Written examination in

PPU080 – Advanced Computer Aided Design

Date: 2021-10-28, 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 2020-11-22

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

- 2021-11-25, 12.00-13.00
- 2021-11-26, 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.

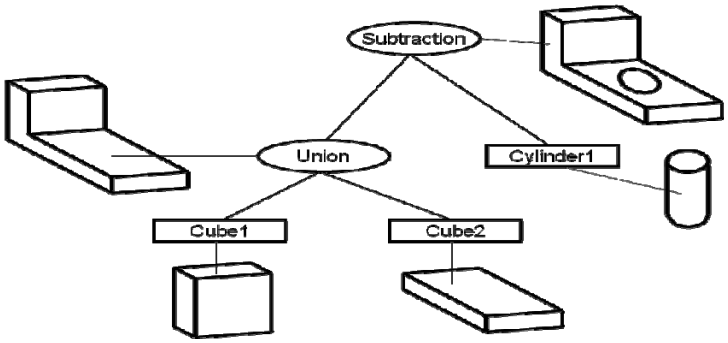
1. Geometry modeling

a) Describe how solid models are created with CSG (Constructive Solid Geometry). (2p)
b) In CSG the concept of half spaces is used. Describe/exemplify how they work and how they are used to define geometry. (3p)
c) Bézier curves are defined by the following equation: $\underline{p}(u) = \sum_{i=0}^{n} \underline{p}_i B_{i,n}(u)$

Describe the different components of the formula and what they are used for. (4p)
d) NURBS is the most commonly used type of curves in modern CAD systems. What geometrical forms can be represented with NURBS but not with Bézier or B-splines? (1p)

Answers

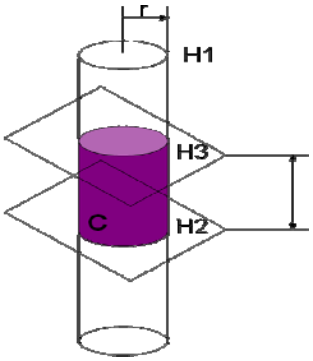
a)
Solid models are created by manipulating "primitives" with Boolean operators (union, sections, subtraction)



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 : $z - h < 0$

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

c)

- Pi: control points, defines the curve
- Bin: weight functions, defines how the different control points affect the curve
- n: Order of the curve
- n+1: number of control points
- u independent variable $0 \le u \le 1$

d)
Bézier and B-splines cannot represent conical and circular forms exactly

2. Geometry assurance

Variation analysis (with Monte Carlo simulation), Contribution analysis and Stability analysis are three different types of analyses used in CAT (Computer Aided Tolerancing) software. Describe how these methods work and what they are used for.

Answers

Variation analysis (with MC)

- Calculates a statistical prediction of the variation in critical measures
- Statistical method – random data
- Tolerances on parts (inputs) are randomly generated within defined distributions, tolerances and Cp
- Distributions for critical measures (outputs) are generated from thousands of iterations
- All kinematical relations and sensitivities are captured in a 3D assembly model

Contribution analysis

- Calculates a ranked list of how all input tolerances contributes to the variation in the critical measures
- All input parameters are varied (one at the time) within their tolerances on 3 levels
- Max output is registered
- Contribution is calculated in percent as $\%\ contribution_i = 100\frac{\Delta output_i^2}{\sum_{i=1}^{n}\Delta output^2}$

Stability analysis

- Can be used to analyze the influence of each part locating scheme on
  - Variation amplification, color-coding
  - Position stability of parts
  - Critical product dimensions (Measures)
- It is done by disturbing each locating point with a unit disturbance
- And summarizing their contribution with RSS
- Is often used to evaluate different positioning systems

3. Computer graphics and virtual reality

a) Describe three different visualization systems for VR. Mention advantages and disadvantages with the different systems. (6p)
b) 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)
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)
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

b)
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.

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. Use of geometry data

a) Give two examples of usage of ergonomic simulation with computer manikins. (2p)
b) What are the tree types of modeling components in a multi-body system dynamic simulation? (3p)
c) Mention two different usages of geometry models within production (2p)
d) Mention three benefits of using virtual product models in the product realization process (3p)

Answers

a)

- Evaluation of user interfaces
- Evaluation of concepts for manual assembly

b)

- Rigid bodies
- Constraints (joints, motions)
- Forces (gravity, spring/dampers, friction etc.)

c)

- Ergonomic simulation
- Off-line programming of industrial robots
- Off-line programming of NC-machines
- Off-line programming of CMMs

d)

- 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)

5. Miscellaneous

a) Describe the concepts of *Component based* and *Feature based* assembly modeling (2p)
b) What characterizes a feature (in the geometry modeling context)? (3p)
c) Mention three reasons for the increased industrial need for IT support for product development (3p)
d) Mention two reasons why it is important for the designer to have knowledge about the manufacturing process. (2p)

Answers

a)
Component based assembly modeling:

- The position of the part in the assembly is determined by specifying its position and orientation in global or relative coordinates

Feature based assembly modeling:

- Associates form features on different parts
- handles restrictions on form, position, orientation etc between mating form features

b)

- A feature
  - is a physical part of a detail
  - can be linked to a generic form
  - has a specific engineering role (function, manufacturing method, simulation method, …)
  - has predictable properties

c)

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

d)
Applying guidelines for manufacturing already at the design stage leads to:

- Reduced manufacturing cost
- Shortened lad time