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Quaternion Blobby Model: Constrained Joint Range of Motions using Real Captured Data

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Abstract

This study presents the quaternion blobby model, a novel approach for constraining the joint range of motions based on real captured data. The feasible region's boundary is modeled using a geometric approach, allowing for an implicit representation of quaternion volume field boundaries. These boundaries define the space of all possible and permitted orientations within the joint. The implicit surface is generated as an iso-surface of a quaternion volume, approximated from data captured by an optical motion capture system and transformed into unit quaternions. By utilizing the blobby model, a popular solid object modeling tool in computer graphics, the iso-surface is generated. The resulting quaternion orientation space represents valid orientations and facilitates the reprojection of any orientation to the nearest valid ones. The effectiveness of the proposed model is demonstrated through verification using motion-captured shoulder joint data.

Keywords: Quaternion volume field, joint range of motions, implicit surface, blobby model, motion capture

I. Introduction

With the increasing popularity of motion acquisition methods, motion analysis has become a vibrant research field. Various advanced solutions have been proposed for motion capture, analysis, and synthesis, finding applications across a wide range of domains. This includes fields such as [1-3]. The focus of this work is on developing a joint limit model based on reference data acquired through a motion capture (mocap) system, eliminating the need for complex medical procedures such as CT or MRI scans [4]. This model serves as a foundation for subsequent tools, such as joint limit tracking, classification, or range comparison. It plays a crucial role in automated methods like physical simulation, forward and inverse kinematics. Joint limits are particularly useful in defining the pose of animated characters, overcoming errors in pose estimation during motion tracking. In inertial motion capture systems, for example, estimated orientations rely on signals from IMU (inertial measurement unit) sensors, which can introduce significant errors (around 10 degrees). By introducing joint angle constraints, the accuracy of pose calculations can be improved [5-6].

The concept of joint motion articulating surface is vital for evaluating joint wear, stability, degeneration, and determining accurate diagnosis and treatment of joint diseases [7]. The method proposed in this paper leverages the principles of joint motion articulating surface. Current tools, especially animation editors, typically express joint limits within the range of three Euler rotation angles (box model), without considering dependencies between the angles. In contrast, this paper introduces a quaternion-based model to represent the valid range of joint orientations. This representation enables the characterization of both intra- and inter-joint dependencies [8-9].

The objective of this study is to present a versatile and adaptable blobby quaternion model for joint orientations. The model can represent the joint limits of an individual or serve as a general model based on a broad dataset. The blobby model is parameterized by two parameters and can be built using different metrics. In this paper, two metrics are employed: Euclidean and geodesic quaternion distance functions [10]. The model is developed using captured motion data, which can be easily

analyzed joint is a three-degree-of-freedom (3-DOF) ball-and-socket joint, known for allowing a wide range of movements. While most models are typically verified through visual inspection of simulation or tracking results, lacking quantitative assessments, this study presents quantitative results in terms of the number of incorrect orientations in the test set. These results demonstrate that the quaternion blobby model provides a better fit to real joint limits compared to more general models.

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