Modeling Continuous Shape Change for Facial Animation

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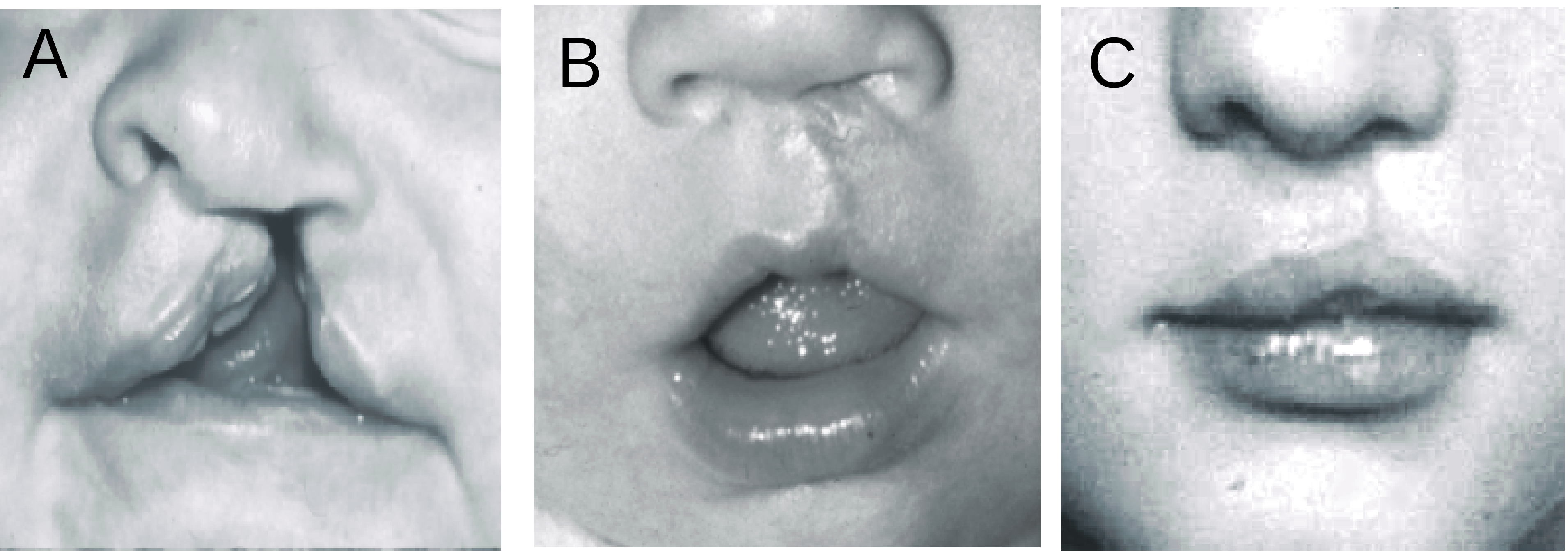
Cleft Lip and Palate



Sequence of surgeries is recommended. Cleft lip surgery at 3 months and palate surgery around 1 year. Surgery often continues into adolescence.

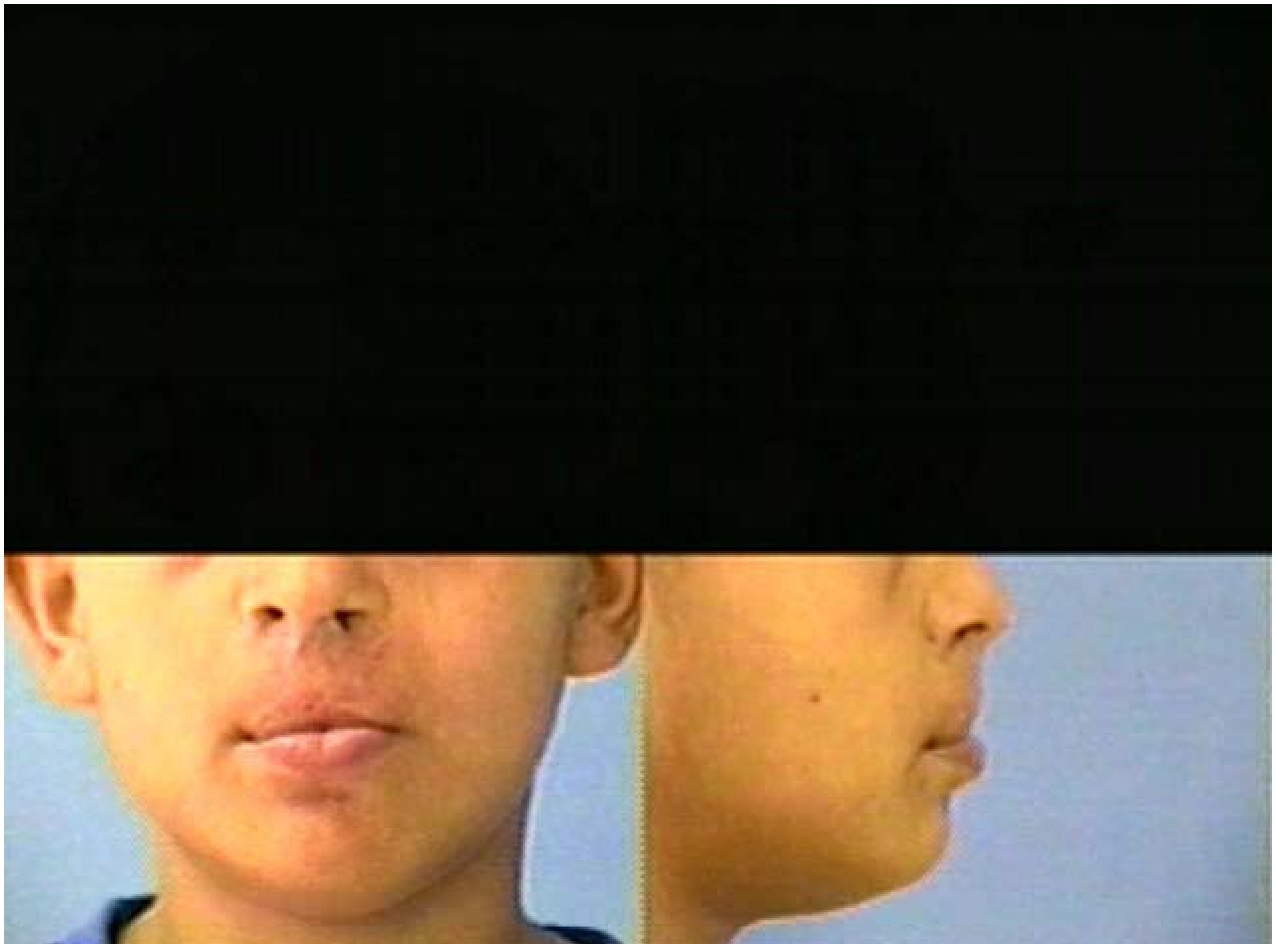
Cleft lip facts

- Common birth defect – about 1 in 1000 births
- More common in males, Asians and Hispanics
- Links to folic acid, smoking/drinking ???
- Heterogenous
- Some genetic linkage

Surgical Decisions

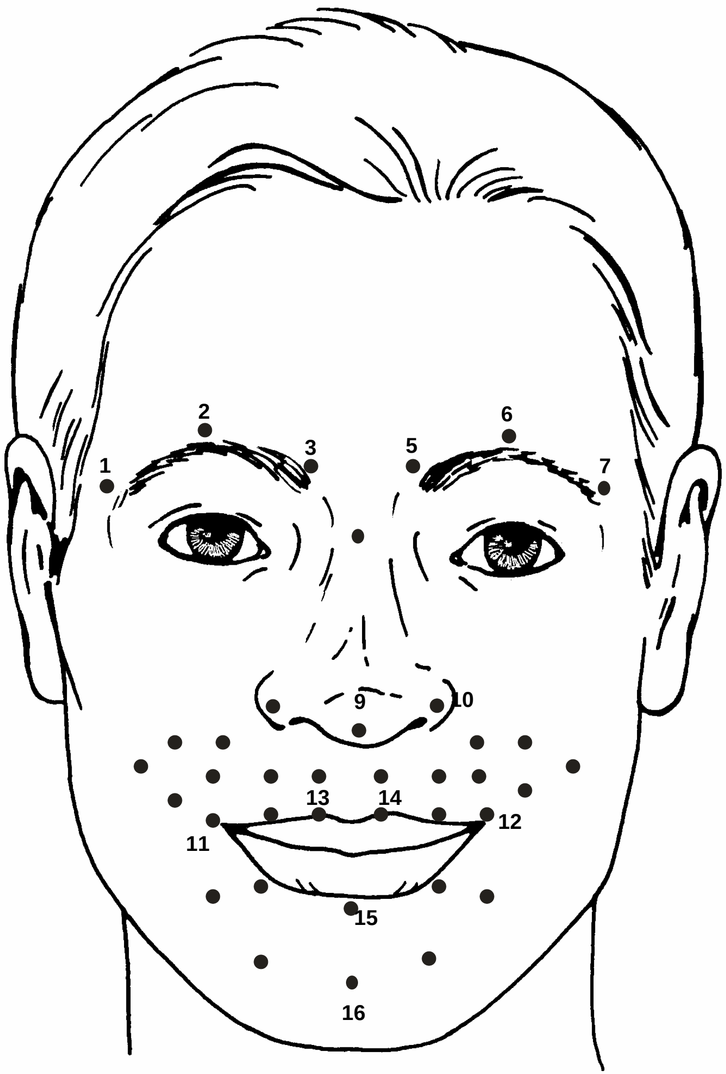
- Repair requires a sequence of surgeries
- Each surgery tends to improve static aesthetic appearance
- Too much surgery can degrade facial function
- Surgeons/Parents tend to be biased towards aesthetics
- Need objective measures of facial function

Example of Cleft Motion



Capturing Facial Motion

Marker Placement



Standard motions

Data

- Each motion represented by
  - 38 markers
  - 3 dimensions
  - 240 frames of motion
- How can we reduce this very large amount of data to a few numbers that capture the essence of the motion?
- Large number of motions – normal and cleft subjects, smiles, grimaces etc, change over time, different studies etc

Relative Motion from Rest

- For each pair of markers i and j we compute the distance over time t as $d_{ij}(t)$
- Now compute the relative change as

$$r_{ij}(t) = \frac{d_{ij}(t)}{d_{ij}(0)} - 1$$

which is invariant to whole head motion, facial shape and variability in marker placement

Reconstructing the Motion

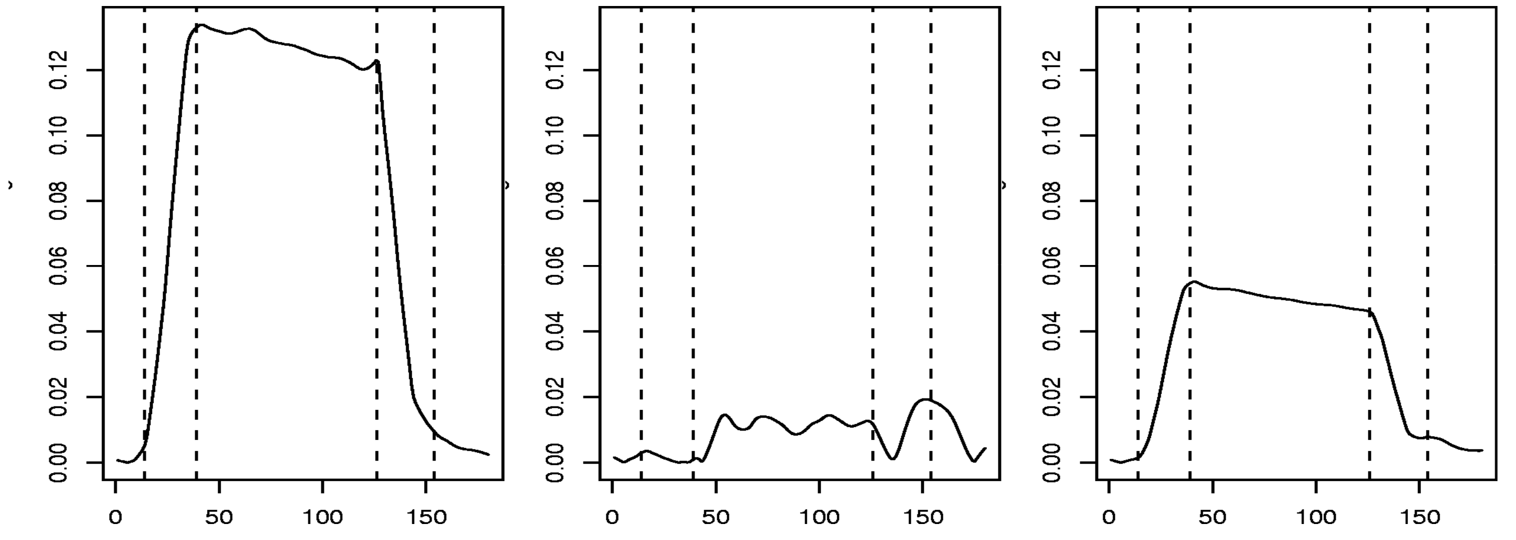
- Given relative change $r_{ij}(t)$ and static face $d_{ij}(0)$
- Can compute $d_{ij}(t)$
- Can use multidimensional scaling to recover the coordinates of the markers at time t up to location, rotation and reflection
- Align successive frames based on almost fixed markers on the nose
- What if a different static face is used or the components of the relative motion are modified?

Projecting onto 3D Motion

- Some predicted $d_{ij}(t)$ may not correspond to 3D objects
- Multidimensional scaling projects to the closest representation in 3D
- Useful because
  - Interested in motion projected onto different faces
  - Interested in averaging relative changes across different motions
- Works because faces are similar etc.

Partitioning the Motion

- Motion consists of five phases
- Rest, go to pose, hold, return from pose, resume rest
- Many different pairwise distances

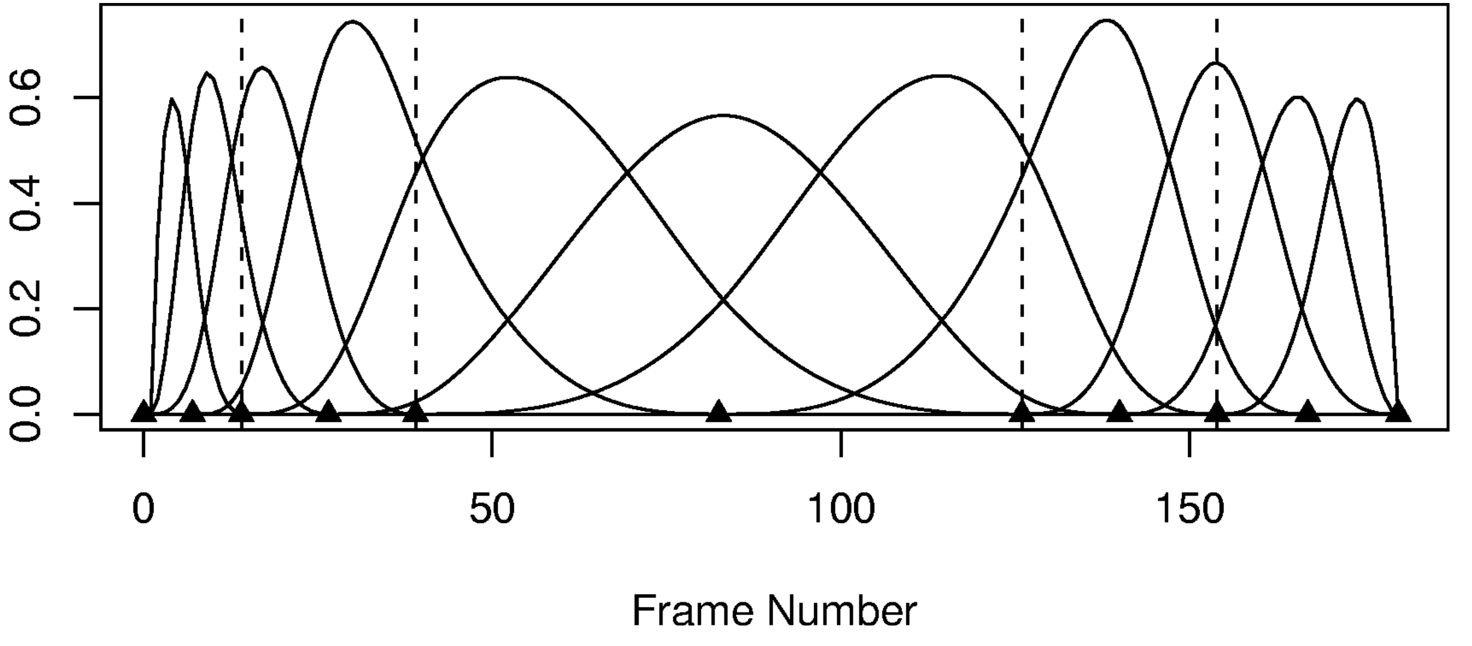


Selecting the cutpoints

- Best distances for cutting vary between and within motions and individuals
- Algorithm determines a weighted average of inter-marker distances that focuses on the particular motion
- Cut points are determined by another algorithm and manually confirmed
- Example of a “registration” problem

B-spline modeling

- Each $r_{ij}(t)$ is fit with a cubic B-spline with 16 basis functions



B-Spline Coefficients

- Because there are 38 markers and all pairwise are considered, this results in a total of 11248 spline coefficients for each motion
- Allows statistics on a group of motions – for example, the coefficients can be averaged
- Given the coefficients, a facial motion can be reconstructed using multidimensional scaling

Principal Components

- Form the coefficients for all motions of a given animation into a, say, 120x11248 if there are 120 motions
- Compute the Principal Components
- Most of the variation in the first few directions
- PC directions represent axes of greatest motion – these can be displayed

PC scores

- Principal component scores for each motion represent the component of that particular motion in the direction of the given principal component
- These scores can be analyzed using such standard statistical methods as linear mixed models
- Can test for differences or trends in groups
- Can identify unusual motions

Summary

- Reduce complex (many numbers) facial motion to simple (1-3 numbers) principal component scores
- Do standard statistics on the scores
- Must visualize motion to understand the scale (PC direction) of the scores

More Information

- Work is joint with Dr. Carroll-Ann Trotman, School of Dentistry, University of North Carolina
- Papers, software available from my web site