Use of Belief Networks for Modeling Indoor Environments*

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Abstract

This article introduces an approach, based on Bayesian Networks, for the grouping of 3-D surfaces extracted from data obtained by a laser ranging sensor. A methodology for the specification of the network is presented along with an approach for determining the conditional probabilities. Determination of the conditional probabilities is based on a compatibility function that measures the uncertainty in the quality of fit of the data to a model of the features in the scene. Several compatibility functions for the grouping of 3-D surfaces are presented. These are coplanarity, parallel, planarity, and proximity. These compatibility functions are used with a Bayesian Network in determining belief values of possible groupings among the surfaces, in particular grouping for continuous surfaces and corners. This operation is a form of perceptual grouping of three dimensional data and is akin to the previous studies in perceptual grouping for two dimensional images.

1 Introduction

Research in the domain of modeling using 3-D data has primarily focussed on the extraction of 3-D surfaces and volumetric primitives for the purpose of either object recognition or creating more precise models from 3-D sensory data of machined parts [12, 4]. These type of objects can easily be carried and placed in a controlled environment and scanned using a high resolution active sensor. This is significantly different from the modeling of large indoor environments where it is necessary to bring the sensor to the environment, changing the characteristics of the sensed data dramatically. The result of this is that nearly all scans taken in these environments consist of sparse data and it becomes necessary to develop algorithms that can hypothesize the existence of surface continuity and intersections among surfaces. This may appear to be as simple as relaxing the tolerances used for computing the surface models from the sensory data, but it is more complicated than that. Objects occluded from the sensor and missing data make it necessary to use knowledge about the environment to hypothesize the existence of more complex surfaces.

Because of the larger domain in which the sensor is operating in, research in the modeling of indoor environments has primarily focussed on the incremental synthesis of sensor views and/or position estimation of the sensor [16, 15, 1]. For these systems to become viable tools for Computer Aided Design (CAD) it is necessary to develop approaches that hypothesize the formation of more composite features from the surfaces. Previous attempts in this domain [10, 14, 6] have integrated intensity data with range data to help define the boundaries of surfaces extracted from the 3-D data, and then used a set of heuristics to decide what surfaces should be joined. In most circumstances these heuristics are a set of rules with predefined thresholds that determine if the surfaces should be joined. In this article a Bayesian Network is proposed to manage the uncertainty associated with such decisions. A Bayesian Network offers a unified approach to the specification of relationships among surfaces as well as a method for computing a belief value in the existence of a compound feature given the evidence from the sensory data.

This article proposes definitions of proximity, planarity, and coplanarity of planar 3-D surfaces. This is akin to the idea of extending the 2-D perceptual organization rules to 3-D sensory data, except that it is not possible to associate these measurements to

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