Computer Vision/Graphics

-- Dr. Chandra Kambhamettu for SIGNEWGRAD 11/24/04

- Computer Vision : Understanding of images
- Computer Graphics : Creation of images

- Courses offered: CISC4/640, CISC4/689, CISC849, CISC890

- Video/Image Modeling and Synthesis (VIMS) Lab: www.cis.udel.edu/~vims
- Robotics and Computer Vision Lab.

NONRIGID MOTION ANALYSIS: RESEARCH AND APPLICATIONS

- Biomedical (NIH)
- Bioinformatics (NIH-COBRE)
- Remote Sensing (ONR)
- Multimedia and Graphics (NSF)

- Novel Deformable Contours formulations
- 2D/3D nonrigid motion analysis

Goals of Tongue Measurement

- Visualize, represent, and predict the complex movements of speech and swallowing.

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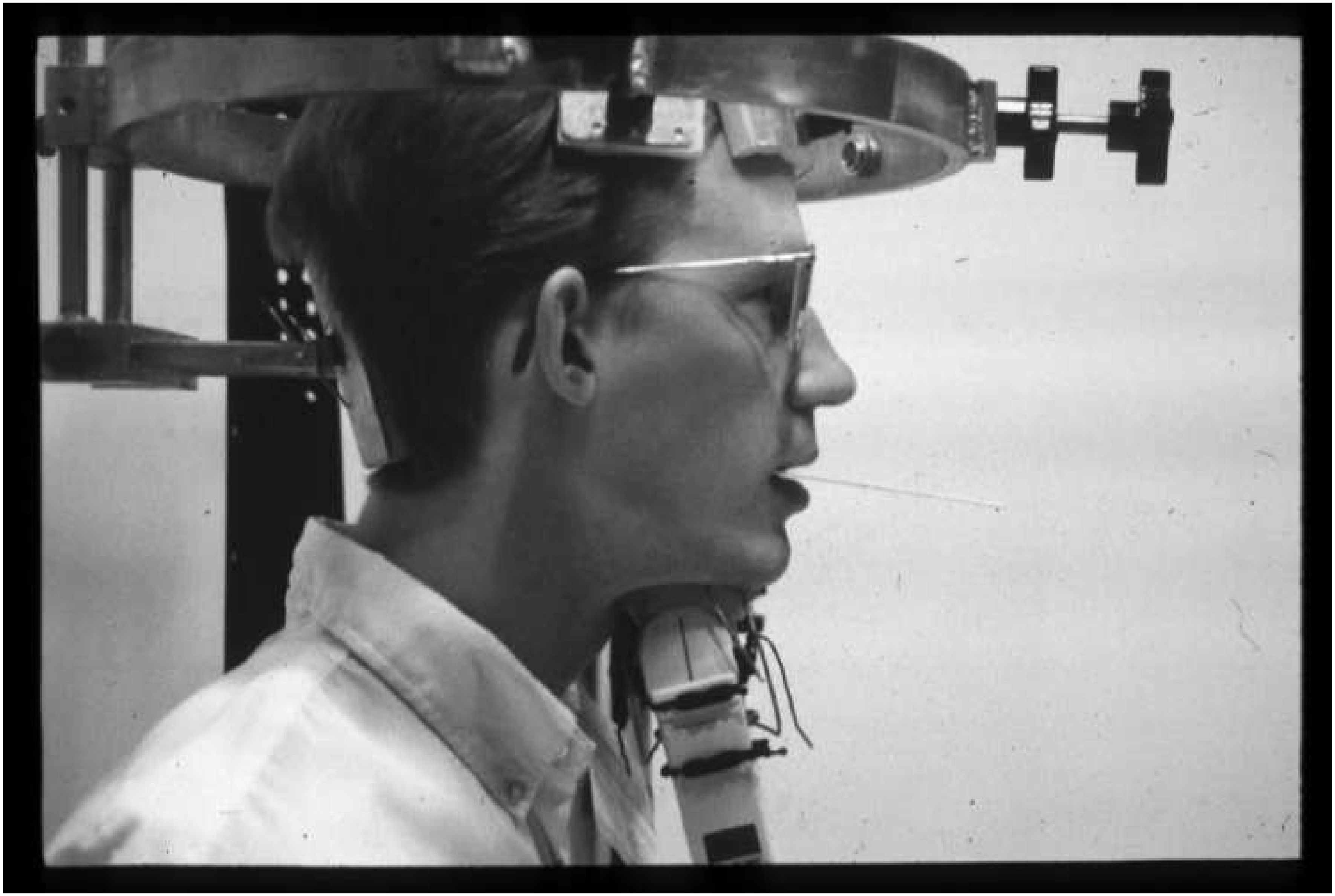
- Visualize, represent, and predict the complex movements of speech and swallowing.

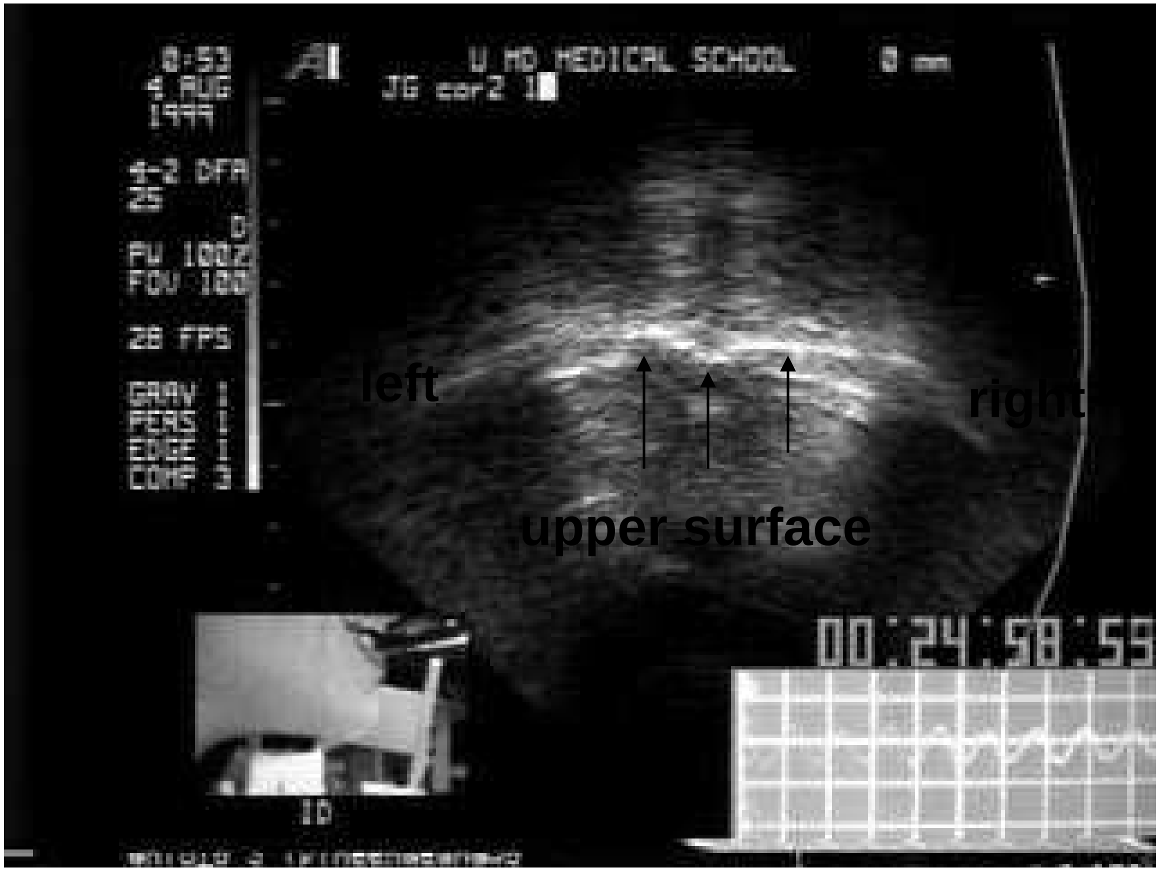
- Gain insight into motor control strategies used in speech production and swallowing.

- Quantify functionally important features of speech gestures.

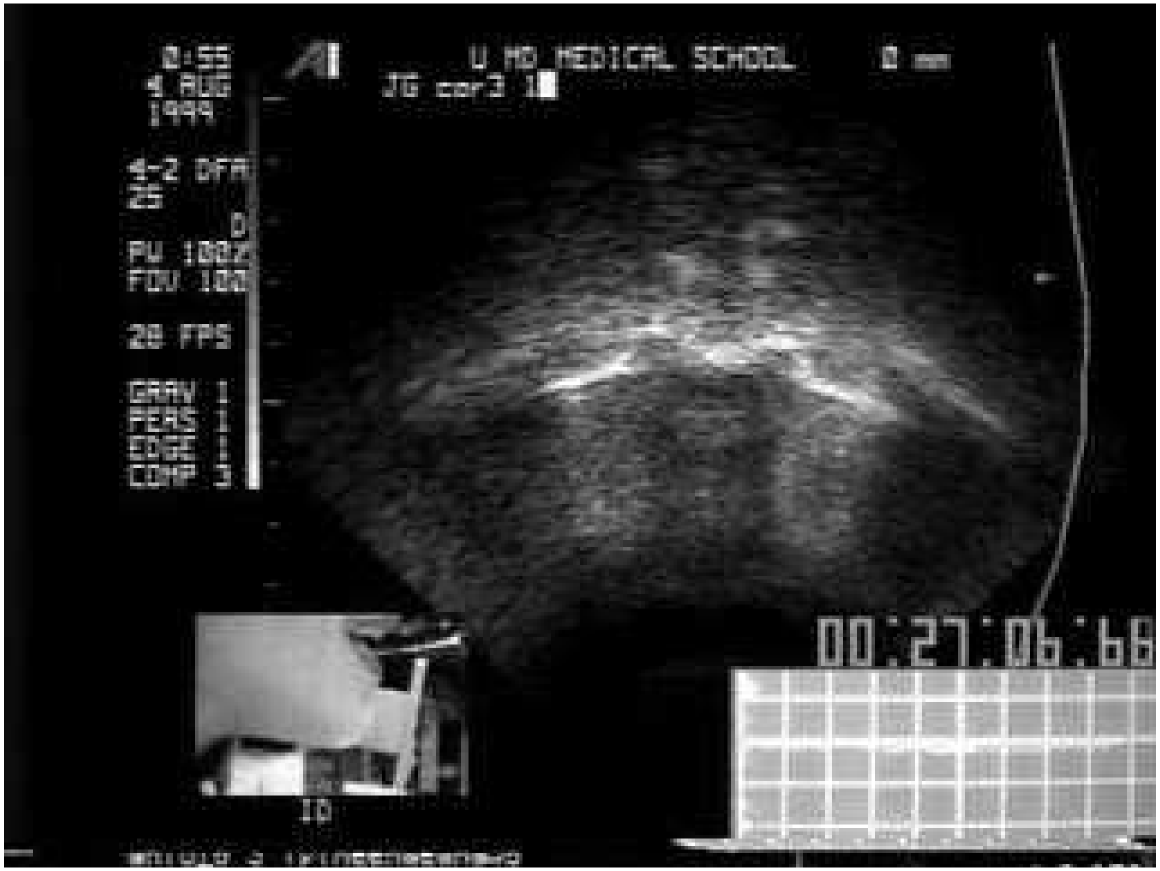
HEAD AND TRANSDUCER SUPPORT SYSTEM (HATS)



“It ran a lot” Midsagittal Slice

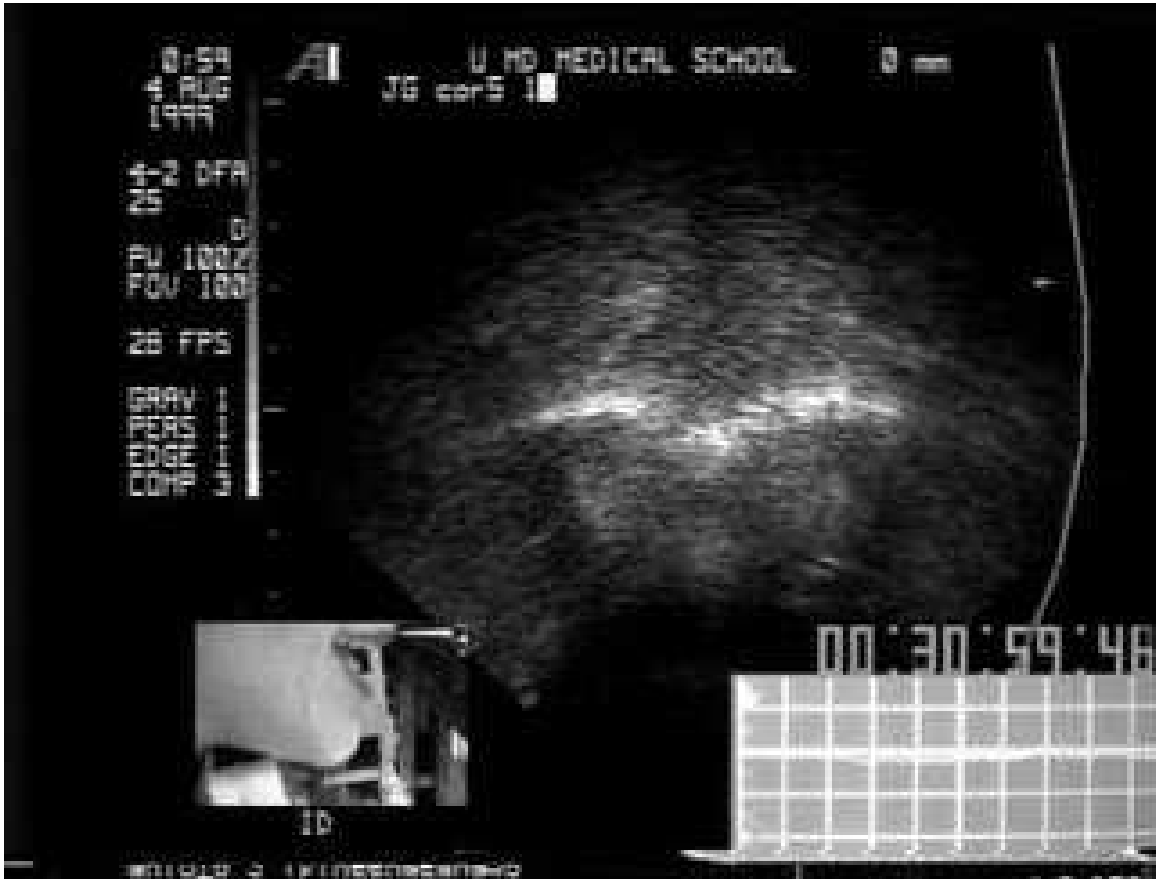


Coronal Slice 1: most anterior

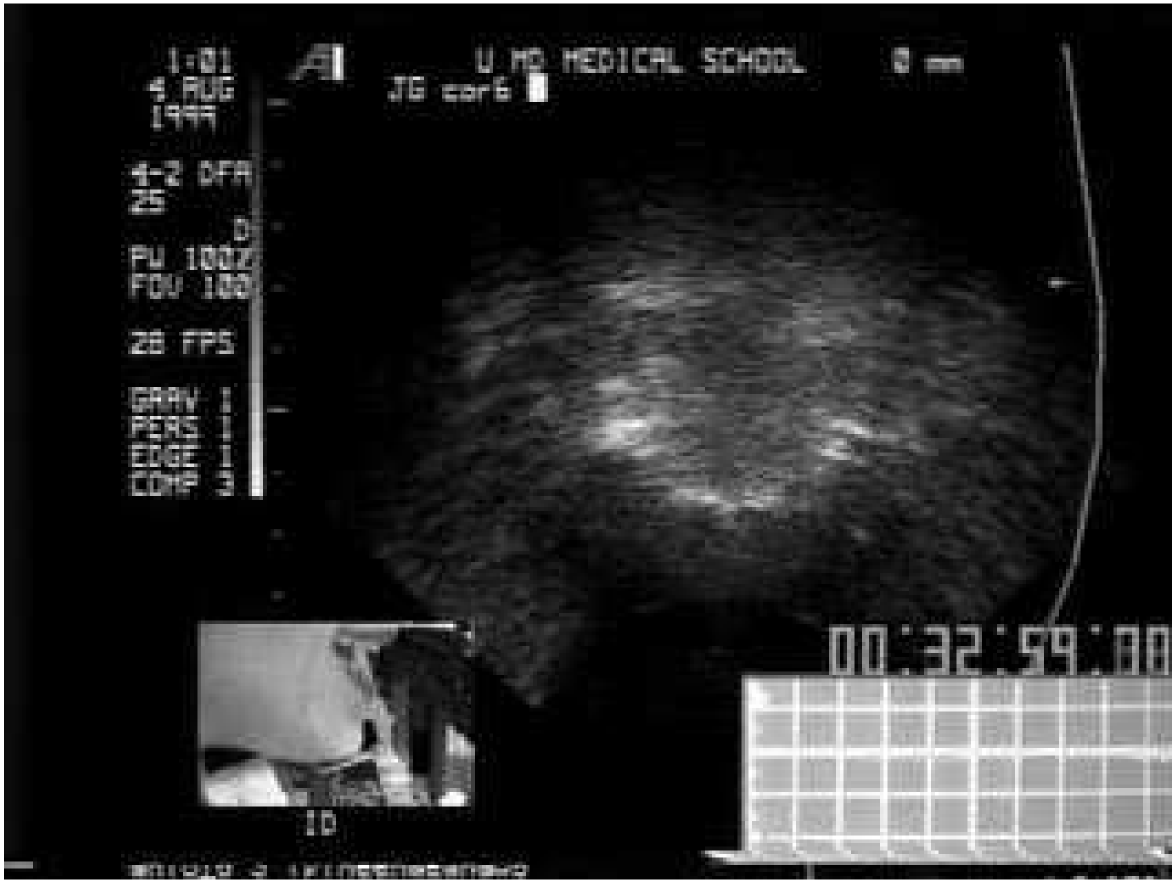


Coronal Slice 2

Coronal Slice 3



Coronal Slice 4



Coronal Slice 5: most posterior

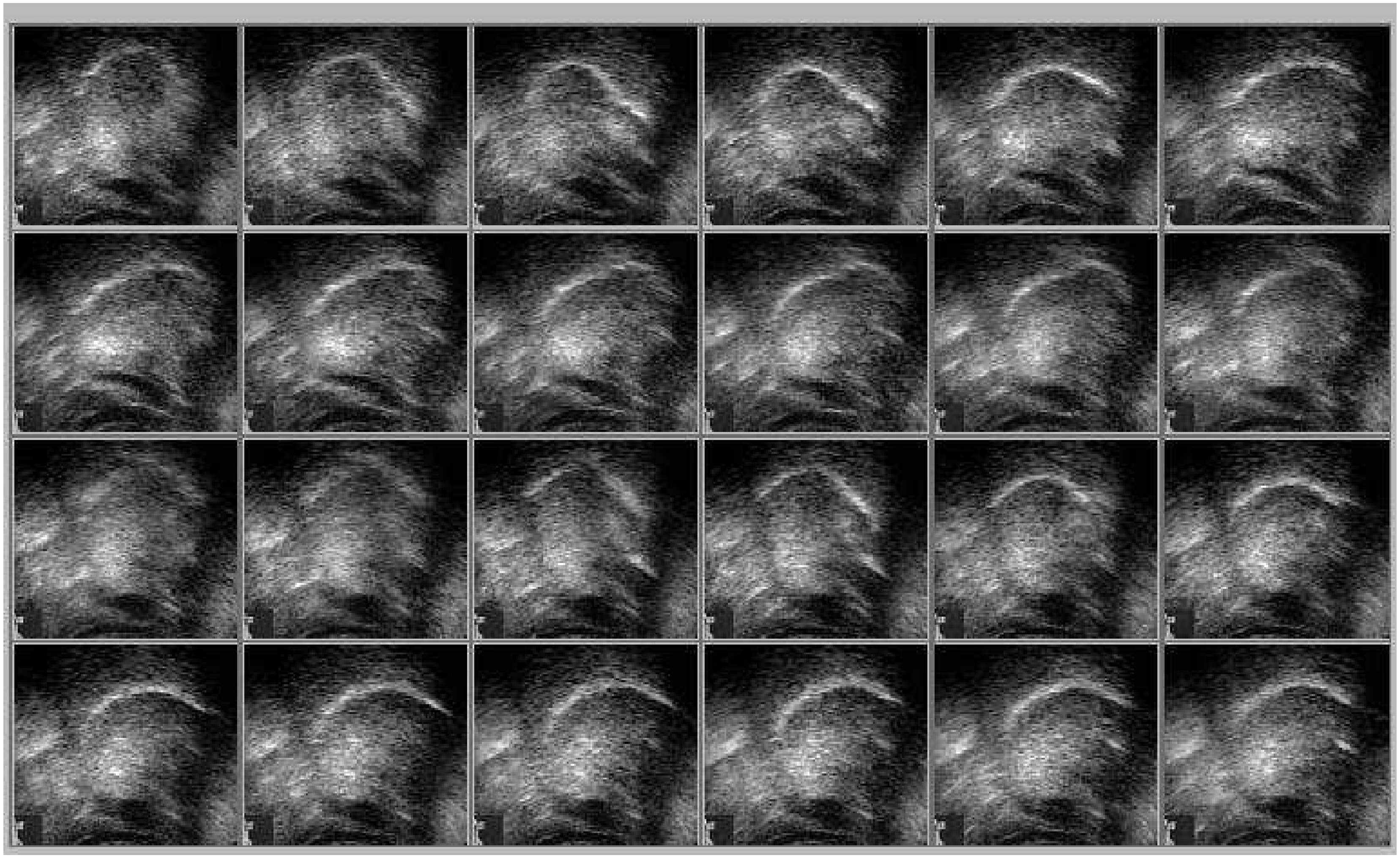
Deformable Contours

A deformable contour is a set of ordered discrete points : $V = [v_1, v_2, ..., v_n]$ with an energy functional which is minimized on an image frame I with a given initial model contour $S = [s_1, s_2, ..., s_n]$.

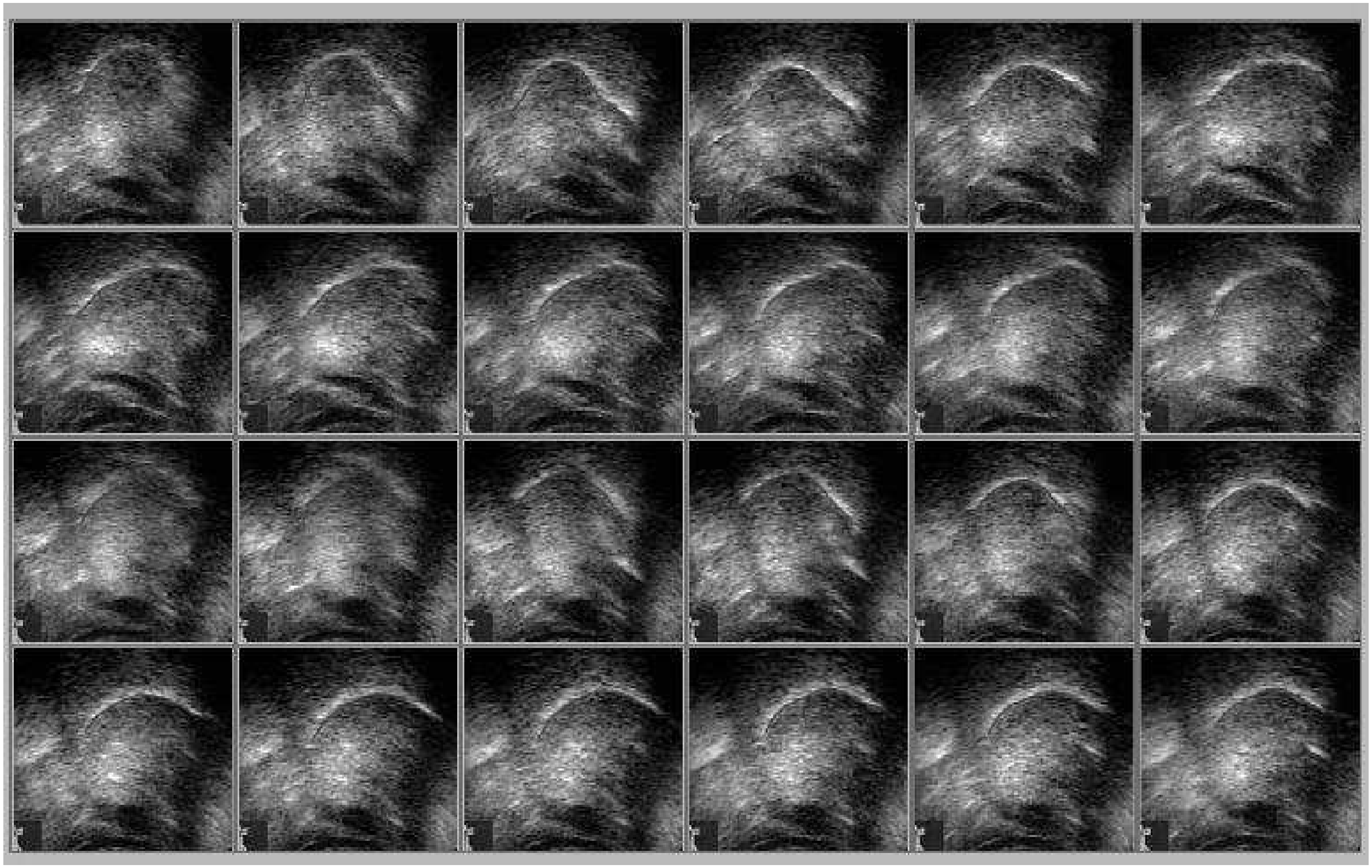
Associated energy on image I:

$$E_{snake}(V, S, I) = \sum_{i=1}^{n} \alpha E_{\text{int}}(v_i, S) + \beta E_{ext}(v_i, I)$$

Experiment Results

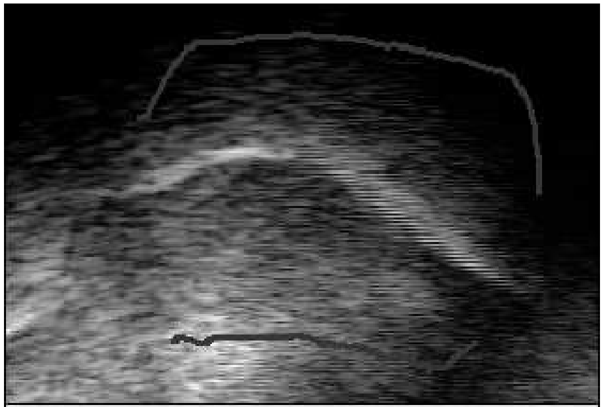


Experiment Results(cont.)



Deformable Dual Mesh

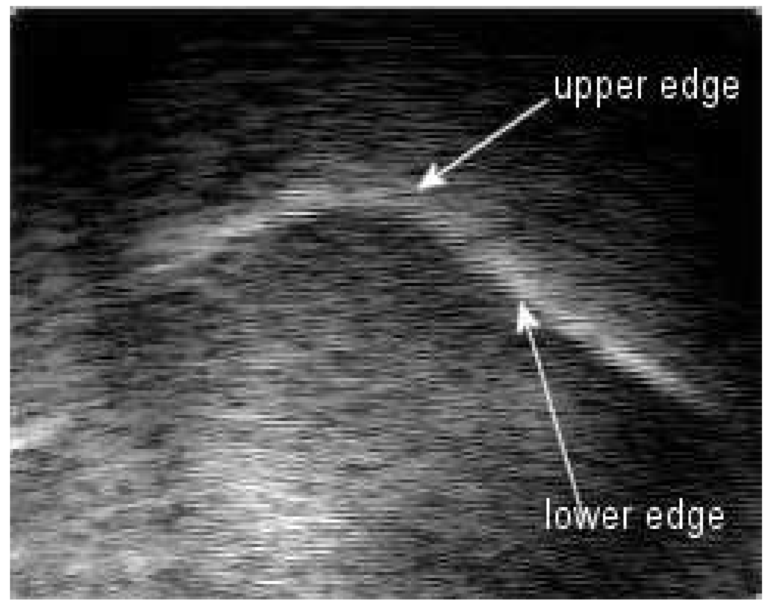
--*application to tongue surface tracking*



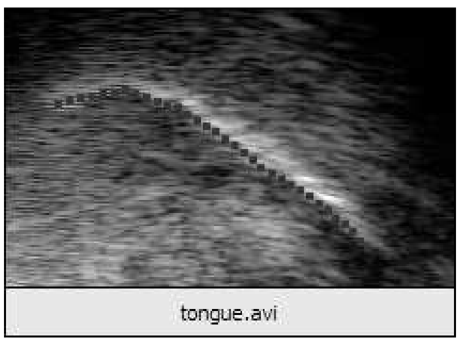
tonTrak.avi

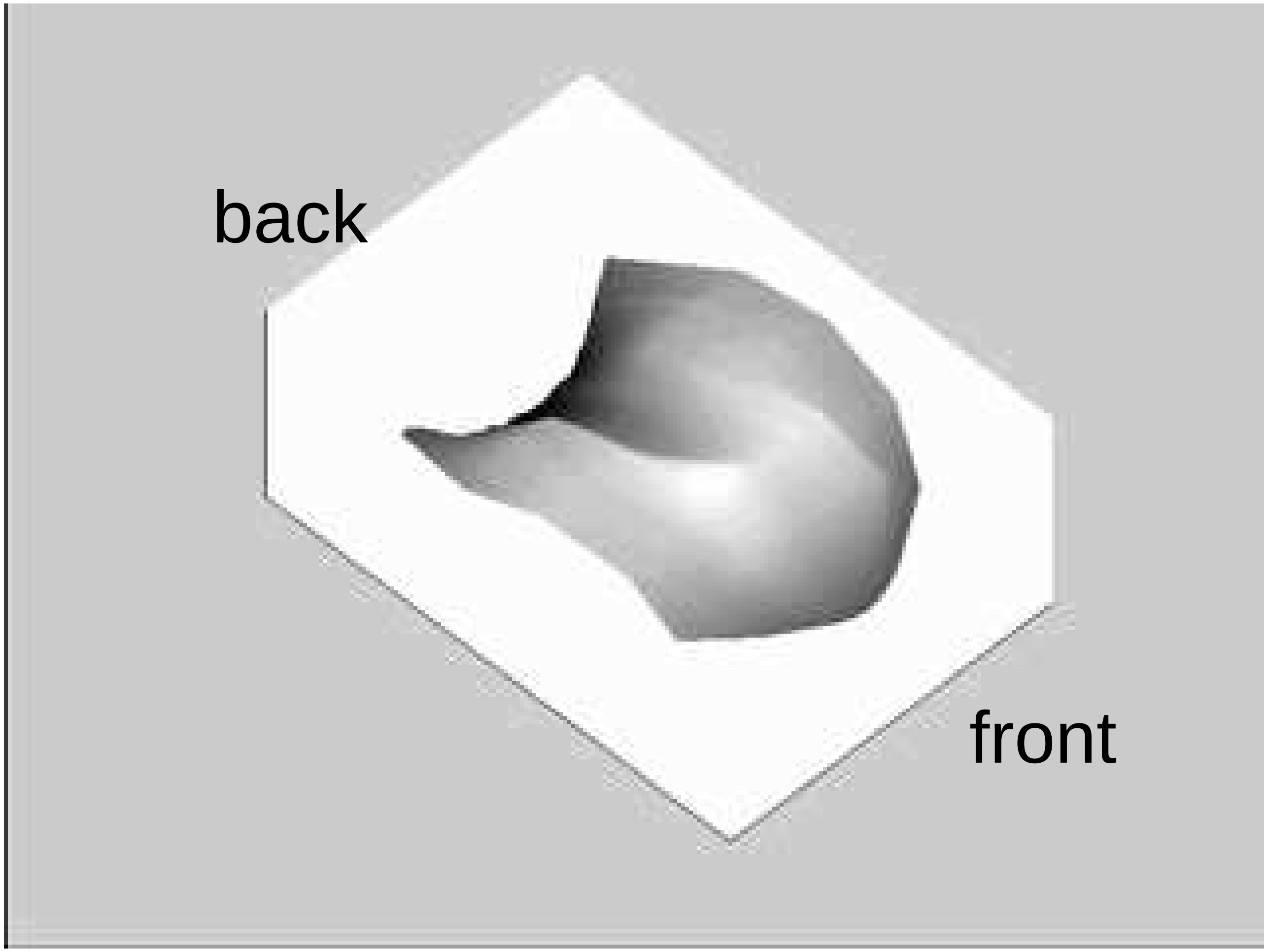
Combination of Intensity and Gradient

- Difficulties for contour tracking:
  - speckle noise
  - unrelated edges
- Our approaches:
  - combine intensity and gradient
  - take the edge orientation into account
  - utilize the fact that every edge has a certain depth
  - obtain intensity information over regions



Combination of Intensity and Gradient(cont.) --*tracking results*

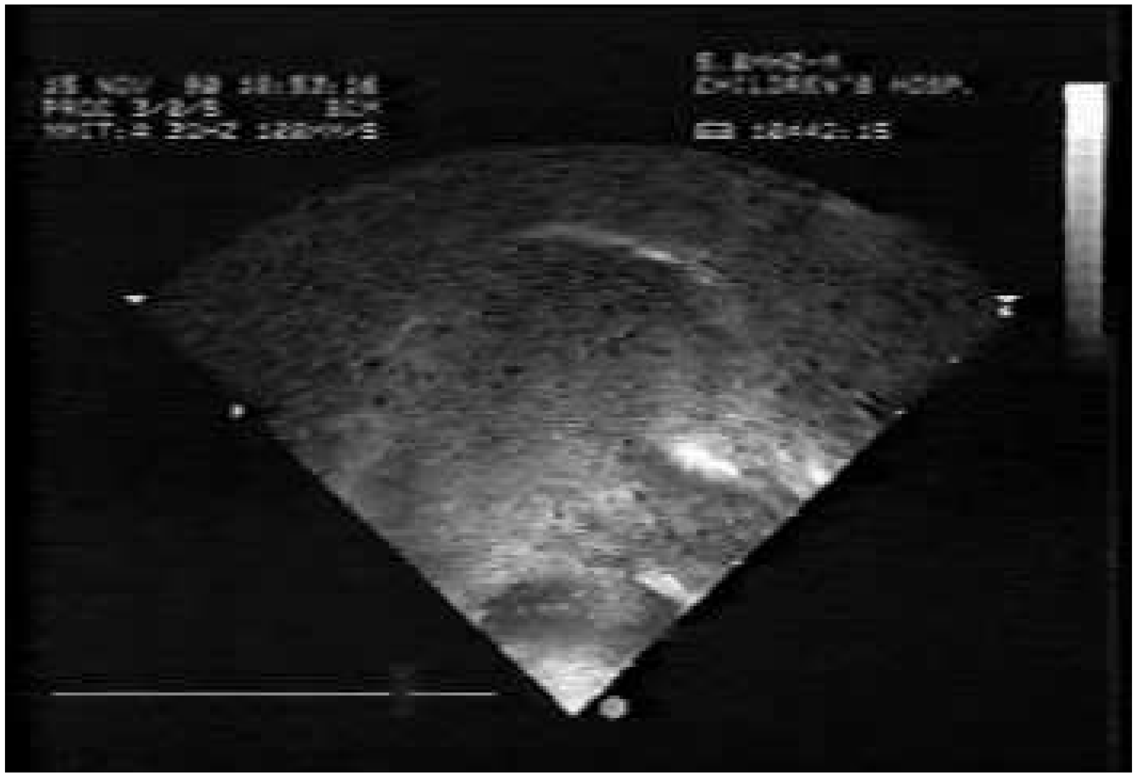




“It ran a lot.”   3D upper surface of tongue.

Continuous Swallowing

Harmonica



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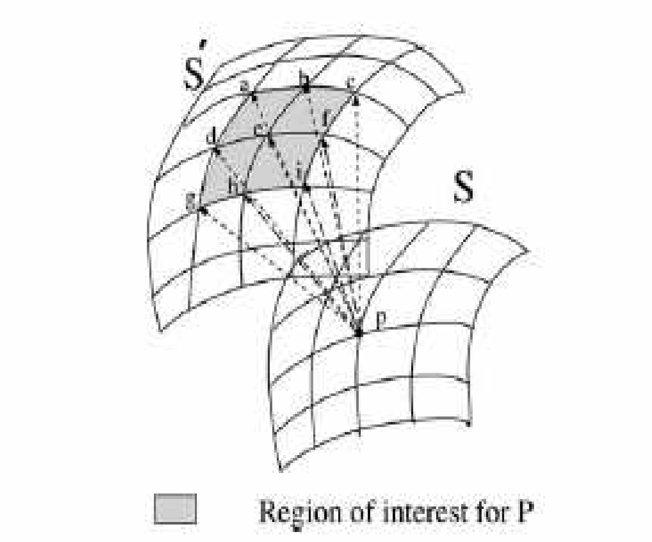
Nonrigid Motion and Structure Recovery

Introduction

- Applications of Nonrigid Motion Analysis:
  - Medical Image Analysis
  - Face Motion Tracking
  - Remote sensing applications
- Approaches:
  - Restricted motion:
    - Articulated
    - Quasi-rigid
    - Isometric
    - Homothetic
    - Conformal
  - Physically-based
    - Snake
    - FEM
  - Shape-based

Nonrigid Shape-based Methods

- A local coordinate system is constructed at each point of interest.
- Problems unsolved:
  - Defined motion has no explicit physical meaning.
  - Motion consistency can not be guaranteed.
  - The orthogonal parameterization requirement of nonrigid shape relationship has to be approximated at the neighbor points inside a local patch around the point of interest
    - A curvilinear orthogonalization method has been introduced in *P.Laskov, C. Kambhamettu. PAMI 2003*

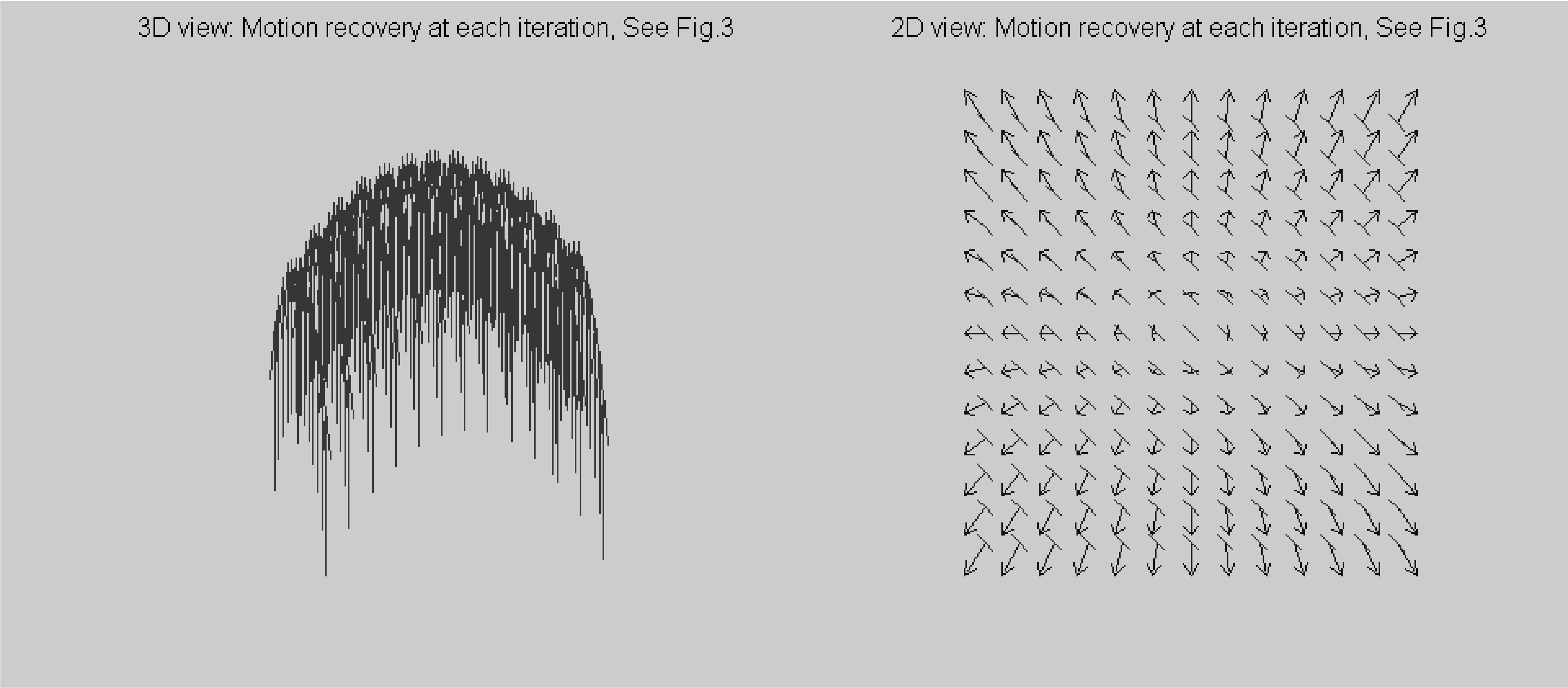


Nonrigid Shape-based Methods
--New Approach

- Nonrigid motion modeling: A ***single*** spline-based motion field over the whole 3D surface.

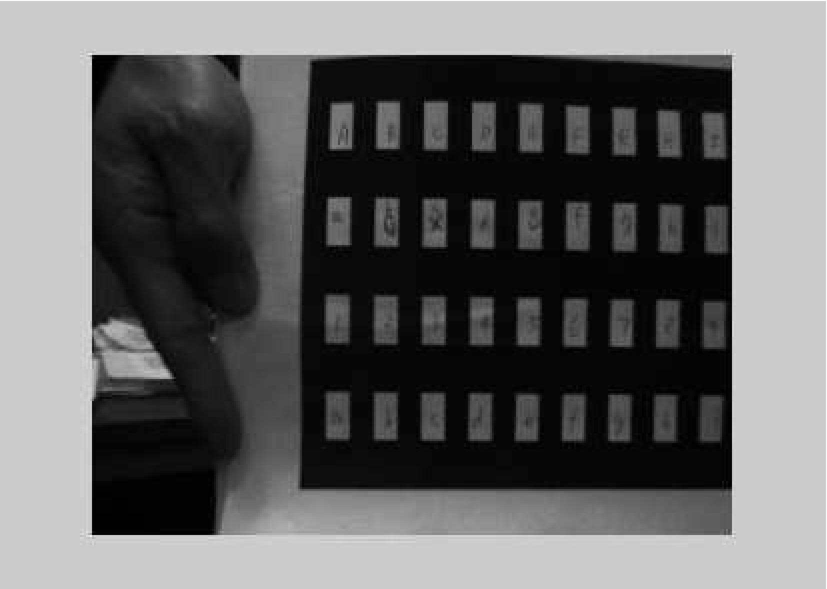
- Nonrigid shape relationship: described in the ***local*** coordinate system constructed at each point of interest.

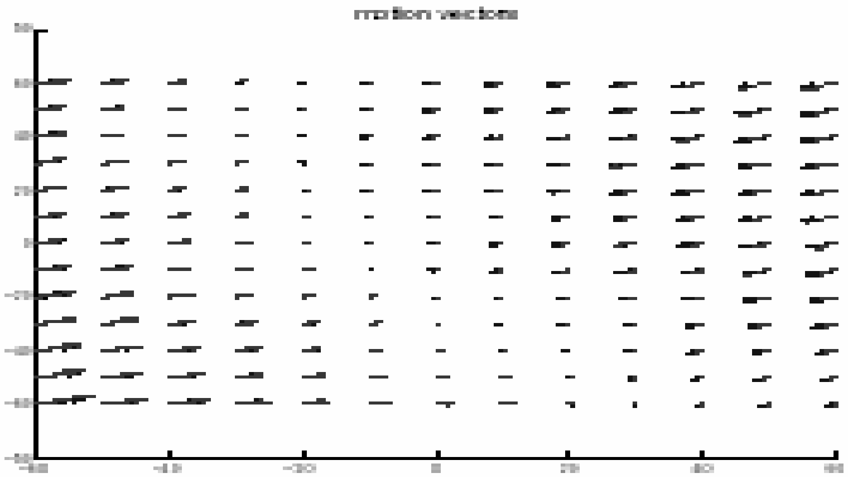
Experiment 2: How good is the algorithm



Experiment 3: real motion

- Paper bending



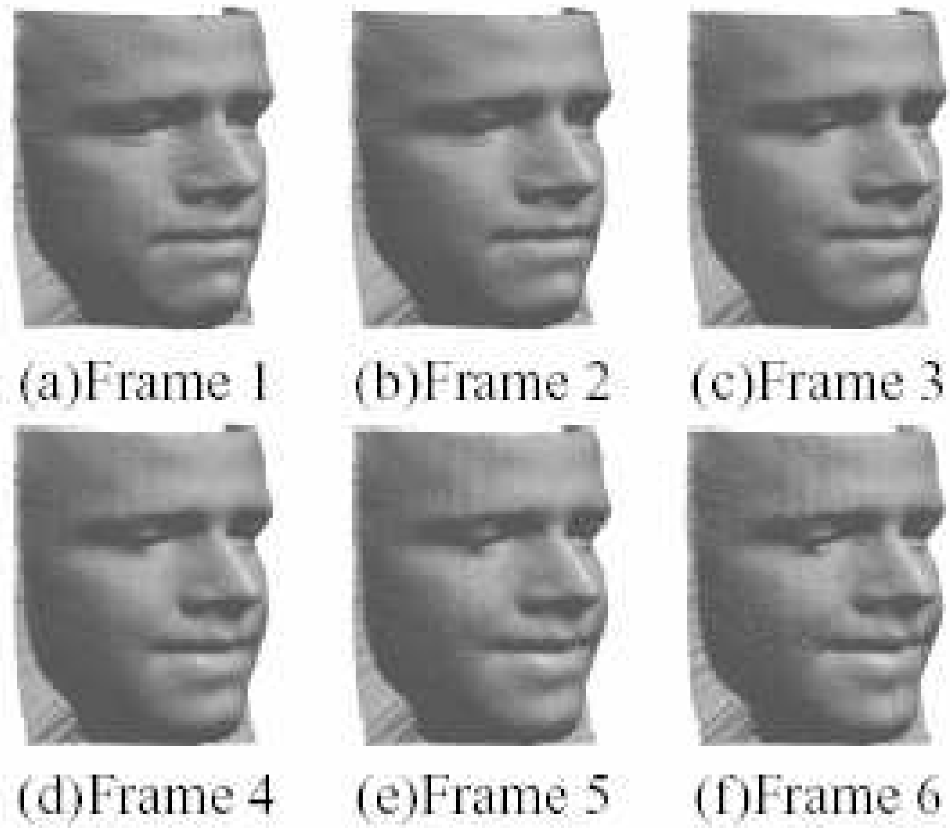


Experiment 3: real motion

- Neutral to smile face
- Neutral to open-mouth face

	trivial c_{err}	recovery c_{err}	imp_{ratio}
Paper	2.83	0.68	76%
Smile	1.31	0.62	53%
Open-mouth	2.00	0.89	55%

Experiment 4: Cyberware data



Protein Docking System

- Protein docking is an important problem in biology and chemistry
- The problem is to predict how proteins interact each other when the 3D structures of proteins are known/given
- Protein docking is helpful in many ways
  - Study of functions of multiple proteins: how they interact in nature, what results of interaction are
  - Disease Diagnosis: what causes particular cells ill function
  - Drug discovery: how drugs possibly work with particular proteins in human body

Problems in Protein Docking

Highly Computationally expensive

Huge search space

Complex formulations

Thus, computer-aided analysis and prediction of **protein-protein docking** becomes increasingly important !!

Our Research

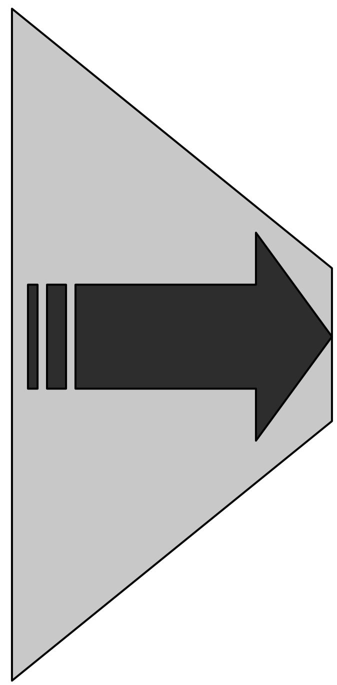
- We have studied and applied techniques based on computer graphics and computer vision to solve the problem of protein docking
- We develop algorithm to perform docking geometrically
- Our docking method reduces search space by docking patch-to-patch based on high level geometric information such as curvatures and other differential geometry parameters

Search Space Reduction

Big Search Space

By rigid assumption,
6-degree of freedom

3 Rotations + 3 Translations



Smaller Search Space

By segment-to-segment docking

< 10,000 reasonable search cases

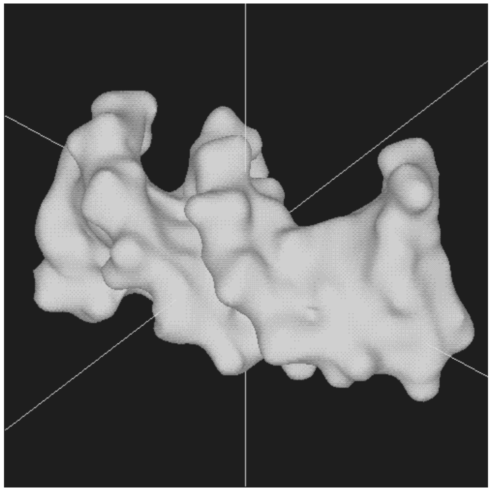
Surface Classification

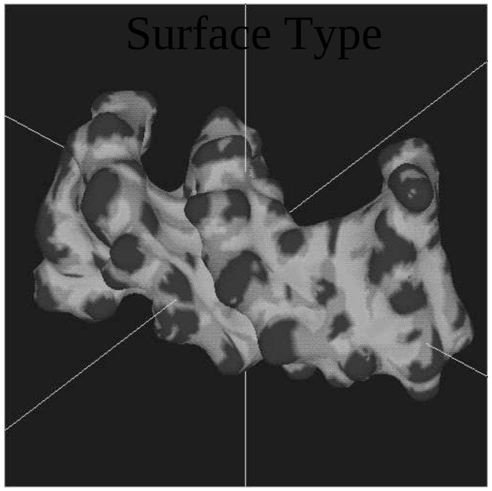
- The surface type (T) of a vertex is classified using Gaussian curvature (K) and mean curvature (H) by Besl and Jain '88

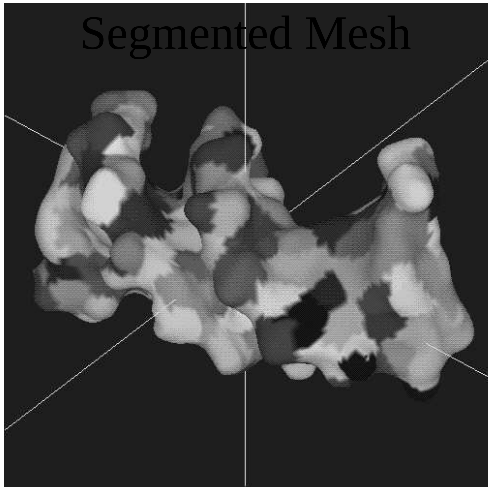
$$T = 1 + 3(1 + sgn(H, \epsilon)) + (1 - sgn(K, \epsilon))$$

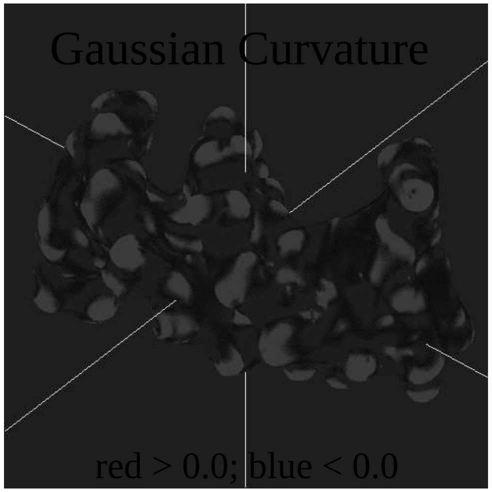
	$K > 0$	$K = 0$	$K < 0$
$H < 0$	Peak T=1	Ridge T=2	Saddle Ridge T=3
$H = 0$	none T=4	Flat T=5	Minimal Surface T=6
$H > 0$	Pit T=7	Valley T=8	Saddle Valley T=9

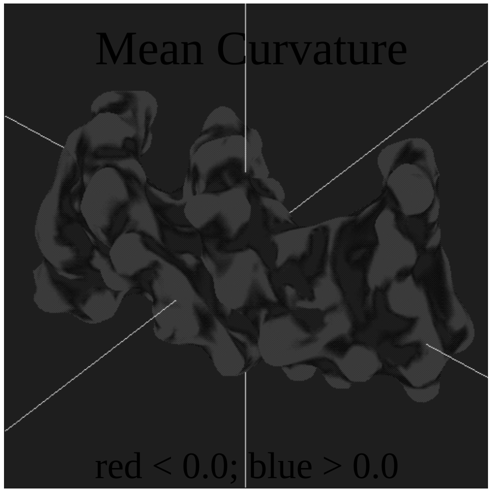
Surface Analysis

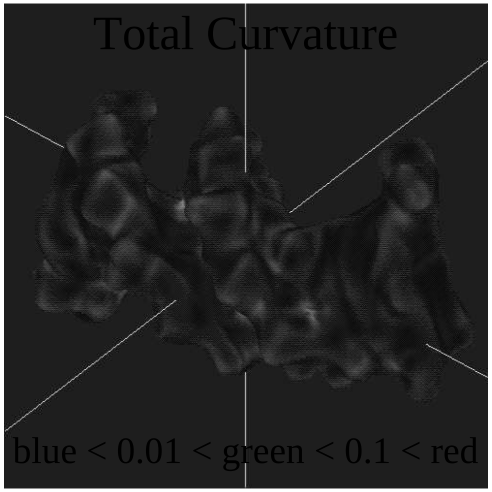




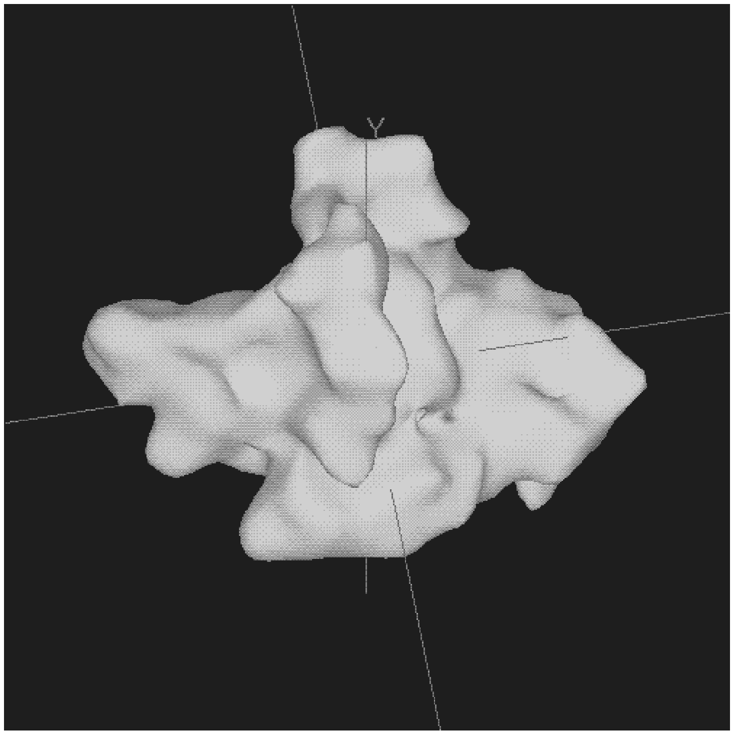


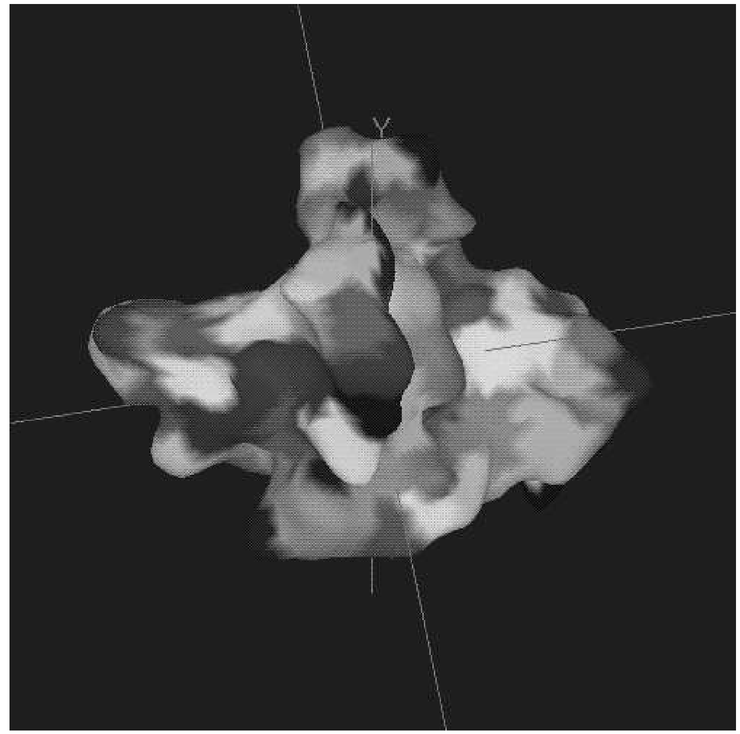






Surface Segmentation – 1EES

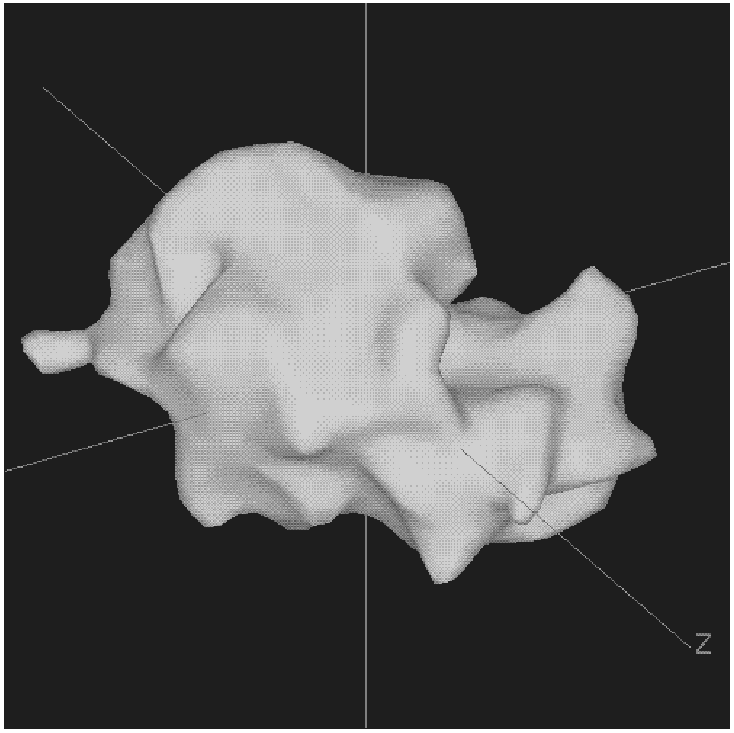


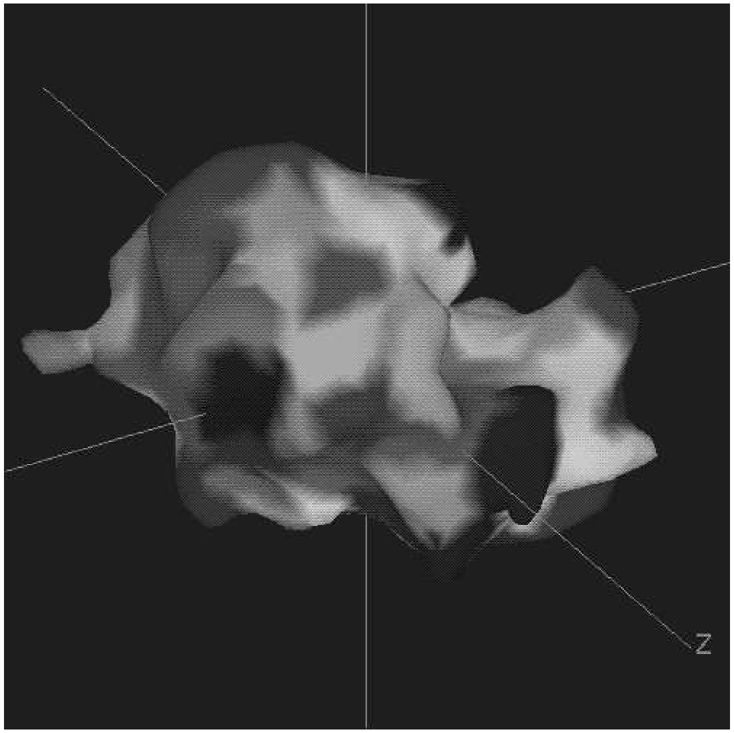


```
#Vertices  = 2551
#Triangles = 5114
#Edges     = 7665
```

```
#Segments  = 124
Exec. Time = 6.762 sec
```

Surface Segmentation – 1H6M

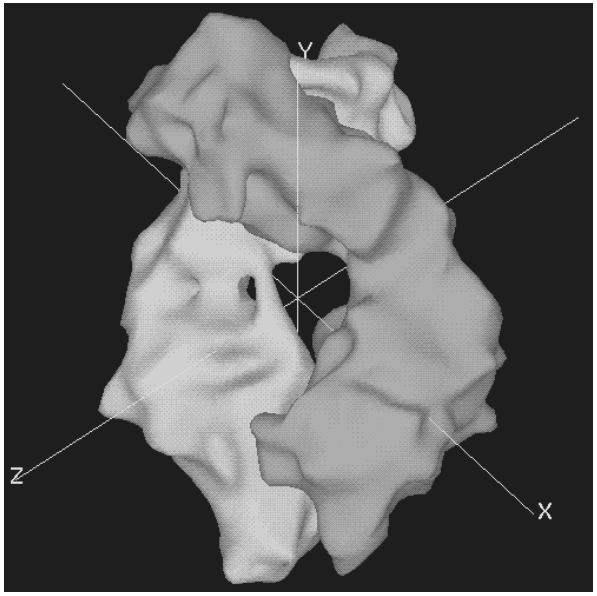




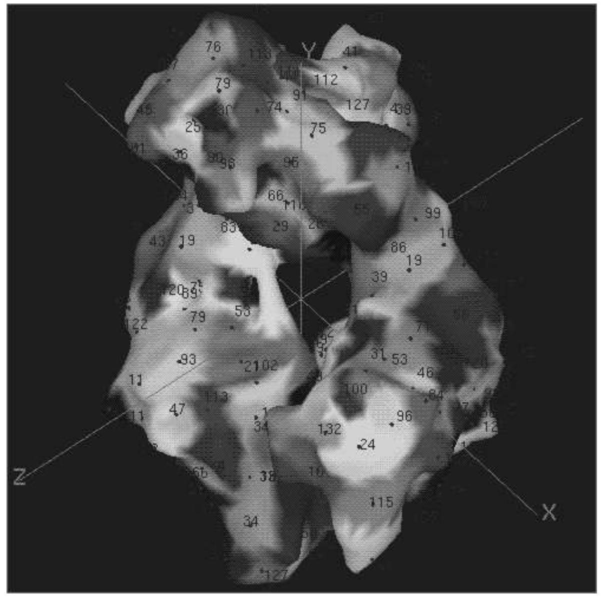

```
#Vertices  = 1400
#Triangles = 4194
#Edges     = 2796
```

```
#Segments  = 76
Exec. Time = 2.379 sec
```

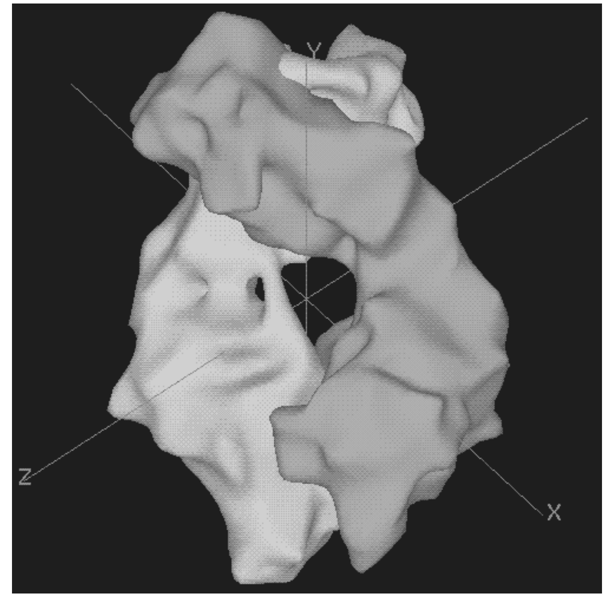
Protein Docking Results



Ground Truth



Docking Result

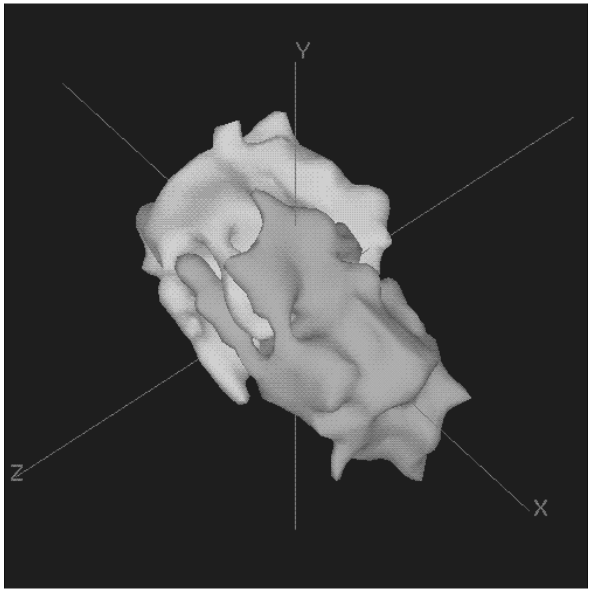


Docking Result

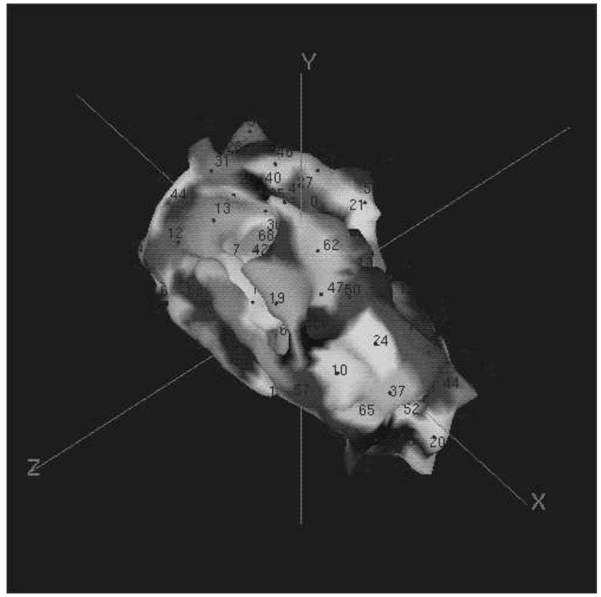
4FAB

```
#Segments    = 129 vs. 133
Closest RMSD = 2.85937
Exec. Time   = 292.263 sec.
#Results     = 8,220
Rank         = 879
```

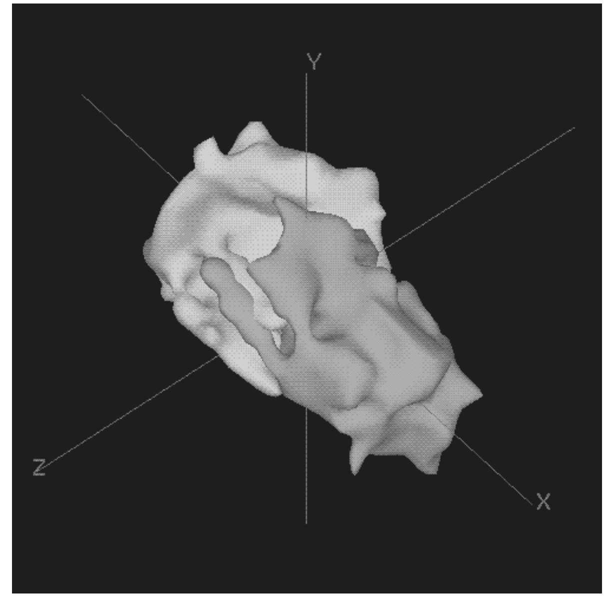
Protein Docking Results



Ground Truth



Docking Result



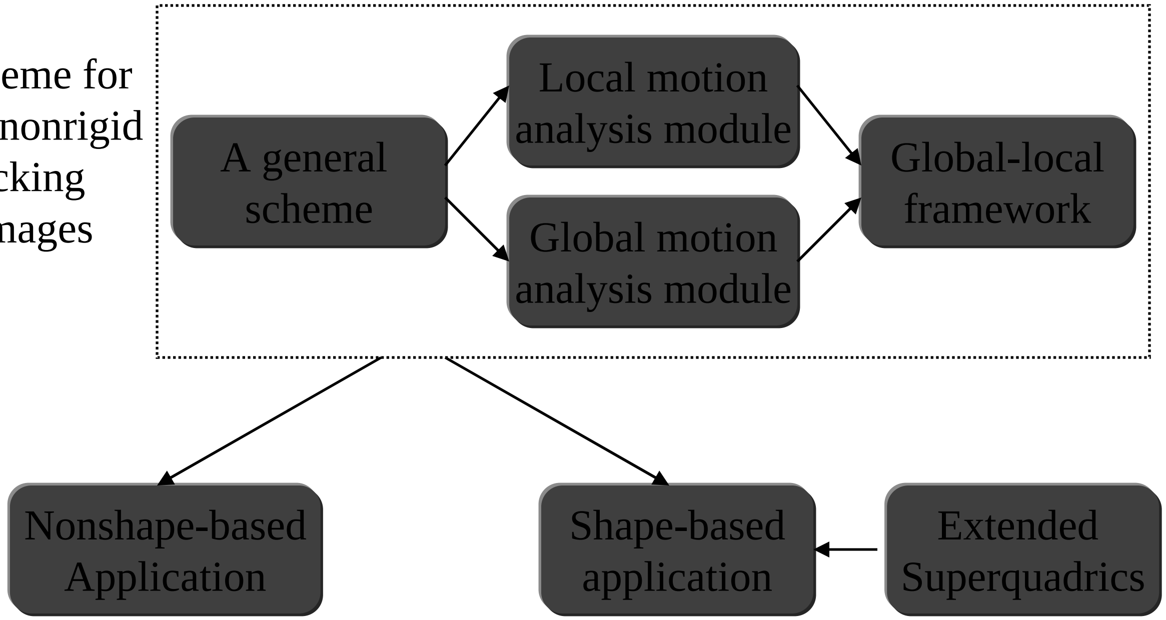
Docking Result

4HVP

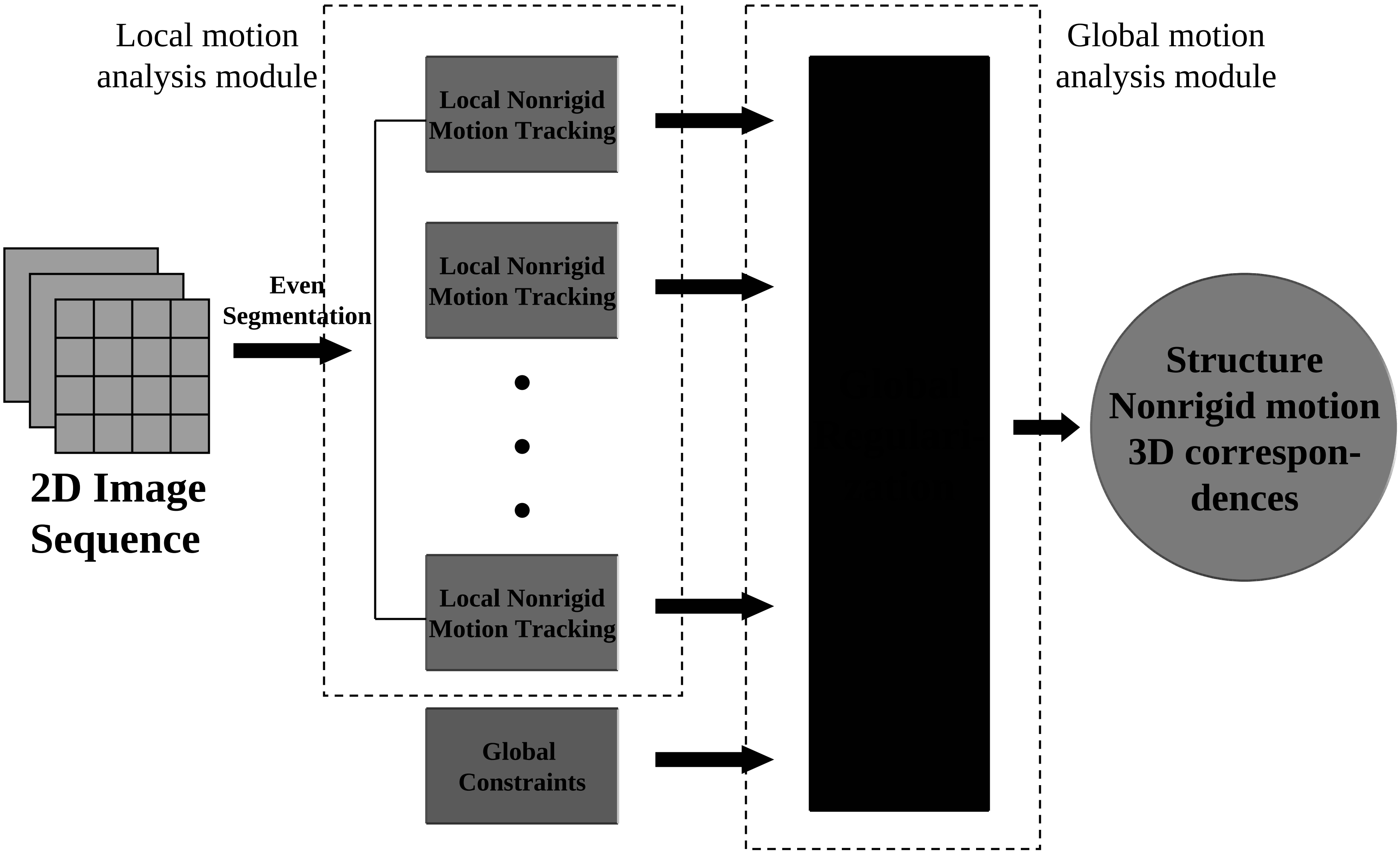
#Segments	= 70 vs. 69
Closest RMSD	= 5.62834
Exec. Time	= 58.217 sec.
#Results	= 2,383
Rank	= 1,391

Structure and Nonrigid Motion

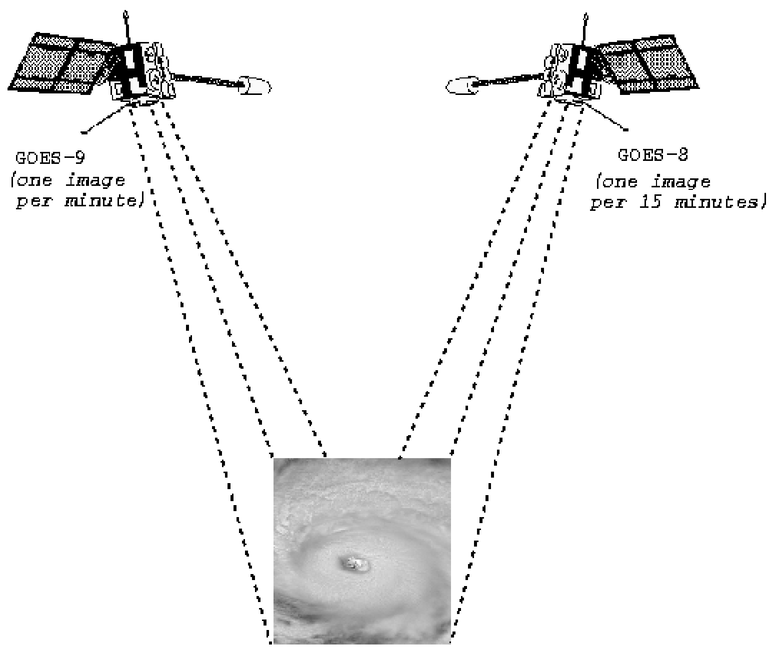
A general scheme for structure and nonrigid motion tracking from 2D images



Scheme Overview



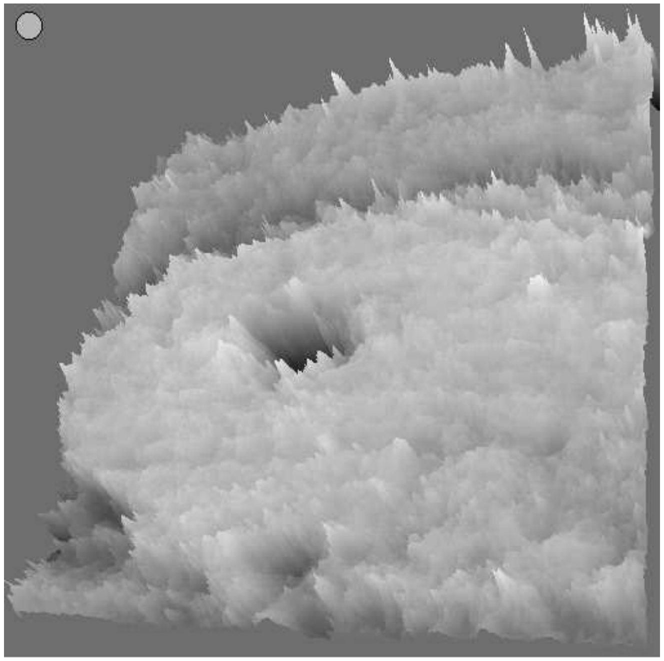
Cloud Image Acquisition

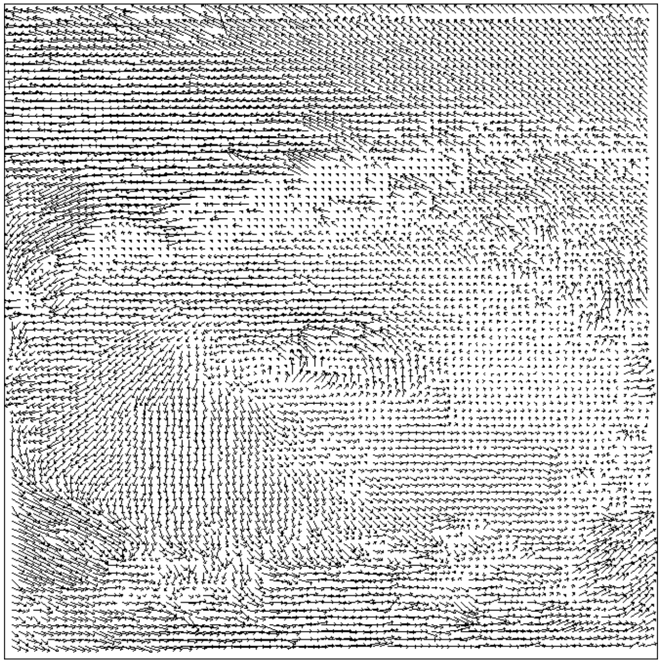


GOES-8 and GOES-9 are focused on clouds;
GOES-9 provides one view at approximately every minute.
GOES-8 provides one view at approximately every 15 minutes;
Both GOES-8 and GOES-9 have five multi-spectral channels.

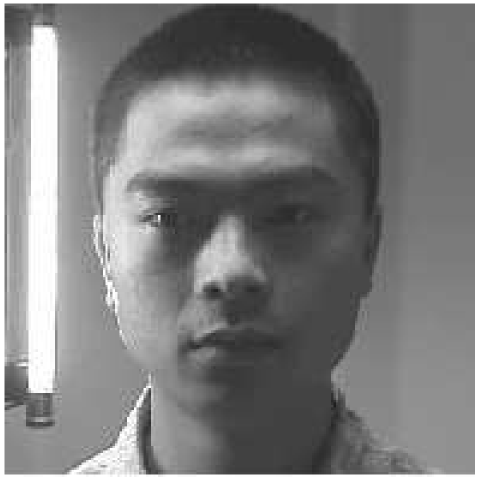
Experiments

- Experiments have been performed on the GOES image sequences of Hurricane Luis, start from 09-06-95 at 1023 UTC to 09-06-95 at 2226 UTC.



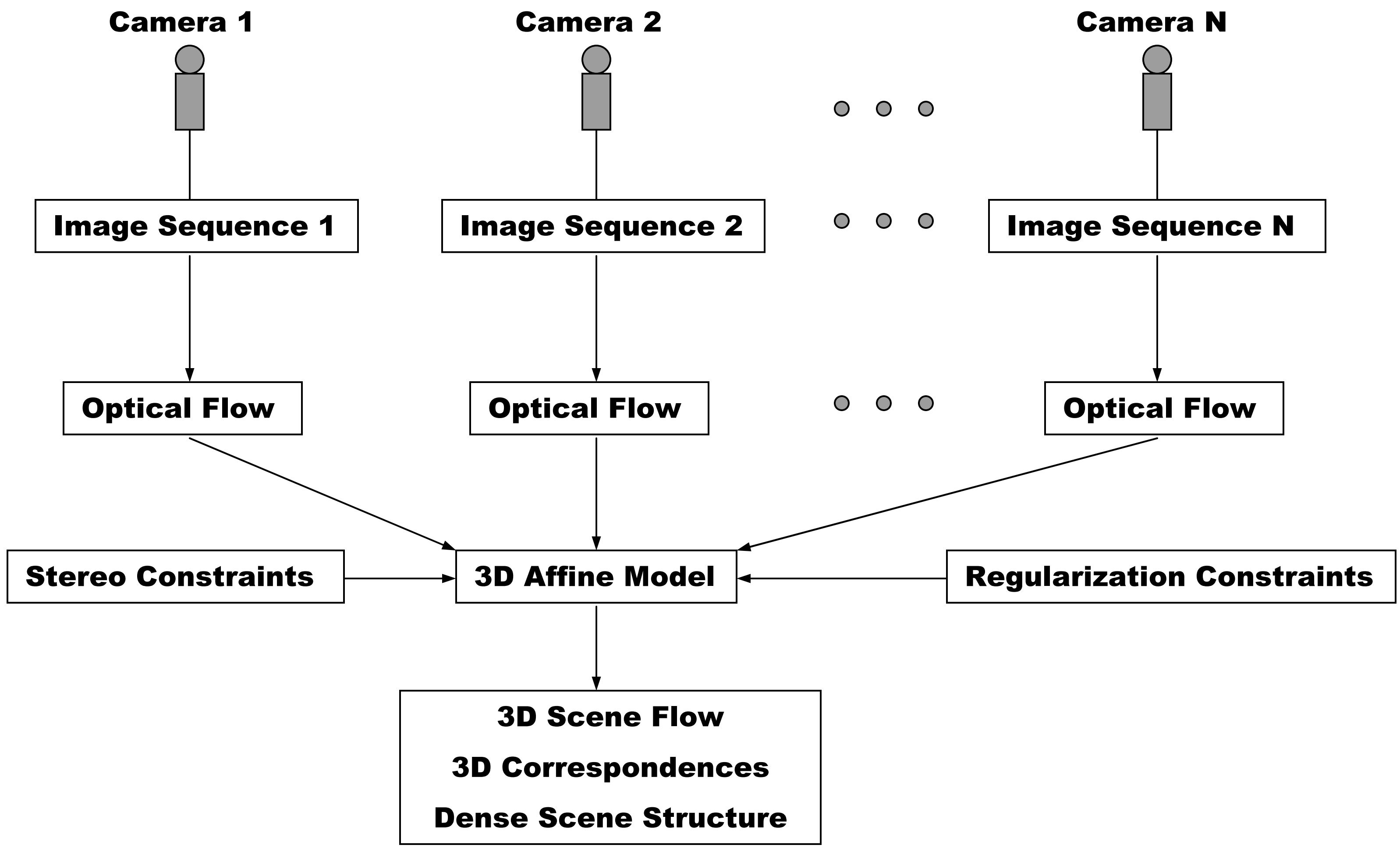


Experiments on Real Images



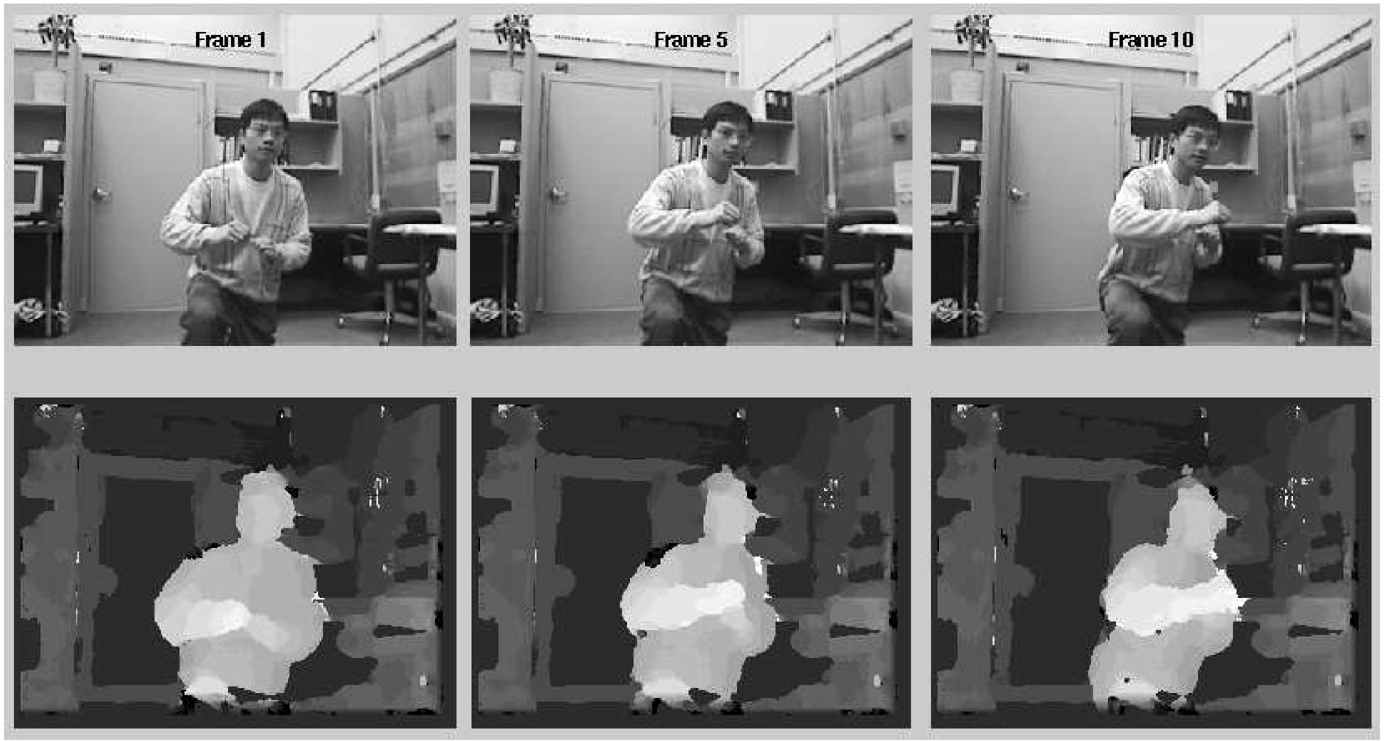
3D Scene Flow and Structure Estimation From Multiview Image Sequences

System Block Diagram



Integrated 3D Scene Flow and Structure

Experiments on Real Data

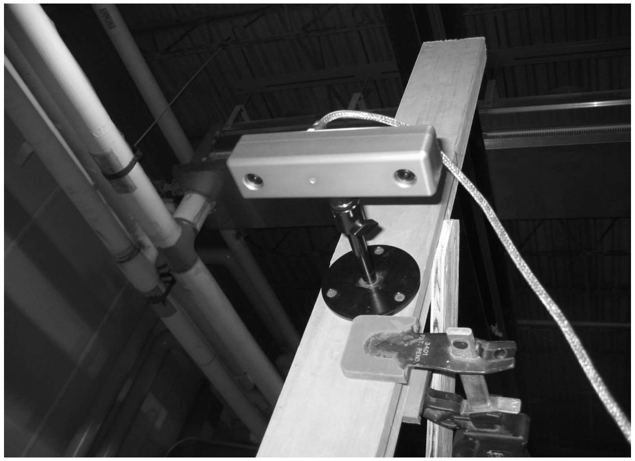


Ice Motion Research (movie)

- Understand sea-ice mass balance and its variability
- Three key questions that need answering
  - How much ice is there? (area and thickness)
  - How does it move? (drift and deformation)
  - How does it grow and decay? (thermodynamics)
- Relevant Projects
  - sea-ice deformation at the meso- & large-scale using
    - buoys
    - remote sensing (SAR (RADARSAT&ERS-1), SSM/I)
  - sea-ice thickness
    - large-scale using ship's and weekly ice charts
    - lab-scale (Today’s Topic)

Pre-study Experiment 5-8 May

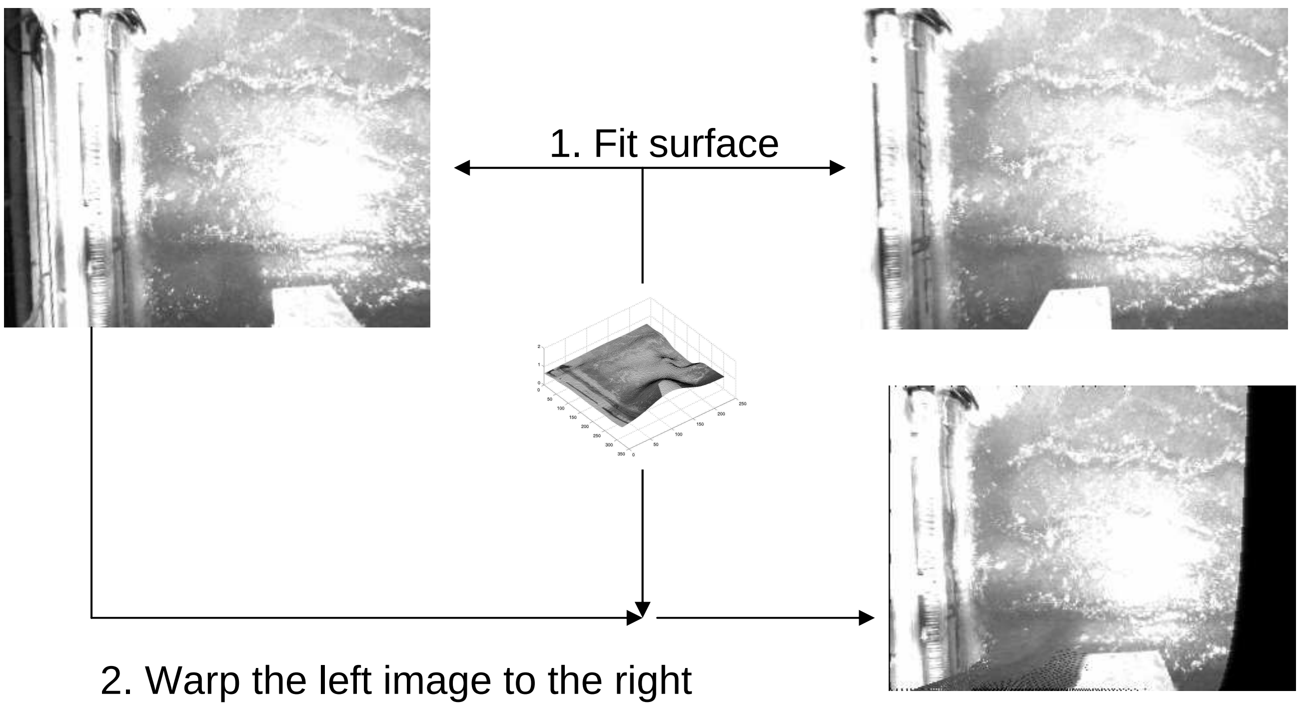
Bumblebee Stereo Camera



- Piggyback on existing experiment (NSF OPP-9814968)
- Equipment: Firewire connection, camera (320x240 pixel), laptop
- Raw Output: Short segments of digital stereo images
  - base length ~10cm
  - object distance ~ 80cm
  - 15 frames/sec
  - duration 30 sec to 2 min
  - recording rate 15 minutes to hourly
- Processed Results: 4D (x,y,z,t) information about the non-rigid motion of discontinuous sea ice in a wave field.

Stereo Analysis Algorithm

Thin Plate Spline Surface With Iterative Warping



Stereo Analysis Algorithm

Thin Plate Spline Surface With Iterative Warping