IMPROVED ALGORITHMS FOR AUTOMATIC REGISTRATION OF 3D POINT CLOUDS

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by

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ABSTRACT

A 3D scanner/sensor is a device that captures shape (and possibly appearance or colour) information of a real-world object or scene. With the introduction of practical 3D systems and the availability of off-the-shelf sensors, the 3D scanning technology has gained strong momentum in its research and development phase. The introduction of low cost 3D sensors such as Microsoft Kinect into consumer market has shifted the direction of 3D research from developing low cost 3D sensors to developing applications using these sensors. The 3D technology market has been growing rapidly with an estimated Compound Annual Growth Rate (CAGR) of 21% foraying into new application areas. The wide array of application areas which make use of the 3D scan data include rapid prototyping, garment fitting and design, reverse engineering, gaming, animation movies, architecture, real estate, medical, archaeology, inspection and quality control, robotic vision etc.

Due to spatial constraints, an object has to be scanned from multiple view points to create a complete 3D model of it. It is essential to bring the scan data (saved as point clouds, one of the popular digital representations of the scan data) to a reference coordinate system. This process of aligning the scans is called registration. Registration task involves estimation of the rigid body transformation parameters (in the case of rigid body modelling) to align the scans to the reference coordinates. Traditionally, registration task is done with the help of manual intervention using external markers on the object or using precisely controlled machinery. The need for robust automatic registration algorithms which avoid expert intervention or supervision in scanning and registration stages becomes prominent due to the ubiquitous nature of problem. However, due to the complexity of 3D registration problem, the potential of existing algorithms for automated 3D registration is confined to only some stages of the 3D registration process. This thesis explores the development of a complete automatic registration pipeline for 3D modelling that eliminates the need for external markers or tracking equipment.

The point cloud matching problem is challenging due to various factors like extend of overlap, availability of distinctive geometric features and unstructured nature of the point clouds. This thesis presents a complete framework for obtaining a single point cloud from a sequence of 3D scans of an object or a scene. The 3D registration problem is usually tackled in two steps - pairwise registration and multiview registration. While the pairwise registration aims to align the overlapping pair of scans, the multiview registration aims to align all of the scans to a common coordinate system using the information obtained from pairwise registration. The pairwise registration is performed in a coarse to fine registration strategy. This thesis proposes a novel robust estimation algorithm named 'ProLoSAC' for coarse pairwise registration. Experiments on various 3D datasets indicate that the proposed ProLoSAC algorithm outperforms the existing RANSAC algorithm in terms of accuracy and computational time. This thesis also presents a novel robust multiview registration algorithm (robust motion averaging) which utilises the Lie group structure of the rigid body motion to find global transformations by averaging the redundant relative transformations. The wrong relative transformations are correctly identified and filtered out before motion averaging. The performance of the developed algorithms is compared with the existing approaches on various 3D datasets (acquired using laser scanners, Kinect etc.). Validation of the results indicate superior performance of the proposed algorithm. The generalizability of the developed pairwise registration algorithm has been assessed by adapting it for automatic registration of several multispectral satellite images. An end-to-end automatic framework for 3D point cloud registration for 3D modelling is proposed and tested for different 3D objects in this thesis. The complete framework for 3D registration is implemented in an object oriented open source platform which enables efficient sharing. The cases of object reconstruction as well as scene reconstruction are considered and accurate registration using the proposed framework is achieved. The robust parameter estimation algorithm for pairwise alignment and robust motion averaging algorithm for multiview alignment are promising tools for high precision and automatic registration of 3D point clouds.