Mobile Robotic Surveillance Systems: Detecting and Evaluating Changes in 3D Mapped Environments

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Abstract: This paper presents a study focused on the performance of three possible techniques to detect changes within the environment. An individual combination of the Earth Mover's Distance (EMD) algorithm along with three distinct methods – Principal Components Analysis (PCA), Gaussian Mixture Models (GMM) and Plane Extraction (PE) – can be used to detect changes among datasets composed by 3D point clouds. These latter, in turn, can be obtained with a laser range finder (LRF) installed on a mobile robot. Advantages of using an LRF instead of cameras, arise from the need of having accurate measurements independent of weather or lighting conditions, in order to reduce the amount of noise. The ability to perceive changes is crucial for truly autonomous mobile robots, such as the ones integrated in surveillance systems.

Within this work, a description is given on how the EMD can be used in conjunction with each of the mentioned methods, yielding three distinct ways to quantify changes between two data sets. The techniques presented herein

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were applied to a series of simulations conceived to evaluate their behaviour in regard to the following aspects: sensibility to data errors, ability to detect objects of different sizes and computational complexity.
Regarding to computational complexity, the obtained results show that the PCA-EMD combination has the best performance; however GMM-EMD possesses a very similar computational cost. Moreover, such results clearly show that GMM-EMD is by far the most stable technique in the sense that it presents lower sensibility to errors, therefore being able to detect changes with greater reliability. In fact, PCA-EMD and PE-EMD techniques yield many numeric fluctuations in the results, making it impossible to distinguish if whether a change was detected or if the obtained result was induced by noise. Conversely, the performed simulations establish that the GMM-EMD technique is quite robust, since it is able to consistently detect changes even in the presence of noise with different variances. It has proven to be, by far, the best option among the three, allowing an accurate detection of changes as desired.

Index Terms: Change detection, Earth Mover's Distance, Principal Components Analysis, Gaussian Mixture Models, Plane Extraction.