Machine Control Systems

This month I am focusing on guidance of heavy earthwork machines, including dozers, motor graders, pavers, tractors and excavators. The rationale behind this is to pinpoint our very first product survey on machine control systems (MCS), a booming application of geomatics technology(see page 32). A report on global trends, demand and applications for high-precision GNSS technology released in spring 2008 by 'Position One Consulting' and Eric Gakstatter predicted the value of GNSS machine control for construction, (precision) agriculture, mining and container handling would grow by 23% to 28% CAGR (Compound Annual Growth Rate) in the period 2008-2012. Twenty-five percent CAGR: that's some gain, a tripling over five years!

Line of Sight

MCS systems working method falls under three broad categories: 2D guidance requiring line of sight, 3D guidance usually based on total-stations also requiring line of sight, and 3D GNSS guidance. The latter requires only clear line of sight to the sky, a decisive advantage on sites full of obstacles such as other machines, trucks, sandpits or trees. However, this gain turns into a drawback below the surface of the earth in tunnels and mines. GNSS precision was insufficient until the turn of the millennium, but in recent years augmentation systems have pitched it to sub-centimetre level. Robotic total-stations, though, deliver still higher precision.

From 2D to 3D

The rise of MCS use goes hand in hand with progress in the hydraulic-valve technology that steers the cylinders moving active parts such as blades or buckets. Today's hydraulics enable directing of the movements of these parts with precision. Their positioning must therefore be in sync with achievable machine accuracy. Until 2005 most MCS systems were based on laser or ultrasonic sensors which capture the site in 2D; these are able to guide a machine parallel along a (laser-) line or keep it at a predefined level physically represented onsite by rotating laser. In the field of heavy earthworks, ultrasonic sensors have found significant application only on motor graders. The operation of 3D systems is based on the use of a Digital Elevation Model (DEM). The difference between the as-designed DEM and actual onsite heights measured by positioning sensors can be easily computed. This difference vector is then used to steer, directly or by human intervention, the hydraulics, for instance to keep the blade of the grader at a predefined height.

Productivity

Why should a construction company equip a dozer, grader or excavator with an MCS? In a social setting of increasingly tight and irksome regulations contractors face pressure to do the job faster, more cheaply and precisely. How to increase productivity while reducing costs? Opportunities arise from reducing worker numbers, operating day and night ('24/7') and minimising machine activity; the latter not only saves time, but also reduces fuel consumption. All this achievable by mounting positioning and other sensors, such as gyro-compasses and inclinometers, on the machine. Sensor measurements are wirelessly communicated to a control unit and confronted with the design. Discrepancies between design and actual situation are displayed to the machine operator or used to directly steer the hydraulics. Systems that enable heavy machines to operate completely autonomously and free of human intervention are still some way off. But today's operational systems already save a lot of work. The site design is stored as coordinates in the onboard computer and continually compared with positional measurements relating to the actual situation, obviating the need for manual onsite stakeout activities. The sight of surveyors at work around the machine will soon be consigned to history too, as rotating lasers, total-stations and GNSS reference stations can be positioned far from the working area and heavy machines. These often wreaked havoc among pegs and markers - our past guiding lights - so that there was a constant need for re-staking, and whenever the crew was off-site the machine sat waiting impotently for their return.

Hazard

The danger of damaging underground parts of utility networks, such as pipes and cables, is the bogeyman permanently haunting every constructor. In Germany, for example, annual loss incurred during digging works is 400 million Euros. Hitting a gas pipeline may also trigger hazards, up to and including explosions. How to avoid waste of material, time, money and, above all, disaster? By integrating utility network plans into the DEM such that the machine operator knows beforehand what is where in the ground and can thus anticipate it. However, many national maps of underground utilities are non-existent or in 'sub-prime' condition, and this is where sensors capable of detecting and warning the control unit of buried metal really come into their own. Combined utility plans and magnetic sensors would provide a truly reliable solution.

Today's standard practice is to install MCS systems either at the factory or by specialised firms, before the contractor takes delivery. MCS systems produce continual, accurate and complete job-site information, which is then transmitted to the office, providing site engineer, foreman, supervisor and financial officer with all 4D information (the fourth dimension being time) needed for keeping track and billing. The day will surely come when the construction contractor rushes to enfold MSC in his warm and welcoming embrace.