LIDAR for Flood Defence

Trevor Burton (BKS Surveys Ltd) and David Scott (Mott MacDonald) explain how LiDAR data can be used to abstract flood defence data from low level LiDAR surveys to provide valuable information that meets policy guidelines whilst also assisting communities.

In 1997, to comply with Section 105 of the Water Resources Act of 1991, the Environment Agency (EA) began developing programmes to survey floodplains and map flood extents. Since this time, LiDAR from fixed-wing aircraft has been widely used by the EA and consultants to measure land topography for flood modelling and flood risk mapping purposes. Individual measurements of the terrain are made at a density ranging between a few points per square metre to 2m intervals and provide excellent coverage of the floodplain and also allow a highly resolved terrain model to be generated.

Introduction

Flood risk management assets protect thousands of homes and businesses from the risk of coastal and fluvial flooding. Accurate survey information of these assets is therefore vital to the EA's approach, both to the day-to-day asset management and to the decision-making process for their improvement or replacement.

With conventional, lower density fixed-wing LiDAR data, there are difficulties in obtaining an adequate representation of important hydraulic features such as embankment crests, flood defence walls and outfalls. Therefore, it was believed that the utilisation of low level LiDAR, with a much higher point density, would enable the EA to identify and evaluate these smaller but critical features.

Since 2004, BKS has been acquiring low-level LiDAR data using the FLI-MAP system to assist the EA in the identification of detailed flood defence information. These include: defence type, defence crest, toe levels and cross-sections for large lengths of fluvial and coastal defences. The surveys have demonstrated that remotely-sensed LiDAR data taken from a helicopter platform is capable of gathering accurate and detailed information on soft and hard defences, not previously possible.

LiDAR Application

The technique of extracting defence data from high density helicopter LiDAR is a quick and accurate method of improving defence asset information and flood modelling, enabling improved flood risk management. Additionally, the simultaneously acquired video and photo images are an invaluable asset for office based inspections and assessment. The use of low-level LiDAR has a major potential to bring asset condition assessment onto a common footing as flood risk mapping and will contribute immensely to the Agency’s asset management strategy and flood risk mapping policy.

In Spring 2005, BKS undertook pilot projects on the Rivers Medway, Swale, Thames and Hamble, amounting to approximately 650 linear kms, to demonstrate the capabilities and effectiveness of the low-level LiDAR technique using the Fli-Map II system developed by Fugro in 2000. The system comprised dual class 1 lasers (each emitting 11,000 single return laser pulses a second with a ranging accuracy of 5cm), Inertial Measurement Unit and GPS for positioning recording information, downward and forward facing digital cameras and video cameras. The data was acquired with an operating ceiling of 100m and a swath width of data also measuring approximately 100m.

Analysis Considerations

The key elements to the success of the pilot studies were the density of the point cloud and the resolution of the images. The point density was set to at least 12pts per m^2 to enable measurements on thin wall defences and the digital images were required at a nominal ground sampled distance of 10cm so that individual flood defence types could be distinguished.

Data acquisition was tied to a series of GPS base-stations within 20kms-25kms of the survey area. In order to quality assure the LiDAR data, small patches of ground survey were established and tied to the local datum at discrete locations throughout the survey area. The LiDAR data was then compared against the ground surveyed data for quality assurance and local bias removed from the final data model.

Data Processing

Collection of the LiDAR data is only part of the project. Once the survey data had been collected, the task of abstracting defence data from the survey can begin. The data was presented in two forms, (1) Point cloud data greater than 12 pts per m^2, (2) Gridded data provided at 0.25m resolution.

There is a marked difference between the data sets in the amount of processing performed and the detail that can be abstracted. The point cloud data has had minimal processing and as a result still includes some outlier results, from reflections etc. The grid data has had greater processing with outliers and noise between points removed. Although it is much faster to use gridded data in analysis and modelling, it lacks the detail of the raw point cloud data, and for the purpose of this project it was the detailed information that was required. Some flood defences are no greater than two bricks thick and whilst it is possible to pick these features up using the laser point cloud data, they can disappear in the grid data.

FLI-MAP 400 System

Following the successful completion of the pilot project, it was decided to upgrade and develop the current system to improve the service offering for 2006, particularly for river embankment monitoring.

The meandering nature of river embankments requires multiple flight lines and it was therefore considered essential that the new system was capable of producing a much wider swath of data. This would significantly reduce the number of single runs required to cover the survey area, so improving operational efficiencies and minimising project costs.

The original FLI-MAP II system was designed and configured for use within a rigid frame that could be deployed and mounted to a range of types of helicopters without the need to modify the airframe. This rigid frame approach enables the system to be transported throughout Europe and be matched to a suitable helicopter near to the survey area. This approach had proved particularly successful and facilitated operations throughout the world. Therefore, it was decided to redesign the new system around the same rigid frame, which would also simplify and expedite the approval and certification of the new system with the appropriate Aviation Authorities.

Accuracy

Maintaining the 60degree scan angle would result in a similar flying height to data swath ratio. It was decided that an operating altitude of 400m would produce a sufficiently wide swath-width for most applications and also yield considerable benefits to the ease of acquisition, particularly in any urban environments where Civil Aviation Authority regulations restrict low-level flying below 250m. For high detail topographical mapping it was also necessary to increase the point density of the data and improve the accuracy of the data. Previously, the only way of increasing point density where finer details were required was to fly additional cross-passes or reverse direction double passes, proving both time-consuming and costly.

In order to meet these exacting requirements the laser manufacturer designed a completely new LiDAR specifically for use in a low-level operating environment. The new sensor is capable of being operated in the 350m-400m altitude range and so producing a similar 350m-400m swath of data. The dual lasers are replaced with a single rotating mirror laser that generates 150,000 pulses per second. This corresponds to a far greater point density of 25 points per m^2 from 350m altitude and in excess of 100 points per m^2 from the former operating altitude of 100m. An improved ranging accuracy of 1cm and higher IMU and GPS positioning rates combine to produce improved vertical accuracies in the order of +/-3cm RMSE on well defined surfaces.

This greater point density is particularly beneficial where it is important to be able to accurately define the height and location of a flood defence that may be a small brick structure.

It was also considered that enhanced penetration of vegetation would significantly improve the quality and usefulness of the acquired data, particularly for river embankment studies. Therefore, the system was designed to produce a maximum of 4 returns per pulse with a minimum target separation of less than 1m. This would greatly increase the chances of a laser pulse returning a true ground position and also provide a good interpretation of tree structure detail.

In conjunction with the redesign of the laser, enhancements were made to the imaging components of the system.

The new Fli-Map 400 system was successfully launched in Spring 2006 and has to date acquired data for in excess of 2,000kms of river embankment assets. The new sensor has enabled higher levels of interpretation through increased point density and higher resolution imagery, improved accuracy and penetration of vegetation.

Technology impact

The EA support the Government's drive to make all its services available on-line and have worked with DEFRA and Local Government Authorities (LGAs) to develop a Geographical Information System (GIS) called the National Flood and Coastal Defence Database (NFCDD). The NFCDD currently contains details of flood defence assets that belong to the Environment Agency and LGAs and is being further developed to become the comprehensive source for all flood risk management data.

The Incident & Flood Risk Management reorganisation at the EA in the summer of 2005, has enabled it to target additional resources into providing more accurate data, not only on flood plains but also on flood defences and flood risk management assets. It is anticipated that the EA will increasingly use high-resolution LiDAR techniques to readily and economically capture the required accurate spatial data. With such data in place, management of Flood Risk will become a more scientific activity, with the possibility to consider and assess multiple scenarios whilst more rigorously determining the correct prioritisation of maintenance and asset inspection activities. The increased data quality and accuracy achievable with high resolution LiDAR will, in turn, drive future enhancements to the NFCDD system, to enable these data improvements to be translated into better graphical presentation.

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