Polarization and Stereo-vision Applied to Water Detection

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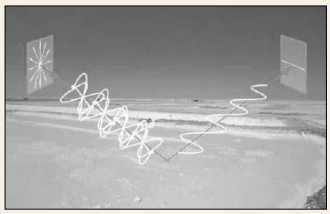
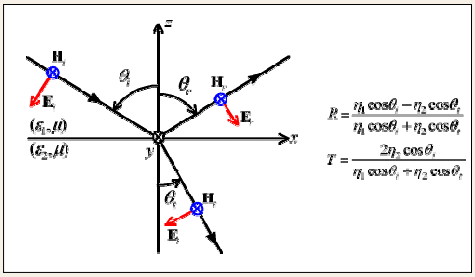
INTRODUCTION

Over the past few year, the ability of a robot to accurately sense its environment and use that information for control, has been grow. Water hazards such a ponds and puddles are one of the most challenging obstacles commonly encountered in outdoor environment. Polarization light information is one of the methods to get clues from environment depending on light conditions. This information will be combined with a stereo vision setup to provide an accurate description of the world. The main idea of this research is to find correspondences between stereo images depending on polarization information from every pixel.

BASIC PRINCIPLE

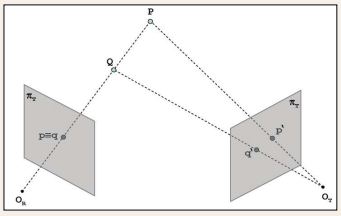
Polarization by Reflection



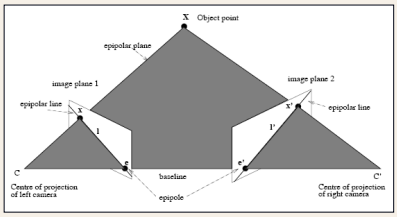


$$R_s = \frac{\eta_1 \cos\theta_i - \eta_2 \cos\theta_t}{\eta_1 \cos\theta_i + \eta_2 \cos\theta_t} \qquad T = \frac{2\eta_1 \cos\theta_i}{\eta_1 \cos\theta_i + \eta_2 \cos\theta_t}$$

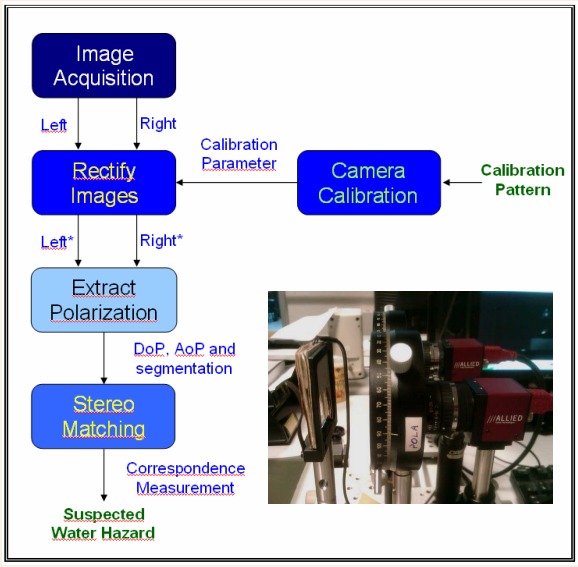
Pixel Correspondence on Stereo images



Epipolar Geometry

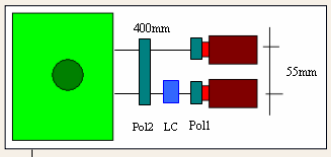


SYSTEM OVERVIEW



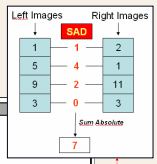
STEP RESEARCH

Images Acquisition



Calibration & Rectifying

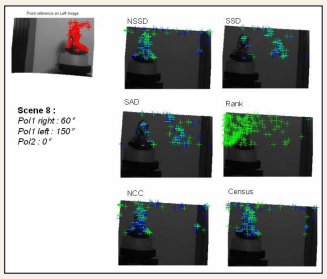
Evaluation Stereo Local Matching Method

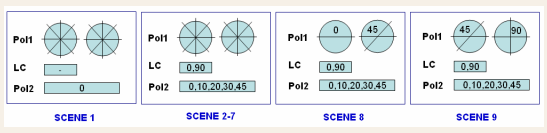


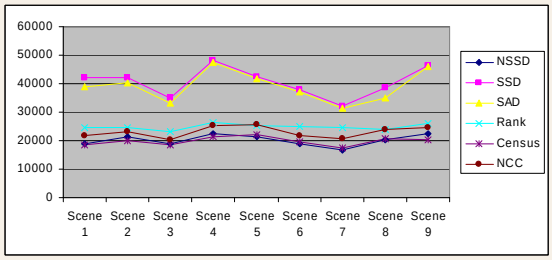
MATCH METRIC	DEFINITION
Normalized Cross-Correlation (NCC)	$\frac{\sum_{u,v}(I_1(u,v)-\bar{I}_1)\cdot(I_2(u+d,v)-\bar{I}_2)}{\sqrt{\sum_{u,v}(I_1(u,v)-\bar{I}_1)^2\cdot(I_2(u+d,v)-\bar{I}_2)^2}}$
Sum of Squared Differences (SSD)	$\sum_{u,v}(I_1(u,v)-I_2(u+d,v))^2$
Normalized SSD	$\sum_{u,v}\left(\frac{(I_1(u,v)-\bar{I}_1)}{\sqrt{\sum(I_1(u,v)-\bar{I}_1)^2}}-\frac{(I_2(u+d,v)-\bar{I}_2)}{\sqrt{\sum(I_2(u+d,v)-\bar{I}_2)^2}}\right)^2$
Sum of Absolute Differences (SAD)	$\sum_{u,v}\lvert I_1(u,v)-I_2(u+d,v)\rvert$
Rank	$\sum_{u,v}\lvert I_1'(u,v)-I_2'(u+d,v)\rvert$ $I_k'(u,v)=\sum_{m,n} I_k(m,n)<I_k(u,v)$
Census	$\sum_{u,v} HAMMING(I_1'(u,v), I_2'(u+d,v))$ $I_k'(u,v)=BITSTRING_{m,n}(I_k(m,n)<I_k(u,v))$

RESULT

From 9 scenes with different orientation of 3 linear polarizer and over 90 stereo pairs of images :







CONCLUSION

Sum of Absolute Difference Error method is one simple way to get the score of the difference between two images. We have found the **NSSD** and **Census matching method** are giving good result for polarized images.
We still want to find a good polarizer orientation to make an improvement over matching result. Finally, we will match using polarization information to detect a water surfaces.