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The correspondence framework for 3D surface matching algorithms

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Abstract

Beyond the inherent technical challenges, current research into the three dimensional surface correspondence problem is hampered by a lack of uniform terminology, an abundance of application specific algorithms, and the absence of a consistent model for comparing existing approaches and developing new ones. This paper addresses these challenges by presenting a framework for analysing, comparing, developing, and implementing surface correspondence algorithms. The framework uses five distinct stages to establish correspondence between surfaces. It is general, encompassing a wide variety of existing techniques, and flexible, facilitating the synthesis of new correspondence algorithms. This paper presents a review of existing surface correspondence algorithms, and shows how they fit into the correspondence framework. It also shows how the framework can be used to analyse and compare existing algorithms and develop new algorithms using the framework's modular structure. Six algorithms, four existing and two new, are implemented using the framework. Each implemented algorithm is used to match a number of surface pairs. Results demonstrate that the correspondence framework implementations are faithful implementations of existing algorithms, and that powerful new surface correspondence algorithms can be created.

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1. Introduction

Rigid three dimensional (3D) surface correspondence is an important problem in computer vision, used in tasks such as 3D modelling and 3D object recognition. Although a host of surface correspondence algorithms exist, no single algorithm that determines a good coarse initial match between two surfaces, has prevailed. This is primarily due to the fact that the algorithms are generally application specific. This paper does not propose a new, all-encompassing surface correspondence algorithm, but rather a framework for developing correspondence algorithms for given surface matching tasks.

The framework is presented as both a conceptual model and as a software design tool for analysing, comparing, developing, and implementing surface correspondence algorithms. It is general, encompassing a wide variety of existing algorithms, and flexible enabling the synthesis of powerful new algorithms.

This paper begins by discussing the major challenges of pairwise surface correspondence in Section 2. Section 3 then reviews a wide variety of existing algorithms. It also identifies five common elements in surface correspondence computation that loosely unify all algorithms. These five elements are combined to form a stage-wise procedure for computing correspondence, which is termed the correspondence framework in Section 4. Section 5 demonstrates the generality of the framework, by restructuring existing algorithms to fit within it. It also demonstrates the flexibility of the framework, by using it to synthesise new correspondence algorithms. Results that validate the integrity of implementing algorithms within the framework are presented in Section 6. Finally, Section 7 summarises the paper and discusses some future directions of the correspondence framework.

2. Background

Surface correspondence has been a focus of computer vision study since the late 1980s and 1990s. This section identifies exactly what rigid 3D surface correspondence is, and how it is related to registration. It then discusses an important type of correspondence, the process of matching surfaces with unknown relative pose. The major difficulties in developing this type of surface correspondence algorithm are outlined, and it is shown how the difficulties result in strongly application specific algorithms.

Rigid 3D surface correspondence is tightly coupled with 3D surface registration. Correspondence computation is the process of establishing the mappings between two rigid surfaces. It is used to determine which portions of the two surfaces overlap. Registration is the process of using the correspondences to compute the transformation that aligns the two surfaces in a common coordinate system. For rigid surfaces,