UNB Fredericton–A Hotbed of GPS Research

by Prof. Richard B. Langley

Fredericton is on the move. Yes, we all know the city is on the move in economic development with the recent opening of the new convention centre, construction of new retail stores, and the expansion of the Knowledge Park, and so on, but did you know that Fredericton is actually physically moving?

Fredericton, along with the rest of Canada, sits on the North American tectonic plate, one of a number of plates or huge slabs of rock into which the Earth's crust is broken up. These plates move with respect to each other due to various driving forces including the heating of the plates from the hot mantle below. The motion is quite slow, on the order of centimetres per year (about the rate at which your nails grow), but it is continuous and at the University of New Brunswick's Department of Geodesy and Geomatics Engineering (GGE), it is being measured by very sensitive GPS receivers.

A recent analysis of the data collected by one of these receivers, in continuous operation for over 10 years, showed that it (along with the rest of Fredericton and the surrounding area) is moving to the northwest at a rate of about 1.7 centimetres per year. That might not seem like a lot but it has to be accounted for in any high accuracy positioning with GPS such as that performed by surveyors and geodesists.

Monitoring plate motion is only one of the many leading-edge GPS research projects underway at UNB. One of the GPS receivers at UNB is dedicated to weather forecasting. The signals from the GPS satellites must travel through the Earth's atmosphere on the way to the ground and they pick up information on its behaviour, particularly how much water vapour it has. Through special processing of the signals, the amount water vapour can be measured. The U.S. National Weather Service uses the data from the UNB receiver, along with others, to improve its daily forecasts.

While the GPS signals can be used for weather forecasting because they contain information about the atmosphere, that also causes problems for the ordinary use of GPS for positioning and navigation. If we don't correct for the effect of the atmosphere, then we get errors in a receiver's position that can amount to tens of metres. At UNB, we developed an accurate computer model for the effect that is included in the operating software of many of the GPS receivers being marketed today.

It is not widely known that development of GPS began in the early 1970s and that the first test satellites were launched in 1978. It was around that time that research on the applications of GPS started at UNB. Although GPS satellites are replaced from time to time as they age, they are very robust and some have operated for over 20 years. And they all still transmit the same legacy signals that the very first satellites transmitted. However, GPS is now going through a modernization program with the launch of a new class of satellite with new, more capable signals. Researchers at UNB have been among the first to work with these new signals and to develop methods to use them to improve the use of GPS in different environments such as wooded areas and around buildings.

You may have heard that several countries are developing satellite navigation systems as alternatives and adjuncts to GPS. Russia recently rejuvenated its GLONASS system, which is now fully operational. Combined GPS/GLONASS receiver microchips have been developed for use in cell phones and vehicle navigation units. Having access to satellite signals from both systems can be a big advantage, especially in built-up areas where buildings might block too many signals from one of the systems to determine a position. But by using the available signals from both systems, the receiver can easily get a position fix.

Researchers at UNB have worked with the GLONASS system for many years. In fact, the Russian Federal Space Agency, which has responsibility for civil use of GLONASS, uses data from one of our continuously operating combined GPS/GLONASS receivers to help it monitor the status and performance of the system.

The Europeans are developing the Galileo satellite navigation system. Like GPS and GLONASS, it will have global coverage. Four test or validation satellites have already been launched and Galileo is scheduled for preliminary operation by about 2015. Once again, UNB is at the forefront and is working with the signals being broadcast by the test satellites. Data from a Galileo-capable receiver is streamed in real time to DLR, the German Aerospace Center, which uses it to monitor the atomic clocks in the satellites. Tests we have carried out with DLR colleagues showed a real benefit of combining data from GPS and even just one Galileo test satellite for navigating in the heavily tree-lined city of Savanna, Georgia.

Although standard uses of GPS in positioning and navigation require no more than a few metres of accuracy, there are some applications such as the plate tectonics example given earlier that require centimetres or even millimetres of accuracy. And developing methods and applications to achieve such accuracies has been the hallmark of a lot of UNB's GPS research and development work. For example, UNB scientists and engineers have developed a system for automatically steering giant cranes around container ports using GPS with an accuracy better than two centimetres. And similar accuracies are being obtained in studying the behavior of the active volcano on the Caribbean island of Montserrat.

And then there is space weather. What is that, you ask? Space weather includes a variety of phenomena taking place in the Earth's upper atmosphere (the ionosphere and magnetosphere), well above the region where ordinary weather develops. These phenomena are caused by outbursts from the sun interacting with the upper atmosphere and the Earth's magnetic field. The aurora borealis or northern lights is a beautiful and benign result of space weather, just like a rainbow is following a storm on Earth. However, severe space weather events can disturb the operation of communication satellites and ground-based systems such as electrical grids and pipelines. They can also affect the performance of GPS and the other satellite-based navigation systems.

UNB researchers have been using GPS to study space weather with the aim of better understanding its effects on GPS signals and have developed techniques to minimize those effects when using GPS for positioning and navigation. While a certain understanding of the effects can be obtained using the signals recorded with a network of ground-based receivers, such as the Canadian High Arctic Ionospheric Network operated by our colleagues in UNB's Department of Physics, even more can be learned by placing GPS receivers on low Earth-orbiting satellites. We designed and developed a GPS instrument, together with the Canadian Space Agency, the University of Calgary and the aerospace industry, to fly on the Canadian scientific satellite CASSIOPE, to be launched in 2012 from Cape Canaveral. The instrument will profile the density of electrons in the ionosphere as well as precisely determine the position, velocity, and attitude of the satellite.

Thanks to its dedicated and motivated researchers–faculty, staff, and graduate students alike, Geodesy and Geomatics Engineering at UNB is a world-leading centre of GPS research. While the department is also well known for other fields in which it excels such as ocean mapping and the development of geographic information systems, the GPS work likely played a major role in the decision of the university a couple of years ago to award the department its highest ranking award for research: 1-star. GGE was the only department on the Fredericton campus to receive this prestigious ranking.

What is the future of GPS research at UNB? When it comes to GPS, literally the sky is the limit.

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