CS597D: Geometric Analysis of 3D Models

Thomas Funkhouser

Princeton University

CS597D, Fall 2003

Introduction

Image courtesy of www.dreamhorse.com

On-line multimedia data is changing the way we get and use information

Call me Ishmael. Some years ago -- never mind how long precisely -- having little or no money in my purse, and nothing particular to interest me on shore, I thought I would sail about a little and see the watery part of the world. It is a way I have of driving off the spleen, and regulating the circulation. Whenever I find myself growing grim about the mouth; whenever it is a damp, drizzly November in my soul; whenever I find myself involuntarily pausing before coffin warehouses, and bringing up the rear of every funeral I meet; and especially whenever my hypos get such an upper hand of me, …

Text

2D Images

Audio

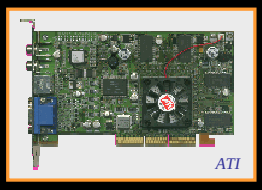
What about 3D data?

Introduction

Images courtesy of Cyberware, ATI, & 3Dcafe

3D data is becoming more commonly available

Cheap Scanners



Fast Graphics Cards

World Wide Web

Someday 3D models will be as common as images are today

Motivation

Images courtesy of Stanford & Utah

When 3D data is ubiquitous, there will be a shift in research focus

Previous research has asked: "How do we acquire 3D data?"

Utah VW Bug

Utah Teapot

Stanford Bunny

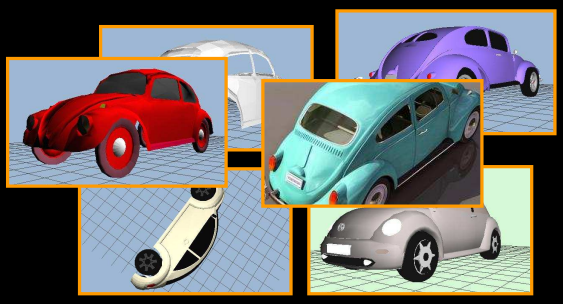
Future research will ask: "How do we find 3D data?"

Introduction

Images courtesy of De Espona & Utah

3D data acquired via the Web will often be void of structural and semantic information

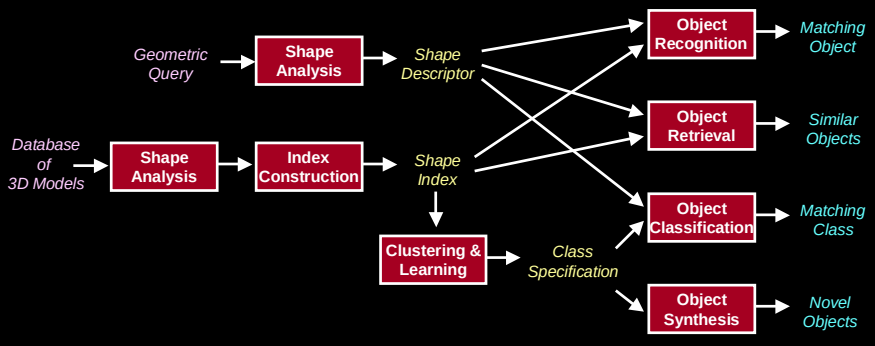
Utah VW Bug



Analysis algorithms also are needed to create "useful" 3D models from "raw" 3D data

Introduction

Research in retrieval & analysis 3D data is warranted as it has been for other media types



Introduction

Images courtesy of Georgia Tech and www.dreamhorse.com

Which is harder to analyze?

3D Model

2D Image

Lecture Outline

Introduction

Problems ←

Applications

Course overview

- Lectures
- Coursework
- Resources

Wrap-up

Shape Analysis Problems

Examples:

- Feature detection
- Segmentation
- Labeling
- Registration
- Matching
- Recognition
- Classification
- Clustering
- Retrieval

Shape Analysis Problems

Images courtesy of Bill Regli, Drexel University

Examples:

- Ø Feature detection
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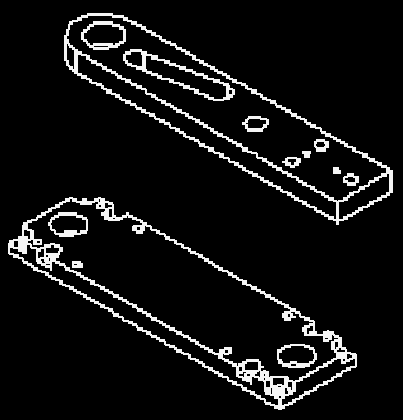

"How can we find significant geometric features robustly?"

Shape Analysis Problems

Images courtesy of Ayellet Tal, Technion & Princeton University

Examples:

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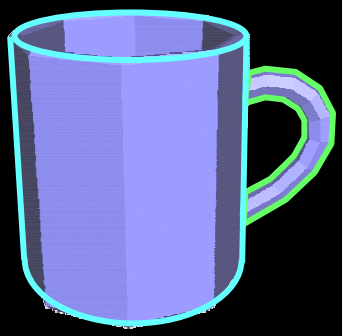

"How can we decompose a 3D model into its parts?"

Shape Analysis Problems

Images courtesy of Ayellet Tal, Technion & Princeton University

Examples:

- Feature detection
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- Retrieval
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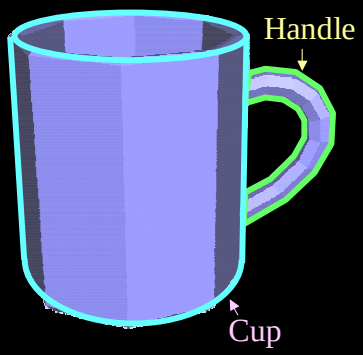

"How can we decompose a 3D model into its parts?"

Shape Analysis Problems

Images courtesy of Emil Praun

Examples:

- Feature detection
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Ø Registration

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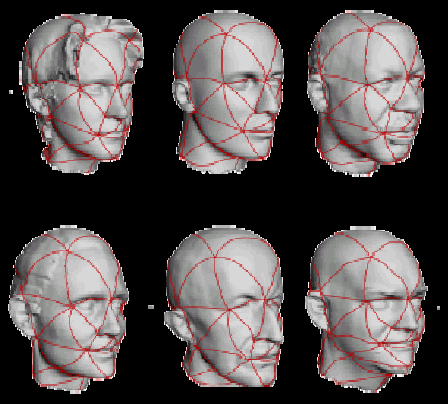

"How can we align features of 3D models?"

Shape Analysis Problems

Image courtesy of Ilya Vakser, GRAMM

Examples:

- Feature detection
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Ø Matching

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- Recognition
- Classification
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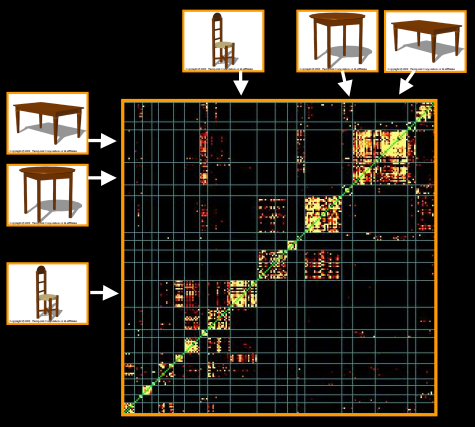

"How can we compute a measure of geometric similarity?"

Shape Analysis Problems

Examples:

- Feature detection
- Segmentation
- Labeling
- Registration
- Matching

Ø Retrieval

- Recognition
- Classification
- Clustering

Query

1) 

2) 

3) 

4) 

Ranked Matches

"How can we find 3D models best matching a query?"

Shape Analysis Problems

Images courtesy of Florida State Univ.

Examples:

- Feature detection
- Segmentation
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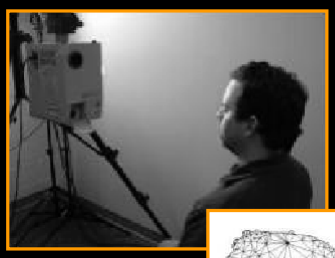
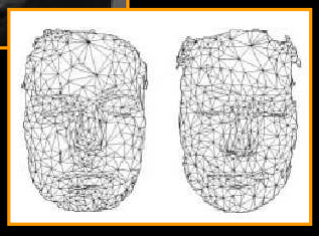
Ø Recognition

- Classification
- Clustering





"How can we find a given 3D model in a large database?"

Shape Analysis Problems

Images courtesy of Darpa E3D Project

Examples:

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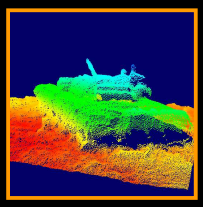
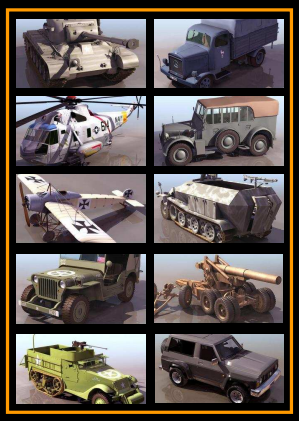
Ø Classification

- Clustering



Query



Classes

"How can we determine the class of a 3D model?"

Shape Analysis Problems

Images courtesy of Viewpoint

Examples:

- Feature detection
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Ø Clustering

"How can we learn classes of 3D models automatically?"

Lecture Outline

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Shape Analysis Applications

Examples:

- Virtual worlds
- Animation
- Mechanical CAD
- Chemistry
- Military
- Paleontology
- Molecular bio
- Medicine
- Forensics
- Art

Shape Analysis Applications

Examples:

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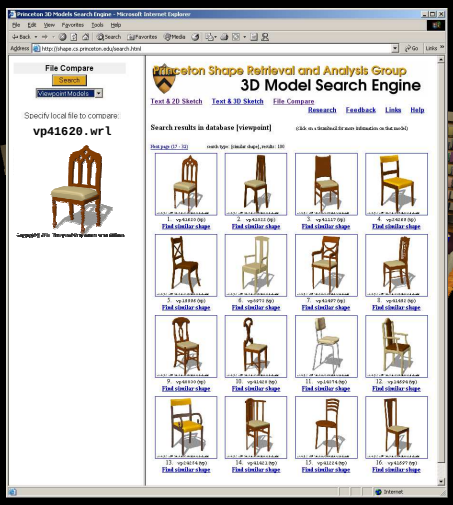

Shape Analysis Applications

Image courtesy of Ayellet Tal, Technion & Princeton University

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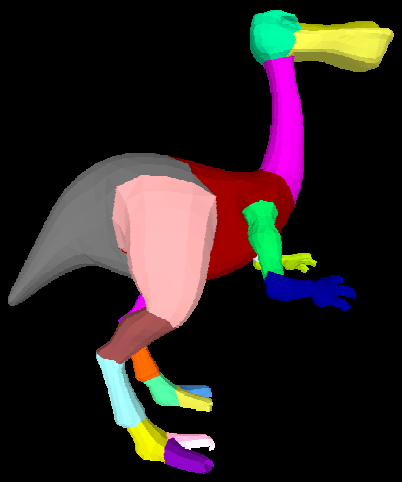
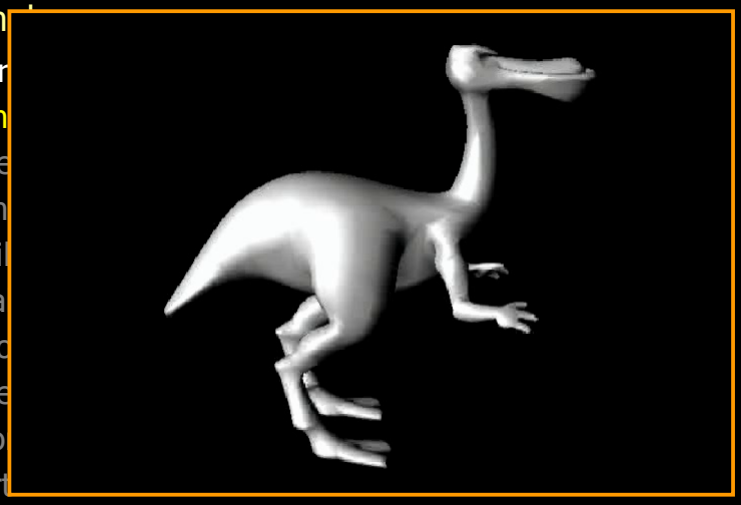


Shape Analysis Applications

Movie courtesy of Ayellet Tal, Technion & Princeton University

Exam

- Vir
- Ø An
- Me
- Ch
- Mi
- Pa
- Mo
- Me
- Fo
- Art



Shape Analysis Applications

Images courtesy of Bill Regli, Drexel University

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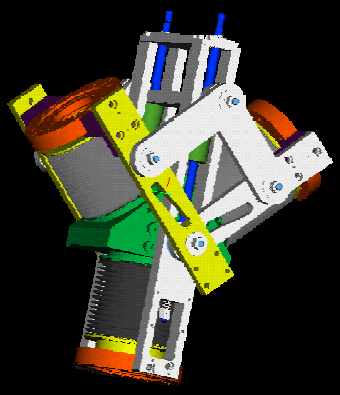

Shape Analysis Applications

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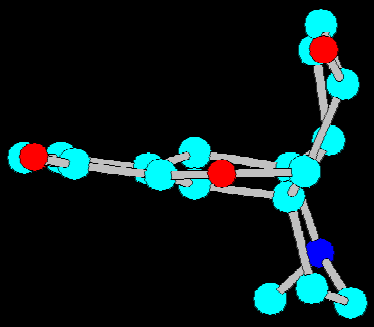

Morphine

Shape Analysis Applications

Images courtesy of Darpa E3D Project

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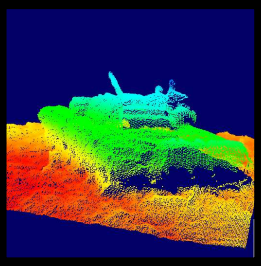

Shape Analysis Applications

Images courtesy of Delson & Freiss

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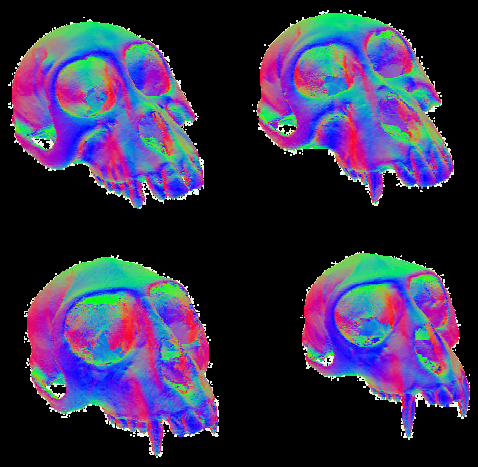

Shape Analysis Applications

Image courtesy of Ilya Vakser, GRAMM

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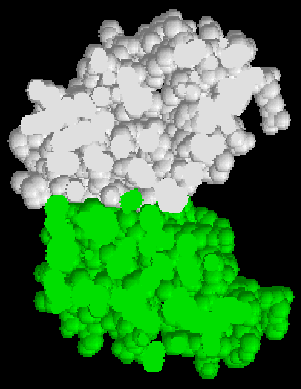

Shape Analysis Applications

Image courtesy of Polina Golland, MIT

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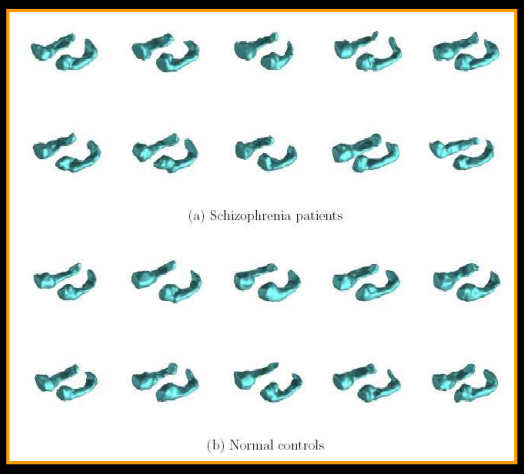

Hippocampus-amygdala study in schizophrenia

Shape Analysis Applications

Images courtesy of Boeing

Examples:

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- Art

Shape Analysis Applications

Images courtesy of Stanford University

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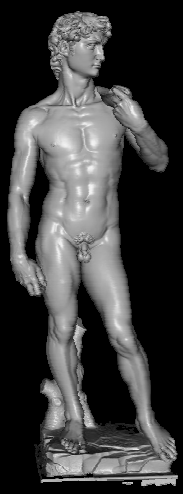

Lecture Outline

Introduction

Problems

Applications

Course overview ←

- Lectures
- Coursework
- Resources

Wrap-up

Lectures

Topics:

- Methods (80%)
- Applications (20%)

Speakers:

- Professors
- Students
- Guests

Date	Topic	Speakers	Readings	Resources	Slides
9/11	Course introduction	Tom Funkhouser		html	pdf
9/16	Geometric representations	Tom Funkhouser		html	pdf
9/18	Global shape descriptors I	Tom Funkhouser		html	pdf
9/23	Global shape descriptors II	Misha Kazhdan		html	pdf
9/25	Local shape descriptors			html	pdf
9/30	Coordinate system registration			html	pdf
10/2	Surface correspondence and matching			html	pdf
10/7	Project I proposals	All students		html	pdf
10/9	Mesh segmentation			html	pdf
10/14	Model-based recognition			html	pdf
10/16	Feature detection			html	pdf
10/21	Global symmetry detection	Misha Kazhdan		html	pdf
10/23	Medial axis			html	pdf
BREAK					
11/4	Skeleton extraction	Deborah Silver		html	pdf
11/6	Topological matching	Ali Shokoufandeh		html	pdf
11/11	Project I reports	All students		html	pdf
11/13	Project I reports	All students		html	pdf
11/18	View-based matching	Ming Ouhyoung		html	pdf
11/20	Project II proposals	All students		html	pdf
11/25	Shape analysis in image retrieval			html	pdf
12/2	Shape analysis in 3D model search	Tom Funkhouser		html	pdf
12/4	Shape analysis in CAD	Bill Regli		html	pdf
12/9	Shape analysis in molecular biology			html	pdf
12/11	Shape analysis in medicine	Dimitris Metaxas		html	pdf

Coursework

In class:

- Present papers
- Lead discussions

Out of class:

- Two course projects (~6 weeks each)
- Proposal talks, written reports, presentations
- Any topic(s) related to course

Course Projects

Sample topics:

- New representations
- New algorithms
- Compare methods
- Use methods
- Other attributes
- New applications
- Non-CS applications

Course Projects

Images courtesy of Misha Kazhdan

Sample topics:

Ø New representations

- New algorithms
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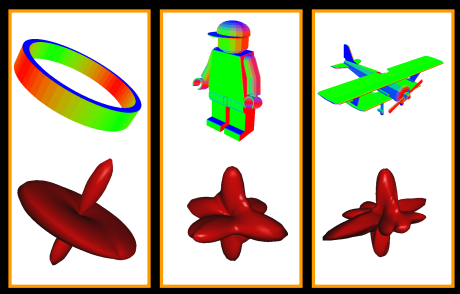

Reflective symmetry descriptors

Course Projects

Images courtesy of Katz & Tal

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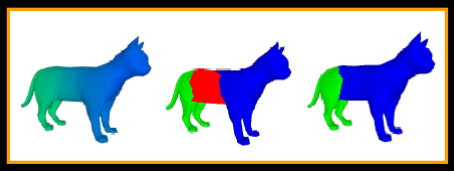

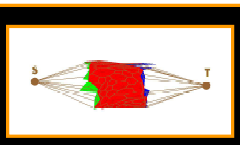

Hierarchical Mesh Decomposition using Fuzzy Clustering and Cuts [Katz & Tal, 2003]

Course Projects

Images courtesy of Kazhdan, Johnson, & Belongie

Sample topics:

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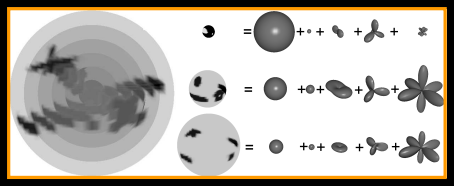
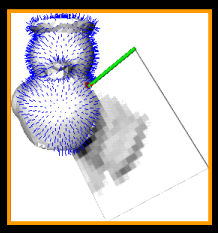
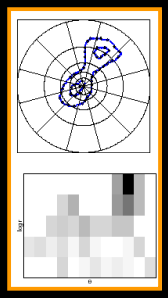


Harmonic Descriptor



Spin Image



Shape Context

Course Projects

Images courtesy of Hoppe & Kazhdan

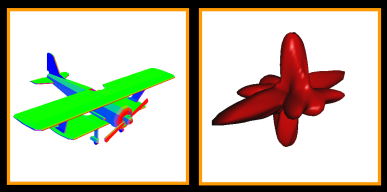
Sample topics:

- New representations
- New algorithms
- Compare methods

Ø Use methods

- Other attributes
- New applications
- Non-CS applications

Mesh simplification



Reflective symmetry descriptor

Course Projects

Sample topics:

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- New algorithms
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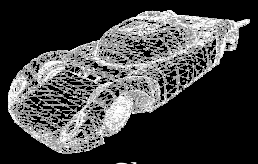
- Use methods

Ø Other attributes

- New applications
- Non-CS applications



Shape

Appearance

Description: Ferrair Very detailed ferrair, although the wheels stick out of the hood, they can still be moved. (1200kb) -- most complex and detailed model in this category

Text

Course Projects

Sample topics:

- New representations
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Ø New applications

- Non-CS applications

Modeling by Example

Course Projects

National Design Repository
Ilya Vakser (GRAMM)

Sample topics:

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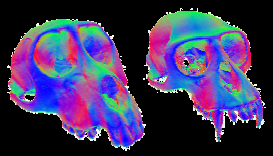
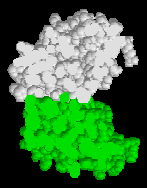
- New algorithms
- Compare methods
- Use methods
- Other attributes
- New applications

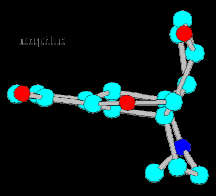
Ø Non-CS applications



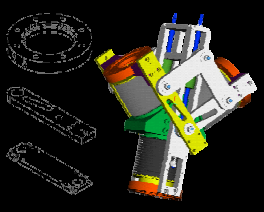
Paleontology



Molecular Biology



Chemistry



Mechanical CAD[1]

Resources

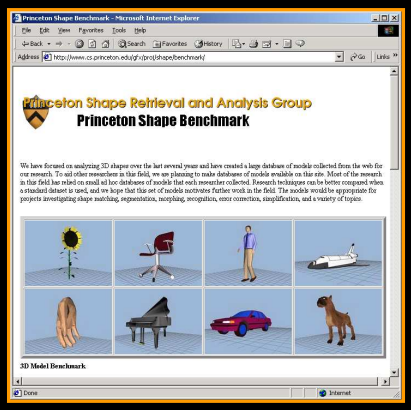
Data sets

- Princeton shape benchmark
- Protein data bank
- CAD databases
- CAT and MRI scans
- Range scans

Software

- Ringlet
- Other useful tools

Papers



Wrap Up

Students' to do list:

- Sign up for in-class presentations
- Start thinking about project topics