A Practical Approach for Analysing SPI Images

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ABSTRACT

Sediment profile imagery (SPI) is a remote sensing technique that is used for determining whether the marine sediments provide the suitable habitat for benthic (bottom-dwelling) fauna. The SPI technique is based on an inverse periscope that penetrates the seabed and the captured images are analysed in order to evaluate the activity of the resident marine fauna and the overall level of sediment contamination. Although this sediment monitoring technique has been widely used by the marine benthic scientists for several years, SPI analysis is based on a visual qualitative and quantitative evaluation performed by the human operator. Independent tests reveal that this method is affected in terms of sensitivity and reproductibility by the subjectivism of the human operator. This paper describes the development of a color-based image processing technique that is applied to decide if the imaged sediment contains an oxidised layer and to detect its area and position within the image. A number of experimental results are presented and discussed.

Keywords: REMOTS, Image Filtering, K-means Algorithm and Color Image Segmentation.

1. INTRODUCTION

The changes in the characteristics of the benthic fauna and the disturbance of the sedimentary environment are of utmost importance in pollution monitoring. Sediment profile imagery (SPI) is a cost efficient method for monitoring marine aquatic environments with a view to establishing if the ambient seabed provides a suitable habitat for the resident marine fauna [5]. The traditional method of sample collection and subsequent laboratory analysis is not only expensive but is also very time consuming.

The SPI method, also known as REMOTS (*r*emote *e*cological *m*apping *o*f *t*he *s*eafloor), consists of a wedge-shaped camera that can capture *in situ* profile images of the upper sediment layer. From these images several biological parameters are measured in order to evaluate the level of sediment contamination [2,4,5]. The SPI camera is an inverse periscope and is based on a prism with a back mirror that reflects the cross section of the sediment to the camera placed horizontally above the prism (see Figure 1).

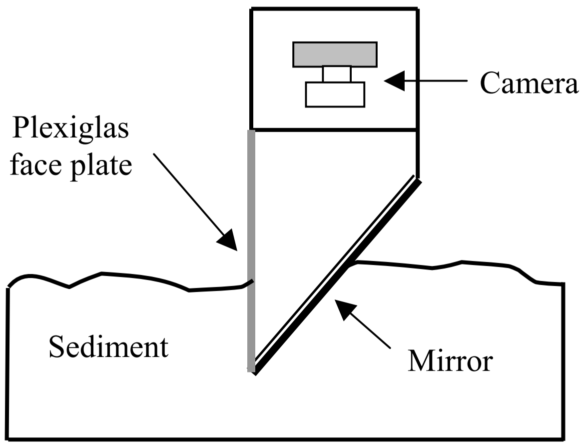


Figure 1. Diagram of the SPI camera.

In recent years the SPI method has been continuously developed [1] but it is surprising to learn that very little has been achieved in the field of automatic analysis of SPI images [6]. In fact, in the initial stage of this project, an exhaustive search for published investigations on the subject of SPI image analysis has shown that little relevant information is available.

Thus, our aim was to develop an image processing technique as a tool to interpret the SPI images. The most important feature measure in SPI images is to detect if the sediments contain oxidised layers as they indicate the extent to which marine animals are ventilating the sediment. Although this paper focuses on the detection of oxidised sediments our research interests also include the detection of *sediment-water-interface* (SWI), to highlight the burrows and voids and the detection of the sediment grain size. In the following sections of the paper we will detail the method employed to detect the oxidised sediments.

2. OXIDISED SEDIMENT DETECTION

Accurate detection of oxidised sediments is of utmost importance in understanding the characteristics of the resident marine fauna and the sedimentary environment. Traditionally the detection of the oxidised layers from SPI images is performed by human operators. However this technique lacks a common standard procedure and furthermore is quite subjective and the results are not repeatable.

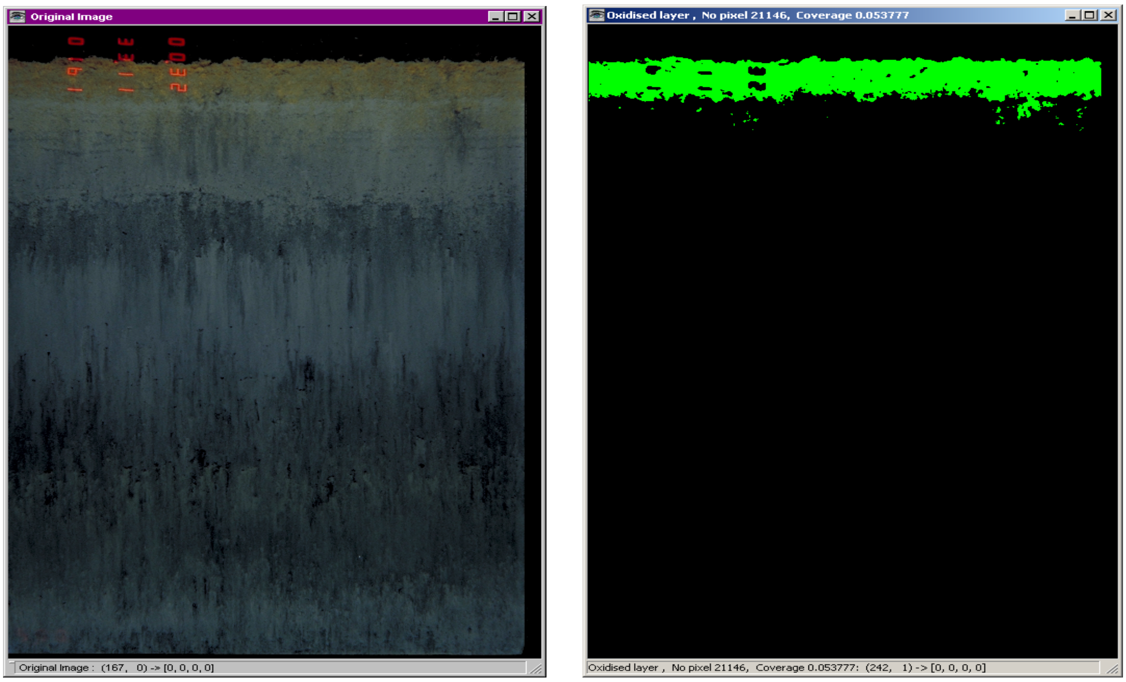
In our investigation we analysed a relative large number of SPI images where various types of sediments are imaged. The analysed images show a high degree of dissimilarity in terms of noise level and image resolution and very often the discontinuity between reduced and oxidised sediments is vaguely defined. A visual examination of the SPI images indicates that the color information is the only robust feature that can be employed to detect the oxidised sediments. Although the color of the oxidised layers can vary to a relative large extent it has been observed that the oxidised sediments tend to have a gold-green-brown color while the reduced sediments have a black or a very dark color. Another important observation is the fact that the oxidised or reduced sediments are organised in layers. Therefore in order to separate the oxidised sediments from reduced sediments it is necessary to perform color image segmentation. For this purpose the *k-means* algorithm [3,7] was employed. The *k-means* algorithm segments the input image by organising the data into *k* different clusters. This process consists of four steps:

1. Make the initial guesses for the means m_1, $m_2,\ldots,m_k$.
2. Proceed through the list of items and each items is assigned to the cluster whose mean is nearest with respect to the metric employed.
3. Recalculate the means for the cluster receiving the new item and the cluster loosing the item.
4. Repeat the steps 2 and 3 until no assignments are made.

The number of clusters is the input parameter for the *k-means* algorithm and the value of this parameter is dependent on the complexity of the SPI image. To determine the optimal number of clusters would be a very difficult problem as this parameter is image dependent. In order to address this issue, we set the number of clusters to a value (e.g. 15) that is sufficiently large to assure that all important regions in the image with similar color characteristics are segmented. Then we refine the initial segmentation by merging the clusters that reveal similar properties. In this regard, two adjacent clusters are merged if the difference between their centre values is smaller than a preset threshold value. This process is iterative and is repeated until no more merges occur. Also in order to reduce the noise and to increase the cluster continuity, before the application of the *k-means* algorithm the input SPI image was subjected to median filtering.

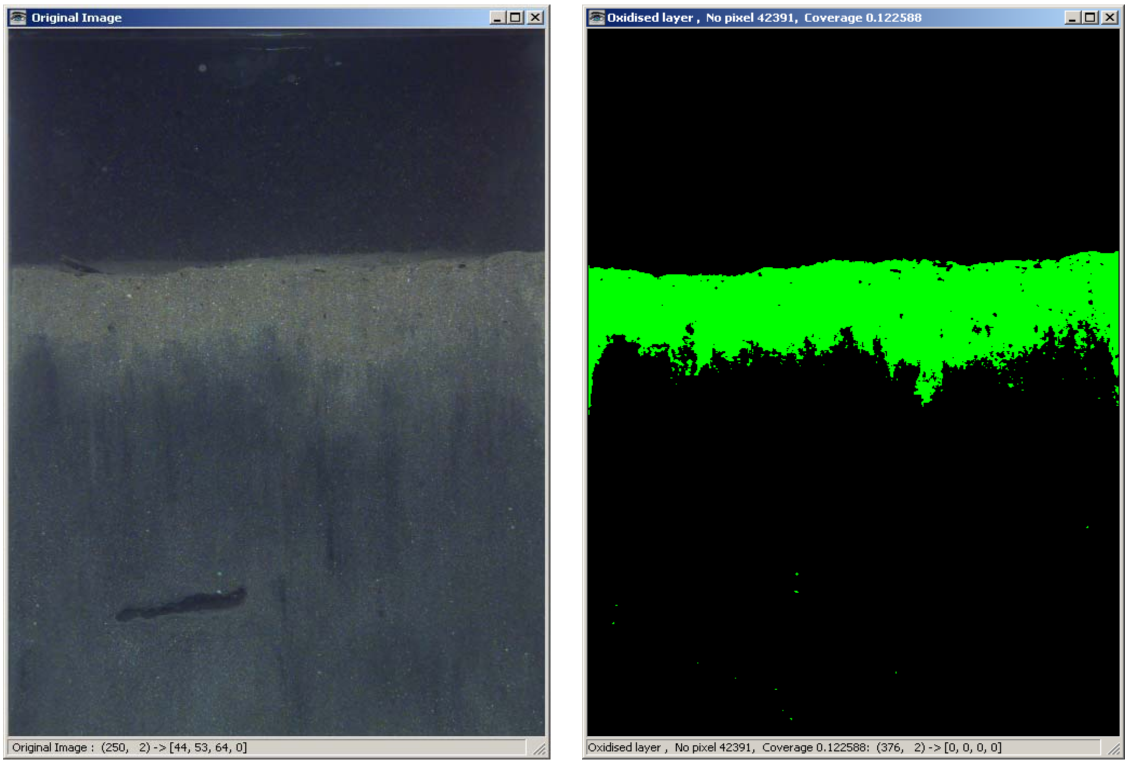
3. EXPERIMENTS AND RESULTS

After the application of the *k-means* algorithm, each resulting cluster is analysed in order to verify if it is an oxidised or a reduced layer. Fortunately, the color histograms associated with oxidised layers are very narrow and the highest count bins are in the range of 79-110 for red, 75-115 for green and 55-100 for blue. Also it was observed that the blue component is never higher than the red or green components. Also the ratio between the red and green components is in the range 0.8-1.1. This analysis was performed on 20 SPI images and all oxidised layers are correctly identified and no reduced layers are classified as oxidised. Figures 2 to 6 depict some experimental results.



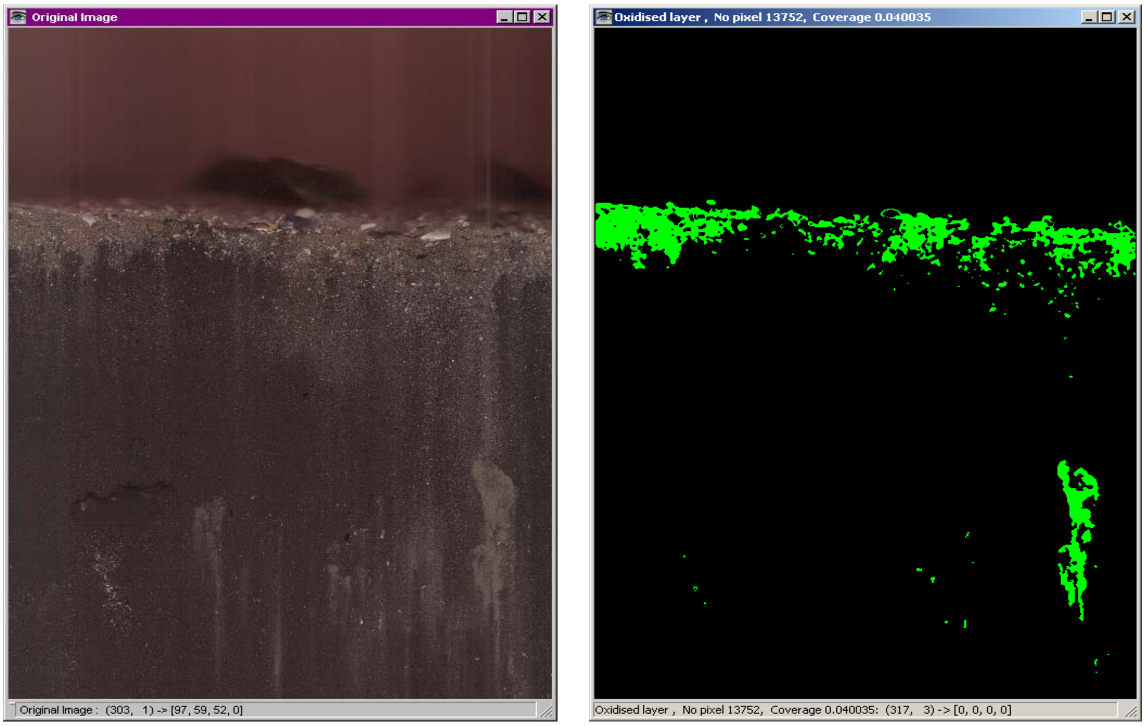
(a) (b)

Figure 2. Detection of the oxidised layer. (a) Original image (sample Caspian laminate). (b) Oxidised layer.



(a) (b)

Figure 3. Detection of the oxidised layer. (a) Original image (sample12-8-02gbds4-3). (b) Oxidised layer.



(a) (b)

Figure 4. Detection of the oxidised layer. (a) Original image (sample Scangbds8-3).
(b) Oxidised layer.

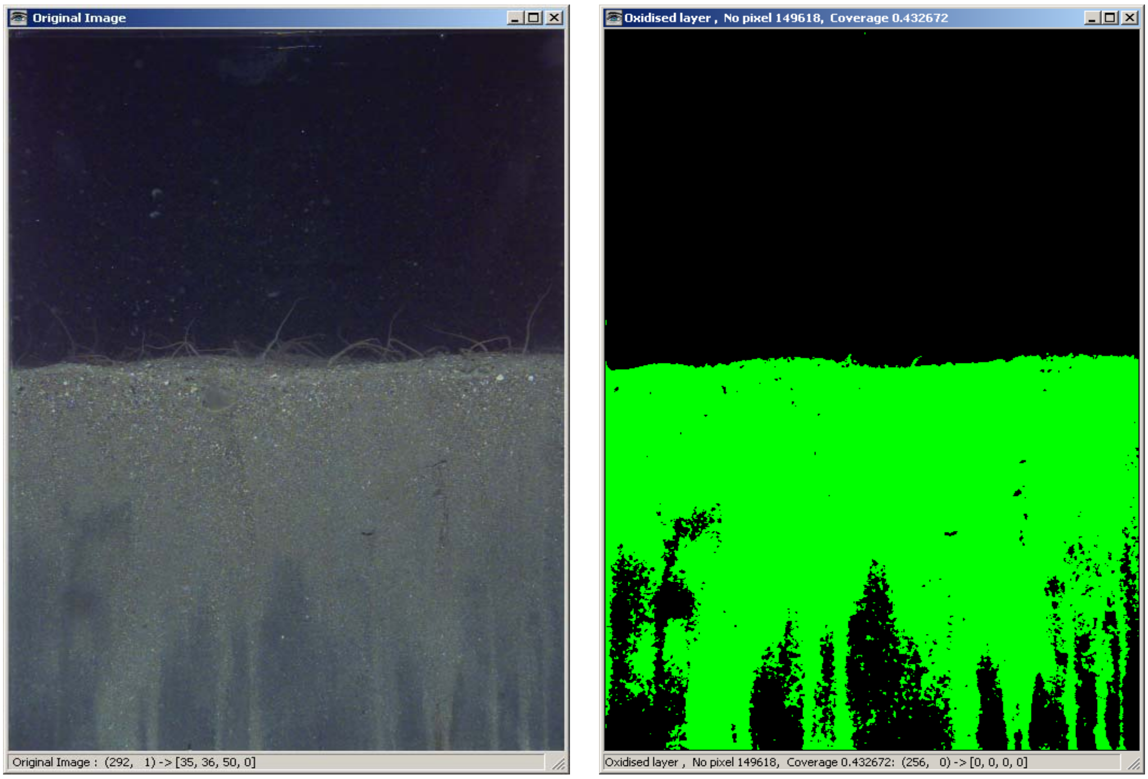
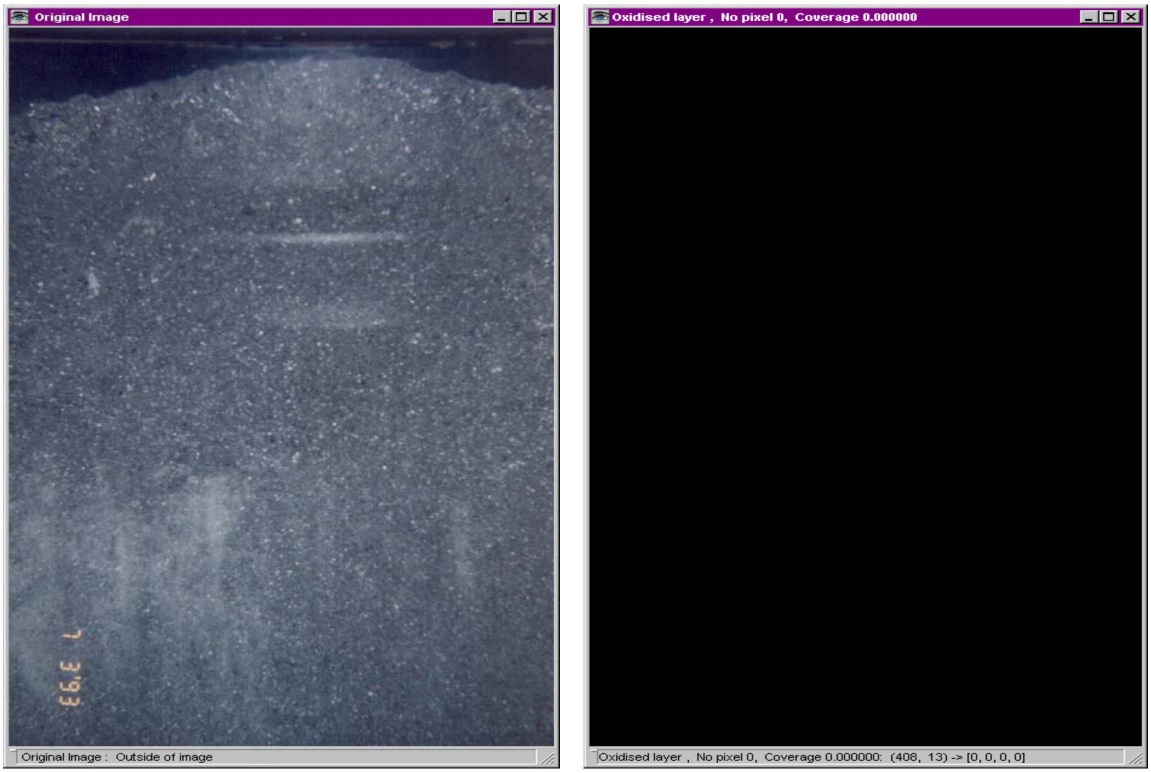


Figure 5. Detection of the oxidised layer. (a) Original image (sampleMarg1).
(b) Oxidised layer.



(a) (b)

Figure 6. SPI image with no oxidised sediments. (a) Original image (sample Eliat3).
(b) No oxidised layer detected.

4. CONCLUSIONS

Although it has been accepted that the SPI method is a valuable tool in pollution monitoring, this method lacks a standard procedure to automatically analyse the image data. Thus, most of the advances in SPI imagery were focused on improving the image acquisition while a reluctance to develop image-processing techniques to analyse the image data has been noticed. To address this issue in this paper we described a practical approach to evaluate if the imaged sediments are defined by oxidised components and to identify the area occupied by them within the image. The experimental results proved to be very encouraging and indicate that this method is appropriate to be applied for detection of the oxidised sediments. Currently, we try to expand this approach to detection of the sediment-water-interface and for identifying the presence of voids and burrows.

5. ACKNOWLEDGEMENTS

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6. REFERENCES

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