Pose Error Effects on Range Sensing

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Abstract

Object reconstruction or inspection using a range camera requires a positioning system to configure relative sensor-object geometry in a sequence of poses. Discrepancies between commanded and actual poses can result in serious scanning deficiencies. This paper provides analytical and experimental characterization of pose error effects for a common type of range camera.

1 Introduction

As illustrated at Fig. 1, the imaging environment for object reconstruction or inspection with active laser-scanning range cameras [1] comprises three main elements: object, range camera and positioning system. Model acquisition involves iterative view planning, sensing, registration and integration. View planning is the task of determining an optimal set of sensor views. Executing the view plan requires physically altering the relative sensor-object pose by means of a positioning system. This may introduce pose error.

Traditional view planning methods use a variety of heuristic techniques relying on surface [5], [13], volume [3], [7] or global [14], [6] scene attributes and generally focus only on object coverage. In performance-oriented reconstruction [9], range data acquisition is based on explicit quality requirements expressed in a model specification - such as sampling precision and density. Performance-oriented view planning requires suitable models of both sensor and positioning system performance. The first should describe the sensor frustum and characterize performance within the calibrated region while the second should describe the positioning system degrees of freedom, range of motion and accuracy within the movement envelope.

This paper summarizes a detailed study [10] of pose error effects on the performance of active laser-scanning range sensors. We address the effects of positioning system inaccuracy in two parts: first an analysis of the impact on a single planned view and then experimental examination of the composite impact on a view plan consisting of multiple views. The analysis is made for a common sensor configuration. Results are generalizable to other range cameras.

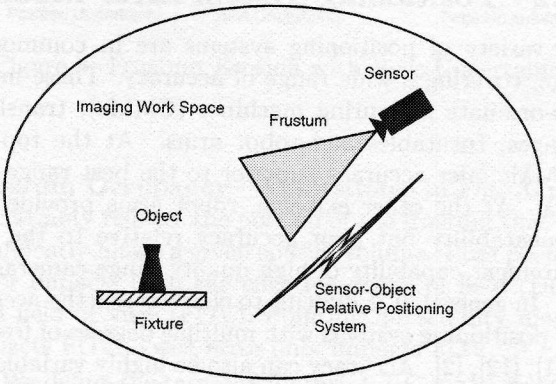

Figure 1: The Geometric Imaging Environment

2 The Range Sensing Context

2.1 Pose Uncertainty Effects

For a surface point to be measurable by a viewpoint, all model specification requirements must be met at that point. Specifically, for the sensing geometry defined by the viewpoint: the surface point must (1) fall within the sensor frustum, (2) be locally visible by the optical source and receiver and (3) have estimated sampling precision and density within specification.

Unfortunately, pose error adversely impacts all of these requirements. Viewpoint position and orientation are corrupted. Orientation error is particularly troublesome as effects are amplified by range. Image coverage (frustum occupancy), measurement precision