Using integrated technology to inspect quay walls

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Introduction

This article's main purpose is to propose a new method to support the establishment of a first general structural diagnosis that helps managers in their decision making process regarding maintenance on quay walls. Our approach is based on a quick and complete scan of the whole infrastructure through an integrated multibeam echosounder (MBES) and light detection and ranging (LiDAR) system. The result is a three dimensional (3D) model from which deformation maps, acoustic backscatter maps or vertical and longitudinal profiles are gathered. Armed with a series of these value-added products, managers can get an idea of the overall condition of the infrastructure that they are responsible for. Therefore, they can better plan maintenance work, focus divers' interventions and deploy complementary technologies only in problematic areas.

Traditionally, the inspection of underwater sections of quay walls is visual and/or tactile and carried out by divers. However, poor visibility often complicates diver interventions and results in longer inspection times and assessments of lower quality. In recent years, in response to the visibility difficulties encountered by divers, the use of acoustic technologies has emerged naturally. Several tests have been conducted using mechanical scanning sonars (eg. BV5000, Kongsberg MS1000), acoustic cameras or even underwater laser scanners. One limitation of these technologies is the lack of precise underwater positioning. This fact complicates the mosaicking of all individual images and scans collected and as a result the production of a global map of the infrastructure. Structural defects are then incorrectly set, global deformations are not detected and then a recurring inspection, which finds its added value when based on the same reference framework, is compromised. The Port of Montreal has been successful in overcoming the positioning limitation of a Kongsberg MS1000 mechanical scanning sonar by using a complex deployment strategy (see figure 1) but at the cost of a greatly increased inspection time.

Whether visual or acoustic, available technologies show good inspection potential for the detection of rather thin structural defects. However, recognising their respective limitations (short range issues and deployment constraints), these technologies would benefit from being deployed only sporadically in very specific places of the structure where a fine inspection is necessary. This article proposes and seriously evaluates a new quick survey method for accurately highlighting problematic areas of infrastructure and therefore helps managers to better plan divers' interventions and use most effective deployment of complementary technologies.

Like the Port of London and the Port of Marseille, the Port of Montreal uses a MBES system for the inspection of underwater sections. We improved this system by using a LiDAR for the inspection of terrestrial (above water) sections. The two sensors, when mounted on a hydrographic survey vessel, can get a full scan of the infrastructure. Beyond the classical 3D point cloud representation of the scanned infrastructure, we propose to provide managers with a range of two dimensional (2D) products suitable for informed decision making.

Deployed system

The system deployed for the dataset capture (see figure 2) is composed of : a pole-mounted Reson Seabat 7125SV MBES tilted 30 degrees on the starboard side; an Applanix PosMV320 position and orientation unit; a Terrapoint ALMIS-350 integrated system composed of a Riegl Q-140 LiDAR; a NovAtel GPS antenna, and a Honeywell HG1700 inertial motion unit. The lever arms and the mounting angles between the different sensors have been accurately measured by a dimensional control survey of the vessel done with a total station.

The acquisition of bathymetric and topographic data is planned using a survey simulator that allows us, depending on customer expectations, to determine the number of passes required, the distance to the infrastructure, the survey speed and the optimal acquisition parameters. The 3D centimetric positioning is ensured by real time kinematic (RTK) differential correction from a global navigation satellite system (GNSS) receiver located close to the infrastructure.

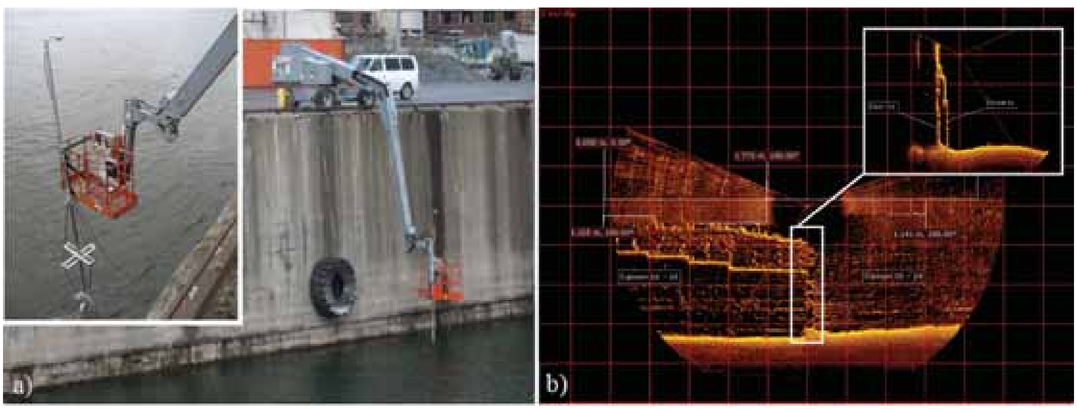

Figure 1: Left: deployment of a Kongsberg MS1000 mechanical scanning sonar from a telescopic boom at Port of Montreal. Right: Kongsberg MS1000 scans of quay wall section at Port of Montreal.

Figure 2: Left: Reson 7125 SV 30° starboard tilted. Right: CIDCO's survey vessel.

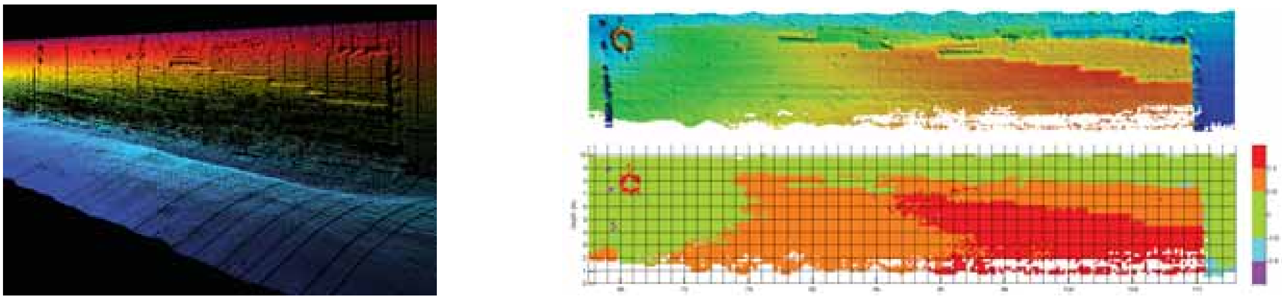

Figure 3: Left: 3D model of a quay wall section at the Port of Montreal. Top right: VDTM. Bottom right: five colour deformation map. The colour scale goes from green (no deformation compared to the theoretical structure's position) to purple (more than 60 cm of gouging) and to red (more than 60 cm of protruding).

Results and products

Following the acquisition, the bathymetric and topographic datasets are individually processed. The two resulting 3D point clouds are then merged into a unified model, see figure 3 for an example.

The 3D model gives managers, for the first time, the ability to see in its entirety the infrastructure they are responsible for. However, the exploration of the model does not yet fit with the habits of managers, even those who are engineers. Most are more comfortable with 2D datasets. That is why, beyond the production of a 3D model, derivative products have been imagined. The 3D model can be used, depending on the specific needs, to produce a vertical digital terrain model (VDTM) of the infrastructure, in the form of a deformation map, an acoustic backscatter map or in a series of longitudinal and transverse profiles.

As seen in figure 3, the VDTM and even more so, the five colours deformation map, help managers to quickly give a first assessment of the infrastructure's general state. For example, the images acquired will help to monitor the concrete wall resurfacing of a quay wall section at Port of Montreal.

Conclusion

The proposed approach suggests that prior to any intervention on a partially wet infrastructure (quay wall, dam wall or bridge pier); an initial overall structural picture should be taken at a point in time. This will help managers to plan maintenance programs and interventions, like using divers or deploying complementary technologies. To achieve this first diagnostic, CIDCO has proposed and seriously evaluated a new survey method based on a hybridised MBES/LiDAR capture solution to quickly obtain a complete and accurate 3D model of an infrastructure at a decimetre resolution. In light of the results obtained on several survey sites in the province of Quebec, infrastructure inspection companies (mainly diving companies) agreed that a paradigm shift is taking place and began to express their interest in the use of hybridized MBES/LiDAR capture solutions. Together with its partners, CIDCO is therefore seeking an effective transfer mechanism to bring new technological solutions and methods to the infrastructure inspection market.

Our next initiative is the creation of an infrastructure inspection expertise centre in Rimouski (Quebec). The centre's objectives would be to: intensify research and development efforts already undertaken and allow Canadian companies to remain well positioned on the international market; establish a training centre to assist companies interested in taking control of new available inspection equipment; develop a certification centre to assess the performance of new equipment and support the legitimacy of their use with clients.

ABOUT THE AUTHORS

Mathieu Rondeau holds a bachelor's degree in surveying engineering from l'École Supérieure des Géomètres et Topographes (Le Mans, France) and a master's degree in geomatic sciences from Laval University (Québec). He was research assistant and research professional at the geomatic sciences department of Laval University, and is now marine geomatics specialist at CIDCO.

Frédéric Pelletier earned a bachelor degree in geomatics sciences from Laval University (Quebec) in 1998. He began his career working in a high-end GNSS company supporting the commercial aspect and development activities. Since 2008, Frederic has been involved in the design and use of geographic information systems applied to infrastructures and various projects employing surveying techniques at Montreal Port Authority. He is now currently acting as project manager within the information technology department.

ABOUT THE COMPANY

The Interdisciplinary Centre for the Development of Ocean Mapping (CIDCO) is a marine geomatics research and development organisation. Dedicated to the enhancement of state-of-the-art technology for marine geospatial data acquisition, management and graphic representation, the CIDCO is a not-for-profit organisation answering the research and development needs of the industry and the community at large.

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