Written examination in

PPU080 – Advanced Computer Aided Design

Date: 2022-10-27, 8.30 – 12:30

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Solution to the exam: On the course home page the day after the exam.
Preliminary results: On the course home page before 2022-11-21

Inspection of your exam result (at Lars Lindkvists office):

- 2022-11-24, 12.00-13.00
- 2022-11-25, 12.00-13.00

Aids

None.

The examination contains 5 tasks, each worth 10 points.
Grades:

< 20 points: Fail
20-29 points: Grade 3
30-39 points: Grade 4
40-50 points: Grade 5

Do not treat more than one task on each page.

1. Geometry modeling

a) Describe the following three types of solid models, mention some advantages or disadvantages for each (6p)
   - Decomposition models
   - Constructive models
   - Boundary representation

b) What are *Half spaces* and how can they be used to create geometric primitives? (4p)

Answers

a)

Decomposition models:

- Can be made of:
  - Voxels: the solid is composed of a number of cubes
  - Cell based: the solid is built up by polygons
- It is an approximate model and requires a lot of memory for high precision.
- It is suitable for different types of calculations

Constructive models:

- Solid models are created by manipulating primitives with Boolean operators.
- It is hard to handle general surfaces
- It is very compact (do not require a lot of memory)

Boundary representation:

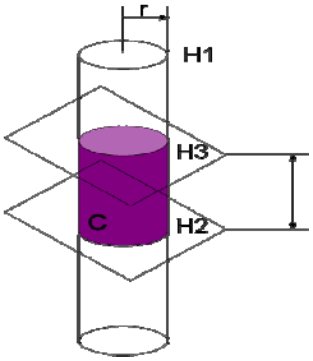
- The solid is defined with points, curves and surfaces plus a definition of what is inside the model
- Uses graphical methods e.g. sweep and rotate
- Can use parametric surfaces
- Can use Boolean methods

b)

Real, analytical functions f(x, y, z) defined in 3D which splits the space in two half spaces:

- one half space where f(x, y, z) < 0
- one half space where f(x, y, z) > 0
- Example: Cylindrical half space $x^2 + y^2 - r^2 < 0$

Solid primitives are created by combining half spaces with Boolean operators



Construction of the cylinder C

H_1 : $x^2 + y^2 - r^2 < 0$

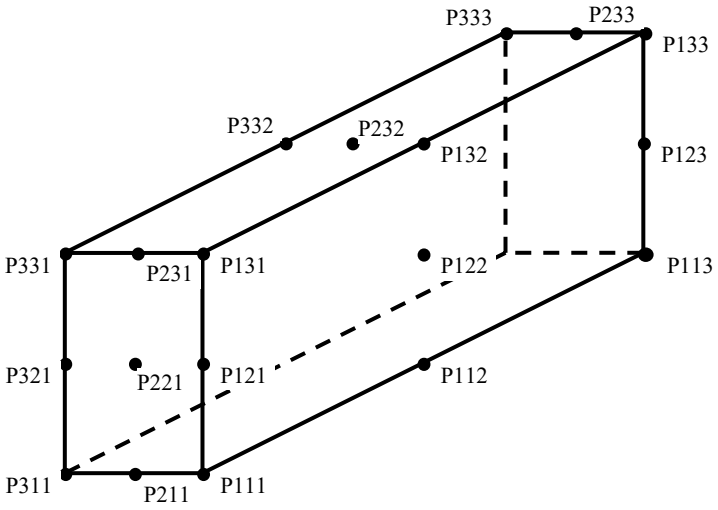
H_2: $z > 0$

H_3 : $z - h < 0$

$C =$ $H_1 \cap H_2 \cap H_3$

2. Geometry assurance

a) Describe how a 3-2-1 locating scheme works (4p)
b) Define a 3-2-1 locating scheme for the box in the figure (6p)
   - Use the points in the figure (P111-P333, located on the three visible surfaces)
   - Try to make it as robust as possible
   - For 6 points you have to **motivate** your selection of points



Answers

a)

- Six DOF are locked by six points
- Primary points A1, A2 and A3 defines a plane and locks the geometry in space in two rotations and one translation: TZ, RX, RY
- Secondary points, B1 and B2, defines a line and locks the geometry in space in one rotation and one translation: TY, RZ
- Tetriary point C1 locks the geometry in space in one translation: TX

b)

A number of different solutions with almost the same robustness exist. This is one solution.

- Primary points A1, A2 and A3:
  - Points: P131, P133 and P112
  - This maximizes the area of the triangle defined by the points
  - Also e.g. P131, P133 and P113 would give the same area but in that case the corner P111 will be less robust
- Secondary points B1 and B2
  - Points P231 and P233
  - This maximizes the length of the line defined by the two points
  - (Also other selections gives the same length but this is the optimal one)
- Tertiary point C1
  - Point P221
  - (Any point on the same surface is OK but this is the optimal one)

3. Computer graphics and virtual reality

a) Describe how the Z-buffer algorithm for depth sorting of objects drawn on a computer screen works. (4p)
b) Gouraud and Phong are two methods for rendering over multiple polygon surfaces. Describe how they work. (4p)
c) Describe how *Parallel* and *Perspective* Projections are calculated. What is the visible difference (on screen) between the two projections? (2p)

Answers

a)

- Initiate video memory and a Z-buffer for each pixel on the screen
- $depth[x, y] = \infty, \qquad refresh[x, y] = I_{background}$
- Polygons are rendered in an arbitrary sequence
- For each pixel: check if the z-coordinate of the current polygon is less than the stored one (use the plane equation for the polygon)

  $Ax + By + Cz + D = 0\,,\ z_{x,y} = \dfrac{-(Ax + By + D)}{C}$
- In that case the video memory is updated for the pixel

  $z_{x,y} < depth[x, y] \Rightarrow depth[x, y] = z_{x,y}, \quad refresh[x, y] = I_{surf}$
- When all polygons are checked the screen is updated with the color closest to the observer

b)

Gourad:

- Calculate normal vector for all polygon surfaces
- Calculate ”mean normal vectors” for the vertices of the polygon
- Mean normal + Illumination model => calculation of intensities (colors) in the vertices
- Intensity values are interpolated line by line over the polygon

Phong:

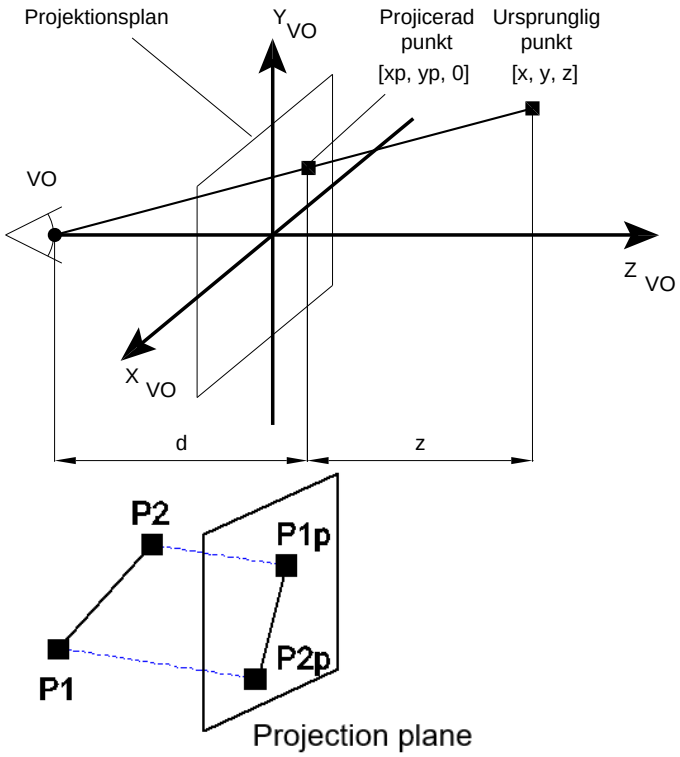
- Calculate normal vector for all polygon surfaces
- Calculate ”mean normal vectors” for the vertices of the polygon
- Surface normals are interpolated line by line over the polygon
- Surface normal + Illumination model => calculation of intensities (colors) in each pixel

c)

Perspective Projection

- Project point on the projection plane with similar triangles
- $\dfrac{x_p}{d} = \dfrac{x}{z + d}$
- $x_p = \dfrac{dx}{z + d}$
- $y_p = \dfrac{dy}{z + d}$

Object further away appears smaller



Parallel Projection

Simply set z=0;
Objects have the same size independent on the distance to the observer

4. Use of geometry data

a) Geometry models, created in a CAD-system, are used by a number of different functions (departments etc.) within the product development process. Describe some problems related to this. (2p)
b) Mention three benefits of using virtual product models in the product realization process (3p)
c) Mention two advantages of using off-line programming. (2p)
d) What is a digital mockup (DMU) and for what is it used? (2p)
e) What type of geometry representation is usually used in a digital mockup (DMU)? (1p)

Answers

a)

- Different functions use different software requiring different file formats: problem with file conversion
- Problem with access to the right models

b)

- Minimizing the need for costly physical prototypes
- Finding problems as early as possible in the development process (easier and cheaper to fix)
- Faster development process with efficient tools (time to market)

c)

- Avoid costly mistakes with real machines
- Faster and more efficient programming
- Possibility to make new programs without stopping the production

d)

- A special type of component based assembly model developed to be able handle large assemblies (> 1000 parts) from different CAD-systems
- Can be used for e.g. packaging studies and assembly simulation but not for e.g. calculation of mass etc.

e)

Triangulated surfaces

5. Miscellaneous

a) Curves used in geometry modeling can be of different order. What are the advantages and disadvantages of higher order curves? (2p)
b) What characterizes a geometrically robust assembly concept? (2p)
c) *Describe* four different aspects that has to be considered when designing for injection molding. (6p)

Answers

a)

- Advantage: increased precision
- Disadvantages: risk for corrupt curves, increased calculation time

b)

A geometrically robust design is a design that allows manufacturing and assembly variation without jeopardizing function or aesthetics.

c)

For example:

- Assign proper draft angles, rule of thumb: 1 deg. per inch cavity depth
- Wall thickness should be uniform, e.g. coring out could be used to avoid thick walls
- Compensate for shrinkage
- Locate parting line, ejector pins and gate appropriately
- Avoid sharp corners and small corner radiuses, gives stress concentration and hinders a streamlined flow for the molten plastics