Image mosaicing can be defined as the registration (or matching) of two or more images that are then combined into a single and usually larger one. The applications of mosaicing comprehend panoramic photography, super-resolution, virtual environments and vision based navigation systems, as a most relevant exponents. Besides generic camera issues as geometric and chromatic distortions, underwater images are affected by particular factors as non-uniform illumination, caustics, blurring, suspended particles and scattering, making even more difficult the alignment and blending. The aim of this work is to perform a review on the existing image blending techniques specially focusing the study on its application on the underwater imaging.

1. Introduction

Underwater photo-mosaics can be used to gain a global perspective of interest sites. Mosaics to be analyzed by underwater biologists or geologists are easier to be interpreted if they are visually pleasant, and should have two desirable properties. Firstly, the mosaic should be geometrically and photometrically as similar as possible to the input images. Secondly, the seam between the stitched images has to be invisible.

Image blending is the final step in producing high-quality image mosaics. Radiometric variations in overlapping views and violation of certain scene assumptions such as rigidity, stationarity, and (or) planarity, lead to geometric misalignments (e.g. due to the parallax effect) and photometric differences. Upon blending, these mosaics usually result in degrading artifacts, such as blurry regions or disturbing seams.

Two main seamless blending methods groups have been differentiated. On one hand, transition smoothing techniques concentrate their efforts on combining information of two or more images with a common overlapping region in order to achieve the optimal contribution, minimizing the visibility of the seam in the joining region. Multiresolution Splining in the intensity [1], gradient [2] and wavelet domain [3] and Energy Minimization Multiresolution Splining [4] apply the idea of multilevel blending on different image domains.

On the other hand, optimal seam finding techniques are based in the main idea of determining the best boundary (or set of boundaries, if multiple stitching is carried out) that minimizes the visibility of the image seams. Methods based on relative differences [5] in order to find the contribution of each image to the final mosaic and methods that find the path with minimal intensity difference [6] fall in this category.

Finally, combined methods [7] try to improve the results taking profit of the benefits of both mentioned approaches.

2. Results and Discussion

In order to compare and evaluate the behavior of the mentioned approaches, the more representative methods have been implemented and applied to a set of images showing typical artifacts in underwater imagery. Two methods have been selected from the transition smoothing approach: Multi-resolution Splining [1] and Energy Minimization Multi-resolution Splining [4]. Graph Cut seam finding based on Watershed Segmentation [6] have been chosen as a representative of the optimal seam finding ap-proach. Finally, the Interactive Digital Photo-montage method [7] has been considered as a combined method. On the other hand, we propose in this work a hybrid method based on the combination of methods belonging to the first two approaches. It is based on Graph Cut Seam Finding on a Watershed Segmentation and a Gradient Domain Blending on the obtained seam. This new method focuses on solving two main problems of image mosaicing: registration inaccuracies and illumination variations. Figure 1 enables comparison among the different methods.
proaches. (c)-(g) show blending results using (c) Multi-resolution Splining, (d) Energy Minimization Multi-resolution Splining (applied only on straight lines), (e) Interactive Digital Photomontage, (f) Graph Cut Seam based on Watershed Segmentation, (g) proposed hybrid method.

3. Conclusions
The reviewed and obtained results demonstrate that transition smoothing methods are adequate for image mosaicking presenting an accurate registration, when moving objects or significant geometrical inconsistencies do not appear in the scene. The vignetting problem is well solved. Energy Minimization Multiresolution Splining is especially valuable to reduce the perception of large photometric inconsistencies. Neverthe-less, the blurring on the overlapping region still being sometimes noticeable. Finding the optimal seam allows reducing the visibility of misalignment problems in the registration. These methods are not able to solve by themselves the photometric inconsistencies, but actually reduce their visibility.

In the proposed hybrid method, Graph Cut based seam estimation allows to reduce the visibility of geometrical misalignments, while the application of this method on the Watershed segmentation increases the speed of the whole process, making it feasible for large images.

4. References

Acknowledgement: This work has been funded in part by MEC under grant CTM2004-04205; RP has been funded by Generalitat de Catalunya under FI grant 2007FIC-00856. LN has been funded by ICREA.