# Elastic Fragments for Dense Scene Reconstruction

# Overview

## ||Fragment Construction||

### Fact: while online reconstruction methods are unstable over long ranges, they are quite accurate in the local regime

### Given an RGB-D scan as input

##### We partition it into k-frame segments (we use k=50 or k=100)

##### Use the frame-to-model registration and integration pipeline developed by Newcombe et al. [16]

11-ISMAR-KinectFusion: Real-time dense surface mapping and tracking

##### Reconstruct a locally precise surface fragment from each such trajectory segment

### Each fragment is a triangular mesh

###### Vertex set

###### Edge set

## ||Initial alignment||

### Initial alignment is to establish dense correspondences between fragments that cover overlapping parts of the scene

### Manual initial alignment

###### 07-ToG-Global non-rigid alignment of 3D scans

### Off-the-shelf SLAM system

###### 12-ICRA-An evaluation of the RGB-D SLAM system

### Given the rough localization, we identify pairs of overlapping fragment

##### With the relative pose provided by the rough initialization

##### We test every pair of fragments and attempt to align it using ICP

##### If ICP converges with stable correspondences over a sufficiently large area (more than 20% of one of the fragments)

##### Retain the correspondences

### The set of correspondences obtained by ICP that fall below a reasonable global threshold (3cm in all our experiments) are denoted by

## ||Elastic registration||

### Define an optimization that combines an alignment term and a regularization term

##### The alignment term minimizes the distances between corresponding points on different fragments

##### The regularization term preserves the shape of each fragment by minimizing the **elastic strain energy** produced by the **deformation**

## ||Integration||

### Volumetric Integration

###### 96-SIGGRAPH-A volumetric method for building complex models from range images

# Elastic Registration

## ||Point-based Registration||

### Input

##### a set of fragments, each parameterized in its own coordinate system

### Our objective

##### to find a mapping that maps each point set to an isomorphic point set ,

##### such that all sets are parameterized in a common coordinate frame and are aligned to form a global model of the scanned scene

### Let

##### be the set of all input points

##### be the set of the corresponding output set

##### Mapping should minimize the distance between while preserving the detailed geometry of each fragment

### is computed by minimizing an energy function

##### is the alignment term

##### is the elastic regularization term

### The alignment term use the point-to-plane distance

##### is the normal of

###### 01-3DIM-Efficient variants of the ICP algorithm

### The regularizer measures the elastic strain energy

##### Measure the change in the first tow fundamental forms of each surface due to

and are the first and second fundamental forms of

are stiffness parameters

87-SIGGRAPH-Elastically deformable models

##### For mild low-frequency deformations, it can be approximated as follows

is the set of neighbors of in

is a rotation transform that maps the local tangent frame of to the local tangent frame of

This linear term conveniently penalizes stretching and bending of Pi at (p, q).

07-SGP-As-rigid-as-possible surface modeling

07-ToG-Embedded deformation for shape manipulation

### Drawbacks

##### Not efficient yielding a linear system with 199 million variables and 7.8 trillion non-zero entries in the matrix

##### Does not control for distortion induced by changes in the relative pose of disconnected surfaces within fragments

## ||Volumetric Registration||

### Fact:

##### The guiding observation behind the reformulation is that the unknown transform is assumed to be smooth over the domain of each fragment

##### This function can thus be evaluated at a small number of samples and reconstructed by interpolation

### Idea

##### Embed each fragment in a coarse control lattice

##### The mapping is defined for and is applied to by interpolation

### Let

##### be

##### Each point can be represented as a linear combination of vertices from

86-SIGGRAPH-Free-form deformation of solid geometric models

##### Each transform is constructed from the transformed control point by the

### Reformulation

##### Defined on

## ||Optimization||

### If and are fiexed, is a quadratic function of

### The matrix …