The Sentient Car: Context-Aware Automotive Telematics

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ABSTRACT

We consider the implementation of a vehicle-based sentient space, which enables context-aware on-board systems with the ability to cooperate and adapt to changing conditions and events. This paper also describes the Sentient Car as a testbed, and the Adaptive Pollution Map as the first application that uses this platform.

Keywords: *Telematics, vehicle, context, mobility.*

SCENARIO

In-vehicle information systems of non-trivial complexity are already commonplace for electronic engine management, entertainment, voice communications and safety systems. GPS-based mapping and guidance systems have made their commercial debut and are already widely deployed in other markets such as Japan.

These subsystems will increase their usefulness once they cooperate with each other to form an integrated system, and once they adapt their behaviour to suit the situation. For example, the cellular telephone that is already present in many cars might be used by the mapping and safety subsystems as a long-range data communications channel for sending out traffic and pollution information about the area currently visited by the car, and for receiving such information for the area that the car plans to visit next. The route finder might then choose to avoid an otherwise convenient-looking route in favour of another that uses a less congested road. Similarly, monitoring driver behaviour (steering, braking, accelerating) and atmospheric conditions may allow the safety subsystem to give early warning of dangerous driving situations. Aircraft-style cockpit recorders ("black boxes"), the high-tech evolution of today's truck tachographs, are another plausible development, and their non-trivial implications on personal privacy are well worth investigating.

We are exploring the above scenarios in the field. We have equipped a vehicle with several sensing, computing and communicating subsystems, all interconnected to form an integrated sentient car system, and we are building a framework to allow each of these subsystems to act as a supplier or a consumer of contextual information about the car, the driver and the environment. In future experiments, a central server will also collate and redistribute the information from several cars. We are also interested in seamless context-driven handover between communication channels of different capacity, coverage and cost, such as GSM and 802.11b.

Figure 1 Sentient car dashboard

SYSTEM RESOURCES

We have equipped our experimental vehicle, a Ford minivan, with two dashboard LCD displays (figure 1), one for the driver and a larger one for the navigator, and with the following subsystems.

Sensing. We measure various air pollutants with sophisticated sensing equipment (figure 2). We also have a tap into the Electronic Control Unit of the vehicle to extract velocity, acceleration, temperature, steering wheel position etc. A GPS receiver gives the geographical position of the car to 10 m accuracy.

Figure 2 Pollution Sensors

On the software front we also sense the availability of the computing and communication resources: network connectivity, communication cost, communication bandwidth etc.

Computing. A full-size tower PC in the back of the van has interfaces to all the sensing and communicating devices, as well as ample storage and computing capacity.

Communication. A GSM cellphone and modem respectively provide voice and low-speed data connection with almost universal coverage. An 802.11b network card provides a much higher speed data link but with limited coverage.

The conceptual model of the sentient car system sees each of the sensors as an input to a "context server" that delivers context information to the on-board systems and to the communication resources manager. Each activity can then be optimally adapted to the current situation.

SAMPLE APPLICATION: ADAPTIVE POLLUTION MAP

One of the first applications we have developed on this platform senses the air quality around the car and overlays it on a map of the area that the car is visiting. In due course, multiple cars will upload such pollution data to a server that will then redistribute more complete and more up-to-date maps to all of them.

The client-server application is split into a client-side map viewer, running in the car, and a server-side map repository running at the fixed base station. We wish to explore the architectural issues that arise when maps have to be delivered over a channel of varying capacity and therefore we pretend that the whole map won't fit on the in-car computer's hard disk. This is not true for our current experimental setup, but it might be once we move to richer media including for example real time video footage of highway traffic (figure 3).

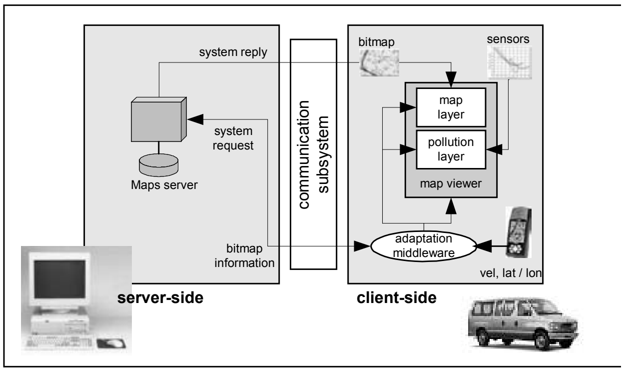

Figure 3 Application overview

The map viewer is arranged into layers. We currently have two: a bitmap layer showing the actual map and a pollution layer showing our air quality measurements. Many other layers could be added: for example a waypoints layer, a vector map layer, a traffic layer and so on (figure 4).

The portion of map that the viewer displays is affected by user input (scroll, zoom in, zoom out) and by the current context, which right now consists primarily of the car's location and velocity as reported by the on-board GPS. However the channel capacity (which goes up when the car is in an area of 802.11 coverage as opposed to just GSM) is another interesting input. As the car moves, we request a new bitmap to cover the relevant area, but we do so taking into account the time it will take to download it over the available channel.

For example, using 8 cm x 10 cm map tiles of 176 kb each, the time it takes to download one tile over the 9.6 kb/s GSM modem is 18.3 seconds. If we are travelling at 100 km/h heading NE, which tile should we request from the server, and at what scale, so that we are still in the middle of it when we have finished downloading and displaying it, 18.3 seconds later? This is a context-dependent calculation which is affected by position, velocity and channel capacity.

We are interested in the architectural issues of managing such updates in real time and with a pool of several cooperating cars all uploading and downloading information into a collective map database.

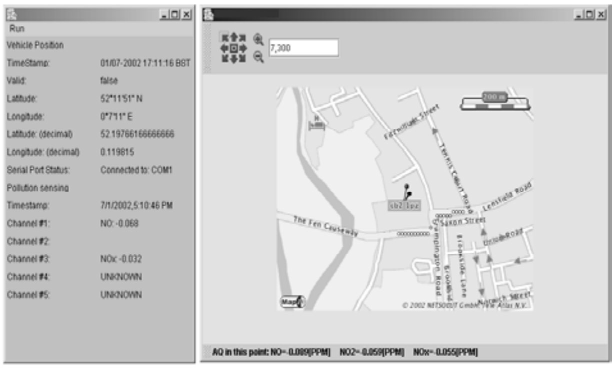

Figure 4 Adaptive Pollution Map

CONCLUSIONS

Sentient spaces are increasingly popular in building environments such as the office and home. The use of sentient spaces in cars will enhance the capacity of on-board systems dramatically, and will allow them to cooperate to provide and consume context information and adapt to frequently changing conditions. On-board systems must deal with more hostile heterogeneous conditions than apparent in sentient buildings, therefore knowing the context is even more important.

The Adaptive Pollution Map application shows the utility of sensing space around the vehicle in order to deliver service with different resources available.

ACKNOWLEDGEMENTS

Pablo Vidales has a scholarship from the Mexican government through the National Council of Science and Technology (CONACYT). The Sentient Car is funded by the Cambridge-MIT Institute (CMI).