Investigation of Quaternion Field Boundary Joint Constraint Method Performance Compared to Other Approaches

Prifysgol Cymru
Y Drindod Dewi Sant
University of Wales
Trinity Saint David

Daniel Gregory

dgregory.140643@student,uwtsd.ac.uk

University of Wales Trinity Saint David,
Mount Pleasant, Swansea, SA1 6ED

Introduction

Joint Constraints are used to restrict the orientation of a joint. This is used in animation and medicine to accurately represent joints, ensuring the joint does not go out of place and looks realistic.

This project implements a joint constraint approach from Herda et al [1] called Quaternion Field Boundaries. The approach uses quaternions to represent orientations and creates a surface around all valid orientations, any invalid orientations are then corrected to the surface.

The approach was experimented with to test its performance with a range of different variables and compared to another approach from Jenkins and Dacey [2] which uses Self Organizing Maps to form a boundary and correct invalid points to the boundary. That approach uses machine learning to correct points by a learning rate.

Aims and Objectives

The project aims to investigate the use of Quaternion Field Boundaries for joint constraining and will look to implement an approach produced by Herda et al[1]. The effectiveness of this approach will be compared to other approaches looking at its accuracy and performance. The objectives of the project are:

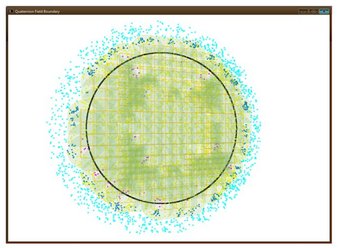
1.To conduct a literature review of approaches to Joint Constraints/Limits
2.Implement Herda's Quaternion Field Boundary approach

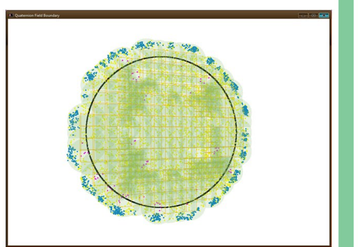
3.Compare the results of the chosen approach with alternate approaches to Joint Constraining.

Implementation

Development Methodology: Agile UP
Tools and Resources: Visual Studio 2015, GitHub, Google Test, C++ 11

Implementation Features:
Load in point cloud data.
Voxelize the space and assign points to voxels.
Fit an implicit surface around the point cloud.
Correct points by Dichotomy to the closest valid orientation.
Visualize the correction procedure (screenshots below).





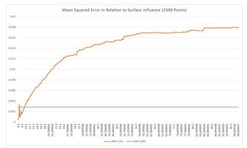
Experimentation

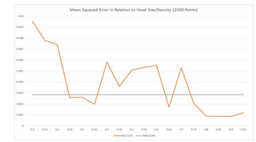
The main aim of this project was to compare it to another Joint Constraint approach to compare its performance, experimentation was a crucial part of the project. The Quaternion Field Boundary approach had a lot of different variables that could be be tweaked that would change how the surface was generated and the overall quality of the corrections.

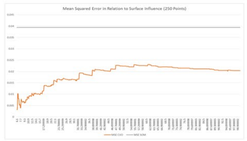
These are the variables that were experimented with:
- Surface Parameters
- Swing Joint Range
- Point Count
- Voxel Dimensions
- Point Density Threshold (Voxel Subdivision)

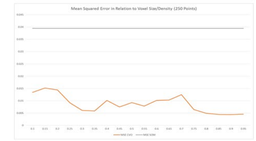
The metric for measuring performance is Mean Squared Error. This is the squared distance from each corrected point to the closest valid orientation. The distances are summed together and then averaged to provide the Mean Squared Error. This measurement is also used in the Self Organizing Maps experiments and allows for direct comparison.

Results

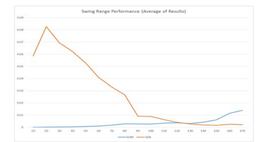












Conclusion & Future Work

The Quaternion Field Boundary approach would generally perform worse than the Self Organizing Maps approach for the majority of swing ranges. But the Quaternion Field Boundary approach is very quick in generating surfaces, with it never exceeding 20 seconds in these experiments. It also performs significantly better when there is a low number of points.
There are plenty of oppurtunities for future research, the use of this approach in Real Time Applications being one. The approach can be very fast and provide good results for its speed. The surfaces can be created or baked offline and then the corrections can be done in real time. With parallelization, it could be possible to perform both the surface generation and corrections in real time in a reasonable time.

References:

1. L. Herda, R. Urtasun, P. Fua, and A. Hanson, "An automatic method for determining quaternion field boundaries for ball-and-socket joint limits," Proc. - 5th IEEE Int. Conf. Autom. Face Gesture Recognition, FGR 2002, pp. 95–100, 2002.
2. G. L. Jenkins and M. E. Dacey, "Self-Organizing Maps for Anatomical Joint Constraint Modelling," 2011.