ecua 2010 İstanbul
5-9 July, 2010
www.ecua-2010-istanbul.org

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When navigating, an autonomous underwater vehicle (AUV) has to characterize the environment, but can rely on few sensors to determine its own position. Instruments of navigation (as inertial measurement unit) can have drifts or inaccuracies. These inaccuracies can be handled through a registration process on sonar images. We have proposed a registration process on classified images. A way to improve our results is to introduce landmarks to drive the registration process. Theses landmarks can be obvious (huge rocks, wreck), but must be specifically search, and identified (basically by human expert). Automatic image classification can show unexpected landmarks on images.

1 Introduction

Autonomous Underwater Vehicles (AUV) can rely only on few sensors to determine their own position. Instrument of navigation such as inertial measurement units tends to present drift or inaccuracies. Other methods must be used to correct theses inaccuracies.

When the mission of the AUV is a seabed survey, sonar sensors are available. Generating seabed maps and relying on them to help the localization can be done through image registration process.

Registration process over sedimentals landmarks was already proposed [1], but the specification of the landmarks was not particularly studied.

We try in this paper to initiate a discussion on useful landmarks for sonar image registration process. First we will present our sonar image registration process. Then we will recall elements of sonar images that tend to become difficulties when processing a sonar image registration. And in the section 4, we will present elements of sonar images that can be used to drive a registration process.

2 Classified sonar images registration

The aim of an image registration process is to overlay two or more images of the same area, taken from different sensors, points of view, and/or times. An image registration process must determine the best geometric transformation t from a transform model T to align the images. The figure 1 shows the problem for two images I1 and I2. Each image has its own orientation and size, and I1 is the reference image. We want to register I2 on I1. The issue is symmetrical so we can a priori switch the reference image. The classification of image registration process is a well known discussion [6,7], and we separate them between two families:

- Geometric methods use features extracted from the images (points, edges, shapes) and try to match them to determine the best transformation.
- Iconic methods use all pixels from the images, and directly compare their intensity, or a function of these intensities.

Recent works on sonar image registration [2], [8] were based on iconic criterion. We have developed an iconic registration process over classified sonar images [9].

A basic registration process can be decomposed in four steps:

Feature extraction is the first step of a geometric registration process and can be omitted in iconic method (directly based on image intensity).

The second step is the transformation of the features, or the images. This transformation must come from a transform set.

Next, the registration process measure the similarity between the reference image, and the transformed imaged.

And the last step is the decision of the transformation from the transform set leading to the best similarity between the two images.

In our process, images were previously classified, and our process decided the best transformation with a measure of dissimilarity of matched classes. In order to improve our results, we want to constraint the decision with a decision coming from a geometric registration on landmarks.

3 Sonar images complexity

Images provided by sonar sensors come from aggregation of successive sonar signals. This specific way of generation tends to produce alterations due to movements of the sensor, speckle or variation of gain over time.

A landmark can be an area, or a specific point and its representation must not be deformed. But the representation of element in sonar image can change along time. And different points of view can modify the perception of such element.

3.1 Point of view

The point of view is very important in sonar image processing. As sonar images are generated by aggregation of unidirectional signals, precisions of information will be different along the signal or across it.

Example of point of view alteration comes from observation of ripples areas. Current applied on sand areas can lead them to ripple. And if the ripples are aligned with the sonar signal, they will disappear from the image.

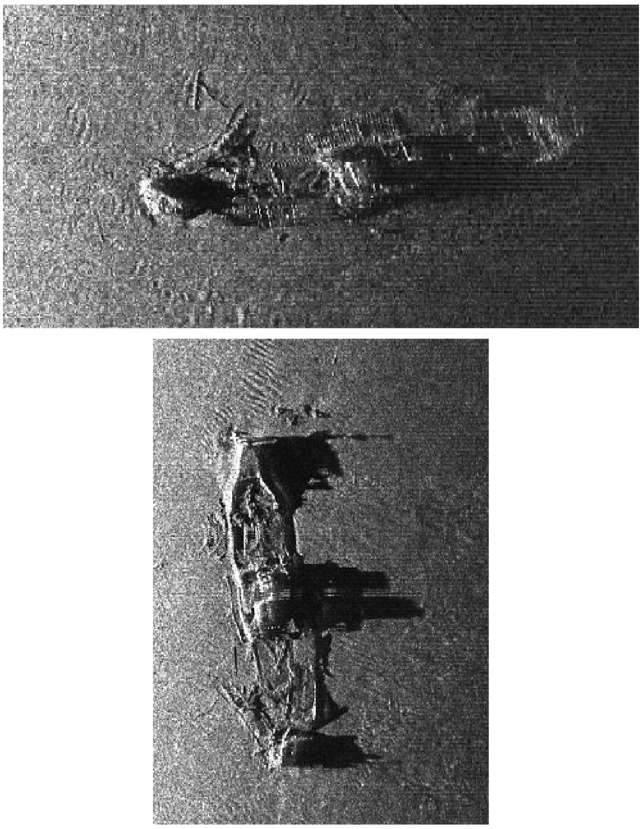

Figure 1: Wreck seen from different points of view

Another example, presented in figure 1 comes from shadows behind large objects. When the signal comes across a rock or a wreck, it bounces, and the area behind the object is not illuminated. Depending the point of view this shadow can be completely different.

3.2 Time

Seabed surveys are made from time to time. The reason is that aspect of seabed evolves over time.

For example, current generate ripples in sand areas, but make them move along time. And variation of current speed can alter aspect of ripples, or their movement speed.

3.3 Fauna and flora

By nature, fauna and flora evolve over time. Shoals of fishes move, and can appear during a sonar campaign, as we can see on figure 2.

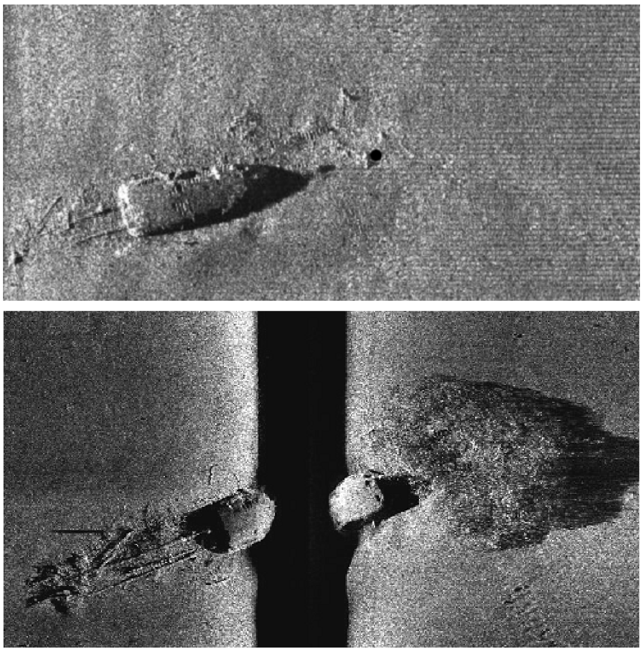

Figure 2: Wreck seen at different time

Presence of flora generates alteration on sonar images. Intensity of reflected signal depends on their density, and this density can evolve over time.

3.4 Sensors

Sonar technology provides various types of sensors. Here we have presented images from sidescan sonar, but, we can use images from other type of sonar. They can work with deferent frequencies, giving different resolutions or appearances. We can also mention optical sensors, but the scope of this technology is limited in underwater environment.

4 Landmarks for image registration

By nature, sonar images imply heavy images processing to make them usable. Defining landmarks to drive image registration might compensate variability of sonar images.

From these landmarks, we should be able to extract features and process them in a geometric registration. Such process should provide us a reference transformation.

4.1 Wrecks

Finding large objects lying on seabed is quite easy, maybe more than large rocks. Moreover we can rely on external and historical information to determine presence or absence of wrecks in studied areas. Due to their rarity we cannot rely only on wrecks as landmarks to drive a registration process. But this rarity implies that decisions taken on this sort of landmark will be surer than on other landmarks.

Another interest of wrecks is their slow degradation over time making them a good landmark for long time registration. On the opposite, presence of shoals of fish can hide part of the wreck, or alter its representation.

4.2 Rocks

Huge rocks lying on seabed can be easily identified by human experts, especially when they are on a large area of sand. The stationary of rocks along time make them good landmarks.

The main difficulty is then to detect and recognize it. Image processing provides lots of segmentation techniques and descriptors we can use to represent rocks as landmarks [3].

Isolated rocks detection can be drive by detection of shadow areas. And segmentation of such areas can be used to generate descriptors as we are able to do with submarine mines [4].

As rocks are not available on all explored area, they cannot be used as landmarks alone.

4.3 Sand, Ripples, and Silt

Seabed characterization defines homogenous areas. When wrecks or Rocks are not available, presence of a small area of sediment in a middle of the area of other sediment can be considered as landmark. For example, ripple area surrounded by sand area can be separated and considered as landmark.

The evolution of such sediments among time must be considered. The shape of areas or their geographical position can change, and we must reduce the effect of decision taken on such landmark depending on elapsed time.

4.4 Edges

Larges areas of seabed can be covered with unique sediment. The edge between two larges areas of sediments can be considered as landmark.

Edge between sediments like sand and silt can be strict, but can also be progressive. Moreover, edges can move among time. Edges between rocks and other sediment will be more stable, but can have different shape up the point of view.

4.5 Constellations

Passing time can alter representation of landmarks define on sediments. Rocks or wrecks can be rare or absent on a whole area.

Depending the frequency, and stability of previously presented landmarks, we can add to their descriptors geometrical relation. Such relations over a group of landmark can be used as landmark.

5 Descriptors and registration

One indentified these landmarks we must represent them with descriptors in order to introduce them in a registration process.

5.1 Descriptors

Image processing provides lots of shape descriptors (Fourier coefficients, moments, bounding box) [3]. They can be used to represent several landmarks: wrecks, rocks, localized sediment areas, shadows.

The main topic about theses descriptors concerns their invariance. For pattern recognition, invariance is important because it protects decision process from irrelevant information such as position or orientation. But in a registration process, this variability is the main information.

Describing edges between areas of sediments can be done with open shape descriptor such as active contour model.

Representations of constellations must contain two types of information. Shape descriptors of the element in the constellation, and geometrical relation between them. All of this information can be hold in a graph.

When describing landmarks we must take into account the variability of their representation. Fuzzy logic provides several models to describe imprecision due to variability of sonar images. The theory of fuzzy sets [11] can be used to model imprecision on position of landmarks, or components of shape descriptors.

5.2 Registration

Matching shape descriptor is a basic pattern recognition problem [3].

Transformation from transform model will alter descriptor, and when we will measure theirs similarity with descriptors from reference image, we will be able to decide which transformation lead the unregistered image to the reference image.

Meanwhile, using a landmarks or not for registration must be lead by its rarity.

When a landmark is over present in an image, the number of corresponding landmark in another image will raise. And the quantity of false alarm will rise too.

Registration of constellations can be based on invariant descriptor. Once shape descriptor will be matched between reference image and unregistered image, we will have to find the transformation that allows the shape descriptors to respect geometrical relation of the reference descriptors. Inverse transformation will give position of the sensor.

Variability of sonar images over time must be taken in account when registrating them. If the landmark is a ripple area, we must consider the movement of the landmark from the first extraction of descriptors.

If we are not able to model the displacement of the landmark, the decision of registration must be feeble when include in another registration process.

5.3 Conclusion

Terrain base navigation is confronted to the difficulty of processing sonar images.

We have presented here landmarks we can use to drive in automatically extract from sonar images and use in geometric registration. The decision provided by this registration can be used to drive an iconic registration.

Automatic segmentation must be more precisely studied on sonar images.

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