Written examination in

PPU080 – Advanced Computer Aided Design

Date: 2017-10-27, 14.00 – 18:00

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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 2017-11-17

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

- 2017-11-20, 12.00-13.00
- 2017-11-22, 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) Describe the steps necessary to create a solid, using surface modeling, in a modern CAD system. (5p)

b) 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)

c) 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)

- Create wireframe elements (points, lines, planes, curves) in 3D or sketches
- Create oversized surfaces from the wireframe geometries (sweep, revolve, ...)
- Trim the surfaces together
- Join the surfaces together to a uniform element
- Transform into a solid (Thick, Closed Surface, ...)
- (Add fillets)

b)

- 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

c)

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)

- Statistical method – random data
- Tolerances on parts (inputs) are randomly generated within defined distributions, tolerances and Cp
- All kinematical relations and sensitivities are captured in a 3D assembly model
- The system is assembled
- The result for the critical measures are calculated and stored
- Distributions for critical measures (outputs) are generated from thousands of iterations

Is used to calculate a statistical prediction of the variation in critical measures

Contribution analysis

- All input parameters are varied (one at the time) within their tolerances on 3 levels
- All kinematical relations and sensitivities are captured in a 3D assembly model
- The system is assembled
- Max output is registered for all measures
- Contribution is calculated in percent as $\% \, contribution_i = 100 \frac{\Delta output_i^2}{\sum_{i=1}^{n} \Delta output^2}$

It is used to calculate a ranked list of how all input tolerances contributes to the variation in the critical measures

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, one at a time
- All kinematical relations and sensitivities are captured in a 3D assembly model
- The system is assembled
- The output is calculated and their contribution is summarized 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) Describe how the Z-buffer algorithm for depth sorting of objects drawn on a computer screen works. (4p)

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)

- 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

4. Use of geometry data

a) Give two examples of usage of ergonomic simulation with computer manikins. (2p)
b) 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)
c) Mention three reasons for the increased industrial need for IT support for product development (3p)
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)

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

c)

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

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) What are the industrial benefits of using parameterization to reuse engineering knowledge? (2p)
b) The Method of Influence Coefficients can be used to perform Monte Carlo variation simulations on non-rigid parts. How does it work? (4p)
c) Describe what PLM and PDM systems are and how they relate to each other. (4p)

Answers

a)
Shorter time – means more iterations, i.e. more design solutions can be evaluated.
More iterations means better products because:

- Larger amount of designs considered and evaluated in concept phase
- Knowledge related to lifecycle aspects (design for: assembly, manufacturing, serviceability, environment…) can be integrated in detail design phase
- Synthesis – analysis loops can be shortened – verification feedback instant

b)

- When doing a Monte Carlo variation simulation more than 1000 iterations have to be done
- To do this with traditional FE methods would take too long time
- Therefore, a FE solver is used to create a linearized model of the assembly
- The linearized model is then used in the simulations
- This gives a very large reduction of the simulation time (~ a factor 1000)
- If the locators or support points are moved, a new linearization has to be done

c)
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.