PORT INFRASTRUCTURE (BRIDGE AND DAM) INSPECTIONS: FIRST DIAGNOSIS SUPPORTED BY MULTIBEAM ECHOSOUNDER (MBES) AND LASER SCANNER INTEGRATION

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ABSTRACT:

This paper's main purpose is the proposal of a new method to support the establishment of a first structural diagnosis that helps managers in their decision making process regarding maintenance on partially wet infrastructure. Our project targets submerged structures as quay walls, bridge piers and dam walls. Our approach bids on the quick and complete scan of the whole infrastructure through an integrated MBES / LiDAR system. The unified 3D point cloud resulting from the acquisition phase is reworked so as to present to the managers an uncluttered condition state which takes the form of a 2D deformation map highlighting the weaknesses of the structure. The major defects are then clearly presented, identified and positioned to support the managers in their decision making process regarding where interventions are needed.

Prior to any intervention, the first diagnosis allows for planning, maintenance or, if more information is needed, the optimization of diver intervention or complementary technology deployment (mechanical scanning sonar, acoustic camera, short-range laser scanner, etc.).

1. INTRODUCTION

Consider yourself for a moment as the manager in charge of the maintenance and the integrity of a port, a bridge or a dam, with all the responsibilities that comes along with them. What would you like to know? You would like to be aware of the general state of the infrastructure (above and below the waterline), to know where it's possible weaknesses are, to assess the extent of potential damage, all that in order to best organize the necessary work.

Traditionally, the inspection of underwater sections is carried out by divers. Sometimes, technologies like mechanical scanning sonar (e.g. Abbott, 2011; Clarke, 2006, Kongsberg, 2010), side-scan sonar (e.g. Woo, 2007), acoustic camera (e.g. Brahim, 2008) or even short-range laser scanner (e.g., Gillham, 2011), can be deployed. However, in most cases, for reasons intrinsic to the technologies mobilized (limited range, deployment difficulties, cost) or for reasons related to the environment (strong currents, poor visibility, maritime traffic), the inspections are very limited in spatial extent and their locations are based on poor information made from surface observations.

The purpose of this paper lies in proposing a method which will provide managers with a complete picture of the infrastructure they are responsible for and from which a first diagnosis can be made. Defects in structures are clearly presented, identified and positioned. This allows, depending on the additional information needed, to guide in an optimal way, the intervention of divers or the deployment of additional technologies.

To support such a diagnosis, we propose, as the Port of London (Dillon-Leetech, 2008) and the Port of Marseille (Fraleu, 2006), the use of a multibeam echo sounder (MBES) for the inspection of underwater sections. We improved the system by using a LiDAR for the inspection of terrestrial (above water) sections. The two sensors 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 to managers a range of 2D products suitable for informed decision making.

2. DEPLOYED SYSTEM

The system deployed for the dataset capture is composed of: 1) a pole-mounted Reson 7125SV MBES tilted 30° on the starboard side, 2) an Applanix PosMV320 position and orientation unit, 3) a Terrapoint ALMIS-350 integrated system (Newby, 2005) 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 metrological survey of the vessel done with a total station.

Auxiliary sensors are also deployed: 1) a Valeport Mini-SVP profiler to measure the sound velocity through the water column, 2) a Valeport Mini-SVS sensor installed on the transducer head needed to perform beam forming, 3) a Thales Z-Max base station to support the navigation data post-processing.

The bathymetric and topographic datasets are acquired simultaneously but independently in one, two or three survey lines done parallel to the infrastructure at low speed and at a distance ranging between 5m to 20m.

3. RESULTS AND PRODUCTS

The bathymetric and topographic datasets resulting from the acquisition step are then processed individually. Two 3D point clouds are then produced and merged into a unified model (Figure 1).

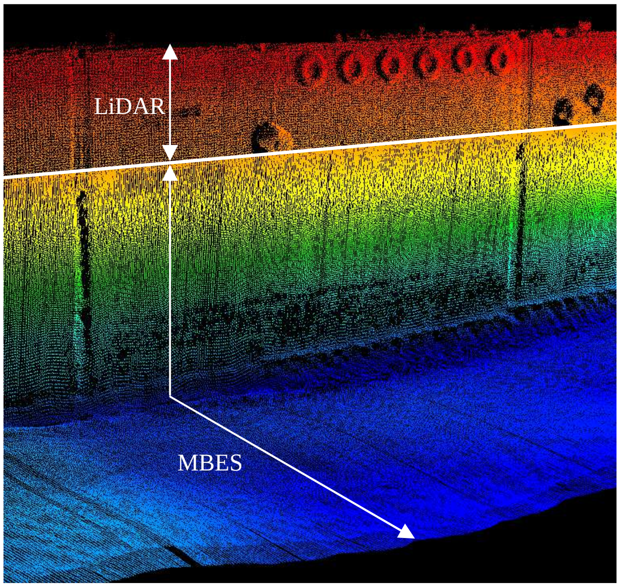

Figure 1 : 3D point cloud of a quay wall section at Port of Montreal.

The handling of such a dataset in addition to being intuitive allows the identification of different phenomena (scouring, undermining, gauging, objects on the seabed). However, depending on the size of the infrastructure (for example, at the scale of a port several kilometers of docks should be inspected), exploration of the 3D model can quickly become tedious. Therefore, beyond the production of a 3D dataset, derived user-friendly products have been created to help give managers a first assessment of the general state of the infrastructure. These products are based on the projection of some of the 3D dataset's attributes on a plane, chosen accordingly to what one wishes to highlight.

For the representation of a vertical infrastructure (quay wall for example), the projection plane of the theoretical vertical side of the infrastructure, is relevant. The projected data can be the distance of each point of the model to the theoretical side of the infrastructure, which provides a deformation map that facilitates the identification of problematic areas (Figure 2). The projected data can also be the intensity of the acoustic return, which provides a backscatter image which shows the changes in textures of materials (wood, concrete, steel) making up the infrastructure.

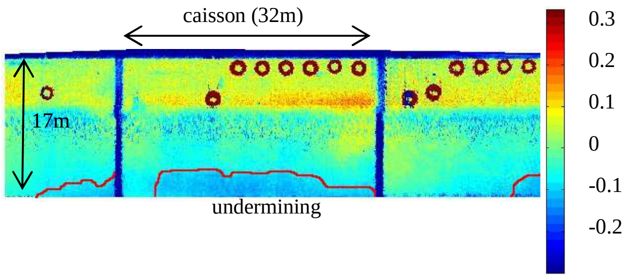

Figure 2 : Deformation map showing an early undermining effect.

At the Port of Montreal authority, beyond the structural diagnosis, this information is also used to validate the location of the caissons (see Figure 2), thereby keeping up to date the inventory module of the quay management and inspection system.

4. PERFORMANCE AND QUALITY

The performance of the approach presented is undeniable. The deployment of the system is easy and the survey is completed in a very short time, about a day for up to 2km of linear infrastructure surveying.

The quality of the product obtained can be evaluated accordingly to various criteria such as density, resolution and accuracy.

The density of points in the model depends on the number of survey lines done and on the surveying speed. Typically, for two survey lines at a speed of up to 3 knots, the density is about 700 points per square meter.

For a MBES set up in equidistant mode (equal spacing between beams), the bathymetric resolution is defined as:

$$R = \frac{\left[2 \times P \times tan\left(\frac{\theta f}{2}\right)\right]}{n} \tag{1}$$

Where P = the sounding depth (here 10m to 15m)
θf = the MBES swath angle (here 140°)
n = the number of beams in the MBES (here 512)

In its submerged part, the resolution of the model varies between 11cm and 16cm.

The Riegl Q-140 LiDAR displays an angular resolution of 0,005° which results in a resolution of the model in its emerged part of 0.9mm to 1.3mm.

The accuracy was measured as follows: During conditions of lower water levels, a 2m by 4m section of the quay wall 55 at the Port of Montreal was scanned with a robotic total station to provide a reference mesh of 740 points uniformly distributed and overlapping both the LiDAR and MBES datasets (Figure 3). The topographic and bathymetric point clouds, acquired using the system presented above are compared to this reference mesh.

In 50% of cases, the difference between the measurement and the reference is less than 1cm and in 95% of cases, this difference does not exceed 5cm.

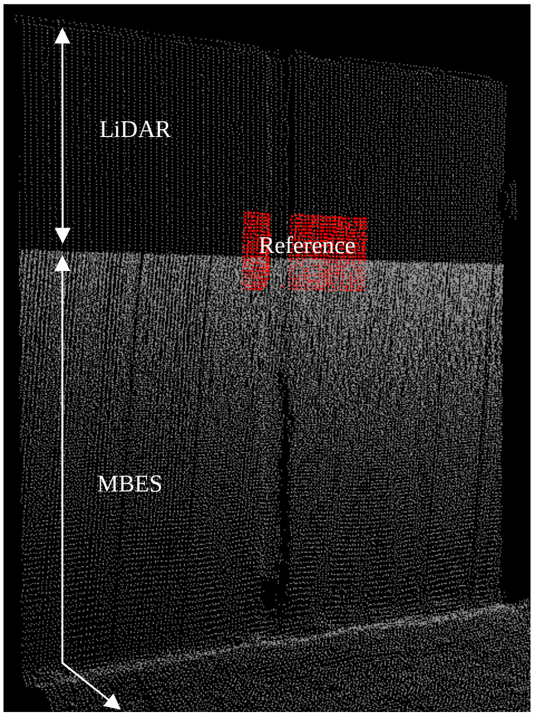

Figure 3 : Evaluation of the product's accuracy.

5. CONCLUSION

The proposed approach suggests that, prior to any intervention on a partially wet infrastructure (quay wall, bridge pier, dam wall), a first overall structural picture should be taken at a point in time. The idea proposed here is to take advantage of the proven performance of the hybridized MBES / LiDAR capture solution to quickly obtain a complete 3D model of an infrastructure at a decimeter resolution and from which a deformation map is produced. This user-friendly map turns out to be a very relevant tool for managers, both to get an idea of the general condition of the infrastructure they are responsible for, but also to plan effective complementary punctual interventions (divers, acoustic technologies) or even on the elaboration of large scale program maintenance.

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