# Multimodal Conspicuity-Enhancement for E-Bikes: the Hybrid Reality Model of Environment Transformation

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## ABSTRACT
A prototypical conspicuity enhancement (CE) system for vulnerable road users (here e-bikes) is described. We stress that CE is a form of multimodal output. We argue that previous CE approaches have the drawback of affecting uninvolved (road) users. We argue further that augmented reality as an alternative is error prone because objects need to be tracked. Our system implements the hybrid reality modality model, where directed information emanates from the objects themselves and therefore no object recognition/tracking is needed. We describe the components of a functional demonstrator based on standard compliant car-to-car communication components.

## ACM Classificatio Keywords
H.5.2 Information interfaces and presentation: User Interfaces, User-centered design

## General Terms
Design,Human factors

## INTRODUCTION
Car-to-car communication is currently being rolled out in large scale field tests. However, researchers have only recently begun to systematically investigate suitable user interfaces. A novel type of UI exploiting car-to-car capabilities was recently explored by the car-to-car communication consortium. The aim of the so called "lateral cross-traffic assistant" is to increase safety at intersections. Car drivers approaching the intersection on minor roads receive a warning message when they (apparently) miss the stop sign. Moreover, when a motorbike is involved, the two-wheeler automatically switches on a so called *conspicuity enhancement* consisting of flashing headlights, additional flashing lights in the side windshields as well as the horn coming on. The motorbike driver remains completely passive in this situation. He does neither switch on the conspicuity enhancement, which is done automatically by car-to-car communication, nor does he act as addressee of the warning. Two forms of presenting the same information to the same user – the car driver – are used: 1. audio-visual inside the car + 2. audio-visual outside of the car (multimodal fission). We call the latter modality *transformation of the environment*.

The scenario has obvious drawbacks: the motorbike driver is not directly involved but may be affected. Moreover, completely uninvolved road users are likely to see the flashing lights and hear the horn as well. Generally, a problem with transformation of the environment is that multiple agents (here drivers, passengers) are interacting with one and the same environment. This becomes even more apparent if we think of personalizing electronic traffic signs or adapt the content of videowalls according to the needs of specific users. One possible solution to the problem is the *hybrid reality approach*: Let us call the original scenario above *full reality*. Alternatively, we could use *augmented reality*, i.e. optical tracking technology and visual markers on the windshield in order to obtain the same effect (at least in some of the cases). Each variant comes with advantages and drawbacks. With augmented reality, objects need to be recognized and tracked. In the above case, tracking is likely to be unreliable because the object (M) moves very fast. In contrast, full reality does not need tracking, because M's flashing lights (and the horn) are immediately perceivable by the addressee. However, as the information is not directed, it is perceivable by anyone and can thus have a negative effect. We define *hybrid reality* as a solution in-between, where (mostly visual) directed information emanates from the objects themselves and therefore no object recognition/tracking is needed. [5]

The demonstration system described in this paper implements the hybrid reality model based on standard car-to-car communication compliant components. It can be regarded as an advanced version of the above described cross-traffic assistant. Before we go into detail describing the hybrid reality aspects, we want to stress another issue that we addressed with this prototype. In order to successfully introduce such warning systems for other vulnerable road users such as scooters or bicycles, the technology needs to be less complex (and therefore less expensive). Our system is especially designed for


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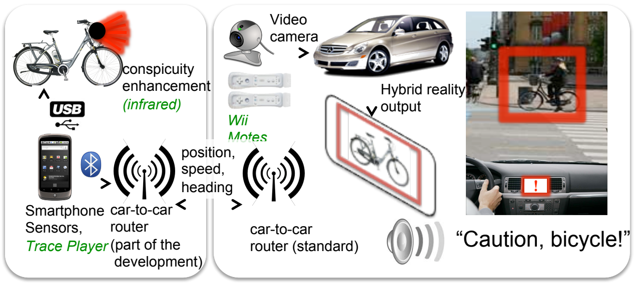


**Figure 1:** Demo System. Green, italic components are simplifications that are necessary for the demo and are not intended to run in a real-life system.

e-bikes, because: 1) e-bikes are an increasingly popular green-mobility solution for inner city traffic, which are able to drive considerable faster than regular bicycles (up to 55 mph). Therefore, safety solutions need to be investigated. 2) E-bikes are less expensive than motorbikes (need for cost-efficient solutions). However, compared to regular bikes, the prices of an e-bike (2000 to 4000 EUR) justify the costs of car-to-car communication hardware (the prototype presented here is based on electronic components worth 120 EUR). The same argument holds for the additional weight of the equipment. 3) E-Bikes already come with a human machine interface (HMI) – a small device mounted on the handle-bar, which allows the driver to control the supplementary power by the electric engine. Unlike a bike computer, this is an essential component. It therefore makes sense to integrate additional car-to-car based function into that HMI.

Figure 1 illustrates the demo system. A customary Android smartphone replaces the regular e-bike HMI. It is mounted onto the handle bar and is connected via bluetooth to the communication unit (CU), which joins the car-to-car communication network via 802.11a wireless LAN. CU is also connected to the conspicuity enhancement component via USB, which can control a variety of modules like LEDs or a horn. We designed the system to be low-cost, modular and easy to install. CU is built upon a low priced routerboard [2] and runs a modified version of the popular OpenWRT [1] distribution, which is publicly available. The system is compatible with current car-to-car communication technology as we use a custom version of the NEC Communication SDK [3] kindly compiled by NEC for our platform. The SDK abstracts a protocol stack for car-to-car communication via Wireless LAN technology.

Technically, the main difference between the proposed solution and the motorbike system cited above is that the e-bike component does not have an application logic by its own. It constantly broadcasts its current position, heading and vehicle type (so called car-to-car beacons). The threat detection is completely done by the car. When necessary, it sends a command to the e-bike to turn on the conspicuity enhancement. This approach allows to run a very lightweight system on the e-bike,

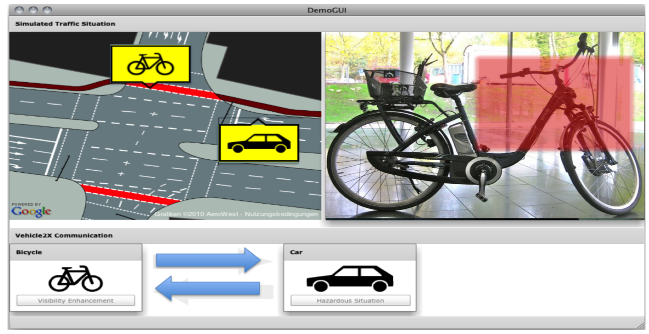

**Figure 2:** Left: pre-recorded GPS traces are played back. Bottom: car-to-car communication is illustrated by blinking arrows. Right: Hybrid reality output is shown by a web camera picture with graphical overlay.

because it does not have to track nearby vehicles and calculate most probable paths. It does not even need to have a map (however, we plan to add one for value added services that go beyond the immediate safety aspect).

Another difference is that it implements the *hybrid reality* model. As mentioned above, conspicuity enhancement could in principle be done by regular lights or a horn. However, we used infrared lights instead. Infrared is not visible by the Human eye and therefore uninvolved road users cannot see it. The car transforms the IR light into a visible marker on the windshield (see Figure 1, right). Together with the audio-visual warning message on the screen it is combined to a multimodal output that fullfils the definition given above. In the prototype system, the transformation of IR light is done simplistically using two IR cameras (Wiimotes) for triangulation and a regular web camera that emulates the view through the windshield. In a real life system, the transformation obviously needs to be integrated into the windshield (which is beyond the scope of this paper). The actual demo consists of: e-bike HMI, IR conspicuity enhancement module, car-to-car routers, video camera and wiimotes, and a 10" screen with loudspeakers (as a replacement of the in-car HMI). Additionally, we show a demo interface that visualizes the car-to-car communication between the two vehicles as well as the hybrid reality output (see Figure 2).

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