SMART ROADS
IN THE PERVASIVE COMPUTING LANDSCAPE

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Abstract
Physical objects capable of supplying computing services to users by utilizing hidden pervasive computing technologies are considered to be smart. Allowing not only a physical correspondence of object and enabling technology but also a logical one substantially increases the set of real objects to be considered as smart.
This paper presents an innovative thought model of virtually smart things, i.e., objects in the real world not physically equipped with sensory gadgets or interaction facilities, but also being aware of their surrounding environment by their virtual representation. The main focus of the following sections concentrates on a Smart Road, a fully implemented use-case, telling its users where to go.

1. Pervasive Computing Landscape

The pervasive and ubiquitous computing landscape is defined by an assortment of enabling technologies attached to small, embedded and mobile devices (often referred to as "smart things", "smart appliances" or "smart spaces") interacting with the user in a pro-active, autonomous, sovereign and user-authorized way [1][2]. Objects of everyday life are equipped with e.g. wireless network technology, microprocessors, etc., invisible for the users, in order to perform and control a multitude of tasks and functions via natural interaction leaving the users unaware of the technical implementation.

Up until now, hardware technology is physically attached to objects or integrated into appliances or the surrounding environment in order to enhance these things with computing services and to therewith make them smart (e.g., smart tables, smart offices, smart environments [3]). In the future, however, smartness will not only be achieved by affixing technical equipment onto tangible devices: Any object in the real world may act as a smart thing by just virtually augmenting it with computing services.

2. Smart Roads

As a major challenge, the road appears to be a good example for a virtually smart thing, being too large to be area-wide equipped with sensor-, actuator-, controller-, and communication technology, but also asserting a claim to provide computing services: A smart road shall e.g., be capable of guiding a driver to a desired destination.

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The services virtually smart things provide shall ubiquitously be accessible to the users in an intuitive and natural way, thus maximizing the degree of perception by the users [4]. To support people living in the real world in acting, perceiving and interacting with virtually smart things, we propose a see-through-based theatre experience of visual perception, seamlessly merging the components of the real and the digital world.

3. Concepts and Design Studies

Regarding the smart road, every car's windshield can transact the allegory of the see-through-based theatre and be used to superimpose the digital information of the smart road in front of the real world outside the car. Having this vision in mind, a smart road can provide the following services to its users (see Figure 1):

a) A smart road guides a driver to a beforehand specified destination by virtually drawing the intended route in color. It therefore takes the task of a car navigation system and appears to be intuitively understandable.

b) A smart road notifies possible hazards on the street to its users, conspicuously increasing safety aspects in the road traffic.

c) A smart road context-sensitively (i.e., in coordination with other smart devices or external sensor instruments) calls attention to points of interest located along the route.

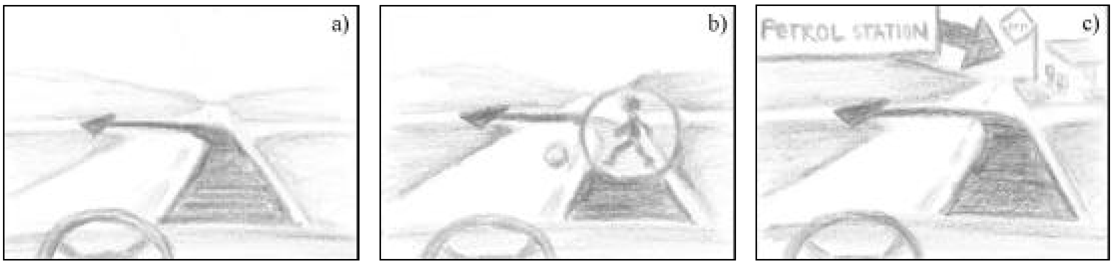

Figure 1. Smart road concepts

We believe the utility of those services of smart roads being better exploited when they are presented in a preferably adequate manner to the user, so we were also engaged in carrying out design studies on the augmentation of the digital information (see Figure 2):

a) A semi-transparent depiction of the path enables users to recognize junctions occluded by other vehicles or blind summits.

b) Bubbles on the road, meant to be collected by the driver (closely associated with the Pac-Man game), represent an alternative approach for visualizing the route.

c) The most natural manner to head for a destination is to follow somebody who knows the way, thus demanding a virtual car in front of one's own car, blinking, braking and accelerating, making the navigation aspect as intuitive as possible.

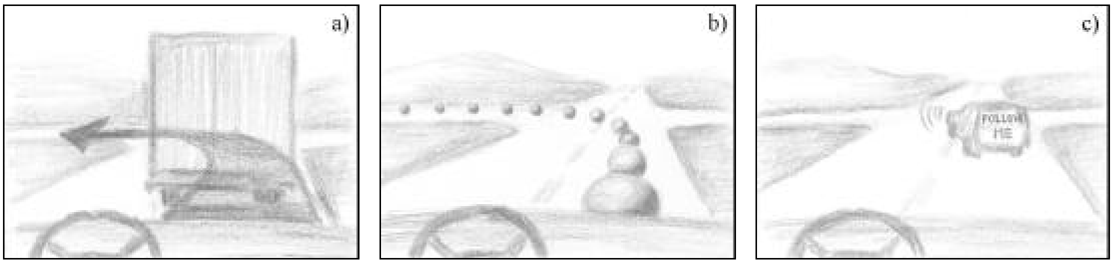

Figure 2. Smart road design studies

4. Technical Approach

Due to the lack of sensory equipment and communication facilities of roads a virtual road model has to be computed by processing the data coming from a conventional navigation system, its maps, and the received GPS signal. A combination of the current position, the orientation, topographical data and the calculated route enables the computation of a three-dimensional depiction of the route as it may look from the driver's perspective, which is then superimposed on a live stream video of the road ahead and shown on the navigation display (see Figure 3). Current head-up displays using the windshield are not yet maturely conceived to be used as a see-though window as originally intended.

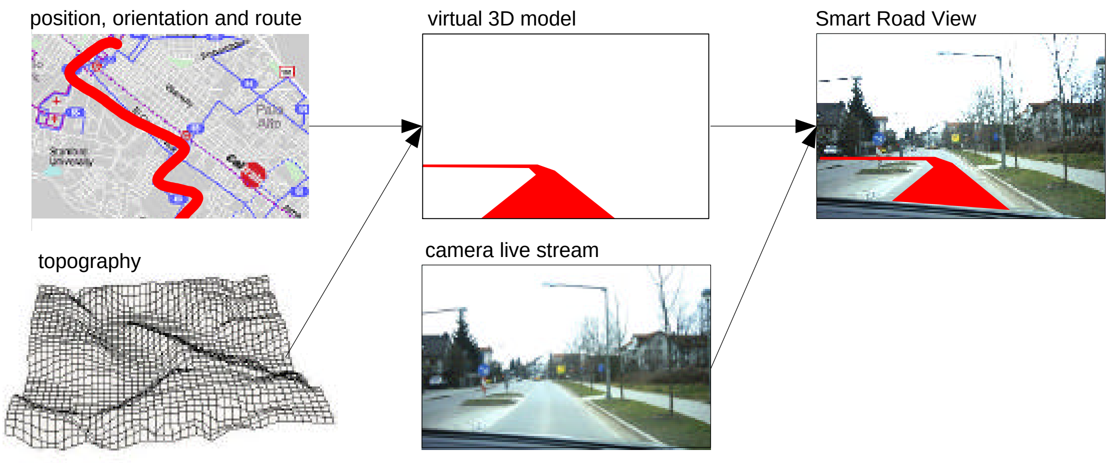

Figure 3. Calculation model for smart roads

5. Implementation and Experiences

A prototypical implementation of a smart road has been developed in cooperation with Siemens Corporate Technology in Munich, Germany, the University of Linz in Austria and the Ars Electronica Futurelab in Linz [5]: A video camera mounted behind the rear-view mirror captures the scene in front of the car and a commercially available notebook computer (plugged on to an off-the-shelf navigation system) calculates the three-dimensional model of the recommended route, while a color display presents the user interface and the smart road illustration (a translucent three-dimensional band) to the driver. The prototype is fully functional and already available in a real car, allowing any real world navigation experiment to be executed (see Figure 4).

Figure 4. Smart road prototype

We consider the smart road to be an excellent example of a virtually smart thing and have therefore applied the basic concepts for a patent. A smart road represents an innovative, self-explanatory and easy to understand paradigm in the pervasive computing landscape, which helps to avoid indistinctness concerning maneuver instructions, and conspicuously enhances traffic safety: The driver perceives navigation information quickly and intuitively and is always aware of the current traffic situation ahead. Even while looking at the navigation display he is able to survey other road users.

In the course of our cooperation, we have been able to realize large parts of our concepts and design studies (see Figure 5), validating the ideas of smart roads and their applicability as hypothesized in the beginning of this paper.

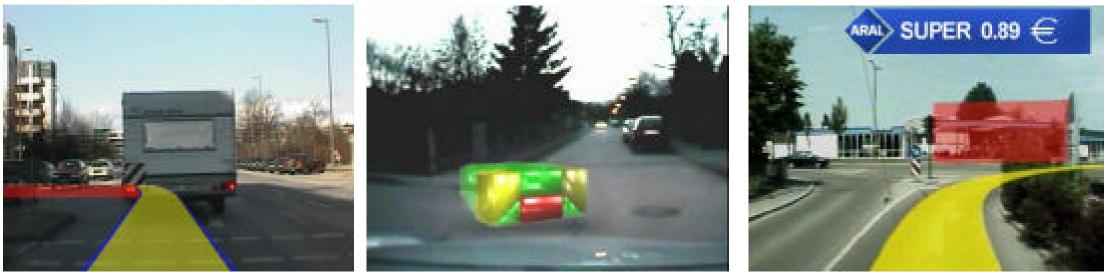

Figure 5. Implementation of smart road concepts

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