論文の内容の要旨

3D Shape Reconstruction by Dynamic Sensing with Range Sensor

（レーザ・レンジ・センサを用いた形状復元のための動的計測に関する研究）

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Building 3D shape models of interesting targets and getting their localization are very important fundamental tasks in the fields like digital culture heritage, robotics, mixed reality, medical application and so on.

Most commonly used sensors for 3D modeling are camera and laser range sensor. Compared with camera, range sensor has the following advantages: 1. It can easily get direct and highly accurate 3D data. 2. Range data is stable, whereas the 3D modeling techniques based on 2D cameras are much more sensitive to illumination, shadows, scale and pose. However, range sensor costs a relatively long time of data acquisition. This causes data distortion and cannot be ignored especially in the case of continuously gathering data on a moving platform.

Existing common solutions to this problem are either taking "stop-scan-go" strategy to avoid distortion or correcting the sensor motion using secondary sensors like GPS, inertial sensor, camera or even another range sensor. Some other researches apply linearization, discretization and other specified constraints to the problem to achieve compromised results.

This thesis focuses on efficient and accurate 3D shape reconstruction under a moving sensing system only with a single range sensor. Different from previous solutions, the proposed system works in an efficiently continuous manner. We don't have to stop the platform to obtain an stationary scan. Sensor can move under a reasonable motion mode and simultaneously scan the target or environment. Data distortion caused by continuous movement will be rectified. This continuous manner is much more efficient and attractive in practical applications.

According to the different prior conditions of targets, we divide the problem to two categories. The first one is based on the assumption that the target shape model is known. The second one is focusing on the unknown targets.

For the known targets, since there is no need to build 3D model for the object, our interesting mainly focus on how to accurate localize them. We propose a method which utilizes the prior shape model to estimate sensor motion. Based on the estimated motion model, distorted measurements can be rectified and accurate localization of targets can be achieved. As an application, we build a real-time pile driver position system using laser range finder. The detail is described is Chapter 2.

For the unknown targets, we develop a feature based polynomial fitting method to estimate 6 DOF motion parameters of moving range sensor. The 3D model can be reconstructed according to highly accurate sensor motion estimation. When using a 2D scanning sensor instead of a 1D scanning sensor, the same region is measured in multiple times when the sensor moves. We will show that we can reconstruct the sensor motion and the scene from only the measured coordinates and times of the same set of points. This reconstruction is intrinsic, which relies on only the intrinsic properties of the distortion, and not relying on the extrinsic information from other sensors. Firstly, for robust estimating sensor movement, we model the sensor motion using polynomial with respect to time. Secondly, to build simple representation of common motion like uniform circular motion or rectilinear motion, we introduce twist coordinates for the representation of rigid body transformation. This method doesn't need the secondary sensor and is not limited with specific environment features. Without linearization of constraint and discretization of trajectory, distorted data is accurately rectified. Details are in Chapter 3.

To obtain the corresponding constraints described in chapter 3, we propose a 3D affine invariant feature detection and matching method which is designed for the deformed 3D data collected by moving range sensor. Firstly a Morse function which measures the object shape is designed. A disconnected graph based method is proposed to extract stable affine invariant region feature in multiple scale. Applied a moment-based affine transformation, the deformed region feature can be normalized. A multiple scale Spin Image is designed to describe the normalized region feature. Both synthetic data and actual scanning range data give robust feature detection and matching results. Details are presented in Chapter 4.

Finally, we present our conclusions and summarize our possible future works in Chapter 5.