Written examination in

PPU080 – Advanced Computer Aided Design

Date: 2016-10-29, 8.30 – 12:30

Teacher: Lars Lindkvist
Questions: Lars Lindkvist, phone 7728616
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 2016-11-19

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

- 2016-11-23, 12.00-13.00
- 2016-11-25, 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

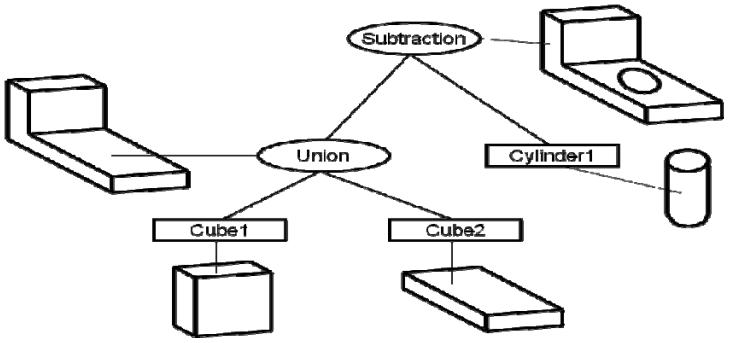
a)
An assembly model needs to include

- 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

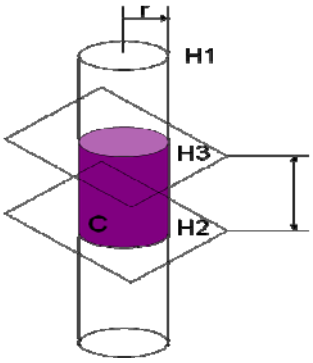
c)
Solid models are created by manipulating "primitives" with Boolean operators (union, sections, subtraction)



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: $z > 0$

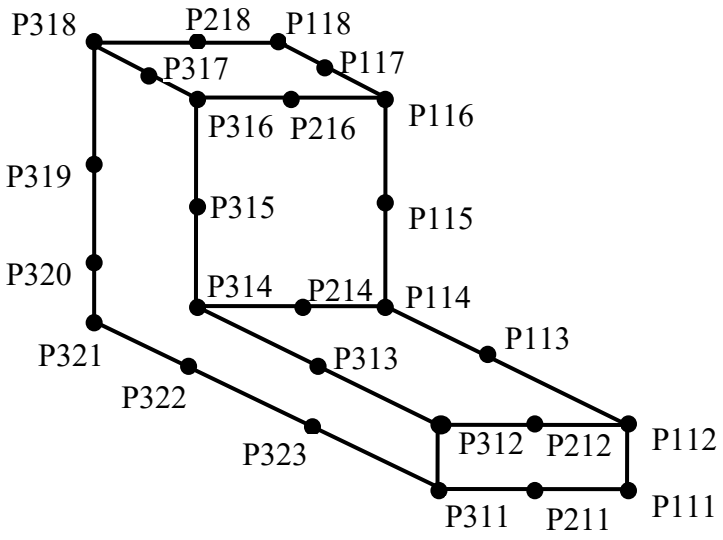
H_3: $z - h < 0$

$C = H_1 \cap H_2 \cap H_3$

2. Geometry assurance

a) How does *stability analysis* work and for what is it used? (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
   - For 6 points you have to **motivate** your selection of points



Answers

a)
Simulation:
- Each locating point is disturbed with a unit disturbance
- The amplification to the output, color-coding, part position or critical product dimension, is calculated
- The amplification for each individual locating point is summarized with RSS to give a value for the locating scheme

It is used to identify sensitive areas and sensitivity factors and guides optimization of locator position

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) Describe (with text, figures and equations) the four steps for collision detection between two objects defined by triangle surfaces (6p)

c) 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)

Answers

a)

Diffuse:

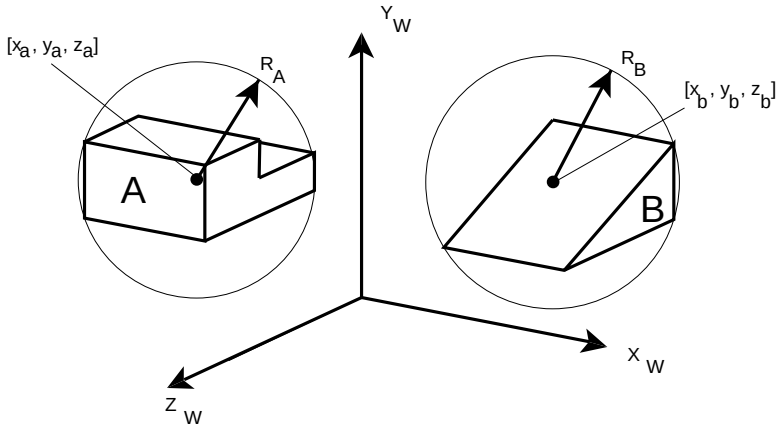
Light hitting the surface is spread equally in all directions => Placement of the light source influences but not the placement of the observer.

Specular:

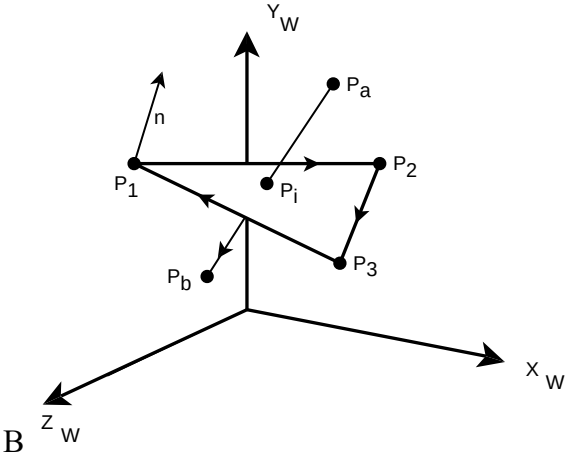
The appearance of smooth, polished, surfaces is dependent of both the placement of the light source and the position of the observer, i.e. the light is reflected mostly in one direction.

b)

- Do a (fast) coarse ”Mini-max-test” with Bounding Boxes/Spheres to determine if a collision might be possible at all



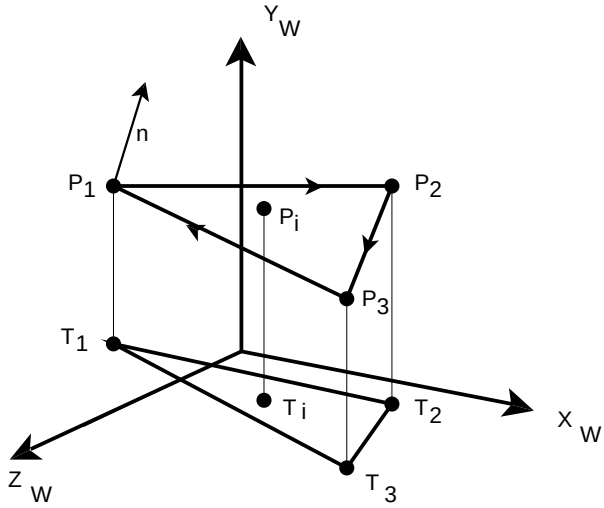
- If yes, check if any of the points on body A is inside body

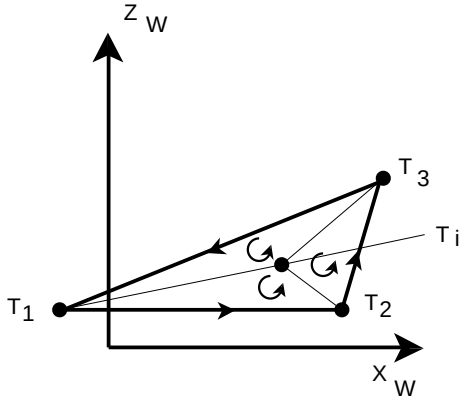


  - Test if any of the edges on body A intersects an infinite plane defined by some of the polygons on body B:

- Test if the endpoints of the edge are on different sides of the plane. This is done by using the equation of the plane

- If yes, calculate the intersection point between the edge and the plane:
  - Use the equation for the line between the points and the equation of the plane.
- Check if the intersection point is on the polygon:





- Calculate the area of the three sub triangles defined by the intersection point and the original vertices of the triangle.
- If all these areas have the same sign, the intersection point is inside the triangle and it is a collision.
- To speed up the calculation this can be done in 2D by projecting the triangle on a plane.

c)
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.

4. Miscellaneous

a) Mention the five basic needs of engineering information management. (5p)
b) Mention three reasons for the increased industrial need for IT support for product development. (3p)
c) What are homogenous coordinates and why are they used in computer graphics? (2p)

Answers

a)

- Capture information at the source
- Organize information
- Distribute information
- Search and re-use information (by others)
- Secure storage of information over time

b)

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

c)

Homogenous coordinates are created by adding an extra coordinate, w, to the Cartesian coordinates: $P_{cartes}[x\ y\ z] \rightarrow P_{homogen}[x\ y\ z\ w]$ normally (in computer graphics) w = 1.

They are used in order to simplify the calculation of transformations. With homogenous coordinates all transformations can be calculated as the same matrix multiplication which can be optimized for speed in the graphics processor.

5. Virtual Geometry Assurance

a) What is virtual geometry assurance? (2p)
b) What are the benefits of using it (4p)?
c) Describe how it can be used in some task in the geometry development process. (4p)

Answers

a)

- Using computer tools to perform geometry assurance tasks on virtual product 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)
- Increased quality

c)

- Analyze different assembly concepts
- Analyze and define robust locating systems
- Simulate and verify the final demands
- Virtual matching for trimming the production process