Using GPS to enhance the control and effectiveness of a public transport system

Bill Goodchild and *Steve Fairhead* of Hanover Displays Ltd, Lewes, Sussex describe how they have used the NavCore V GPS board to design a passenger bus navigation and control system. This design was their winning submission to the *Electronic Engineering*, Rockwell International/RCS Microsystem's Design Challenge.

We will describe here the use of GPS navigation to assist in the control and monitoring of a public bus transportation system, for use initially in Montreux, Switzerland.

The finished system uses the RCS Microsystems NavCore V board [1], shown in figure 1 and the M37450 controller board.

Prior to commencing this project the authors' company had gained considerable experience in the design and development of vehicle navigation and monitoring systems.

One example developed by the author's company is currently operating around Heathrow Airport, in London, and uses the vehicle odometer as the basis of a system based on dead reckoning. That system receives periodic zero reference signals from infra-red beacons located around an established route.

While such systems are successful, the use of the odometer alone offers a solution but not one that is tolerant of diversions and route changes. Transport navigation systems are enhanced if the cost of the beacons and associated land costs can be removed and the vehicle can become autonomous. A GPS-based navigation system has the potential to offer such a solution, especially if it is combined with data obtainable from an odometer.

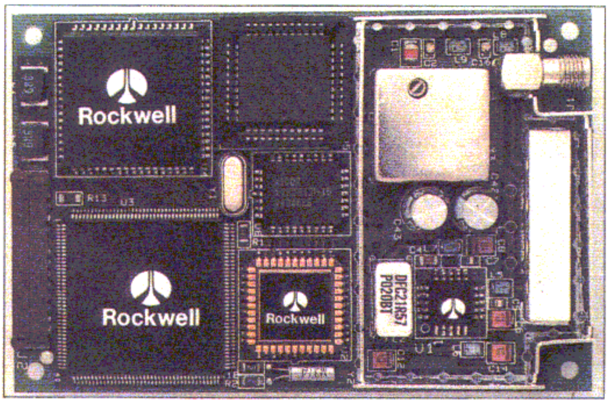


Figure 1: The NavCore V GPS receiver engine

Defining the problem

The problem that was presented to the authors' company came from a Swiss bus company who needed a navigation system that could serve a number of purposes at moderate cost. They were: to provide public information to the passengers, ie, next stop information; to control the issuing of tickets with reference to the correct fare and travel zones; and finally to enable automatic control of traffic lights to optimise the movement of the bus though the town.

As well as making the vehicles autonomous (ie, no beacons), another part of the specification was the need to service multiple routes with the same basic equipment, routes that could be a mixture of both scheduled and non-scheduled. The initial routes were "tight" in that the distance between stops could be less than 150m.

System design

Figure 2 is a schematic diagram of the system as finally configured for the bus navigation application, with the basic GPS navigation system in one colour (mauve) and the additional GPS components in another (beige).

As well as the input from the odometer and the GPS board the system (figure 2) also shows another input, which is a signal that the bus doors

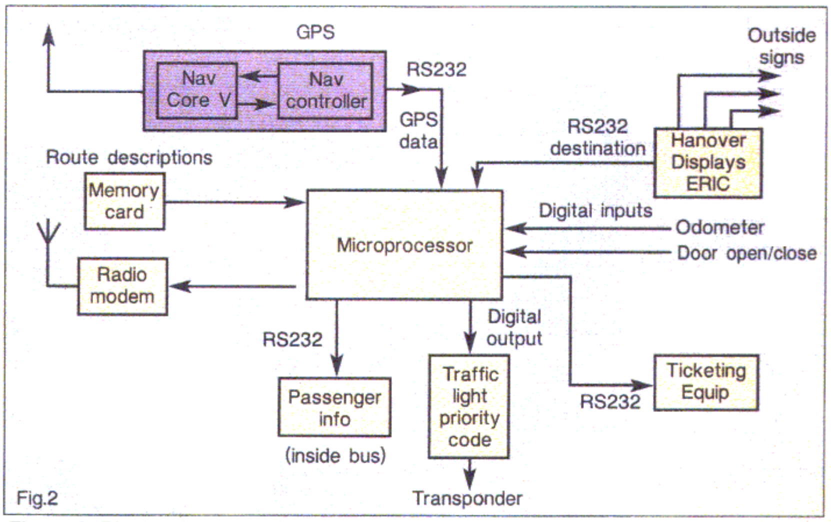


Figure 2: Block schematic of the complete bus navigation system

have been opened. Door opening, while not a certain indication that a bus stop has been reached, is a highly probable indication, and can be qualified by context.

The system is provided with three types of navigation information. The odometer can provide excellent accuracy but becomes inaccurate if for example the bus is diverted, especially if the diversion is of the same order as the distance between bus stops. The door opening is precise within a metre or so, but doors are not opened exclusively at bus stops. The GPS system can provide accuracy typically, but not invariably, within 100m.

Other inputs and outputs of the system are RS232 links to the ticketing machine and to the passenger display of the next stop inside the bus. The driver control console (ERIC), which provides output to destination signs on the outside of the bus, also inputs the chosen route to the system via an RS232 link.

The route descriptions are provided to the system from a memory card. A digital output interfaces the traffic light priority code to a transponder which couples to loops buried in the road. Some systems will require a means of reporting back to route managers and a VHF radio modem can be supplied for this purpose.

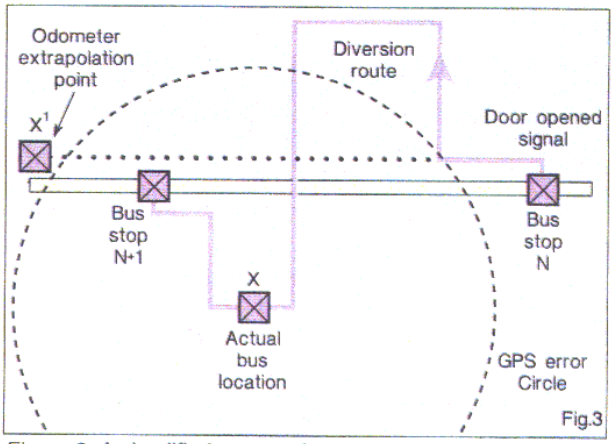


Figure 3: A simplified aspect of the navigation

The navigation algorithm

Before discussing the manner in which two processors, the Mitsubishi M37450 and the industrialised PC, are used, it is worth outlining the navigation problem.

Figure 3 illustrates just one part of the navigation problem between two bus stops N and N+1. Assume the bus stops are about 150m apart. The bus recognized that it was at bus stop N from the door open/close signal that locks the system reference, within a metre or so. The bus starts its journey, and the internal indicator now shows the next stop as N+1. The bus gets diverted, perhaps along side streets. At bus location X the odometer signals will indicate the bus has travelled a distance greater than the stop-to-stop distance. The question that the navigator must be able to answer is: has the driver passed the stop N+1, or is the bus on a diversion?

The GPS system will locate the position to within about 100m. If the inferred odometer distance along the true route is outside the error circle of the GPS system then the probability is high that the next stop is still N+1.

The exact description of the algorithm is proprietary and will not be discussed further here. However, the algorithm plus the I/O servicing is processor time consuming for the PC. If to this is added the further overhead of sorting the multitude of data that is available from the GPS engine board, it was the view of the designers there was a chance that the PC would become overloaded, slow down and impair the system response.

The solution was to use the RCS Microsystems controller board to "pre-digest" the wealth of GPS data down to a few essential parameters needed by the bus navigator. These were: time of day; latitude and longitude; speed; heading; the status or figure of merit. Some data filtering was carried out, eg, to maintain the heading data when the speed is zero.

The use of the controller board allows the GPS system to be treated as an intelligent peripheral of the navigator.

While the RCS Microsystems NavCore V is used for the final version of the system, others were evaluated. Under conditions of multiple reflected signals, obscuration and signal discontinuities, it proved to be superior.

Although many competing GPS systems operate effectively in open-sky situations, bus routes operating in towns and closed areas must be tolerant of imperfect data. The bus

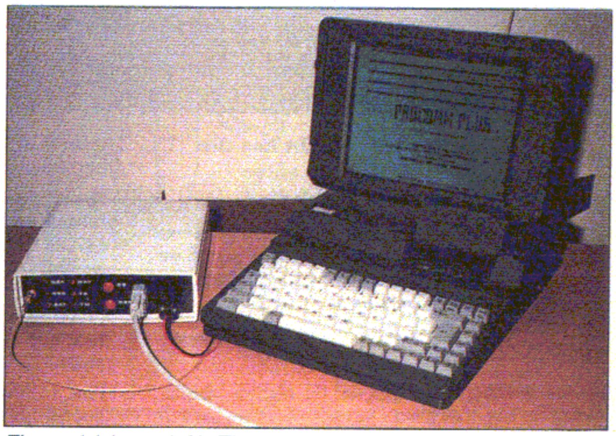


Figure 4 (shown left): The prototype system
Figure 5 (shown above): The GPS system as an I/O unit

navigator algorithm was designed to be very tolerant of such imperfections. Furthermore the GPS acts in a confirming role rather than the single source of navigation data.

Dual processors

The prototype system, which also served for system development, is shown in figure 4. It used an off-the-shelf industrialised PC as the main processor. Within the PC enclosure are: a 386SX processor, digital I/O, a high spec power supply unit, memory card reader and floppy disc. The separate GPS system is shown in figure 5.

The software development budget for the main system was about six man months while that for the NavCore V controller board was about two man weeks. The authors would like to acknowledge assistance of the customer service department of RCS Microsystems, which considerably reduced the controller board software development time.

All the software has been written in 'C' and, other than that which is DOS specific, this will allow it to be ported via a cross compiler to the embedded processor that will replace the PC in the final version of the navigator. The embedded processor chosen for the final design will be the Hitachi H8.

Field trials

The field trials of the system proper have consisted of two phases.

Phase 1, which has already been completed, used the Swiss bus system for data collection. One of the buses was fitted with a data logger to record the odometer readings, door opening and GPS signals as the bus moved along various routes. This data was recorded on a memory card which could then be returned to Lewes in the UK to be used as a simulator tool for the system under development. Figure 6 shows a section of route data obtained from one of the memory cards (and also demonstrates some of the imperfections of the GPS signal, such as phantom sideways jumps caused by building reflections); the circles are 150m in radius and centred on bus stops. The second phase will be to deploy a fully developed system with the embedded processor for test in vehicles operating in a real route situation.

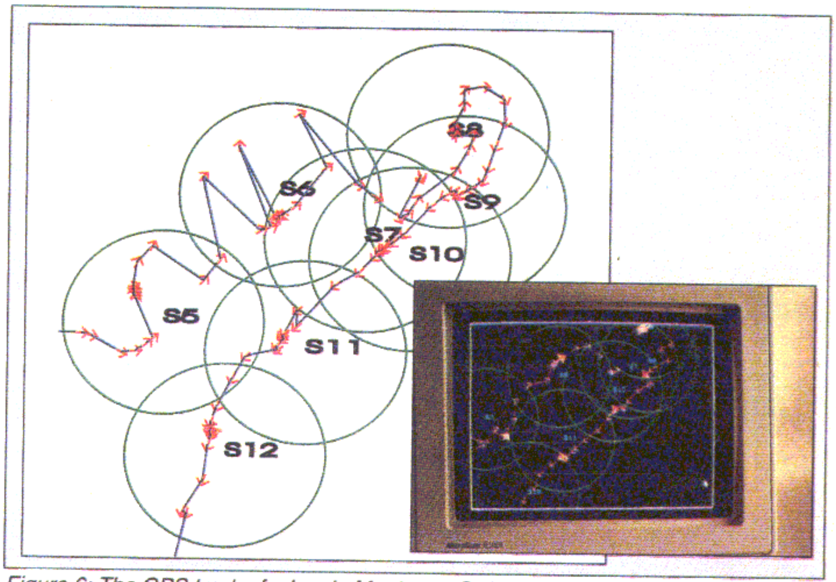


Figure 6: The GPS track of a bus in Montreux, Switzerland

Extensive tests to evaluate the accuracy and reliability of the GPS system were undertaken in the area of Lewes and Brighton in Sussex, in both rural and urban conditions.

Figure 7 shows the track of a vehicle exiting the Cuilfail tunnel on the A26 and joining the A27 via a roundabout. The arrow heads are 5s markers. The track first appears at the exit to the tunnel, the driver clearly slows down to enter the roundabout, the distance between arrowheads shortens. Then the path round the roundabout can clearly be traced. The roundabout is approximately 30 metres in diameter; there is no doubt with respect to the location of this vehicle. □

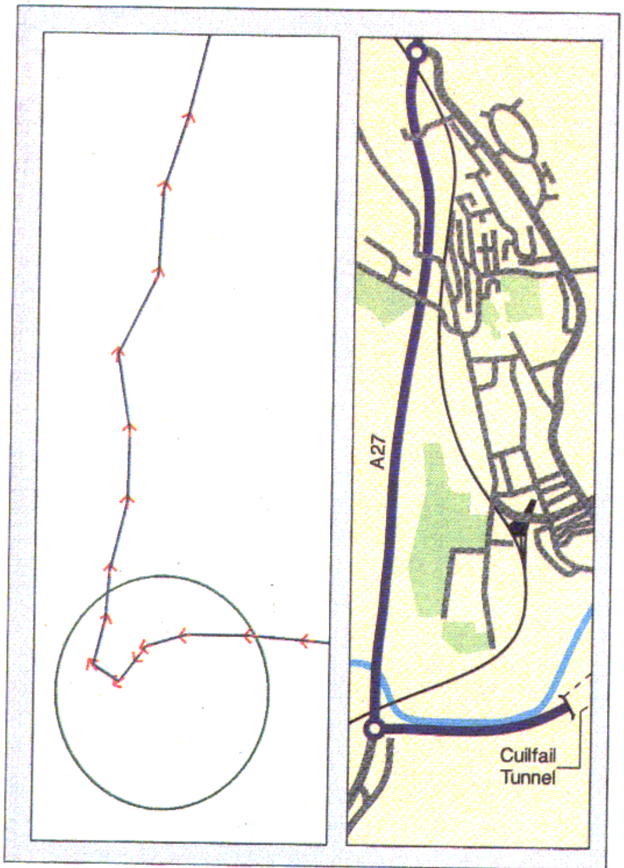


Figure 7: A vehicle mounted GPS system, moving along the A27 in Sussex, having just negotiated a roundabout.

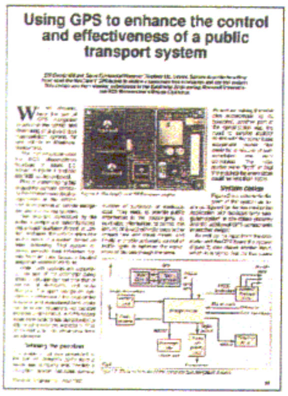
Reference

[1] NavCore V — an OEM component for a satellite based global positioning and navigation system, Electronic Engineering, June 1992, pp41-46.

EEDC-92/93 presentation

Success and good fortune always seem to go together with hard work. We would also add, from our perspective, that good engineers and serious engineering are also prerequisites for success. The two engineers from Hanover Displays, Lewes, Sussex, shown in our picture below, receiving their award for the *Electronic Engineering* Design Challenge '92/93, are part of a double success story. As we go to press, as well as the Design Challenge, it has been announced that Hanover Display's are the recipients of a Queens Award for Export.

Reader's must now focus on the next design challenge, the preliminary announcement of which was in last month's edition on p5. Maybe it will help someone else gain a Queen's Award!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Shown right: At the recent Design Challenge award presentation, from left to right, recipients Steve Fairhead and Bill Goodchild of Hanover Displays, and joint presenters Mike Callison, Publisher of Electronic Engineering, Roy Phillp of Rockwell International and Brian Coleman of RCS Microsystems Ltd.

Shown left: The lead page of the winning submission to the Electronic Engineering/Rockwell International/RCS Microsystems' Design Challenge, from Electronic Engineering, April 1993, pp49-53.