Written examination in

PPU080 – Advanced Computer Aided Design

Date: 2012-10-25, 14:00 – 18:00

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Department: Product and Production Development

Solution to the exam: On the course home page the day after the exam.
Preliminary results: On the course home page before 2012-11-13

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

- 2012-11-14, 12.00-13.00
- 2012-11-15, 12.00-13.00

Aids

A Chalmers-approved calculator is permitted.

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) Mention three different aspects that have to be included in an assembly model (in e.g. a CAD system). (3p)
b) Mention two advantages of using solid models instead of e.g. surface models. (2p)
c) Describe how solid models are created with CSG (Constructive Solid Geometry). (2p)
d) In CSG the concept of half spaces is used. Describe/exemplify how they work and how they are used to define geometry. (3p)

Answers

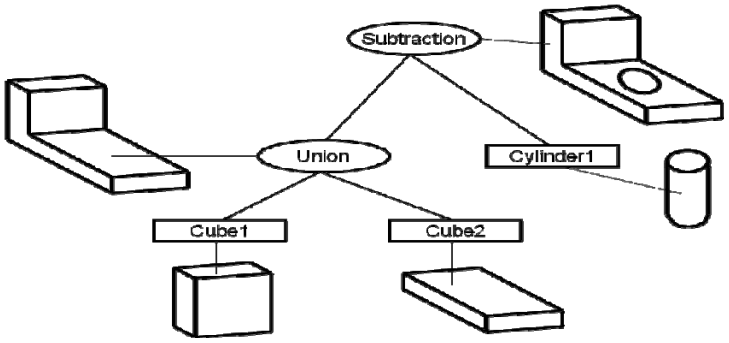
a)
An assembly model needs to include

- Hierarchical relations
  - assembly -> sub-assembly -> part
- Mating conditions
  - geometrical restrictions, etc
- Mechanical degrees of freedom

b)

- Solid models support higher levels of functionality and automation than surface models
  - Example: Calculation of mass and moments of inertia
- Solid models allow the designer to work with higher level objects rather than points, curves and surfaces

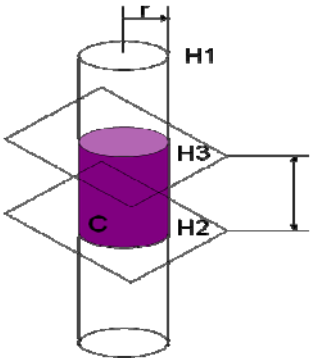
c)
Solid models are created by manipulating "primitives" with Boolean operators (union, sections, subtraction)



d)
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: $z > 0$

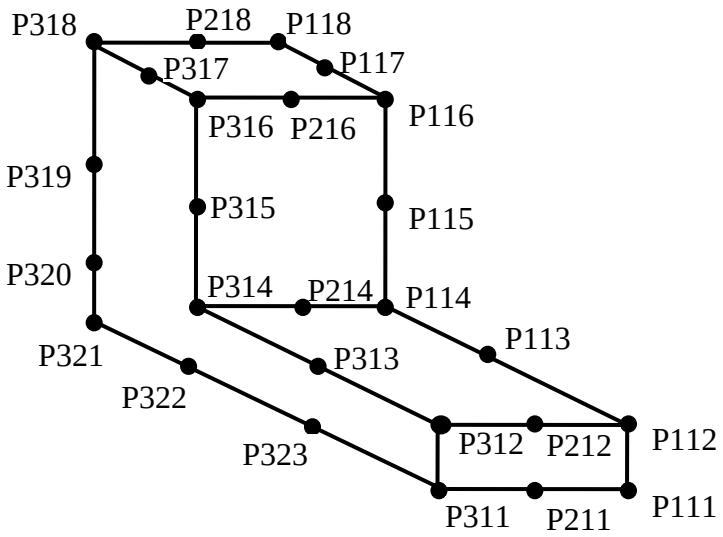
H_3: $z - h < 0$

$C = H_1 \cap H_2 \cap H_3$

2. Geometry assurance

a) How does Monte Carlo variation simulation work? (4p)

b) Define a 3-2-1 locating scheme for the part in the figure. (6p)
   - Use the points in the figure (P111-P323, located on the visible surfaces)
   - Try to make it as robust as possible
   - Motivate your selection of points



Answers

a)

Model consist of:

- 3D assembly model with defined locating schemes
- Input tolerances with range and type of distribution
- Critical measures

Simulation:

- Randomly assign one value for each input within its defined tolerance
- Assemble the model according to the defined locating schemes
- Calculate the critical measures and store the result for each iteration
- Repeat this at least 1000 times
- Calculate the distribution of the critical measures

b)

Select P311, P321 and P318 as A1, A2 and A3 defining the plane. This will maximize the area of the triangle which makes it robust.

Select P311 and P321 as B1 and B2 defining a line. This gives a long line which makes it robust.

The selection of C1 does not have a large influence on the robustness we can, e.g., select P321 which might make it easier to make a fixture.

Many other solutions could be correct, some even more robust (but with other disadvantages). In order to get 6 points the choices should be motivated in a correct way.

3. Computer graphics and virtual reality

a) Light from a point light source can be reflected in two ways from a surface in a computer model, diffuse and specular. Describe the difference between diffuse and specular reflection. (2p)
b) Gouraud and Phong are two different methods to obtain smooth shading of triangulated surfaces. Why is Gouraud called vertex shading and Phong pixel shading? (2p)
c) Describe three different visualization systems for VR. Mention advantages and disadvantages with the different systems. (6p)

Answers

a)
Diffuse:
Light hitting the surface is spread equally in all directions => Placement of the light source influences but not the placement of the observer.
Specular:
The appearance of smooth, polished, surfaces is dependent of both the placement of the light source and the position of the observer, i.e. the light is reflected mostly in one direction.
b)
Gouraud:
The color of a triangle is calculated at each vertex (corner) with the normal at that corner. The color is then interpolated over the surface of the triangle.
Phong: The normal at the vertices (corners) are interpolated over the surface of the triangle and the color is calculated for each pixel.
c)
Desktop (”Fishtank”) VR

- PC (+tracker) (+glove) (+stereo glasses)
- Advantages
  - High display resolution (1600x1200)
  - Cheap
  - Simple to use
- Disadvantages
  - Narrow field of view (FOV)
  - Low degree of immersion
  - Not the natural scale (for e.g. cars)

Helmet (HMD)

- Function
  - Some sort of helmet or glasses with one display for each eye
- Advantages
  - Wider FOV
  - Stereo viewing
  - High degree of immersion
  - Relatively cheap
  - Simple to install
- Disadvantages
  - Helmet weight 1 - 4 kg
  - Isolation from the world
  - Only one user
  - Relatively low screen resolution

Powerwall (Large Volume Display)

- Function
  - Two or more projectors working together
  - Special software to coordinate the picture
- Advantages
  - Wide FOV
  - Natural size (cars)
  - Stereo display (with shutter or polarized glasses)
  - High resolution (3200x1024)
- Disadvantages
  - Not so high degree of immersion
  - Advanced computers
  - Advanced technology to obtain invisible edges between projectors
  - Expensive

4. Miscellaneous

a) Describe how the Z-buffer algorithm for depth sorting of object drawn on a computer screen works. (4p)
b) Mention three benefits of using virtual product models in the product realization process. (3p)
c) Mention three reasons for the increased industrial need for IT support for product development. (3p)

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

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

b)

- 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)

- Shorter lead-times and product lifecycles
- Increased complexity: variants, functions, components etc.
- Collaborative product development

5. PLM/PDM

a) PLM and PDM are two acronyms used in relation to the product realization process. What do they stand for? (2p)
b) Describe what PLM and PDM systems are and how they relate to each other. (4p)
c) How can PLM systems support an Engineering Change Management process? (4p)

Answers

a)

- Product Lifecycle Management
- Product Data Management

b)

A PDM system manages all information needed to manage the product definition during its lifecycle. It is not only a database but also a toolbox for rationalizing engineering work.
A PLM system aims to support the **creation** and management of all information related to a product throughout its lifecycle. That means that it includes a PDM system for data management bur also tools to create data, e.g. a CAD, simulation software, etc.

c)

Automation, e.g.:

- Workflow functions automate information transfer
- Standard templates for change documents
- Parameterized CAD/CAM/CAE models

Monitoring, e.g.:

- Follow-up of engineering changes status
- Overview of all engineering changes

Information access & retrieval, e.g.:

- All have access to engineering changes in PDM database
- All info and doc’s related to an engineering change is connected

Quality assurance, e.g.:

- Only authorized individuals may promote change requests
- Control of versions, status and effectivity

Review, e.g.:

- Check change history, rollback possible