CmpE 360
Numerical Methods

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CmpE 360 Numerical Methods

- **Instructor:** Lale Akarun, ETA 28, akarun@boun.edu.tr
- **TA:** Cem Keskin, office hours TBA keskinc@cmpe.boun.edu.tr
- **Course Hours:** MMT 122 ETA A2
- **Textbook:** Michael T. Heath, Scientific Computing, McGraw Hill, 2002.
- **Reference Book:** Burden and Faires, Numerical Analysis, 7th ed, Brooks/Cole, 2001.

Topics

1. Floating point numbers and arithmetic
2. Solutions of nonlinear equations in one variable
3. Systems of linear equations
4. Linear least squares
5. Eigenvalue problems; SVD
6. Interpolation and curve fitting
7. Numerical integration and differentiation
8. Intro to signal processing, FFTs

Grading

- Homeworks (and quizzes): 20 %
- Midterm 1: 20 %
- Midterm 2: 20 %
- Final: 40 %

Homeworks

- The homeworks will involve:
  - on-paper classical problems,
  - programming,
  - MATLAB
- MATLAB : MATrix LABoratory
- Matrix based system for scientific and engineering calculations
- Interactive
- Has built-in functions for almost everything we will need in this class

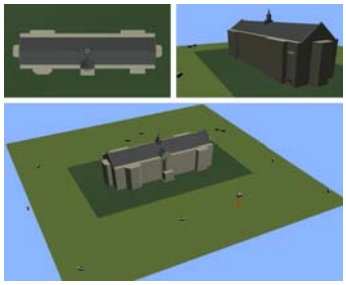
Where are numerical methods used?

Numerical methods are used in
- All engineering problems
- All calculations

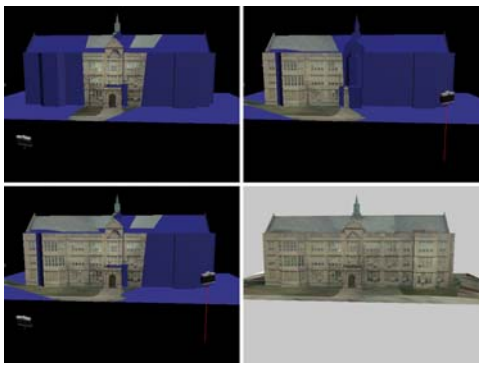
Some examples:
- Computer graphics
- Computer vision

Computer Vision

- Computer Vision deals with understanding the 3D world by using 2D images



GRAPHICS – Texture Mapping from Corresponding Views



Berkeley Facade Project by Paul Debevec, Taylor Camillo, Jitendra Malik,1997

What is involved?

- Systems of linear equations

$$\begin{bmatrix} kx_i \\ ky_i \\ k \end{bmatrix} = \begin{bmatrix} a_{11} & a_{12} & a_{13} & a_{14} \\ a_{21} & a_{22} & a_{23} & a_{24} \\ . & . & . & . \\ a_{41} & a_{42} & a_{43} & a_{44} \end{bmatrix} \begin{bmatrix} wx_0 \\ wy_0 \\ wz_0 \\ w \end{bmatrix}$$

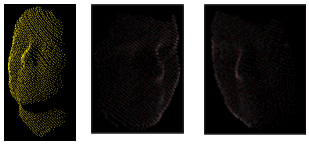
- Solution of large linear systems
- Solution of linear systems when there are more equations than unknowns ➔ linear least squares

Example 2: Face Recognition

- PCA lets you identify directions where energy is concentrated in a vector space
- To do that, eigenvalues and eigenvectors of the covariance matrix are found
- The eigenvector with the largest eigenvalue points in the direction of largest energy

Problem Definition

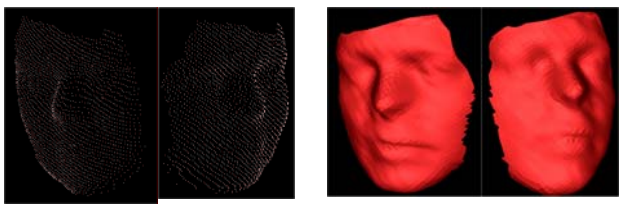
- To use the learning ability of a 'Point Distribution Model' (PDM) to recognize human faces
- Dataset: point cloud data of 30 persons; 3 sets of data for each.



Data on the Base Mesh

4) Base Mesh and Dense Correspondences

1) Points on the base mesh that are present in all faces:



PDM

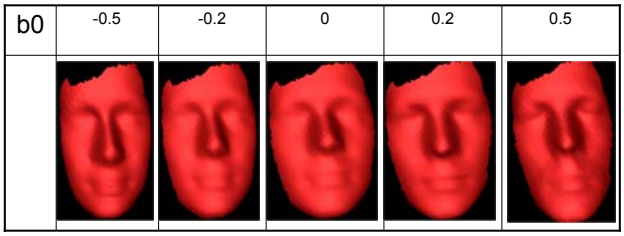
4) Point Distribution Model

- It is time to apply PCA to 2324x3 landmarks points.
- 9 dimensions explain %99.5 of the variation of the data.
- With $x_{new} = \bar{x} + \phi W b$

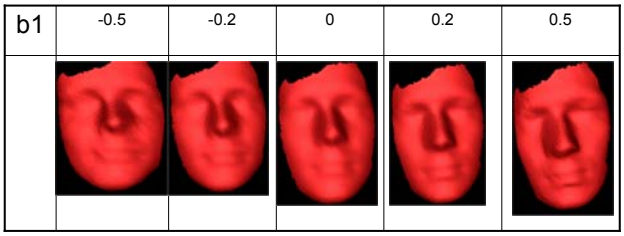
Where Φ : Eigenvectors matrix
W : Diagonal eigenvalues matrix
b : Independent shape coefficients vector.

We can generate new faces.

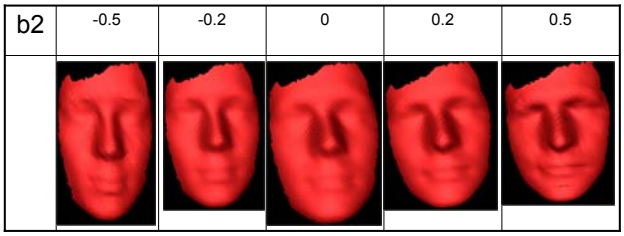
Effect of Parameters in a PDM



Effect of Parameters in a PDM



Effect of Parameters in a PDM

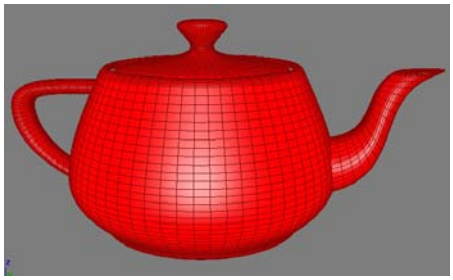


Example 2: Computer Graphics

- Use interpolation and curve fitting to model objects

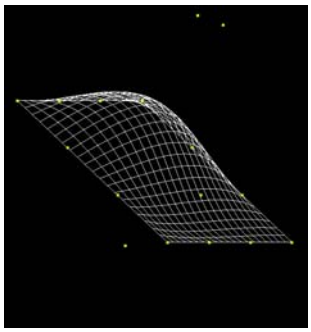
Modeling: Design of an artificial object

- How do you model an object like this?

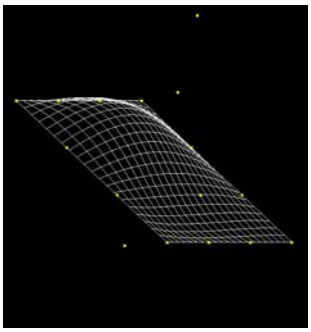


Modeling: Parametric polynomial curves

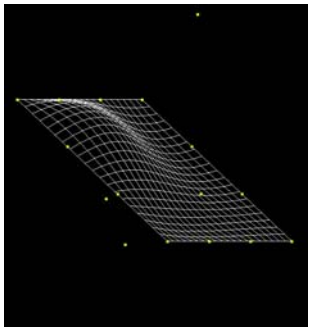
Parametric polynomial curves in 2D



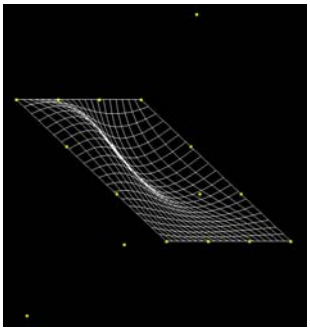
Parametric polynomial curves in 2D



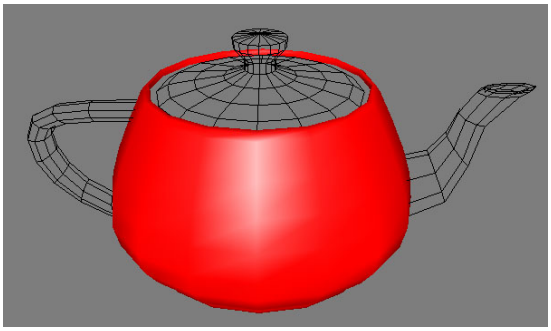
Parametric polynomial curves in 2D



Parametric polynomial curves in 2D



Utah teapot



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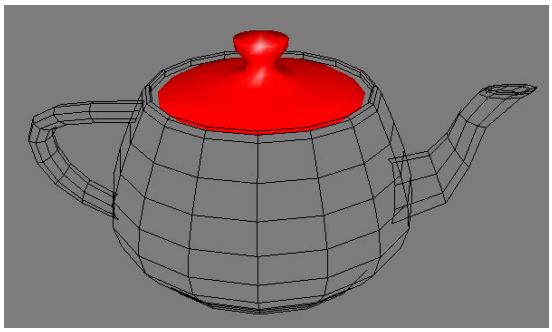

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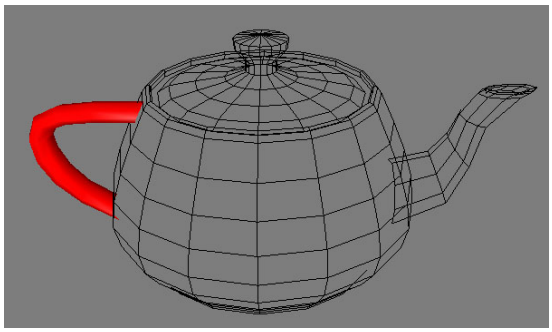

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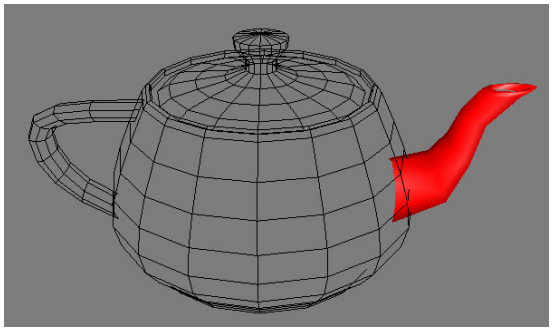
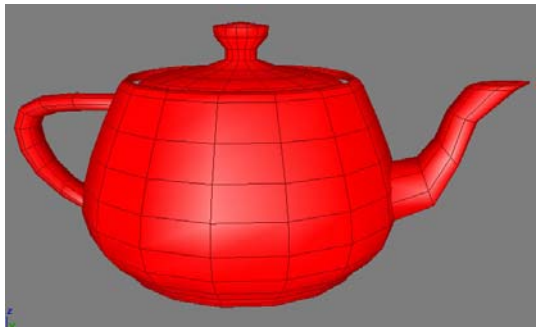
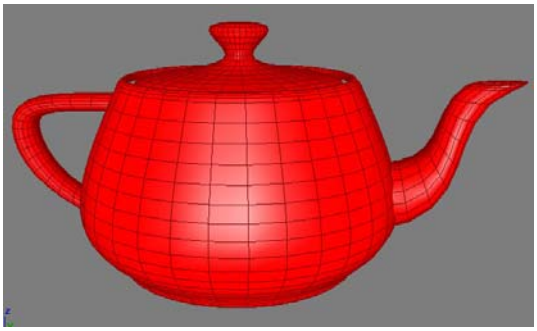


Effect of delta



Effect of delta



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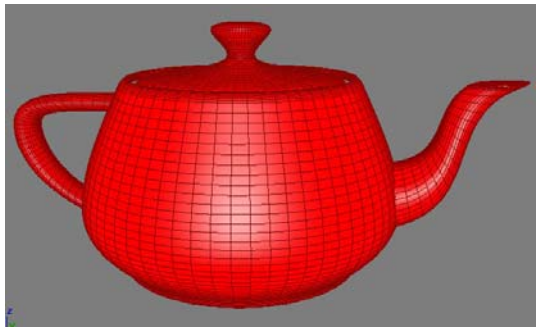

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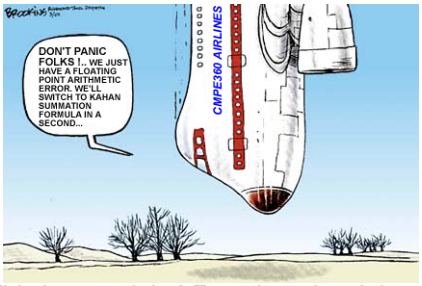
Flaoting point numbers and approximation errors



- This is not a joke! French rocket Ariane 5, Challanger and many others self destructed because of this!