FROM THEORY TO PRACTICE

Field Area Checks Using GPS (2)

In our July issue we published the first of two articles addressing the use of GPS in agricultural field measurement, particularly in relation to EU subsidy checks. In it the author gave some background. In this second article he answers questions such as how do we know that the equipment works, is GPS better than a wheel, and is it worth paying double for brand X as opposed to brand Y?

The story that people like to tell is this. Soon after selective availability was turned off in 2000 an inspection team arrived to measure a field on a farm somewhere in the EU. After producing various tapes, wheels and suchlike the inspectors saw the farmer grinning at them: "Youâ€™re certainly confident that your fields are the right size," they remarked. "Oh yes," said the farmer, "I measured them - with this." And he pulled from his pocket a palm-sized computer attached to a GPS. The following year the inspectors were back in the field with GPS.

Survey Theory
Classical surveying has focused on point positioning of well-defined features on the ground: vertices that can be used to â€˜digitiseâ€™ the boundary between two features. Most survey measurements emphasise linear or planar position and do little to guarantee the area of the polygon measured. For example, most mapping services give details of planimetric â€˜ambiguityâ€™ of points for different map scales but do not accept responsibility for the area estimate. As described in the first article, we found that a continuous collection of points neatly solved this problem and helped to cancel out random errors in the observations, giving a good estimate of land parcel area. The mathematical theory can be summarised as follows. Any measurement tool has error or uncertainty associated with the measurement. The error is basically either random or systematic. Systematic error, which appears as bias, can usually be handled through various technical approaches. But uncertainty of measurement means that you cannot improve on the accuracy of your estimates except through statistical processing and analysis. One simple way to improve accuracy is to take an average result of many observations. For example, many off-the-shelf receivers offer a function that collects data over some seconds and gives you a mean of the position rather than the instantaneous one.

Parcel Measurement
The approach we developed for land-parcel measurement does just that: it assumes that for half the points the error will be outside the land parcel, and the other half will be inside; in other words, the errors start to cancel each other out. Another neat thing is that if the measurements are biased â€“ for example, all shifted 3m to North â€“ this bias is cancelled out. Statistically, we were able to show that for certain kinds of GPS data the assumptions required by the theory were met in typical conditions; errors are pretty random over longer periods of time. GPS data over shorter time intervals is in fact quite auto-correlated: in other words, one GPS position has very similar errors to those immediately following it. But data collected for around 1min is not significantly correlated, so for most land-parcel measurements this is no problem; to walk around a perimeter of 100m usually takes at least one minute (at 5km/h). This does, however, set a minimum size on the parcel that can be measured.

Uncertainty
The uncertainty on the measured area decreases as the field size increases; this is because the absolute area of uncertainty is linked to field-boundary length, times â€˜buffer corridorâ€™ of the error left and right of the operatorâ€™s path. For fields of 0.5ha to 5ha there is a range of 1% to 5% in typical Coefficient of Variation (standard deviation expressed as percent) values (CV). Of great importance is that field shape has a very limited effect upon the statistical uncertainty of the measured area, so two parcels with the same area (but differing shape) can be measured with about the same accuracy. Further, field measurement should be carried out at a speed appropriate to the size of the parcel being measured; depending on operator speed and acquisition rate there is a combination of these values for which the CV values are less favourable. For parcels up to 4ha the â€˜optimumâ€™ range of speeds for operators on foot is between 2km/h and 7km/h, the faster speed for bigger parcels.

Theory into Practice
In March 2005 we began a study executed by three universities to check the theory using two experi-ments designed around sets of 36 parcels of different size, shape and condition. The first experiment set out to measure the parcels using GPS, testing three different kinds of equipment and twenty operators allocated to four teams; some â€˜experiencedâ€™ whilst others were novices, never having used GPS before. The second experiment was similarly designed but used satellite imagery and aerial orthophotos. Each experiment made over 3,500 individual measurements that were recorded in GIS and then rigorously analysed. The study confirmed the theory: CV decreases with parcel size, but â€˜buffer corridorâ€™ error is only slightly related to size. Parcel shape was not an important factor in error, nor was experience of operator, meaning that the systems tested were easy to use in a wide range of conditions and with just a basic amount of training. System bias was less than 1% of error, and the type of border (for example, GPS signal obstructed by trees) was significant for the more precise instruments.

Validation Protocol

The measurement method is not dependent only upon GPS but also upon the equipment. We need a standardised way of checking that equipment worked; a validation protocol. Since 2002 the European Union Joint Research Centre has been checking systems from manufacturers using a pragmatic approach. We go out and measure a well-defined land parcel, repeating the measurement on from five to eight different occasions and collecting two or three measurements on each visit. This way we can undertake a mini-statistical analysis of the performance and see if the equipment is good enough for our needs. Not surprisingly, cheaper off-the-shelf systems have some difficulties in reaching required performance standards due to the internal precision of the processing, which is often limited to a couple of metres (or 0.1arcsecs). The more familiar family of code-processing survey tools from big manufacturers generally perform well. However, there are a good number of mid-range systems, usually linked to customised software that helps in the decision-making process in the field, that perform equally well and are often better for the non-specialist user. As a result of the field trials we will be revising our testing procedures to include a wider range of testing conditions, including more stringent checks of difficult measurement conditions.

Galileo and EGNOS

The first phase of the joint European Space Agency and European Union Galileo programme is nearly at a point when real users should start to take an interest. The European Geostationary Navigation Overlay Service (EGNOS) should enter preliminary operational service during 2006, with full operation programmed for the beginning of 2007. EGNOS provides two improvements for someone measuring a land-parcel area: better precision, especially when only few GPS satellites can be observed, and more reliability of correct signal. Although EGNOS passed its â€˜operational readiness reviewâ€™ in June 2005, it is possible with some receivers to start testing the signal operationally. We found that the GPS data enhanced with EGNOS was more random than pure GPS data. This means that the assumptions of our mathematical model also work better. Using EGNOS measurements will be made that are actually more accurate than the physical uncertainty of (for example) a farmerâ€™s field, which has no very definite edge. It may emerge that the most important aspect of EGNOS for this application is improved integrity of measurements. In other words, it will be possible to place some faith in the quality of the signal being used, since this information will be provided under services to be broadcast from 2007 onwards.

Concluding Remarks

The full deployment of the Galileo system, still quite some years away, will continue to improve the quality of positioning, both in respect of accuracy and reliability. In terms of farmersâ€™ fields it is not likely that these improvements will have much significance, but they will open the door to more detailed measurements required for other land-administration and mapping applications.

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Further Reading

- Bogaert, P., DelincÃ©, J., Kay S. (2005) Assessing the error of polygonal area measurements: a general formulation with applications to agriculture, Meas. Sci. Technol. 16 (2005) 1170â€“1178.