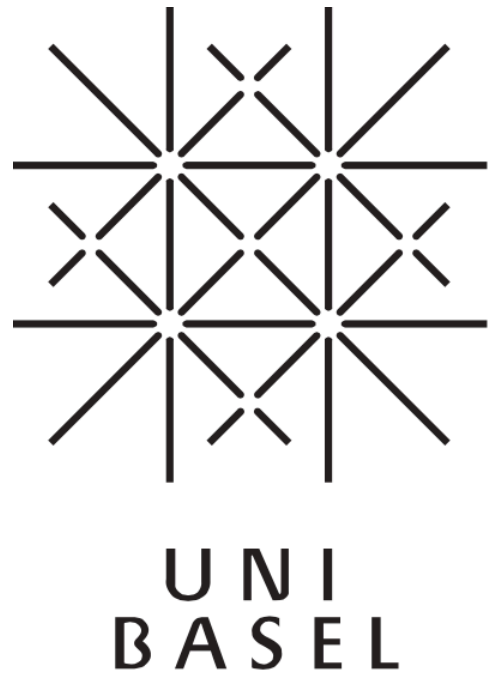


# The Value of Statistical Shape Models to Spine Surgery



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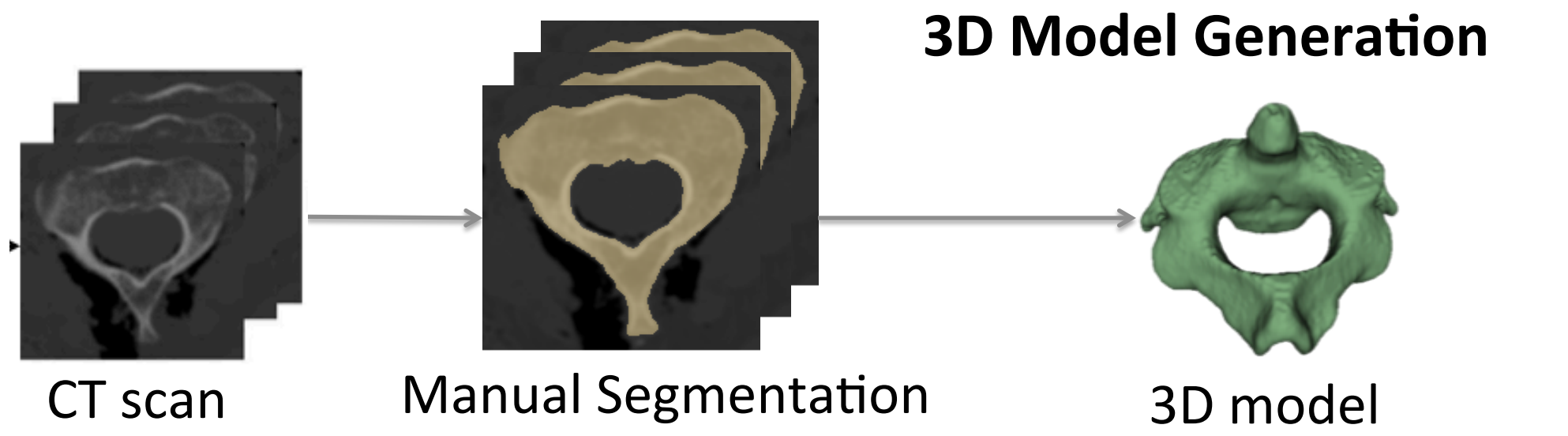
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## Introduction

The increased use of 3D models of organs or bones by the surgeon has led to rapid development of new methods to automatize model generation.



1-2 hours with software  
(ex: Slicer 3D [1])

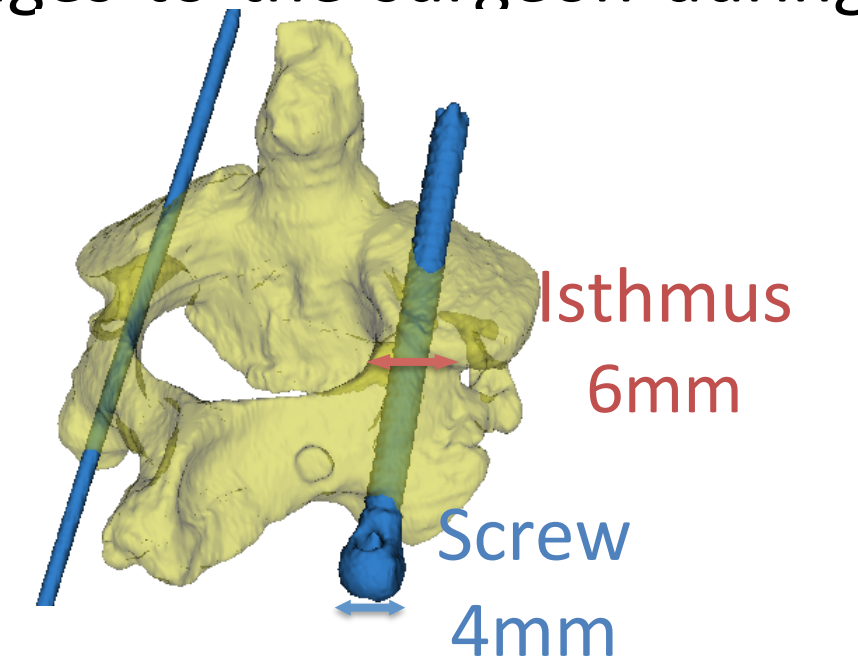
unsuitable for some procedures, especially emergency surgeries

**Need:** Rapid and precise automatic segmentation method

**Solution:** Statistical Shape Modeling (SSM)

Our case study focuses on segmentation and 3D model generation of the second cervical vertebra (C2). The C2, (or axis), presents very specific challenges to the surgeon during C1-C2 screw placement:

- Unique shape
- The most **complex** in the entire spine
- The most **risky** for implant placement
- Maximum variation in implant placement:  $\pm 1\text{mm}$



A C2 3D model will optimize screw placement and provide rapid automatic planning for the surgery procedure.

## Overview

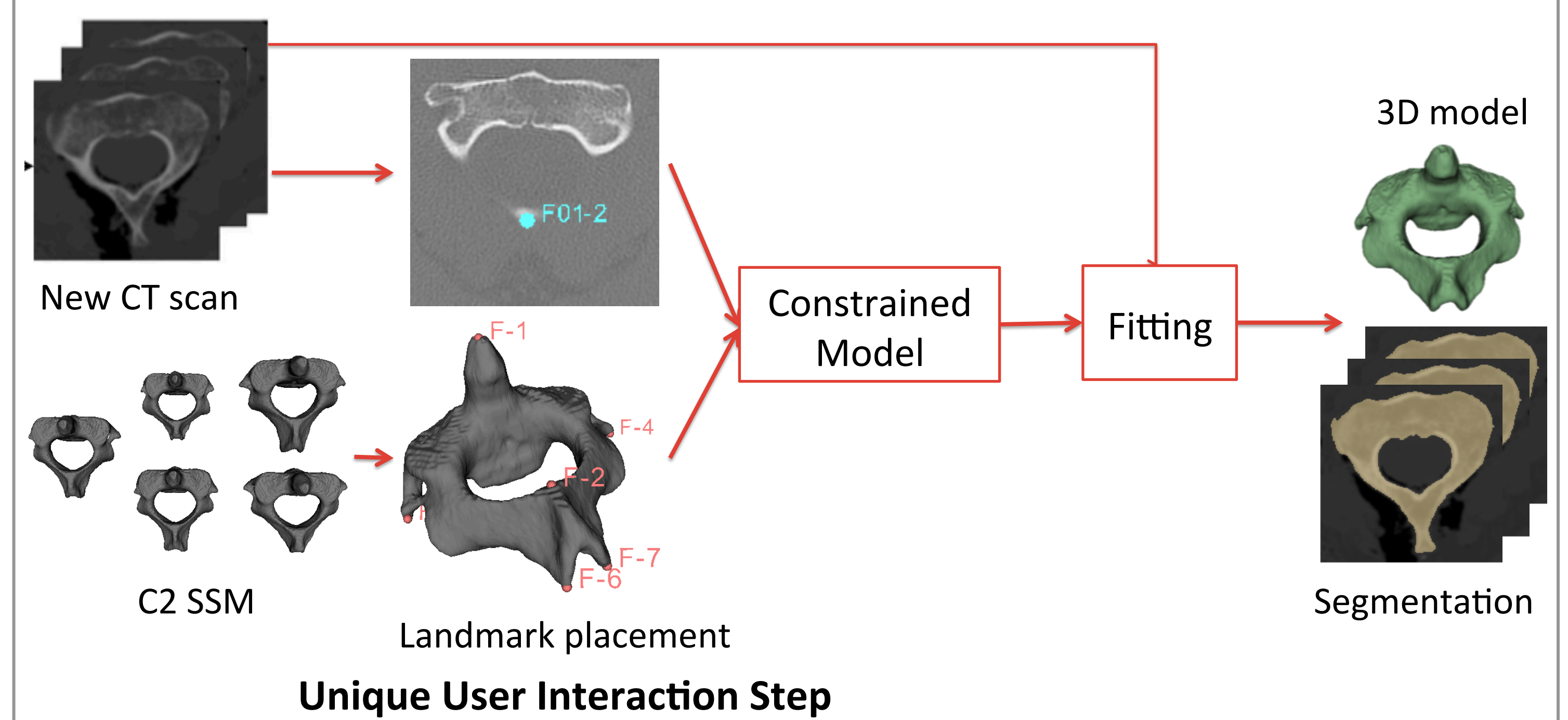
**Method:** SSM-based segmentation

- C2 SSM Building → Done one time used for each new patient
- C2 Model Generation → landmarks constrained shape model fitting

Implemented with Statismo [2]

## C2 Generation

**Method**

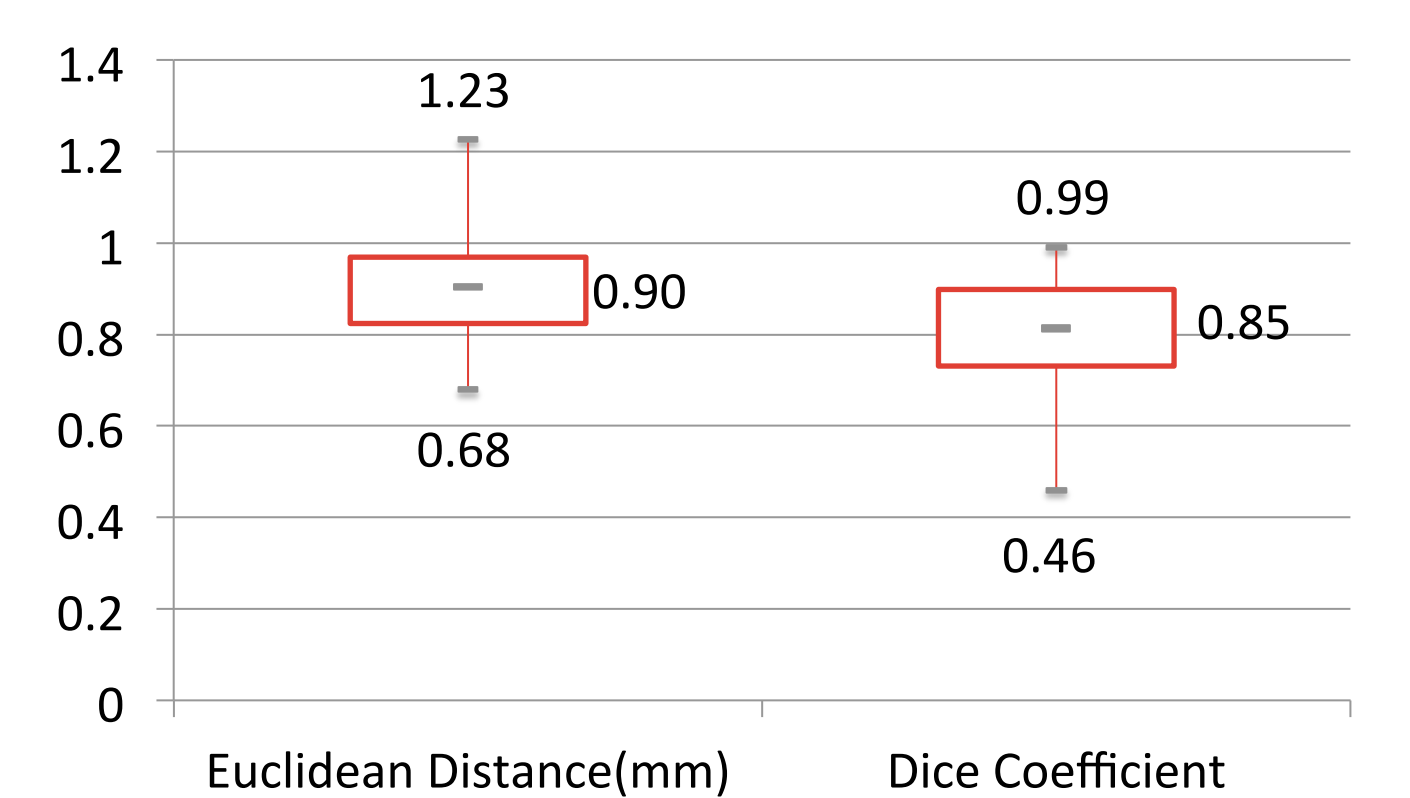


**Unique User Interaction Step**

**Results**

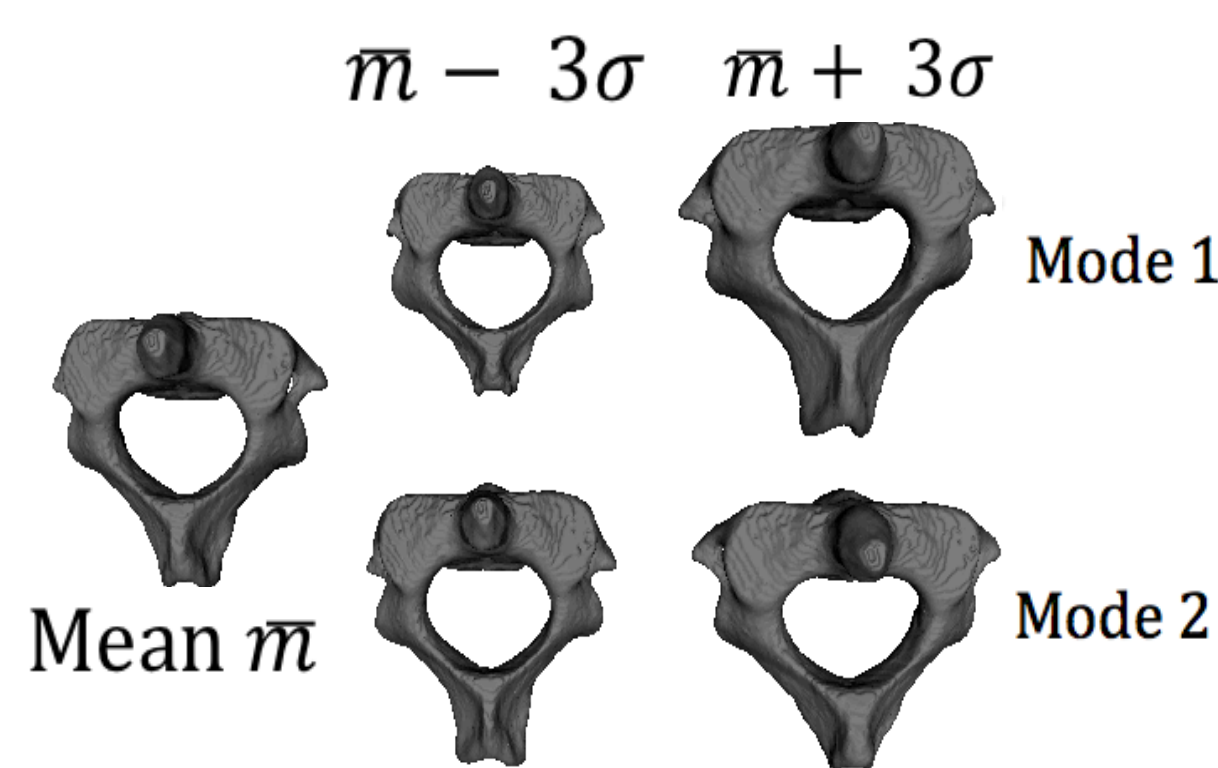
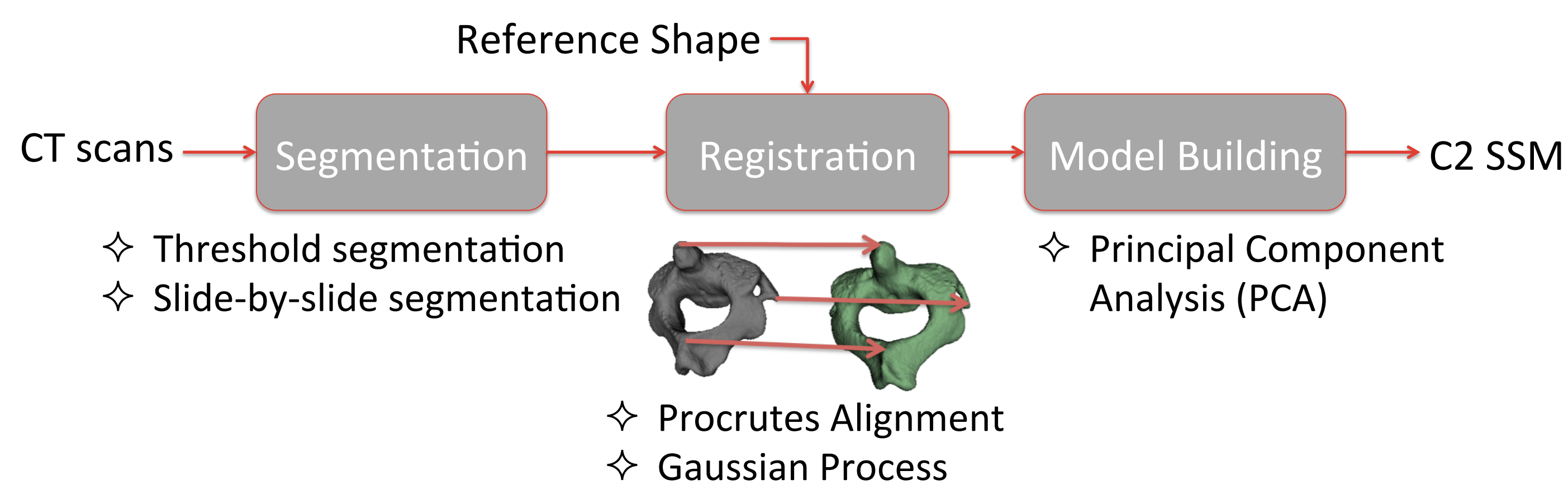
Comparison of the 3D model between manual segmentation (obtained with Slicer [1]) and our method:

- Euclidean Distance: mean error:  $0.9 \pm 0.2 \text{ mm}$
- Dice Coefficient: mean:  $0.85 \pm 0.1$
- Time reduced: 1h → 2min



## C2 Statistical Shape Model

**SSM Generation**

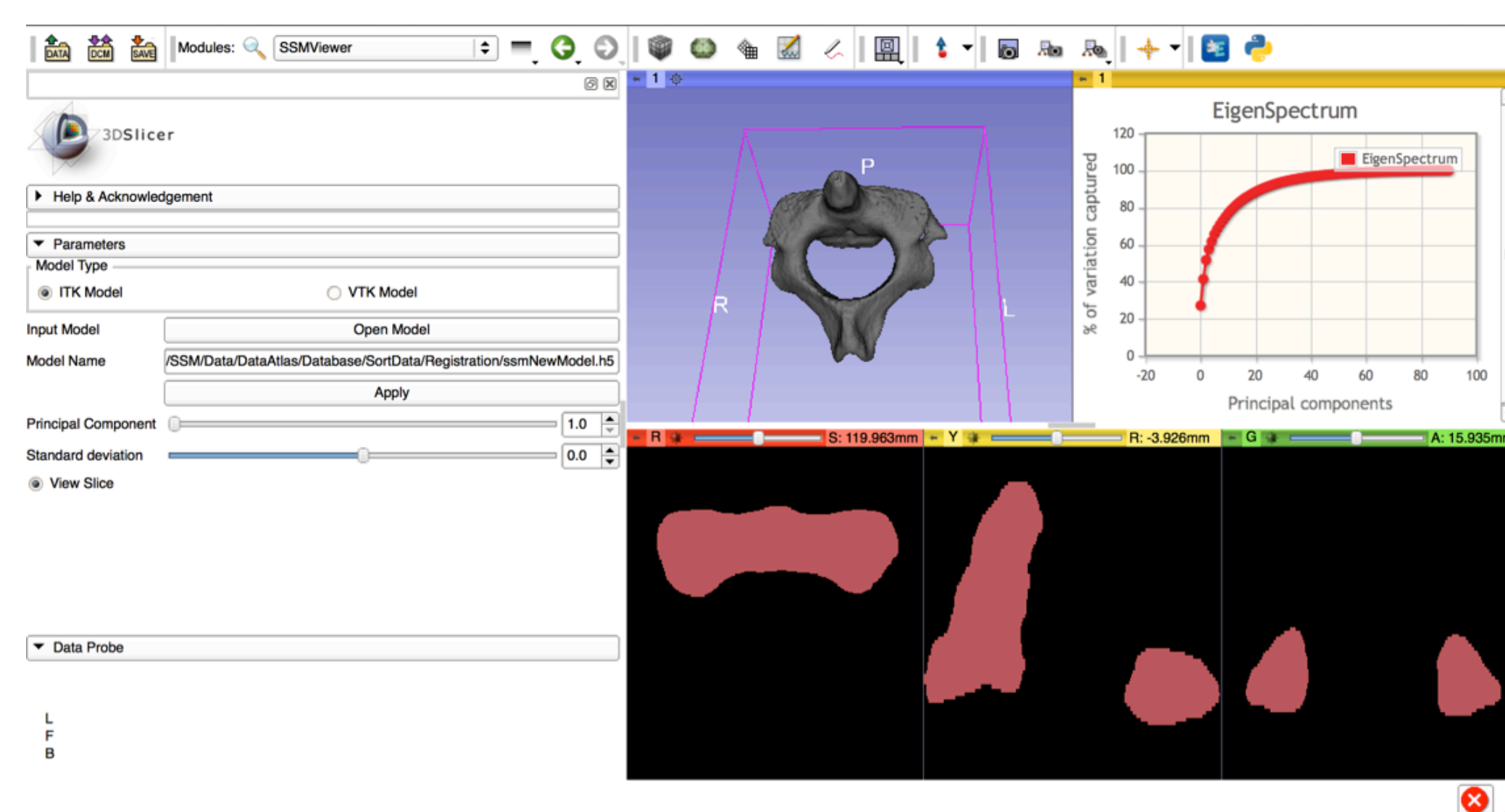


**C2 SSM**

- Large variability found in the C2
- Size of the bone mainly captured in the first modes.

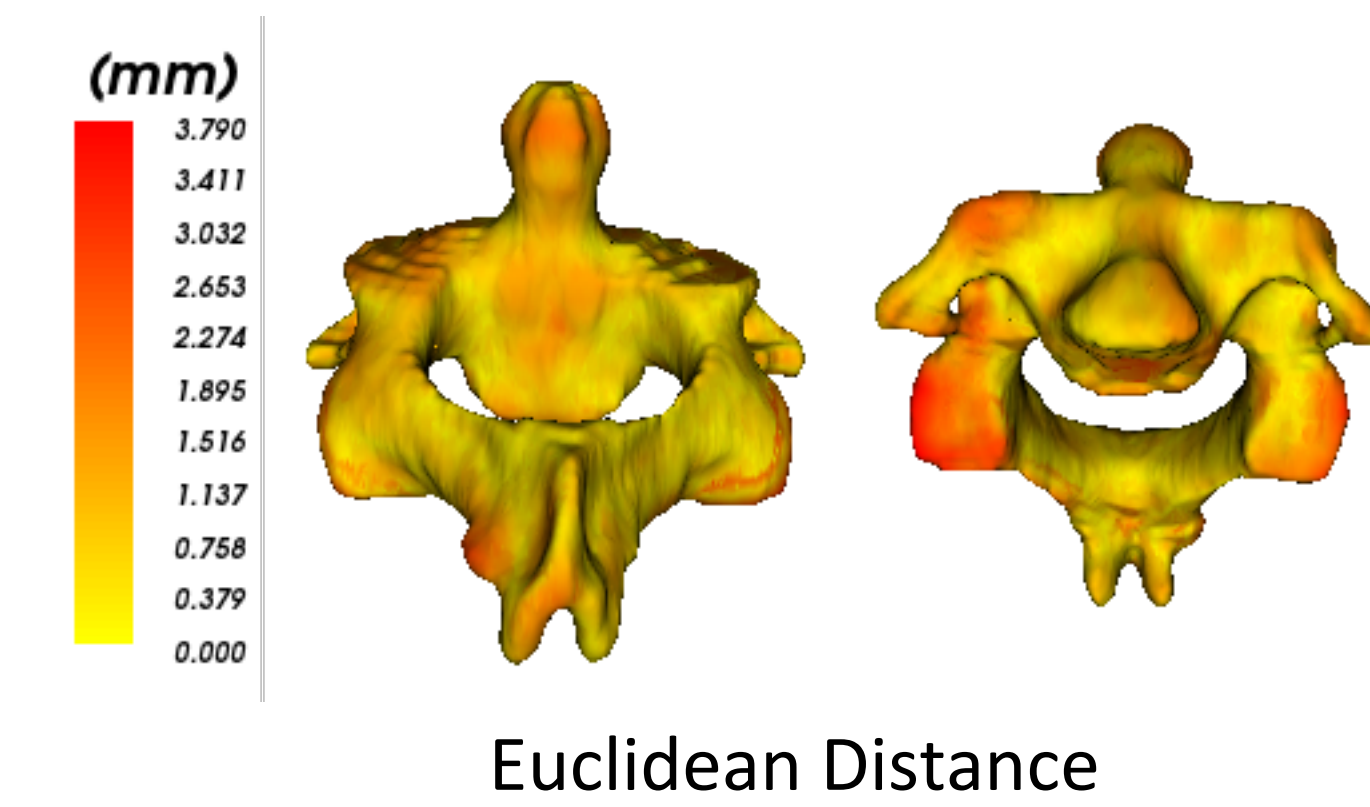
**SSM Viewer**

Slicer module to visualize the main variation of SSM.



**Eigen Spectrum**

88.5% of the C2 variation captured by the first 20 modes.



shape differences: in the inferior articular facet of the vertebra: zone where the distinction between two vertebrae is difficult to identify even by direct viewing of the CT scan

In the isthmus: error inferior to 1mm

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**Bibliography:**

- A. Fedorov et al., "3D Slicer as an image computing platform for the Quantitative Imaging Network," *Magn. Reson. Imaging*, 30(9), 1323–1341, Nov. 2012
- M. Lüthi et al., "Statismo-A framework for PCA based statistical models," *Insight J.*, 1, 1–18, 2012

## Conclusion

**Before**

C2 segmentation done manually slice-by-slice and very time consuming.

**Now**

- Simplified user interaction
- Reduced the time the surgeon waits for the 3D model
- Enabled rapid planning or adaptation of planning for spine surgery

**Possible improvements**

- Focused the landmarks in the isthmus of the C2
- Enforced fitting in particular zone such as the inferior articular facet

SSMs are invaluable tools for rapid and precise 3D model generations in:

- surface merge algorithms,
- diagnosis (scoliosis, trauma modeling of broken vertebrae elements)
- and robotic surgeries.