Computer Science for Engineers

Lecture 2

Introduction

Prof. Dr. Dr.-Ing. Jivka Ovtcharova
Dipl. Wi.-Ing. Dan Gutu
31st of October 2008
1. Introduction

1.1. Preface

1.1.1 Objectives and Literature
1.1.2 Historical Development
1.1.3 What is Computer Science?
1.1.4 Introduction to Computer Science

1.2. Engineering applications

1.2.1 Application of Comp. Sci. in Engineering
1.2.2 Application of Comp. Sci in IMI
1.2.3 Product Lifecycle Management (PLM)
1.2.4 Computer Aided Design (CAD)
1.2.5 Computer Aided Engineering (CAE)
Construction Office at the Beginning of the 20th Century: Construction on „Paper“

Source: Prof. Eigner, VPE 1
Product Development at the Beginning of the 21st Century: Construction in 3D - CAD

1. Introduction

1.2 Eng. Appl. / 1.2.1 Application of Computer Science in Engineering

Source: BMW AG
1. Introduction

1.2. Application in Engineering

Integrated Product Development
Automated Manufacturing Systems
Conveyor Systems
Material and Process Simulation
Information Management in Engineering
Mechatronics
Robotics

1.1. Prof. Dr. Dr.-Ing. Jivka Ovtcharova – CSE - Lecture – Ch. 1 - WS 08/09 - Slide 5
1. Introduction

1.2. Eng. Appl. / 1.2.1. Application of Computer Science in Engineering

**Application of Computer Science in Engineering (2)**

- **Representation**
- **Team**
- **Knowledge**
- **Application**
Simulation

- Model Parameters
- Test Definitions
- Controller Data

Verification from calculations and measurements
- Model parameters identified
- Model improvement

1.2. Application

Prof. Dr. Dr.-Ing. Jivka Ovtcharova – CSE - Lecture – Ch. 1 - WS 08/09 - Slide 8
**Aim:**
Simulation of the thermal behaviour of components in the machining process for the optimisation of machine parameters, working sequence and improving production processes for cost minimisation.

**Motivation:**
- Complex components exhibit a high number of nodes.
- Complex components require a lot of different process steps.
- Heavy simplification of components and processes are needed to make simulation possible.

**Application of high performance computers:**
- Simulation of complete components
- High degree of detail in each process
- Reduce computing time
- No memory overflow

*Source: wbk*
Traffic Noise Reduction:

Tires / Road Noise Simulation

Modelling of tires/lane changing taking in to account age and road surface texture, drive and brake torque, friction and air displacement.

Source: Continental
Application of Computer Science in IMI

1. Introduction

1.2. Eng. Appl. / 1.2.2. Application of Computer Science in IMI

- 3 Research Areas
  - Lifecycle Engineering
  - Collaborative Engineering
  - Virtual Engineering

- Application of key Virtual Reality (VR) technology

- Layout the Lifecycle Engineering Solutions Center (LESC)
Lifecycle Engineering: Product Lifecycle Management (PLM)

- MANUFACTURING
  - PLANNING
  - CAD / CAM
- CONSTRUCTION
  - CAD / CAE
- PRODUCTION
  - ERP / PIM
  - PRODUCTION
- SALES
  - CIS
- UTILISATION
  - CIS
- DEVELOPMENT
- SALES AND UTILISATION
- SERVICE & MAINTENANCE

Legende:
- CAS Computer-Aided Styling
- CAD Computer-Aided Design
- CAE Computer-Aided Engineering
- CAM Computer-Aided Manufacturing
- VIS Visualization
- PLM Product Lifecycle Management
- PIM Production Information Management
- CIS Customer Information System
- ERP Enterprise Resource Planning
- MIS Marketing Information System
Lifecycle Engineering - Vision

- Requirements
- Specification
- „Design-in-Context“
- Prototype-reference configuration
- Integrated virtual validation
- Customer presentation
- Product optimisation

Product Lifecycle

- Development
- Testing
- Manufacturing
- Sales
- Usage
- Maintenance
- Recycling

Customer

- Customer requests
- Customer relationship
- Customer feedback

Organisation

- Project organisation
- Line organisation
- Supplier
- Distributor
- Workshop

Process

- Customer presentation
- Product optimisation

Information

- Information Management in IMI

Prof. Dr. Dr.-Ing. Jivka Ovtcharova – CSE - Lecture – Ch. 1 - WS 08/09 - Slide 13
Using modern information and telecommunications technologies it is possible for several participants world-wide to participate in conferences.

**Aim:**
- No physical boundaries
- Not bound to time
- Easily and economically organisable
- Automatic saving of the meeting
- "free" team composition
- Accelerated problem solution
- Provide sketches within a discussion
- Share written or electronic documents

**Example:**
Digital Video Camera
Virtual Engineering: Virtual Vehicle

Complete, computer-based and integrated modelling of a vehicle throughout the entire product life cycle, from the specification to service and recycling. The virtual vehicle allows a "purely virtual" handling of the future vehicle for the developers, suppliers, manufacturers and clients alike, so that they are all able to judge it from the point of all its qualities and functions.
Virtual Engineering: Vision

“Build the product right the first time!“

Virtual Product

- Context-Orientated Design
- Prototype-Oriented Configuration
- „High-end“ Visualisation
- Validation
- Feedback und Optimisation

Team Collaboration

- CAx
- PLM
- VR/AR
- Web-Portale
- Telecommunications Services

Information and Communication Technologies

Know-how

Engineering Network

- Iterative Workflows
- „Workflow“ & „Workload“ Management
- Quality Gates
- Deliverables & Progress Management

Product life cycle

Product Development Process

Prof. Dr. Dr.-Ing. Jivka Ovtcharova – CSE - Lecture– Ch. 1 - WS 08/09 - Slide 16
Crash Simulation

Ergonomy Test

Assembly

Quelle: Adam Opel AG
Interactive Virtual Living Lab
Stationary widescreen projection for high-definition immersive visualisation

Collaboration Room
• Integration of different groups
  (End users and cluster users)
• Flexible access to the projection facilities

Mixed Reality Labor
• Mobile projections
• Haptic input/output

LESC Front End
Pool
- Product Lifecycle Management Labor
- Simulation laboratory
LESC opening ceremony on the 25th of June 2008
Qualification for new professions: science meets industry!

**Design Engineer**

**Virtual Mock-Up Engineer**

**Process Integration Manager**

**Multi-project Manager**

LESC Lifecycle Engineering Solutions Center
Tasks during the product development process

- **Development of new application fields** in the product development through the use of innovative technologies.
- Orientation towards **improvement of industrial processes** and **optimization of the entire product life cycle**.
- Extending existing local business procedures and infrastructures to allow continuous IT-supported business process.

Need for a **distributed solution** for the integration of
- Data
- Processes
- Resources

New management and organizational concept:

**Product Lifecycle Management (PLM)**!

*Source: Berliner Kreis, Technology Monitoring*
Aims

Engineering Improvement

Guarantee of a **constant, virtual and transparent information flow** within the **entire product life cycle**

- **Business processes**
  - Optimization of management and processes

- **Resources**
  - Optimal usage

- **Information**
  - Supply at the right place and the right time with quality and quantity which meet demands

**IT and Communication technologies**

Engineering covers not only the construction, but all process for product manufacturing (from the product idea to recycling).

This is achieved through control of business processes in the entire product life cycle and supply of information and resources at the right place and time, with quality and quantity which meet demands. Resources can be people, machines, technologies etc.

Using IT and communication technologies all engineering from a company can be improved

**Source:** Eigner, „Produktdatenmanagement-Systeme: ein Leitfaden für Product Development und Lifecycle Management“
Motivation

Product Lifecycle Phases and Tasks

Applications
Design
Simulation
Process Planning

Digital Mock-Up
Digital Factory

Working Status?
Compare
Archiv
Classification
Search
Request
Test
Change

Data Status?
Version
Status

IT Systems

CAD Data
CAE Data
CAM Data

CAD System
CAE System
CAM System

Prof. Dr. Dr.-Ing. Jivka Ovtcharova – CSE - Lecture– Ch. 1 - WS 08/09 - Slide 25
• **Product elaboration:**
  - Reduction of the “lead time“ (for example through simultaneous engineering)
  - Reduction of the product manufacturing costs (for example through lean production)
  - Spatial and organizational separation of development and production
  - Strengthened engineer's team work (for example virtual teams)

• **Business management:**
  - Use of new business organizations (e.g. cooperations)
  - Frontloading in the early stages of product development

• **Customer service:**
  - Strengthened feedback and use of customer information to optimize product development

• **Specifications und Regulations:**
  - New, aggravated laws and regulations (e.g. environmental ordinances, quality regulations like ISO 9000)
Basic functionality of PLM

**Product Lifecycle**
- Graphically intensive working methods, Viewing, Browser
- Illustration of product data structures
- Version-based administration system
- Illustration of life cycles
- Access administration
- Interaction with external systems (CAx)
- Data files and queries

**Web based user interface**

**Product data models**

**Administration functions**

**Data interfaces**
- CATIA
- ProE
- SAP
- AutoCAD
- Nastran

**Meta data**

**Product data**
Management of Access Rights

PLM Access

1. User

- Thomas Maier

User Access: tmaier
- assigned to the person Thomas Maier

2. User Group

- Project "Delta"
- Team Project team 1
- Designer
- Role User a

- Project team 2
- Technical Staff
- User x
- User b
- User y

User Access: tmaier assigned to
- Project “Delta”
- Team Project team 1
- Group Designer
- Role User a
Configuration example for a car

Source: Daimler AG
Different structures (views) on the same product are used, allowing a targeted approach on the different processes and tasks.

- **Construction view**: contains structural relations.
- **Assembly view**: Represents the assembly order.
• On the lowest PLM system level, the database, as well as the tools for the administration of files can be found. Usually a commercial database system runs on this level (e.g. SQL-Server or ORACLE).

• When designing a PLM system, a database concept must be chosen. This database concept establishes basic principles, according to which the data will be archived and correlation between them can be formed. There are various forms of databases, for example the
  - hierarchical database (HDBMS)
  - relational database (RDBMS)
  - Object oriented database (ODBMS)

• While hierarchical database systems are scarcely used, today most applications primarily implement the relational database concept.
CAD Basics

CAD stands for:

- **Computer Aided Drafting** – simple drawing preparation systems
- **Computer Aided Design** – efficient construction systems.

One understands that **CAD** is computer aid in development and construction and refers strictly to graphically intense production and manipulation of an object.
Construction on “paper”

View on the assembly axle driving shaft

Perspective representation of the assembly „axle driving shaft“
Assembly Modelling in 3D

- Assembly representation
- Explosion representation

Local coordinate systems
CAD systems can be fundamentally differentiated according to whether their model space is a 2D or 3D system.

2D CAD systems:

Component geometry is illustrated in a two dimensional co-ordinate system by one or two dimensional elements such as points, lines, curves and surfaces. Commonly used systems include:

- AutoCAD LT from Autodesk
3D CAD Systems:

The model of a construction unit / building group is illustrated using a three dimensional co-ordinate system and consists of one, two or three dimensional model elements such as points, lines, two and three dimensional curves, surfaces and solid primitives (cube, cylinder, ball, torus etc.).

Common 3D systems are:

- **Catia** from Dassault Systemes
- **UG NX (5)** from Siemens PLM
- **Pro/Engineer** from Parametric Technology Corporation
3D CAD systems allow the **production of solid models**, e.g. of construction units / building groups, and offer **extended modelling techniques** such as:

- Parametric design
- Feature based design.

**Modelling in 3D CAD requires a modified way of thinking and working for co-workers**

The solid model can be used in the next phases of the product development process e.g.:

- Programming manufacturing machines (CNC)
- Calculation und Simulation: e.g. finite element methods (FEM), multiple body systems (MBS)
- Assembly planning and Virtual Mock-Up (VMU).
2D and 3D approach

2D drawing

Manual conversion

Manufacturing

Computation

Prototype

3D model

Interfaces

CNC-Model
CNC-Program

Computation model
FEM-Model

Virtual Mock Up
VMU-Model
Product Informationen in the Product Model

**Product definition**
- i.e. over
- Reference: Valve housing
- Identification number: 1234509876
- Classification number: VE-0815-4711

**Product representation**
- i.e. as
  - CSG-Structure
  - B-Rep-Structure
  - Feature-Structure

**Product model**

**Product presentation**
- i.e. As an exploded representation, parts list or technical design

**Source:** DiK, TU Darmstadt
The Product Structure contains the outline of product geometry in module structures. As such, single modules are divided into assemblies and single parts.

On the figure above, the product structure of a robot arm is represented. At the highest level of the product structure, the product „robot arm“ is located. The single parts and a sub-assembly („Produkt3“) are located in the product structure.

The structuring of the product is done in compliance with the conditions between the parts and sub-assemblies.
Crash Simulation (1)

Crash-Test with a DMU

Source: Torsten Kuhlen „Virtuelle Realität in der Automobilindustrie“
Crash types:
- Frontal crash
- Side crash
- Rear-end collision
- Crash with a tree
- Protection from cargo
- Seat belt
- Pedestrian crash.

*Source: Adam Opel GmbH*
• **System & Software Engineering**
  - **Software Architecture**
    - SOA: Service Oriented Architecture (techn.) - approach for interlinking of engineering applications
    - Distributed applications – programs, that run on resources that are spatially distributed in different locations: servers in America, database in Europe
  
• **Software Engineering**
  - Development/Customizing of PLM systems
    - Ex. requirements modelling
    - Working in a interdisciplinary teams (Computer Scientists + Mechanical Engineers)
  - **Mechatronic**
    - Mechatronic = Mechanic + Electronic + Software
      - Development of mechatronic systems
• Data structures
  - Product structures –
    ▪ Representation of a product structure in software
  - Data exchange
    ▪ Data formats / structures for data exchange (ex. XML-based solutions)
  - Scene graphs (3D-visualisation)
    ▪ Treelike structures for representing a 3D scene in software.

• Algorithms Simulation
  ▪ Finite Elemente Method (FEM),
  ▪ Multibody Simulation
  ▪ Virtual factory: material flow,
  ▪ Kinematic Simulation (parts movement)

- Cryptography
  ▪ Information encryption for data exchange.
  Security aspects in product data exchange
<table>
<thead>
<tr>
<th>Reference</th>
<th>Author/Title/Institution/Dates</th>
</tr>
</thead>
<tbody>
<tr>
<td>[Balz05]</td>
<td>Helmut Balzert: „Lehrbuch Grundlagen der Informatik“, Spektrum Akademischer Verlag, 2005</td>
</tr>
<tr>
<td>Reference</td>
<td>Title</td>
</tr>
<tr>
<td>-----------</td>
<td>----------------------------------------------------------------------</td>
</tr>
<tr>
<td>[Stud05]</td>
<td>Rudi Studer: „Grundlagen der Informatik 1, SS 2005“, Institut für Angewandte Informatik und Formale Beschreibungsverfahren, Uni-Karlsruhe, 2005</td>
</tr>
</tbody>
</table>
Sources

[RNKS05] http://www-rnks.informatik.tu-cottbus.de/
[InfA05] http://www.informatik.uni-augsburg.de/
[Bogd05] http://www.uni-koblenz.de/~bogdan/TCP_IP_Presentation.ppt
[MatM05] http://www.mathematik.uni-marburg.de/
<table>
<thead>
<tr>
<th>Reference</th>
<th>Source Description</th>
</tr>
</thead>
</table>
| [BSK_1]   | o. Prof. Dr. Dr.-Ing. Jivka Ovtcharova: Vorlesung „Berechnung und Simulation in der Konstruktion“, RPK, Universität Karlsruhe, WS 04/05  
Vorlesung 1 (BKS_V1.ppt) |
| [BSK_1]   | o. Prof. Dr. Dr.-Ing. Jivka Ovtcharova: Vorlesung „Berechnung und Simulation in der Konstruktion“, RPK, Universität Karlsruhe, WS 04/05  
Vorlesung 2 (BKS_V2.ppt) |
| [BSK_3]   | o. Prof. Dr. Dr.-Ing. Jivka Ovtcharova: Vorlesung „Berechnung und Simulation in der Konstruktion“, RPK, Universität Karlsruhe, WS 04/05  
Vorlesung 2 (BKS_V3 San.ppt) |
| [BSK_9]   | o. Prof. Dr. Dr.-Ing. Jivka Ovtcharova: Vorlesung „Berechnung und Simulation in der Konstruktion“, RPK, Universität Karlsruhe, WS 04/05  
Vorlesung 2 (BKS_V9 Kri.ppt) |
| [VEI_13]  | o. Prof. Dr. Dr.-Ing. Jivka Ovtcharova: Vorlesung „Virtual Engineering (VE I)“, RPK, Universität Karlsruhe, 2005, WSSS 0405  
Vorlesung 13 (VEI_V13_CAE_FEM.ppt) |
| [VEI_14]  | o. Prof. Dr. Dr.-Ing. Jivka Ovtcharova: Vorlesung „Virtual Engineering (VE I)“, RPK, Universität Karlsruhe, 2005, WSSS 0405  
Vorlesung 14 (VEI_V14_CAE_FEM.ppt) |
| [Ovtc05]  | o. Prof. Dr. Dr.-Ing. Jivka Ovtcharova: Vorlesung „Virtual Engineering“, RPK, Universität Karlsruhe, 2005 |