EXTREME HIGH-PRECISION SURVEYING

Cosmic Science and Dam Monitoring

Advances in surveying technology continue to shape the way we understand our universe and monitor earth. Radio astronomy, key to disclosing the mysteries of the universe, is impossible without high-precision aiming of the telescope. The same is true with respect to the monitoring of dams for safety purposes. The present authors, both with Sokkia, first treat the collimation technique applied to monitor worldÃ¢â‚¬â„¢s largest millimetre-wavelength telescope in Nobeyama, Japan that resulted in discovery of the first black hole. They next consider automatic deformation monitoring system at thirteen of South KoreaÃ¢â‚¬â„¢s multipurpose dams.<P>

Radio astronomy, established in the 1960s, records and analyses waves radiated from astronomÂical entities. The technology introduced a new era of cosmic science led from the outset by the US, Europe and Japan. Cosmic rays and magnetic fields could be observed using centimetre-long radio waves. In the 1970s the focus shifted to millimetre-wavelength, allowing the observation of interstellar molecules and enabling research into the formation of stars.

Surveying the Universe
The first millimetre-wavelength telescope, an 11m parabolic antenna developed by a US research team, was soon followed by a 6m Japanese one. The resolution of this telescope was approximately two arc-minutes, which lacked sufficient accuracy. The 1970s saw a race to develop larger and higher-performance radio telescopes, ending in 1981 with construction of the world's largest millimetre-wavelength telescope, diameter 45m, at the Nobeyama Radio Observatory (NRO) in Nagano Prefecture. NRO is a division of the National Astronomical Observatory of Japan (NAOJ) under the National Institutes of Natural Sciences (NINS). The Mitsubishi Electric Company, which undertook the telescope construction project, faced three major challenges in attaining adequate performance and precision:
-achieving 0.1mm precision for the parabolic reflector surface, consisting of independently moveable reflector panels; 0.06mm precision was achieved for a single reflector panel and 0.09mm overall reflector precision; four motors on each individual reflector panel, one on each corner, allowed automatic position adjustment
-lack of a sufficiently sensitive receiver, so that a new receiver was developed using the latest superconductor technology
-precise aiming of the telescope at its target proved cumbersome because the movable portion of the telescope weighs 700 tons and is consequently deformed by its own weight.

Aiming the Telescope
Precise aiming of the telescope requires an immovable benchmark, of which an optical collimator sensor forms the core. The tower housing the benchmark is fixed firmly on the ground directly below the telescope centre and is independent of other parts of the telescope. Upon receiving a signal from the control system, the collimator freely rotates to precisely aim in the specified direction, emitting a light beam to a mirror installed on a single panel of the telescope. Using the reflected beam, the control system calculates the difference between mirror and collimator, and based on this data automatically aims the telescope with an accuracy of 1/1,000 arc-degrees or higher. The collimator operates on the same basic principles as auto-collimators for industrial machine tools, only with a different target. The biggest technological hurdle was accuracy; the telescope requires accuracy ten to twenty times greater than existing collimators.

Black Hole
One of the most important results of NRO in the early stages was the discovery of interstellar material. Where optical telescopes see only empty space between stars, radio telescopes can see molecular gas and clouds. Where these molecular clouds are extremely thick, a star is born. The most important accomplishment of the 45m radio telescope was the discovery of a "black hole" in 1994. While observing radio-waves radiating from the centre of spiral galaxy NGC4258 the presence was discovered of water masers, proving that the gas was spinning around the centre of the galaxy at about 1,000km/s, or 1/300th the speed of light. As under normal circumstances gases cannot spin at such a high speed within such a small area, an extraordinarily heavy object was believed to be at the centre of the galaxy. This transpired to be nothing less than a black hole. In 2006, 25 years after the construction of the optical collimator for aiming of the 45m telescope, Sokkia provided a next-generation collimator sensor with far higher accuracy and the entire collimator tower was renovated to include the latest advances in collimation technology. Indeed, it is a great honour for Sokkia to be a member of the cutting-edge engineering community that has made history in the field of cosmic science.

Dam Monitoring
The state-run Korea Water Resources Corporation (KOWACO) has introduced an automatic deformation monitoring system at thirteen of South Korea's multipurpose dams. It is hoped that this will result in increased dam safety and operation. Based in Daejeon, home of South Korea's "Silicon Valley", KOWACO manages and operates fourteen multipurpose dams throughout the country, providing water and sewage utilities, managing service water and controlling water to prevent flooding. The move to an automated system is part of a government initiative to create a ubiquitous society focused on the construction of infrastructure and technological advancement known as "u-Korea". Based on the success of this system, increased networking with other segments of society will follow, furthering the creation of

an advanced information-based society.

Auto-pointing

Fully automatic prism sighting, data collection and storage ensure data reliability by eliminating human error. Another major benefit is the instantaneous graphing of data, allowing its effective use. The core sensor of the system is a Sokkia Monmos 3-D Station "Net1" which has the ability to automatically sight and measure prisms placed on the dam body and surrounding embankments in three dimensions in real-time. A dedicated auto-pointing algorithm allows automatic sighting that has the ability to recognise and accurately sight the target even when multiple prisms and other reflective objects lie in the telescope's field of view. At the remotely located dam-control office the data is compared to reference date and graphic displays are immediately displayed for a visual representation of the processed data.

Extreme Conditions

The placement of the unmanned observation room was dictated by:
-assured visibility of approximately forty measurement points on the dam and surrounding embankments
-solid footing, allowing the Net1 to be securely fastened
-out of general public reach while providing easy access to maintenance personnel
-no disturbance of scenery from a tourism perspective.
Prism placement was also a challenge. Dams may be roughly grouped into two types: concrete dams and fill-dams. The system was mainly installed on fill-dams, which are made with compactedearth and stone. The dam has a crest over 1km in length, meaning workers have to descend a steep rocky slope many times to place the prisms. Of even more concern was construction of the control-room during wintertime, because in the mountains temperatures may drop to -0Â°C or less. Fortunately, that year Korea experienced the warmest winter on record and construction was completed without incident.

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