1.1 Introduction

Overview · Data Sources and Applications · Problem Statement
Overview
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Tutorial Outline

Overview

- **Part I:** Introduction (1.25h)
- **Part II:** Local Registration (1.5h)
- **Part III:** Global Matching (1.75h)
- **Part IV:** Animation Reconstruction (1.25h)
- Conclusions and Wrap up (0.25h)
Part I: Introduction

Introduction (Michael)
- Problem statement and motivation
- Example data sets and applications

Differential geometry and deformation modeling (Mark)
- Differential geometry background
- Brief introduction to deformation modeling

Kinematic 4D surfaces (Niloy)
- Rigid motion in space-time
- Kinematic 4D surfaces
Part II: Local Registration

ICP and of rigid motions (Niloy)

- Rigid ICP, geometric optimization perspective
- Dynamic geometry registration (Intro)

Deformable Registration (Michael)

- A variational model for deformable shape matching
- Variants of deformable ICP

Subspace Deformation, Robust Registration (Hao)

- Subspace deformations / deformation graphs
- Robust local matching
Part III: Global Matching

Features (Will)
- Key point detection and feature descriptors

Isometric Matching and Quadratic Assignment (Michael)
- Extrinsic vs. intrinsic geometry
- Global matching techniques with example algorithms

Advanced Global Matching (Will)
- Global registration algorithms

Probabilistic Techniques (Michael)
- Ransac and forward search

Articulated Registration (Will)
- Articulated registration with graph cuts
Dynamic Geometry Registration (Niloy)
  • Multi-piece alignment

Deformable Reconstruction (Michael)
  • Basic numerical algorithm
  • Urshape/Deformation Factorization

Improved Algorithm (Hao)
  • Efficient implementation
  • Detail transfer
Conclusions and Wrap-up (Mark)

• Conclusions
• Future work and open problems

In the end:
• Q&A session with all speakers
• But feel free to ask questions at any time
Problem Statement and Motivation
Deformable Shape Matching

What is the problem?

Settings:

- We have two or more shapes
- The same object, but deformed
Deformable Shape Matching

What is the problem?

Settings:
- We have two or more shapes
- The same object, but deformed

Question:
- What points correspond?

Data courtesy of C. Stoll, MPI Informatik
Applications

Why is this an interesting problem?

Building Block:

- Correspondences are a building block for higher level geometry processing algorithms

Example Applications:

- Scanner data registration
- Animation reconstruction & 3D video
- Statistical shape analysis (shape spaces)
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Deformable Scan Registration

Scan registration

• Rigid registration is standard

Why deformation?

• Scanner miscalibrations
  ▪ Sometimes unavoidable, esp. for large acquisition volumes

• Scanned Object might be deformable
  ▪ Elastic / plastic objects

• In particular: Scanning people, animals
  ▪ Need multiple scans
  ▪ Impossible to maintain constant pose
Example: Full Body Scanner

Full Body Scanning
Applications

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3D Animation Scanner

New technology
• 3D animation scanners
• Record 3D video
• Active research area

Ultimate goal
• 3D movie making
• New creative perspectives
Structured Light Scanners

- space-time stereo
  courtesy of James Davis, UC Santa Cruz

- color-coded structured light
  courtesy of Phil Fong, Stanford University

- motion compensated structured light
  courtesy of Sören König, TU Dresden
Passive Multi-Camera Acquisition

segmentation & belief propagation

[Zitnick et al. 2004]
Microsoft Research

photo-consistent space carving

Christian Theobald
MPI-Informatik
Time-of-Flight / PMD Devices

PMD Time-of-flight camera

Minolta Laser Scanner (static)
Animation Reconstruction

Problems

- Noisy data
- Incomplete data (acquisition holes)
- No correspondences
Animation Reconstruction

Remove noise, outliers

Fill-in holes (from all frames)

Dense correspondences
Applications

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Statistical Shape Spaces

Morphable Shape Models

- Scan a large number of individuals
  - Different pose
  - Different people
- Compute correspondences
- Build shape statistics (PCA, non-linear embedding)

Courtesy of N. Hassler, MPI Informatik
Statistical Shape Spaces

Numerous Applications:
- Fitting to ambiguous data (prior knowledge)
- Constraint-based editing
- Recognition, classification, regression

Building such models requires correspondences

Courtesy of N. Hassler, MPI Informatik
Data Characteristics
Scanner Data – Challenges

“Real world data” is more challenging

- 3D Scanners have artifacts

Rules of thumb:

- The faster the worse (real time vs. static scans)
- Active techniques are more accurate
  (passive stereo is more difficult than laser triangulation)
- There is more than just “Gaussian noise”...
Challenges

“Noise”

• “Standard” noise types:
  ▪ Gaussian noise (analog signal processing)
  ▪ Quantization noise

• More problematic: Structured noise
  ▪ Structured noise (spatio-temporally correlated)
  ▪ Structured outliers
  ▪ Reflective / transparent surfaces

• Incomplete Acquisition
  ▪ Missing parts
  ▪ Topological noise
Challanges

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Outlook
This Tutorial

Different aspects of the problem:

• Shape deformation and matching
  ▪ How to quantify deformation?
  ▪ How to define deformable shape matching?

• Local matching
  ▪ Known initialization

• Global matching
  ▪ No initialization

• Animation Reconstruction
  ▪ Matching temporal sequences of scans
Problem Statement:
Pairwise Deformable Matching
Problem Statement

Given:

- Two surfaces \( S_1, S_2 \subseteq \mathbb{R}^3 \)
- Discretization:
  - Point clouds \( S = \{s_1, \ldots, s_n\}, s_i \in \mathbb{R}^3 \) or
  - Triangle meshes

We are looking for:

- A deformation function \( f_{1,2}: S_1 \rightarrow \mathbb{R}^3 \) that brings \( S_1 \) close to \( S_2 \)
Problem Statement

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- A deformation function $f_{1,2}: S_1 \rightarrow \mathbb{R}^3$ that brings $S_1$ close to $S_2$

Open Questions:

- What does “close” mean?
- What properties should $f$ have?

Next part:

- We will now look at these questions more in detail