Probability maps for sea mine risk assessment

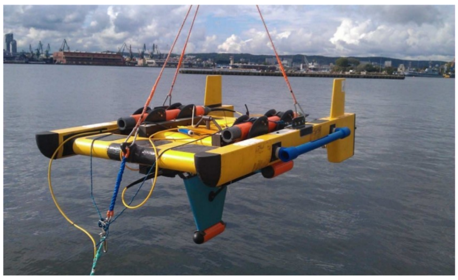
Eric Mersch, Xavier Neyt and Pascal Druyts

Royal Military Academy, Avenue de la Renaissance, 30. 1000 Brussels. eric.mersch@elec.rma.ac.be

INTRODUCTION

The security of seaways is of crucial importance for an open economy such as the Belgian one, with two big international harbors. Belgian navy is aknwoledged for its mine countermeasures capacities, but it is still important to bring forward the limits of the detection sea mines for the security of its staff and the other users.

When a mine is placed on the sea bottom, it can be challenging to detect it because it can be covered by sand or sediments. One of the possible approach relies on the use of a magnetic gradiometer. A magnetic gradiometer is a sensor that measures the gradient of the magnetic field. The seafloor and the water have negligible influence on its measurements. However, if a magnetic object such as a mine is present, it will locally modify the earth magnetic field and this deformation can potentially be detected by the gradiometer. This project focuses on the use of a magnetic gradiometer for seamine detection by using probability and risk maps.

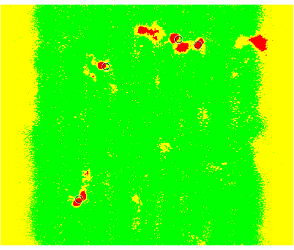


This picture was taken by TNO and shows the platform carrying the magnetic gradiometer for the EDA UMS BURMIN project.

RISK MAPS

The objective of the work presented here is to produce target presence probability maps. Such maps are helpful form an operational point of view: they can help to assess the risk of the presence of a mine is some area, together with its localization uncertainty.

The probability maps can be difficult to interpret. We therefore propose to use a three colors risk map that highlight the risky (red), unknown (yellow), and clean areas (green).



This Figure shows a three-color synthetic risk map together with the ground truth coordinates of the targets. The green area is classified as safe, the red area is classified as dangerous, and the yellow area corresponds to the area where there is not enough information to conclude.

APROACH

The mines are modeled by magnetic dipoles. The signal is modeled as the field produced by several magnetic dipoles contaminated by some Gaussian noise of known covariance matrix. In order to take into account the measured location limited accuracies, we model the positions uncertainties by a Gaussian noise.

We are interested to compute the target presence probability distribution. We can compute it for an unknown number of dipoles by marginalizing the posterior probability distribution obtained by the Markov chain Monte-Carlo (MCMC) method.

SIMULATION VALIDATION

We simulated a series of 600 synthetic data sets for different realization of the noise and different target parameters. For each of these simulations, we computed the target presence probability. Our model consistency was validated by plotting the mean observed target number as a function of the expected target number.

EXPERIMENTAL RESULTS

Some experiments were conducted in the Bay of Gdansk, Poland, within the EDA UMS BURMIN project.

Some targets were buried in the seafloor, six of the targets were magnetic and potentially detectable by the gradiometer. The burial depth varied between 0 and 1 m. The ground truth coordinates of the targets were measured using an acoustic transponder and a differential GPS.

For these experiments, the gradiometer was attached to a platform that contained other sensors and this platform was towed from a small vessel. The depth and attitude of the platform were controlled by two fins. All the magnetic targets were detected and correctly localized using this technique.

CONCLUSIONS

We have developed a method to produce target presence probability maps for magnetic gradiometer survey that could be useful for sea mine presence risk assessment. This was done in a Bayesian context using Markov chain Monte-Carlo (MCMC). The method works even when the target number is unknown, for a characterized sensor noise and takes the sensor localization uncertainties into account.

The method consistency was validated by checking the histograms for a large number of simulations.

Some data were collected on real targets in the Bay of Gdansk, and a map was produced for these data, with correct detection and localization of all magnetic targets.

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