Quality Management of Software and Systems

Reuse

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Problems

- Problems
  - Normally, each software development reinvents the wheel several times
  - This luxury cannot be afforded be afforded any longer
- /Weber 92/
  - The reusability of concepts, products, and procedures is the key concept of advanced industries
  - Implementing reusability aims for cost reduction and quality improvement of products
  - Not using existing products as components or not estimating market opportunities for products and components before development is industrial stone age

Problems

- *»Golden Rule of Reusability:*
  - *Before you can reuse something, you need to*
  - *1st find it*
  - *2nd know what it does*
  - *3rd know how to reuse it.«*

Problems

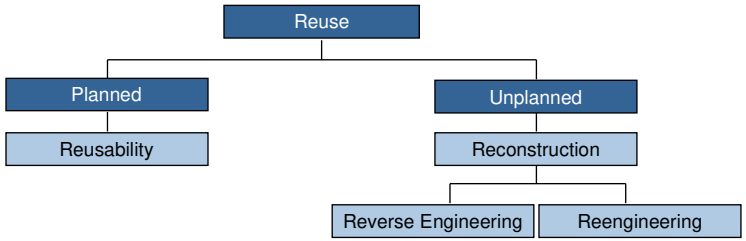
- Goals of reuse
  - Significant improvement of productivity
  - Quality improvement
  - Reducing development time
  - Cost rediction

Reusability and Reuse

- Reusability
  - Development and provision of reusable software
- Reuse
  - Operation of reusable software
  - Highly reusable software components ease the reuse of these components
- Precondition: Optimal collaboration of
  - Technique
  - Organization
  - Management

Reusability and Reuse

- Planned vs. unplanned Reuse



Reusability and Reuse

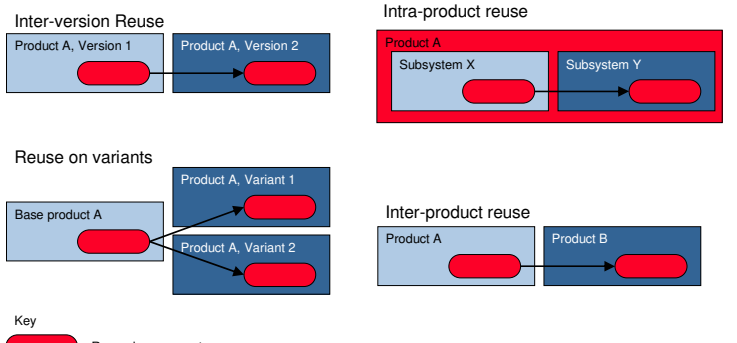
- Today: Unplanned reuse
  - Existing software systems
    - Have to be redesigned due to additional requirements or changed hardware/software platforms
  - Original systems
    - Not designed for reuse in other contexts
  - Usage of Reverse Engineering, Reengineering and Reconstruction
    - To identify and prepare software components for reuse

Reusability and Reuse

- Planned reuse
  - Design software components in the first place in a way that they can be easily reused
  - Good reusability imply a software component to be
    - Highly generic
    - High quality
    - Well documented
  - Software component
    - Each explicit, physical existent development result
    - Each result, offering easy solutions for later projects

Reusability and Reuse

- Four types of reusability



Reusability and Reuse

- Reuse on versions and variants
  - Already good understood
  - Especially, using object-orientation
- Intra- and inter-product reuse
  - Hardly seen
- Layers of reusability
  - Product definition
  - Product design
  - Product Implementation
    - Nowadays: Reuse of code components is prevalent

Reusability and Reuse

- Differentiation by application domain
  - Vertical differentiation
    - Within the same domain
  - Horizontal differentiation
    - In different domains
      - Example: Libraries with scientific routines
      - Example: Libraries with base classes
- Types of reuse
  - *white-box*-reuse
    - The developer modifies, adapts, and tests the reused components
  - *black-box*-reuse
    - The reused components are not changed

Technique

- Reuse with respect to the layer of abstraction
  - Functional abstraction
    (functions, procedures, methods)
  - Data abstraction
    (abstract data objects and abstract data types)
  - Classes using inheritance and polymorphism
  - Additionally, all three abstraction in a generic way (except abstract data objects)

Technique

- Functional abstraction
  - \+ Suitable for specific application domains, e.g. mathematical libraries
  - – Low layer of abstraction
  - – Functional perspective not broad enough
  - – Separation of value, state, and processing
  - – Inflexible parameter mechanism
  - – Only some programming languages support generic functional abstraction

Technique

- Data abstraction
  - Attributes and operations aggregated to one unit (encapsulation and information hiding)
  - Removes disadvantages of functional abstraction
  - \+ Suitable for many different application domains, especially for fundamental data structures (e.g. stack, queue, list, etc.)
  - \+ Highly generic and good adaptability through type parameterization
  - \+ Easily understandable
  - – Applicable only with strongly typed languages
  - – Not as generic as inheritance

Technique

- Data abstraction
  - Comprehensive reusable libraries despite the disadvantages
  - Example: Ada-Library by /Booch 87/
  - Many class libraries do not use inheritance, but use only options given by generic class concepts
- Object-oriented components
  - Best options to achieve high reusability
  - Depends on the proper usage of options
  - Wrong usage may decrease reusability

Technique

- Object-oriented components
  - + Inheritance permits specialization, super class can be reused as it is (black-box-reuse)
  - + Adding additional features with little new code
  - – For the most part system inherent complexity shifts to system dynamics
  - – Deep inheritance structures are hard to control
- Reusability in larger units
  - Frameworks
  - Analysis and design patterns
  - Componentware

Organization

- Reuse
  - Not automatically through the use of appropriate technique
  - Must be organized
- Organization must include
  - Development, installation, and operation of a reusability repository
  - Evolutionary advancement of reuse
  - Including reuse in process model

Organization

- Reusability repository
  - Today, reuse often fails, because existing components cannot be found in a fast, easy, and sure way
  - Example
    - Software developer wants to reuse software
    - Question to colleagues for relevant developments
    - Remembrance of a similar problem two years ago in another project
    - Reference to a certain file within the streamer backup of the project
    - Search for the streamer within the archive

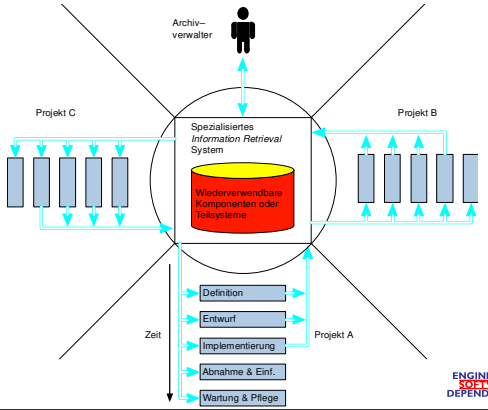
Organization

- File with similar name found after a long search
- Only source code with comments, without further documentation
- Needed compiler version cannot be obtained
- Depressed, the developer starts implementing an own solution: the wheel is reinvented

- Requirements: reusability repository
  - Project independent
  - Easily accessible
  - Each employee needs access at any time directly from his desktop

Organization

- Reusability repository concept



Organization

- Reusability repository can be
  - Independent repository
    - With or without connections to a CASE environment
  - Integrated in a reuse oriented CASE environment
- Retrievability must be constructed
  - Reusable components and subsystems must be classified
- Classification
  - Research: Many classification systems for storing and retrieving reusable components
  - Important method: facet classification

Organization

- Services of a repository administration
  - Development of classification systems
  - Classification and retrieving components and subsystems
  - Export of components to other management systems
  - Imports from other systems
  - Documentations about classification systems and classified components
  - Saves not only links to sources, but sources itself
    - E.g., if an OOA-model is found, the graphical representation must be accessible

Organization

- Requirements for reuse-oriented CASE environments
  - Support for assembling applications from components
  - black-box-reuse
    - Management of an “use”-relation between component and using application
      - Changes at the component can be communicated to all applications using the component
  - white-box-reuse
    - Additionally, each application must be able to derive and enhance their own version from the original component
      - Application needs test environment (i.e., test scope, test cases, test protocols) of the component

Organization

- Online management of all results from all tools during the whole development cycle
  - All results need to be manipulable with all their relations
- Configuration and change management of the reusable components

Organization
Maturity levels of reuse

- Level 1: Ad hoc-reuse
  - Unsystematic reuse
    - Occasional, dependent on the project staff's work style, uncoordinated, normally undocumented
    - Rule: copy, adapt, divergence
    - Combined versioning with the original does not occur
  - Multiple maintenance and bugfixing
  - Better part of today's reuse is in this way
  - Better than no reuse
  - Simple, with only short-term benefit
    - Benefit compensates if too many undocumented copies circulate uncontrolled, leading to unmaintainable software

Organization
Maturity levels of reuse

- Level 2: Reuse of available software
  - Systematized through implementation of appropriate arrangements
  - Basis for the development of reusable components were established
  - Available and reusable software must be collected and documented in a structured way
  - System parts with different change frequencies are localized
    - Variants and versions of correspondent systems can be developed more efficiently
  - Acquisition of market-available software based on the process
    - Specifically, software development oriented
  - Development of modular software systems
    - Basis for the reuse of system components
  - Commercially available and internal standards are met
    - Portable systems

Organization
Maturity levels of reuse

- Level 3: Development for reuse
  - Domain-oriented software development
  - Establish appropriate infrastructure for reuse-oriented development
  - Develop software components
    - Not with respect to the current application
    - But with respect to the future applications
  - Reusable software components were developed incrementally as subassemblies

Organization
Maturity levels of reuse

- Functionality of such software can be enhanced without changing the original source code
- Incrementally extendable software eases the development of versions and variants
- Development of subassemblies project independently or separated of domain specific projects
- Subassemblies based on an application domain analysis
  - Goal: domain model, describing a generic and therefore reusable architecture for products of the application domain

Organization
Maturity levels of reuse

- Additional necessary activities
  - Establish a reusability repository
  - Arrange reusability related trainings
  - Creation of an appropriate in-house communication structure (e.g., Bulletin Boards)
  - Provision of standards for selection, evaluation, and adaptation of components

Organization
Maturity levels of reuse

- Level 4: Usage of domain models and statistical process control
  - Application development using domain models
  - Control of reuse-oriented software development based on statistics
  - Provide a domain model for each well defined application domain
    - The model should describe a generic and therefore reusable architecture for products in the application domain
  - Domain analysis permits integration to software development processes

Organization
Maturity levels of reuse

- Each domain model consist of
  - Architecture
  - Integrated components and subassemblies including self developed and commercially available components
- Focal point of software development
  - Application modeling
  - Not programming
- Applications development through assembly of subassemblies
- Application developer develops only application specific parts

Organization
Maturity levels of reuse

- Additional activities
  - Implementing life cycle for development, certification, and usage of components
  - Establish reusability-oriented CASE environments
  - Project progress statistically controlled by characteristics and cost/benefit models
    - Characteristics calculated from measurements

Organization
Maturity levels of reuse

- Level 5: Organization wide reuse orientation
  - All division activities completely reuse oriented
  - Alike level 4, applications are developed by assembling existing and widely standardized subassemblies
  - New: Divisions that do not develop software, act reuse oriented
  - All sales activities with available components in mind
  - Each software component is considered company asset
  - Amount of assets and life cycle length incorporated in
    - Decisions for software development
    - Strategic decisions of the company management

Organization
Maturity levels of reuse

- Reuse levels

Level	Reuse in percent	Requirements
5 Domain-based reuse	80 – 100 %	Domain analysis and architectures
4 Consistent reuse	50 – 70 %	Libraries, processes, metrics, training
3 Planned reuse	30 – 40 %	Approval and support of management, motivation programs, libraries
2 Exploit existing applications	10 – 50 %	Luck and maintenance problems
1 No or ad-hoc reuse	< 20 %	No organizational changes

Organization

- 3 level maturity model
  - Practical experience with financial and assurance domain

Level I: Maintainability
- Reuse within a single project

Level II: Balance
- Reuse between similar projects

Level III: Standardizing
- Basis for domain comprehensive reuse

Organization

- Reuse-oriented process model
  - Necessary requirement to establish reuse
  - All development phases
    - Adequate components are searched
    - New reusable components were classified and put into the repository
  - Reusable components applicable in
    - Definition phase
    - Design phase
    - Implementation phase
  - Developed intern or obtained from extern

Organization

- Constant observation of software market needed
- Task for buying components
  - Specifying of all today's and future requirements for the own application
  - Examination
    - Components sufficiently parameterized in order to adapt to changing requirements
    - Can the components be evaluated, adapted, and maintained by CASE- and Reengineering-tools
    - Clarification of legal aspects of the components usage

Management

- Change of management tasks
  - Software manager has to develop a software product
  - Today
    - Crucial question: »How can I solve the problem with my available resources?«
  - Prognosis
    - Crucial question: »Where has somebody solved a similar problem, and how can I obtain the solution?«
  - Main management task in the future
    - Ensure reusability of components

Management

- Reusability
  - Today not primary a technical problem
  - Organizational and management problem
  - Who decides today to reuse software, can start tomorrow
- Culture of reusability
  - Task of software management
    - Provide an adequate organizational environment
    - Establishing of a culture of reusability

Management

- Example
  - Employee develops software component during project
  - During the development he has ideas to generalize the component for the usage in other contexts
  - Under high deadline pressure, only a project specific solution is developed
  - Scenario shows
    - In nearly all software companies the appeal to develop generic solutions is missing
  - Thus: Development of bonus systems for
    - Provide reusable components
    - Reuse of such components

Management

- Example
  - Nippon Novel pays each software developer 5 Cent per line of code, if he puts a component in the repository or reuses a component
  - Additionally, the developer of a reusable component gets 1 Cent per line of code for each reuse
- Management has to answer the following questions
  - Who pays for the development of a reusable component?
  - Who is responsible for maintenance?
  - What is the gain of providing a reusable component?

Costs and Benefits of Reuse

- Qualitative statements
  - Rule of thumb: »Formula 3«
    - Software has to be developed three times until it can be developed for reuse
    - Not until the software is reused three times can the reuse yield fruit
  - Break-even at approximately three reuses of a component specifically developed for reuse
  - Afterwards, the 30-50% higher development costs can be earned

Costs and Benefits of Reuse

- 60% higher development costs
  - 25% for additional generalization
    - E.g., parameterization, design, review
  - 15% for additional documentation
  - 10% for additional testing
  - 5% for repository and maintenance

Costs and Benefits of Reuse

- Reuse and productivity

	0%	25%	50%
Total time in MM	81,5	45	32
Number of Employees	8	6	5
Costs per LOC	40,74	22,5	16
LOC per MM	165	263	370
Savings	0%	45%	61%

  - Examined were three real applications, consisting of 10,000 line of COBOL-Code

Costs and Benefits of Reuse

- Reuse and productivity

	0%	10%	30%	50%	80%
Total time in MM	200	176	131	89	33
Savings	0%	12%	34%	56%	84%

  - Examined were Objective-C programs consisting of 20,000-30,000 LOC

☐ Cost/Benefit ratio for class libraries

- Library supply has serious impact on the cost/benefit ratio
- If no library classes are available at the start, the cost/benefit ratio is <1 not until the 3rd project

Costs and Benefits of Reuse

- Benefit prevails after the sixth project has finished, if
  - Library size, starting with ten classes, continually increases and
  - Development costs for reusable classes are twice as high as for project specific classes
- Potential reuser has higher efforts
  - He has to search, find, understand, install, test, parameterize, and integrate a component
  - Chosen component may inadequate
- Effort may pay off, as developers strongly underestimate the development effort

Costs and Benefits of Reuse

☐ Japanese experiences

- Not primarily a technical question
- Since the end of the 1980ies reuse has a high priority
- Results through firm organization and strict compliance of methods
- NEC
  - 6.7 times better productivity
  - 2.8 times better quality of economic applications
  - Achieved by
    - Identification and standardization of 32 logical templates and 130 common algorithms
    - Strict use of CASE environment

Costs and Benefits of Reuse

- Fujitsu
  - After establishing a reusability repository 70% on schedule
  - Before only 20%

☐ American experiences

- Raytheon
  - Analysis and revised design of 5,000 COBOL programs in use
  - 50% productivity increase in six years
  - Within new systems approximately 60% code reuse
- Independent American study
  - > 70% shorter delivery times because of reuse

Costs and Benefits of Reuse

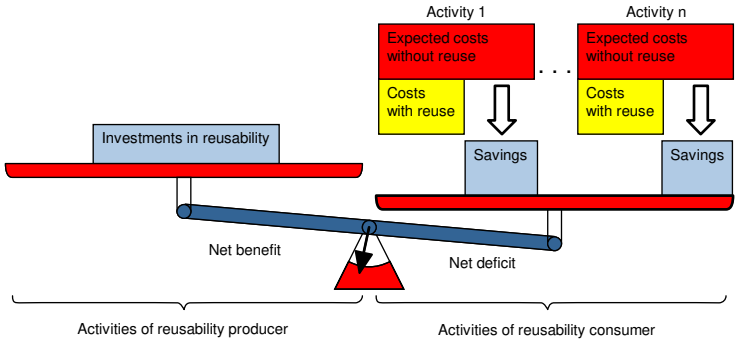
- Hewlett-Packard
  - Project 1
    - Error reduction: 51%
    - Productivity increase: 57%
  - Project 2
    - Error reduction: 24%
    - Productivity increase: 40%
    - Decrease of development time: 42%

☐ Quantitative Statements

- Each reusable software component has to be seen as company asset
- Afterwards, reuse can be calculated as normal financial investment

Costs and Benefits of Reuse

☐ Cost/Benefit ratio of reuse



Costs and Benefits of Reuse

☐ A reusability investment is cost-effective, if K < N

- K = Overall costs if the investment
- N = Savings

☐ Benefit N

$$N = \sum_{i=1}^{k} n_i = \sum_{i=1}^{k} (o_i - m_i)$$

- n_i: Savings for activity i
- o_i: Expected costs for activity I without reuse
- m_i: Costs for I with reuse
- k: Number of activities affected by the investment

Costs and Benefits of Reuse

- The Return-On-Investment relation is given by

$$R = \frac{N}{K}$$

- R < 1 means deficit
- R >> 1 means good profit
- 3 possible strategies for R >> 1
  - Increase reuse rate
  - Reduce average reuse costs
  - Reduce investment costs needed to gain a reuse benefit

Costs and Benefits of Reuse
Metrics to measure reuse

- 6 categories
  - Metrics for the cost/benefit analysis
  - Metrics for the maturity classification
  - Metrics for the reuse rate
  - Metrics to calculate reuse impediments
  - Metrics to estimate the reusability of a component
  - Metrics for the usage of the reusability repository

Costs and Benefits of Reuse
Metrics to measure reuse

- Metrics for the maturity classification
  - No metric in the stricter sense
  - More like a characteristic to help an organization to identify the current maturity level
- Metrics for the reuse rate
  - Used, to estimate the reuse rate and to track the development over time

$$\frac{\text{Number of reused components}}{\text{Number of components}}$$

Costs and Benefits of Reuse
Metrics to measure reuse

- Metrics to calculate reuse impediments
  - Determine impediment factors while trying to reuse components
  - Impediment factors are
    - Number of tries to reuse a components
    - Component does not exist
    - Component is not available
    - Component was not found
    - Component was not understood
    - Component is not valid
    - Component cannot be integrated

Costs and Benefits of Reuse
Metrics to measure reuse

- Each impediment factor are assigned impediment causes
  - E.g., the factor 'Number of tries to reuse a components' are assigned the following causes
    - Resource restrictions
    - No reuse incentive
    - Missing training
- Usage of such a metric
  - Organization collects data about impediment factors and causes
  - She uses this information to improve reusability activities

Costs and Benefits of Reuse
Metrics to measure reuse

- Metrics to estimate the reusability of a component
  - Measure component attributes, indicating potential reusability
  - Problems arise, as attributes depend on the component type and the programming language
  - Example
    - The following attributes are good indicators for a high black-box reusability of Ada components
      - Less calls per LOC
      - Less input/output parameters per LOC
      - Less read/write statements per LOC
      - More comments in relation to code
      - More auxiliary functions per LOC
      - Less lines of code

Costs and Benefits of Reuse
Metrics to measure reuse

- Metrics for the usage of the reusability repository
  - Quality of classification scheme
    - Costs
    - Search effectiveness
    - Understandability
  - Quality of components
    - Number of reuses within 3 months
    - Judgment of reused components
  - Usage of reusability repository
    - System availability
    - Number of users
    - Executed archive functions
    - Number of available components, etc.

Implementing Reuse
Procedure

- ☐ Introduction of Reuse
  - Typical introduction of innovations, with all associated characteristics
- ☐ Orientation at maturity model of reuse
  - 1. Task: Determination of current state
  - Afterwards, plan to iteratively reach next level
- ☐ Define realistic and measurable goals
- ☐ Time needed to achieve a reuse ratio of 20%
  - 1 year from experience

Implementing Reuse
Procedure

- Requirements for reusable components initially not too demanding
  - If only tested, ready components are allowed in the repository, developers do not dare adding their software
- Solution
  - Divide repository
    - Tested components
    - Provided components, but to be tested and to be completed
- Introduction of reuse leads to investments and changes in the organization

Implementing Reuse
Procedure

- Lasting practice of reuse
  - Has to enter the company's culture
  - Has to be trained daily
- Change of development tasks
  - From a writing developer to a reading, evaluating, and creative composing software architect
- Developers
  - Show distinct resentments against software, they have not developed themselves
  - Fear poor quality and feel stroked at their creative self-image

Implementing Reuse
Impediments during the introduction of reuse

- Economic
  - Missing Commitment
  - Vague company strategy
  - Investment level
  - Losing Deal
  - Missing rights of use and patent rights
- Organizational
  - Not scheduled in the process
  - Responsibilities not assigned
  - Missing promoter
  - Missing infrastructure

Implementing Reuse
Impediments during the introduction of reuse

- Sociological
  - Not-invented-here syndrome
  - Resistance against changes
  - Existential fear »*Re-Use* is a Job-Killer«
  - Self-image of the developer / changed role
- Technical
  - Missing experience with practical applications
  - Missing Know-how
  - Weaknesses in the Software-Engineering process
  - Missing tools