A Sensor Platform for Sentient Transportation Research

Jonathan J. Davies, David N. Cottingham, and Brian D. Jones

Computer Laboratory, University of Cambridge,
15 JJ Thomson Avenue, Cambridge, CB3 0FD, UK
{jjd27,dnc25,bdj23}@cam.ac.uk

Abstract. This paper describes the creation of a vehicle-based sensor platform as part of research into sentient computing. We outline the challenges faced when building this platform and describe our techniques for overcoming them.

1 Introduction

The field of sentient computing is concerned with computers interpreting and reacting to sensor data in our every-day environments [1]. One such environment is that of transportation. We have prepared a vehicle-based, scalable sensor platform that is capable of sensing properties of the vehicle and its environment to provide context for intra- and extra-vehicular applications. Our goals for the platform included the ability for non-technical users to be able to use the vehicle without specialist knowledge, the collection of a large corpus of data and the creation of a general-purpose research platform.

2 Deployment

Cars are the most popular form of transportation on our roads and are thus an obvious subject for research into sentient transportation. However, building and operating an effective research platform requires significant in-vehicle space for its deployment, testing, and operation. Additionally, the vehicle should provide sufficiently unobtrusive trim in order to facilitate the installation of the equipment. We selected a Renault Kangoo van which meets these demands whilst maintaining a car-like exterior.

A vehicular environment is harsh, involving physical shocks, extremes of temperature and a lack of abundant power. This imposes limits on the computing equipment. We selected a Mini-ITX industrial-form-factor PC with a 1 GHz CPU consuming only 18 W, which performs comparably to an equivalent desktop PC (50 – 100 W), as a suitable choice for this environment. A 2.5" laptop hard drive was chosen to provide higher tolerance to vibration than conventional desktop drives.

2.1 Sensor Infrastructure

In order to facilitate research into context-aware applications, a platform is required which allows a wide range of sensors to be easily installed.

Sensors have a wide variety of power requirements and data rates. For example, a thermometer might emit a one-byte reading per second whereas the data rate from a digital video camera will be many orders of magnitude larger. Rather than attempting to provide a single data bus to meet these needs we elected to provide three separate communications buses. This permits the simple deployment of low data-rate sensors without precluding the use of sensors with more ambitious demands.

Low data-rate sensors are accommodated on a Controller Area Network (CAN) bus. Due to its rugged nature, similar technology is commonly used in vehicles for communication with built-in sensors. Interfacing a sensor with this bus does not require complex or high-speed hardware and is thus cheap.

Interaction with commodity devices such as GPS units and RFID readers is through a USB tree. This facility can also support ad-hoc attachment of personal devices. RS232-to-USB converters permit easy support for legacy serial devices. The length of the cabling required means that a USB 1.0 bus is more suitable than the higher-speed USB 2.0.

Higher data-rate devices are supported by a 100 Mbit Ethernet network. However, for such sensors, it is most preferable for them to perform as much processing as possible in hardware—such as MPEG encoding of video data—to relieve the on-board computer of this burden. The high speed nature of Ethernet means that interfacing is significantly more demanding than with the CAN bus.

At the time of writing, the platform integrates the following sensors:

- **CAN bus.** Thermometer, humidity sensor, barometer, tilt sensor, two-axis accelerometer, two-axis magnetometer;
- **USB.** GPS receiver, RFID reader, OBD-II interface;
- **Ethernet.** Digital video cameras.

The OBD-II interface is a standard supported by all modern vehicles for accessing data regarding the vehicle's operation. The specification of this standard supports a huge range of sensors but the subset which is available is vehicle-specific. In our vehicle, the available data include the engine speed (rpm), road speed, engine load (as a percentage of the peak available torque), air intake temperature, fuel rail pressure, intake manifold pressure and engine coolant temperature. Furthermore, the maximum rate at which data can be read from our OBD-II interface is limited to approximately 2 Hz. However, sensors such as the engine's velocity and load can vary substantially over the course of half a second. To minimise this problem as much as possible, we sample the sensors at adaptive rates sensitive to their operating characteristics.

2.2 External Communications

Data collected by our platform is not only useful for on-board context-aware applications, but also for those on other vehicles or fixed infrastructure. Hence, the vehicle needs to support communication with infrastructure providing ubiquitous coverage, and with more localised communication end-points. As a vehicle travels it will experience varying degrees of network connectivity; high-speed networks should be exploited when available.

To make use of WiFi hotspots, the vehicle has an IEEE 802.11b/g wireless LAN interface, which is also used as the primary means of communication when the vehicle is at base. In the future, inter-vehicular and vehicle-to-roadside communication will take place using the Dedicated Short Range Communications standard. To conduct testing of this technology in urban environments, we employ an IEEE 802.11a interface which operates in a similar manner. Meanwhile, a GPRS/UMTS interface provides a near-ubiquitous, low-bandwidth Internet connection.

2.3 Power

Vehicles cannot rely on any permanent connection to an external power source. This necessitates careful management of available power resources. In particular, it is important never to flatten the vehicle's main battery and to provide a stable power supply to the sensing platform. These goals were achieved through the use of an auxiliary battery, charged from the vehicle's alternator whilst the engine is running. A failsafe hardware power cut-off protects against draining the auxiliary battery in the event of the computer erroneously entering a stuck state.

For non-technical users to be able to use the vehicle, no specialist knowledge can be required to operate it. They cannot be expected to switch equipment on or off or monitor its state. We have designed the system to function in a fully-autonomous fashion, for all sensor data to be logged to permanent storage and uploaded automatically on return to base to enable post-processing.

3 Evaluation

Both technical and non-technical drivers have contributed to a corpus of sensor data for journeys in both urban and motorway environments. To date, we have collected over two and a half million data points, allowing a comprehensive picture to be built up of how the environment varies with location and time.

We have been able to easily install new sensors into our existing platform due to its scalability and modularity. In particular, we have found that utilising a dedicated sensor CAN bus has greatly simplified the communication interface between arbitrary sensors and the on-board computer.

Context-awareness plays an important role controlling the collection of data. One example is the use of camera data, where the frame rate is linked to the speed: when travelling at high speed on a motorway, there is little of interest, and hence the frame rate is decreased, whilst for low speeds (particularly in cities), a higher frame rate is desirable.

Our platform is being used for applications as diverse as driver expression inference [2], with a view to running real-time analysis on the driver's emotions;

automatically deriving digital road maps from GPS traces; and evaluating the performance of wireless technologies.

4 Related Work

An emerging example of utilising vehicles for mobile sensing is that of the collection of road traffic data [3] to permit authorities to better manage the transportation infrastructure and to permit navigation based on real-time congestion information.

Work has also been done in producing a platform for general collection of sensor data, such as the Instrumented Car [4] which is equipped with a variety of sensors obtaining data about the driver, the vehicle's emissions and its environment. Another related project is CarTel [5] which seeks to provide a mechanism for distributed sensor data to be queried and transferred. Our work builds upon and generalises these ideas into a multi-purpose vehicular platform for research into all aspects of sentient transportation, where the goal is accessibility, extensibility and scalability in the sensing platform.

5 Conclusion

This paper has described a vehicular sensing platform and has highlighted some of the challenges we experienced in its construction and their resolution. We hope that these experiences will help to inform the construction of similar vehicles in the future.

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