Master Student Project Proposal

Efficient and Reliable Hausdorff Distance Calculation for freeform NURBS models

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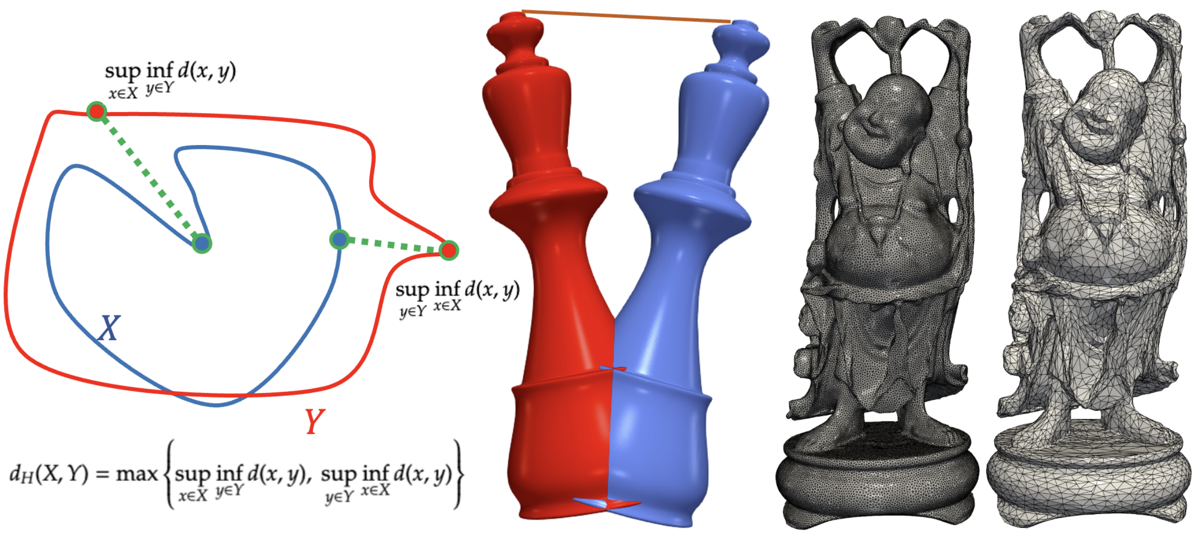


Figure 1: The Hausdorff distance calculation (left) is a critical metric in Computer-Aided Design (CAD) and Computer Graphics (CG), with broad applications including shape matching (middle) and mesh simplification (right). This project aims to enhance the efficiency and reliability of computing the Hausdorff distance for freeform NURBS models.

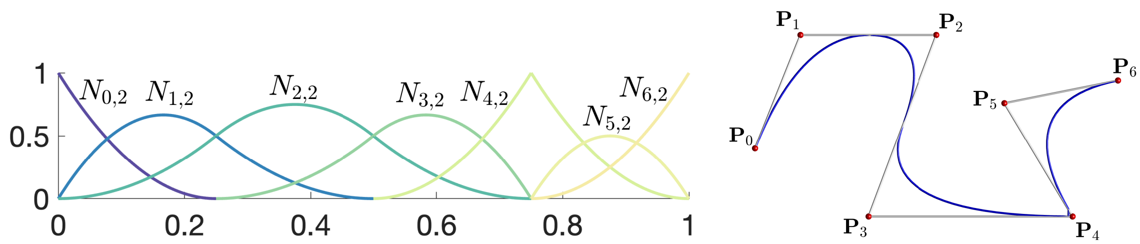
Description

Non-Uniform Rational B-Spline (NURBS), are pivotal in the realms of computer-aided design (CAD), manufacturing (CAM), and engineering (CAE), serving as the de facto standard for representing geometric models. Renowned for their versatility, NURBS curves and surfaces adeptly handle a wide range of shapes, from precise analytic forms to complex freeform forms, and enable intricate design and manufacturing processes with unparalleled accuracy and efficiency.

The Hausdorff distance [1, 2]

$$d_H(X, Y) = \max \left\{ \sup_{x \in X} \inf_{y \in Y} d(x, y), \sup_{y \in Y} \inf_{x \in X} d(x, y) \right\} \quad (1)$$

is a useful measure of the similarity between two geometric objects X and Y. This metric finds extensive applications in shape matching, mesh simplification, and geometric approximation, as depicated in Figure 1. While the computation of the Hausdorff distance is a well-explored area within computer graphics, most existing research predominantly focuses on polygons and polygonal meshes.



(a) Quadratic B-Spline basis functions (b) A free-form B-Spline curve

Figure 2: Illustration of univariate B-Spline basis functions (a), and free-form B-Spline curve(b).

This project, therefore, aims to bridge a significant gap by focusing on enhancing the efficiency and reliability of Hausdorff distance calculations for free-form NURBS models. These models, depicted in Figure 2, are constructed from a series of control points $\mathbf{P}_i$ and their corresponding smooth basis functions $N_{i,p}(\xi)$, and are widely utilized in CAD and other computer graphics software to accurately represent the shape of three-dimensional objects. G+Smo (Geometry + Simulation Modules), an open-source library for modelling freeform NURBS models and performing numerical simulations, that is developed by the supervisor's group together with colleagues in Europe can be used. A trivial method and implementation is available in the library.

Milestones

- **Preliminary Research and Familiarization**:
  - Deepen understanding of NURBS and geometry computation, including creating NURBS objects and applying nonlinear iterative methods, such as simple or Newton-Raphson iteration.
  - Review existing algorithms for calculating the Hausdorff distance, particularly in the context of NURBS.
- **Algorithm Development**:
  - Develop a theoretical framework for an efficient algorithm to calculate the Hausdorff distance between NURBS models.
  - Design algorithmic enhancements or novel approaches to improve computational efficiency and accuracy.
- **Implementation and Testing**:
  - Implement the devised algorithm and conduct rigorous testing to evaluate performance, efficiency, and reliability.
  - Compare with existing methods to demonstrate improvements in efficiency and accuracy.
- **Documentation and Dissemination**:

- Document the research findings, algorithm design, and testing results.
- Prepare a comprehensive thesis and presentation.

Prerequisites

Basic knowledge of linear algebra, numerical analysis and at least one programming language is required, preferably C/C++ or Python. Experience with B-Splines and NURBS will be helpful.

References

[1] X.-D. Chen, W. Ma, G. Xu, J.-C. Paul, Computing the hausdorff distance between two b-spline curves, Computer-Aided Design 42 (12) (2010) 1197–1206.

[2] Y.-J. Kim, Y.-T. Oh, S.-H. Yoon, M.-S. Kim, G. Elber, Efficient hausdorff distance computation for freeform geometric models in close proximity, Computer-Aided Design 45 (2) (2013) 270–276.