Robust 3D Features for Matching between Distorted Range Scans Captured by Moving Systems

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Figure 1. An example of dynamic sensing system in [1]: (a) balloon mounted with a laser range sensor. (b) a distorted range scan captured by the balloon sensor.

1. Introduction

With the popularity of accurate and long-range laser sensors, efficient 3D reconstruction of large-scale objects, such as culture heritages or urban environment, requires the dynamic sensing techniques which often mount sensors on moving platforms, e.g., vehicles [3], drones, or balloons [1] (shown in Fig. 1(a)). In spite of the physical convenience and efficiency brought by these dynamic sensing systems, range scans are often deformed due to sensor motions (as an example shown in Fig. 1(b)). This disadvantage may significantly inhibit its development, and therefore it’s an essential issue to match such kind of distorted data for reconstruction, recognition, rectification, etc.

2. Methodology

Novel 3D features approximately invariant to the distortion caused by moving systems are presented in this paper. Our approach consists of two main parts:

1) Feature detection: Morse theory is applied for deriving Morse functions that can robustly describe distorted surfaces with critical points invariant to surface distortion. Critical points of local extrema are taken as our key points and then the maximally stable regions on the Morse function are captured as our support regions. Through defining the region stability by i) maximal extreme regions and; ii) maximal disconnected regions, we derive the maximally stable extreme region (MSER) feature (mathematically equivalent to [4]) as well as a novel feature termed maximally stable disconnected region (MSDR). Our image matching results show that both methods have good performances.

2) Feature description: Given support regions, we design the feature description with two processes: i) canonical shape normalization; ii) description with multi-scale support regions. The detected regions are firstly normalized to canonical shapes based on an assumption that the local region changes can be approximated as affine transformations; then one key point is encoded by several support regions extracted at different scales (Morse function values).

In order to achieve the goal of matching distorted range images within a large number of laser scans, the following novel contributions are made in comparison with the most recent work in dealing with deformed non-rigid objects [5, 6].

1. Morse theory is applied to define Morse functions which can robustly capture the critical points from range scans with distortion.
2. Maximally stable regions are derived for critical points (of index 0 and 2) by a novel maximal disconnectivity detection using Disconnectivity Graph (DG).
3. Local support regions are normalized to canonical shapes for robust matching, thus we can simply encode them by rotation-invariant descriptors like Spin Image [2].

3. Experimental Results

We evaluate the algorithm in comparison with the state-of-the-art methods on both synthesized and real datasets. Experiment results show that it achieves a substantially better performance for i) repeatability of feature extraction; and ii) precision of 3D surface matching.

Around 30 models are collected from the Stanford and AIM@Shape 3D scanning repository to make the synthesized data set. Several selected famous models are shown
A novel approach for detecting and describing 3D features based on Morse theory is presented in this paper. Facing the problem of range scan distortion, we propose a \( \beta \)-stable Morse function combined with MSDR to be superior to the others including the popular non-rigid methods \([5, 6]\). Its feasibility is demonstrated in experiments. We also show that it provides an interesting way of dynamic sensing, because the robust matching of deformed range scans provides good initials for non-rigid region to the data rectification.

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### References


