the major technological aspects of the project. It will analyse and adapt the selected communication and sensing technologies and will additionally work on data fusion.

WP5 System development
In WP5 the different subsystems are developed as well as the on-board and wearable devices and related software applications. A particular attention is given to the HMI design for the driver and for the VRU.

WP6 Cooperative system test and validation
In WP6 the WATCH-OVER application will be integrated in the demonstrators for testing. The demonstrators will be: the vehicles, cars and motorbike and the wearable module. Besides technical and user acceptance tests will be performed.

WP7 Deployment strategies and dissemination
WP7 deals with the strategies related to the deployment of the WATCH-OVER system. In particular, the main activities are a thorough market analysis as well as a cost/benefit analysis, the evaluation of the impact on road safety and the dissemination of the project activities.

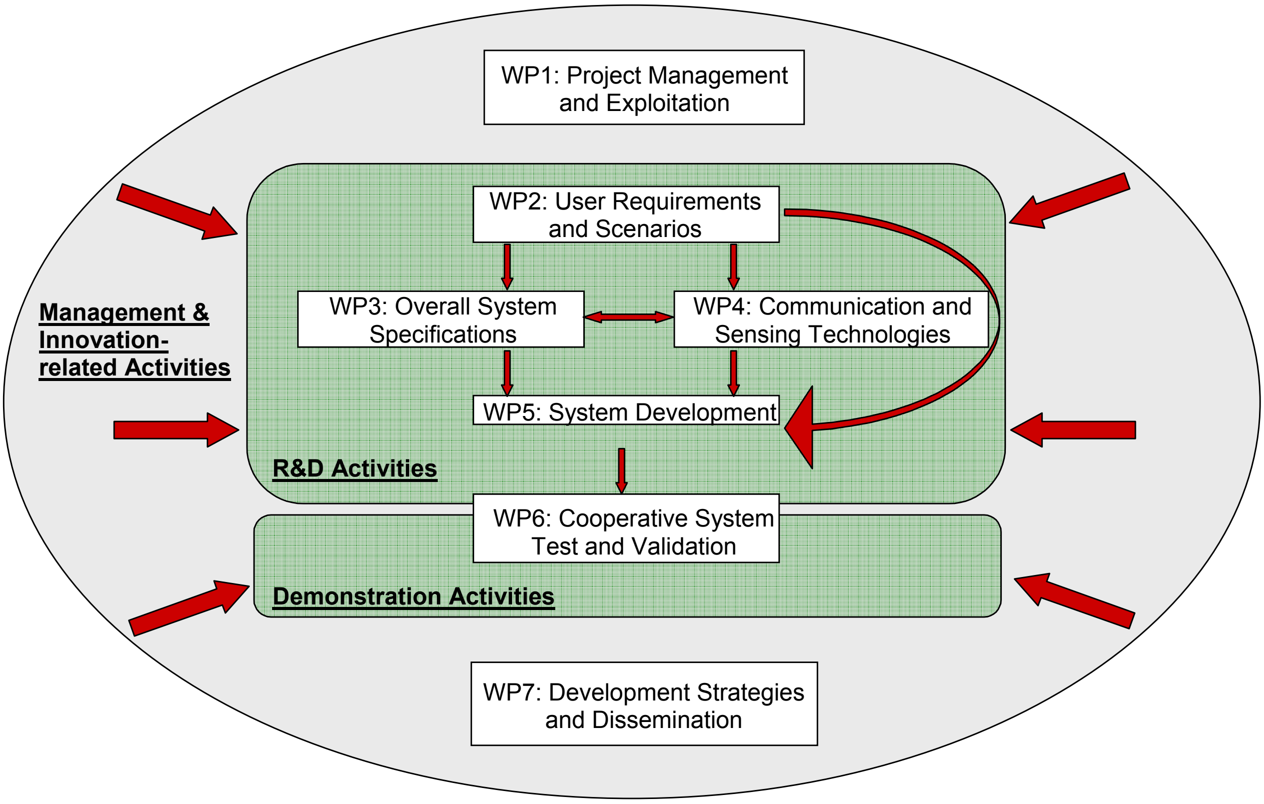


Figure 1. Overview on the WATCH-OVER project activities.

The chart visualises the organisation of the WATCH-OVER project, structured in the following main phases:

- "User Requirements and Needs" phase (WP2).
- "System Specification" phase (WP3).
- "System Development" phase (WP4 / WP5).
- "Testing and Validation" phase (WP6).
- WP1 and WP7 belong to the transversal phase that includes all horizontal activities.

THE WATCH-OVER SYSTEM CONCEPT

The WATCH-OVER system is composed of different components that are cooperating at the detection of vulnerable road users in urban or extra-urban scenarios. The system will enable the cooperation of different actors who communicate with each other in order to exchange data and share information.

While the vehicle moves along a road there are two sensing system in charge of collecting information of the external scenario, a vision sensor device and a communication module.

Vulnerable road users that are in a potentially dangerous position in front or nearby a vehicle equipped with the WATCH-OVER system will be identified with the vision sensor that recognises objects and motions and with the communication module that gathers the responding signals in the covered area. The vision sensor device focuses on the frontal part of the car and recognises objects and their motion on the image pattern. The communication module searches for responding signals in the area covered from the antenna(s) and calculates the relative position of each answering signal. The on-board device collects the different input and evaluates the risk level for possible colliding trajectories by means of data fusion. In case the risk level passes a certain threshold there will be both an alert to the driver and to the VRU module.

The reference architecture for the WATCH-OVER system is depicted in Figure 2. It presents the different components that each specific actor shall be equipped with:

- The car shall be equipped with the vision based sensor, the communication device and an on-board unit that performs data fusion and evaluates the objects relative positioning.
- The motorcycle shall be equipped with a communication system and an on-board unit able to collect and store information on the surrounding traffic flow.
- The pedestrian or bicyclist shall be equipped with a wearable communication module in order to be able to be recognised from vehicles equipped with the WATCH-OVER system

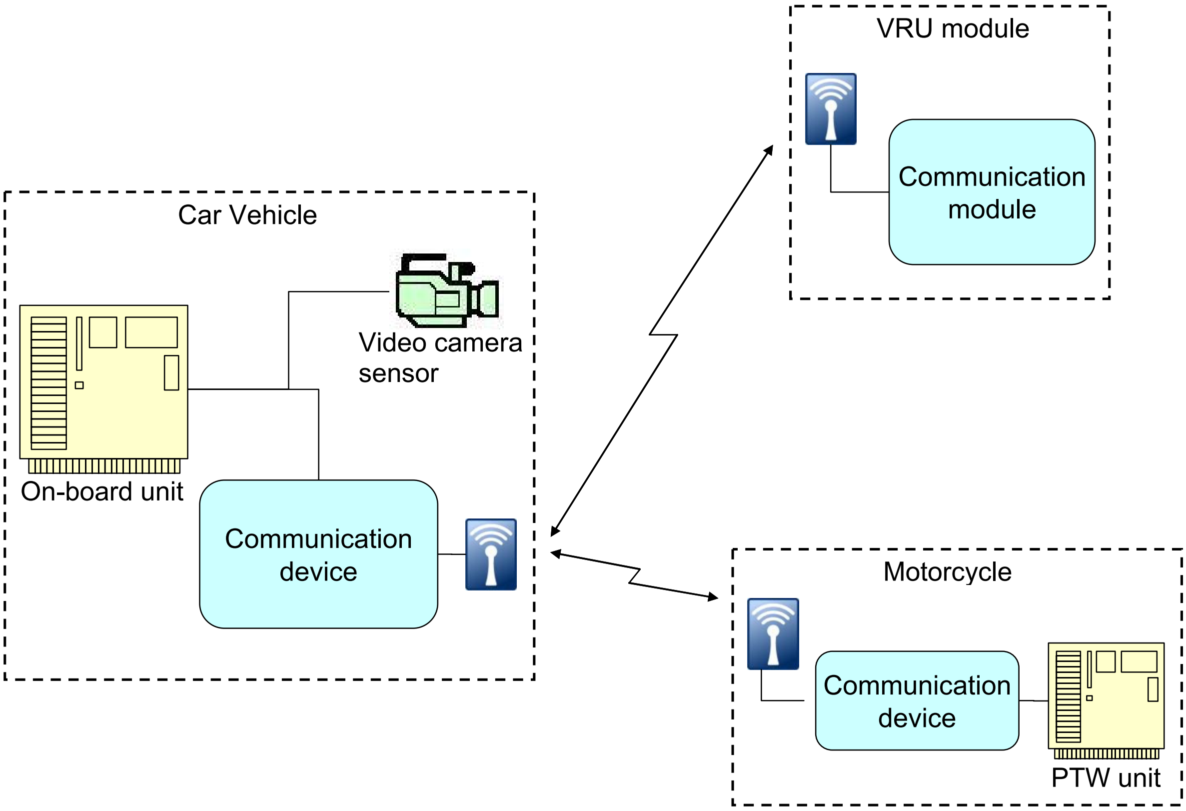


Figure 2. WATCH-OVER reference architecture scheme.

The above illustrated architecture organisation gives an overview on the used technologies for the different involved actors of the WATCH-OVER system. For general observation the video camera sensor is used on all car makers vehicles, the communication module will be present in one of the car manufacturer vehicles and in the PTW and additionally there will be a vulnerable road user module that is assembled with the communication short range technology.

The idea behind this architecture approach is that the WATCH-OVER cooperative system shall guarantee:

- a wider scenario coverage including blind spots and
- a flexible and open architecture.

Based on the use of most promising communication technologies in combination with most promising vision sensor technologies the WATCH-OVER system architecture presents the foundation for an efficient system for accident prevention that will further advance the findings of the preceding European projects PROTECTOR and SAVE-U. In order to do so the following characteristics will account for the design of the WATCH-OVER system:

- the extension of the “protection concept” by an effective driver warning and vehicle braking strategy,
- an increased vehicle speed range (up to 50 km/h) at which the system is operable,
- high reliability and timely performances related to the detection and localisation of the vulnerable road users,
- low cost sensor and communication technologies,
- an increased processing speed (more than 10 Hz),
- an increased sensor coverage (0–20m).

Specifically, the WATCH-OVER cooperative platform is expected to perform the following tasks efficiently:

- to promptly answer to vehicle's stimulus delivering its identification parameters,
- to send back a few self-localisation parameters,
- to give feedback to the specific traffic participants with an appropriate interface.

The WATCH-OVER application, consisting of the in-vehicle control unit and the communication and image sensing modules as well as the wearable devices including communication technology, will be tested to verify technical performances and user acceptance. Therefore it will be implemented in three demonstrator vehicles. As demonstrators two cars and one motorcycle will be used. For more complex traffic scenarios simulation tools will be applied.

COMMUNICATION AND SENSOR TECHNOLOGIES FOR VEHICLES AND VULNERABLE ROAD USERS

From the preceding projects PROTECTOR and SAVE-U substantial progresses have been achieved. While the PROTECTOR project showed that sensor technologies, such as stereo vision, laser scanner or 24 GHz radar, are suitable for the detection of pedestrians, the SAVE-U project showed that the fusion of GHz radar, a far infrared and a colour-video camera improved the detection performance of the PROTECTOR system by an order of magnitude concerning the number of false classifications.

The cooperative platform of the WATCH-OVER system will not only reduce the number of false classifications and extend the actual coverage of the state of the art technologies but will also be open to integrate localisation technologies.

The huge variety of different urban and extra-urban scenarios that involve numerous vulnerable road users is one of the main challenges the project is facing. Therefore the in-vehicle system is conceived to feature the following functionalities:

- real-time detection of pedestrians, cyclists, motorcyclists equipped with the WATCH-OVER module,
- calculation of the relative positioning of the user vs. drivers,
- detection of dangerous situations,
- appropriate warning to the driver, providing information only in really dangerous situations.

The sensing technologies that support the detection of vulnerable road users can be summarised in the following categories:

- Far infrared systems
- Vision based systems
- Microwave radar
- Laser radar.

The short range wireless communication technologies that support the detection of vulnerable road users can be summarised as following:

- Wireless Fidelity (WI-FI)
- IEEE 802.15
- Bluetooth
- Radio Frequency Identification (RFID)
- Ultra Wideband (UWB).

To identify those technologies suitable for the use in users' localisation mechanisms and to enhance cooperative systems even further, a set of state of the art technologies have been examined.

The communication system shall allow a two way communication between vehicles and vulnerable road users. The vulnerable road user shall be able to communicate with several vehicles and, conversely one vehicle shall be able to communicate with several vulnerable road users.

The in-vehicle and the wearable modules shall both have identical functionality regarding their Radio-Frequency-(RF)-modules.

The two way communication is required due to the following reasons:

- It should be possible to send out data from the vulnerable road user to the vehicle, so that the in-vehicle module can receive information about the position and the activity of the vulnerable road user. In addition, the RF-waves help to determine the local position of the VRU with regard to the vehicle.
- It should also be possible to send data from the vehicle to the vulnerable road user. This data might include:
    a) Information about the actual results of the in-vehicle module, e.g. a warning to the vulnerable road user about a potential risk.
    b) Control information to the wearable unit, e.g. detection of presence to increase the frame frequency.

The following pictures show typical situations in which the WATCH-OVER system platform will be applied and where the communication between the in-vehicle and the vulnerable road user module is established:

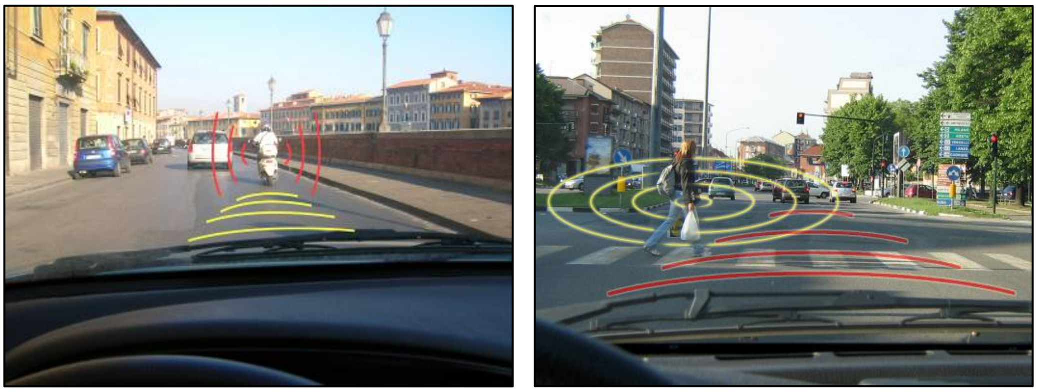


Figure 3. Typical scenarios in which the WATCH-OVER system will be applied.

From the scouting activities mentioned above, the following overall situation could be derived.

- It is assessed that communication based localisation and information flow between a vulnerable road user and a vehicle provide an additional means of increasing the accuracy of detection, ranging, and localisation.
- A broad variety of technologies exist. Due to cost, size, energy consumption and availability reasons, Short Range Wireless Communication (SRWN) are a major candidate to provide communication and localisation.
- Technologies and products for SRWN rapidly evolve. A broad choice is available for communication purposes.
- From this large choice, only selected technologies are inherently suitable to offer ranging and localisation.
- The number of technologies can be further reduced when two additional parameters are regarded:
    1. The accuracy of many of the inherently location-capable systems is at a low level, so that the use cases of the WATCH-OVER project cannot be covered.
    2. Practically all RF-systems working in the GHz-range are theoretically capable to support ranging. However, for doing this they must be equipped with additional circuitry, which accesses the low-level, high-accuracy timing information at the signal input. Therefore, it is only realistic to use existing hardware.

Many of the ranging-capable systems are either only prototypes, or are addressing a different market.

- This could be observed for most of the UWB-based products, where contacts to the manufacturers showed their meagre interest in applications beyond consumer electronics.
- Unfortunately the same situation was encountered during the examination of other eSafety-related communication protocols and products.

Taking into account the above mentioned parameters and the evaluation of existing technologies, it was decided to further proceed with the following approaches Based on the evaluation done above:

- A Chirp Spread Spectrum (CSS)-based system, described in IEEE802.15.4a, turns out to provide a good trade-off between bandwidth consumption, hardware efforts and achievable accuracy. This was evaluated under real-life conditions in extensive measurement sessions.

  CSS-based systems are already available as an integrated circuit (IC), allowing low power, low footprint and flexible designs at reasonable cost.
- UWB-systems promise a good accuracy, if time-of-flight measurements are used. This could be affirmed through various simulations.

  The simulation was oriented towards an UWB-emulator. This system comes with a very generic approach and promises a very high flexibility.
- Systems for self-localisation allow accuracy well below the level of the two relative ranging systems selected above). However, due to their absolute positioning, they allow consistency checks and maps. As GPS / Galileo based systems are assumed to come for free in future product generations, it is reasonable to include their information into the sensor fusion, as well.

During all the future efforts, the aspects of security and privacy must be considered.

USER REQUIREMENTS AND RELEVANT SCENARIOS

Besides defining the technologies used for developing a cooperative system for the prevention of accidents, it is very important to analyse the needs of the future user and to describe the relevant scenarios in which the system will be applied.

The analysis of the user requirements has to be conducted at the beginning of the project as they are of crucial importance for the development and implementation of the system hardware and software architecture. In the WATCH-OVER project user requirements have been interrogated by a questionnaire that was answered by non-technical experts, who were pedestrians and drivers themselves and commute regularly with cars, motorcycles and bicycles. The questionnaire was divided into two different parts:

1. One part acquired the user requirements concerning the in-vehicle Human Machine Interface (HMI).
2. The other part retrieved the prioritisation of the before established traffic scenarios and the possibility to propose new accident situations.

The first part of the questionnaire focused on the prospective output of the WATCH-OVER system. In particular on how and when a warning or information should be given. Users were asked to specify their preferences and, according to their answers, system requirements could be derived:

In case of no accident risk,

3. the system should only inform the driver of the presence of VRUs (location, distance, etc.) on demand.
4. the visual information should appear on the head up display or on the instrument cluster.
5. the system should inform the driver of the presence of VRUs regarding the distance and the heading of the vulnerable road user on demand only.

In case of an acute accident risk due to the presence of a VRU,

6. the system should warn the driver.
7. the warning should be a tone/beep or an icon on the display.
8. secondary important information provided, are the relative position, the weather, the height of the pedestrian and the momentum.
9. These information (see item 5 and 6) should be presented by an icon on display or by a tone/beep.

In addition general conclusions concerning the set up of an efficient HMI could be derived from previous projects and they were considered important for the WATCH-OVER project as well:

- The allowance for false alarm should be very low. If a driver perceives too many false alarms, the warning will be ignored.
- The warning should be given acoustically and therefore must be heard.
- Mere visual information is not sensible and might possibly decrease safety due to its distraction effect. A combination with acoustic information might be useful.
- The warning should be given early enough to allow the driver to react well considered.

The second part of the questionnaire displayed 16 traffic scenarios to the users and asked for a prioritisation according to the estimated frequency, the level of support needed and the conditions under which support would be needed most. The scenarios were defined beforehand by a multiple approach. First of all the available data on road accidents involving vulnerable road user were analysed as well as the outcomes of previous projects focusing on similar topics as WATCH-OVER, then an expert group of the WATCH-OVER project reviewed the systematic definition of the scenarios and assigned the final list of relevant scenarios. This list of relevant scenarios was then displayed to the external non-technical users.

The result of this user requirement survey is the selection of eight use cases that will be approached in the course of the WATCH-OVER project. The use cases are prioritised according to the estimated relevance for road safety. The key parameters that describe the use cases even further were set up by experts and evaluated by users and can be described as the following:

- Type of vehicle / vulnerable road user
- Type of road.
- Relative trajectories.
- Vehicle’s / vulnerable road users’ speed.
- Time to collision.
- Time of day.
- Weather.

The scenarios have been grouped according to the estimated occurrence and the relevance for road safety. Only those scenarios indicating a high estimated occurrence as well as a high relevance for road safety will be directly addressed by the WATCH-OVER system development. Scenarios with only a medium estimated occurrence and therefore with a medium expected impact on road safety were also considered but will not directly affect the WATCH-OVER project.

The following sketches demonstrate those scenarios affecting the WATCH-OVER system directly and thus being addressed in the testing phase.

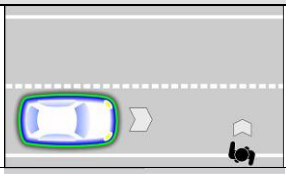
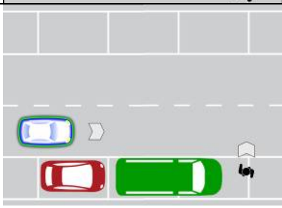
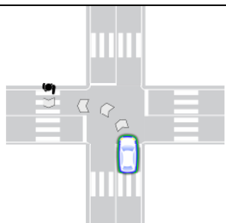
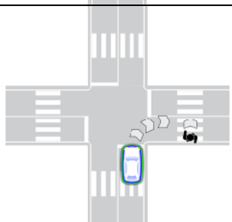
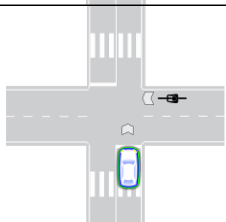
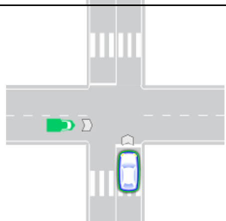
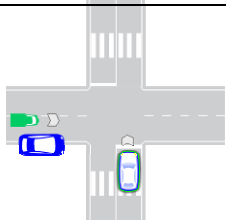
Description	Sketch
1. Pedestrian (or cyclist) crossing the road from the right to the left.	
2. Pedestrian (or cyclist) crossing the road from the right to the left (or from the left to the right) occluded from parked or stopped cars or other obstacles.	
3. Vehicle turning left at an intersection, pedestrian crossing the road from the right to the left (or from the left to the right).	
4. Vehicle turning right at an intersection, pedestrian (or cyclist) crossing the road from the right to the left (or from the left to the right).	
5. Vehicle on a crossroad, pedal cyclist crossing the road from the right (or from the left).	
6. PTW arrives from left side (or from right side) at intersection, paths perpendicular.	
7. PTW arrives from left side at intersection, paths perpendicular, occluded from parked car or other obstacles.	
8. PTW (or pedal cyclist) and vehicle travelling in opposite directions, vehicle turns in front of PTW.	

Figure 4. Scenarios addressed by the WATCH-OVER system.

WATCH-OVER HMI CONCEPT

In the WATCH-OVER expert workshop not only issues regarding the identification of traffic scenarios and user needs have been discussed, but also issues relating to the development and implementation of the WATCH-OVER Human Machine Interface (HMI). The main objective of the HMI was to diminish the number of false alarms or warnings given by the interface in order to avoid an information overload for the driver or the vulnerable road user. The best solution of course would be to evade false alarms completely. To realise a system that is efficient in driver warning it is important to be coherent throughout the warning strategy and to avoid redundancy.

To establish a coherent warning strategy, the WATCH-OVER warning concept follows the approach of Wickens et al. (2004): “The goal [of a warning] is to get the user to comply with the warning and, therefore, use the product in a safe way, or avoid unsafe behaviour.”

To achieve this professed goal four elementary requirements have to be fulfilled:

- The warning must be noticed.
- The warning must be perceived (read/heard).
- The warning must be understood.
- The warning must be accepted.

That means in detail that a warning has to draw attention of the driver or the vulnerable road user. In a second step it has to be ensured that the warning is not only noted by the addressee but moreover apprehended and then accepted. In addition the system should be able to give information about the identified risk and about recommendable actions to be taken by the driver or the vulnerable road user.

Besides defining the approach for an efficient warning strategy it is also crucial to analyse and then follow existing standards, guidelines and recommendations for HMI design as well as those still under construction in order to comply with statutory provisions.

The major requirements for HMI functionality that will be followed by the WATCH-OVER system are listed below:

- The system must comply with relevant regulation and standards.
- The system supports the driver and does not increase driver distraction from driving task.
- The system shall not require uninterruptible sequences of interaction.
- The system does not distract or visually entertain the driver.

- No part of the system should obstruct the driver's view of the road scene.
- The system response (e.g. feedback, confirmation) following driver input should be timely and clearly perceptible.
- Information which has the highest safety relevance should be given priority.
- The behaviour of the system should not adversely interfere with the display or controls required for the primary driving task and for road safety.
- The system must be error relevant.

The main goal of the WATCH-OVER HMI, as stated before, is the avoidance of misunderstandings and of an overload of the addressee, in WATCH-OVER namely the driver or the vulnerable road user. Only information assisting the driver more than distracting him in complex traffic situations should be provided by the HMI.

Thus the WATCH-OVER HMI persecutes the following approach:

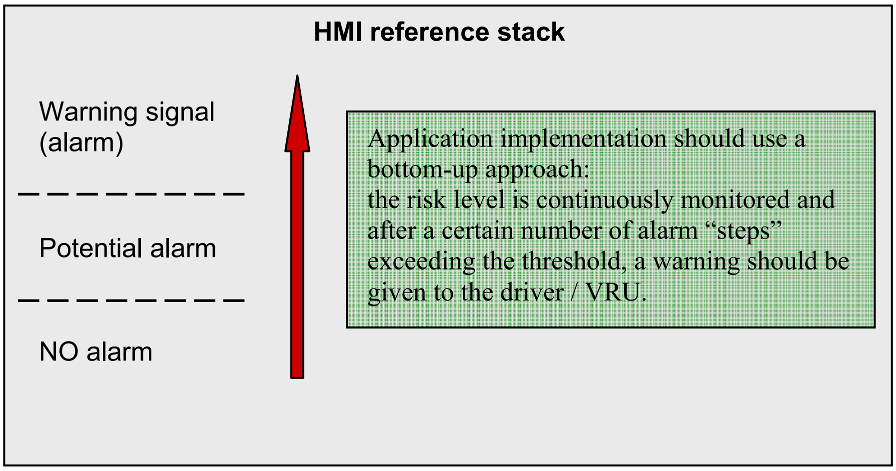


Figure 5. HMI approach followed within the WATCH-OVER project.

This concept foresees a continuous evaluation of the risk level by the WATCH-OVER system. If the risk level is approaching a certain threshold that was specified beforehand, the system will give a warning to the driver or the vulnerable road user respectively. The thresholds will be identified according to the different risk levels.

This approach is adopted because the WATCH-OVER experts assume that it will ensure a system development that does not potentially distract the driver or the vulnerable road user but will instead assist him in complex traffic situations. Intrusiveness by the system has to be prevented as it may lead to switching off the system altogether. If the HMI interface is too pervasive, with an intensive visual or acoustical output presented to the user, it will give rise to an increase of distraction of the addressee. Thus it is important to not only minimise but eliminate false alarms as well as an overload of information in all cases if possible.

CONCLUSION

WATCH-OVER is a European project that aims at the design and development of an integrated cooperative system for the accident prevention involving vulnerable road users in urban and extra-urban areas. The project is coordinated by Centro Ricerche Fiat and assembles in its consortium 13 project partners from six different European countries. The consortium presents vehicle and PTW manufacturers, automotive suppliers, technology and research centres for the development and testing phase.

The system core is the cooperation of an in-vehicle unit with a user module based on communication and sensor technologies. The in-vehicle module will locate vulnerable road users that are in potentially hazardous locations and will then give a warning signal to the driver. On the other hand the wearable user module will draw attention of the vulnerable road users to dangerous traffic situations. The interaction of the different modules rests on the exploitation of innovative wireless short range communication technologies and promising sensor technologies. With this cooperation the actual coverage of existing systems will be extended and the WATCH-OVER platform will in addition be open to the integration of localisation technologies.

The WATCH-OVER in-vehicle platform will then be supplied with the following main functionalities:

- Real-time detection of vulnerable road users (pedestrians, bicyclists, motorcyclists).
- Relative Positioning of the vulnerable road user vs. the driving vehicle.
- Identification of dangerous situations.
- Appropriate warning to the driver.

The project activities are now focusing on the final design of the system architecture. The most appropriate communication technologies will be selected and a new generation of CMOS cameras is being developed. Furthermore, the development phase of the WATCH-OVER HMI has just started and will be further promoted within the ongoing project activities.

An important milestone has been achieved by establishing the collaboration with the European project SAFESPOT. The applicability of the WATCH-OVER system is aspired within the future framework of the cooperative system for road safety developed within the SAFESPOT project.

Such cooperative platforms will significantly help accomplish the goal of reducing the number of road fatalities and thereby to further enhance road safety

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