Software measurement

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Definitions

Measure - quantitative indication of extent, amount, dimension, capacity, or size of some attribute of a product or process.

– Number of errors

Metric - quantitative measure of degree to which a system, component or process possesses a given attribute. “A handle or guess about a given attribute.”

– Number of errors found per person hours expended

Why Measure Software?

- Determine quality of the current product or process
- Predict qualities of a product/process
- Improve quality of a product/process

Example Metrics

- Defects rates
- Errors rates
- Measured by:
  - individual
  - module
  - during development
- Errors should be categorized by origin, type, cost

Metric Classification

- Products
  - Explicit results of software development activities
  - Deliverables, documentation, by products
- Processes
  - Activities related to production of software
- Resources
  - Inputs into the software development activitie
  - Hardware, knowledge, people

Product vs. Process

Process Metrics:

- Insights of process paradigm, software engineering tasks, work product, or milestones
- Lead to long term process improvement

Product Metrics:

- Assesses the state of the project
- Track potential risks
- Uncover problem areas
- Adjust workflow or tasks
- Evaluate teams ability to control quality

Types of Measures

Direct Measures (internal attributes)

- Cost, effort, LOC, speed, memory

Indirect Measures (external attributes)

- Functionality, quality, complexity, efficiency, reliability, maintainability

Size Oriented Metrics

- Size of the software produced
- Lines Of Code (LOC)
- 1000 Lines Of Code KLOC
- Effort measured in person months
- Errors/KLOC
- Defects/KLOC
- Cost/LOC
- Documentation Pages/KLOC
- LOC is programmer & language dependent

LOC Metrics

- Easy to use
- Easy to compute
- Can compute LOC of existing systems but cost and requirements traceability may be lost
- Language & programmer dependent

Function Oriented Metrics

- Function Point Analysis [Albrecht '79, '83]
- International Function Point Users Group (IFPUG)
- Indirect measure
- Derived using empirical relationships based on countable (direct) measures of the software system (domain and requirements)

Compute Function Points

- FP = Total Count * [0.65 + 0.01*Sum(F_i)]
- Total count is all the counts times a weighting factor that is determined for each organization via empirical data
- F_i (i=1 to 14) are complexity adjustment values

Complexity Metrics

- LOC - a function of complexity
- Language and programmer dependent
- Halstead's Software Science (entropy measures)
    - n_1 - number of distinct operators
    - n_2 - number of distinct operands
    - N_1 - total number of operators
    - N_2 - total number of operands

Example

```
if (k < 2)
{
if (k > 3)
x = x*k;
}
```

- Distinct operators: if ( ) { } > < = * ;
- Distinct operands: k 2 3 x
- $n_1 = 10$
- $n_2 = 4$
- $N_1 = 13$
- $N_2 = 7$

Halstead's Metrics

- Amenable to experimental verification [1970s]
- Length: $N = N_1 + N_2$
- Vocabulary: $n = n_1 + n_2$
- Estimated length: $\tilde{N} = n_1 \log_2 n_1 + n_2 \log_2 n_2$
  - Close estimate of length for well structured programs
- Purity ratio: $PR = \tilde{N} / N$

Program Complexity

- Volume: $V = N \log_2 n$

  - Number of bits to provide a unique designator for each of the *n* items in the program vocabulary.

- Program effort: $E=V/L$

  - $L = V^*/V$

  - V^* is the volume of most compact design implementation

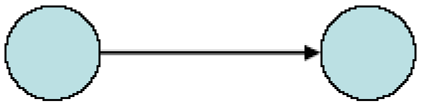
  - This is a good measure of program understandability

McCabe's Complexity Measures

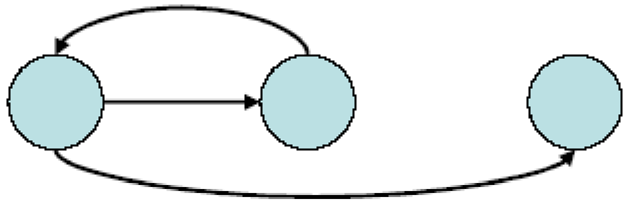
- McCabe's metrics are based on a control flow representation of the program.
- A program graph is used to depict control flow.
- Nodes represent processing tasks (one or more code statements).
- Edges represent control flow between nodes.

Flow Graph Notation

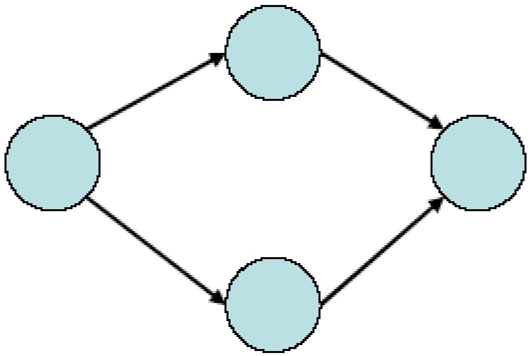
Sequence



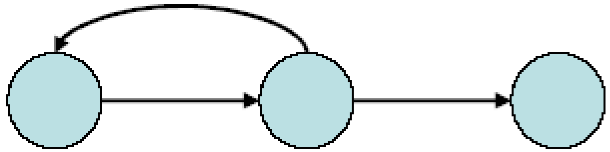
While



If-then-else



Repeat-until



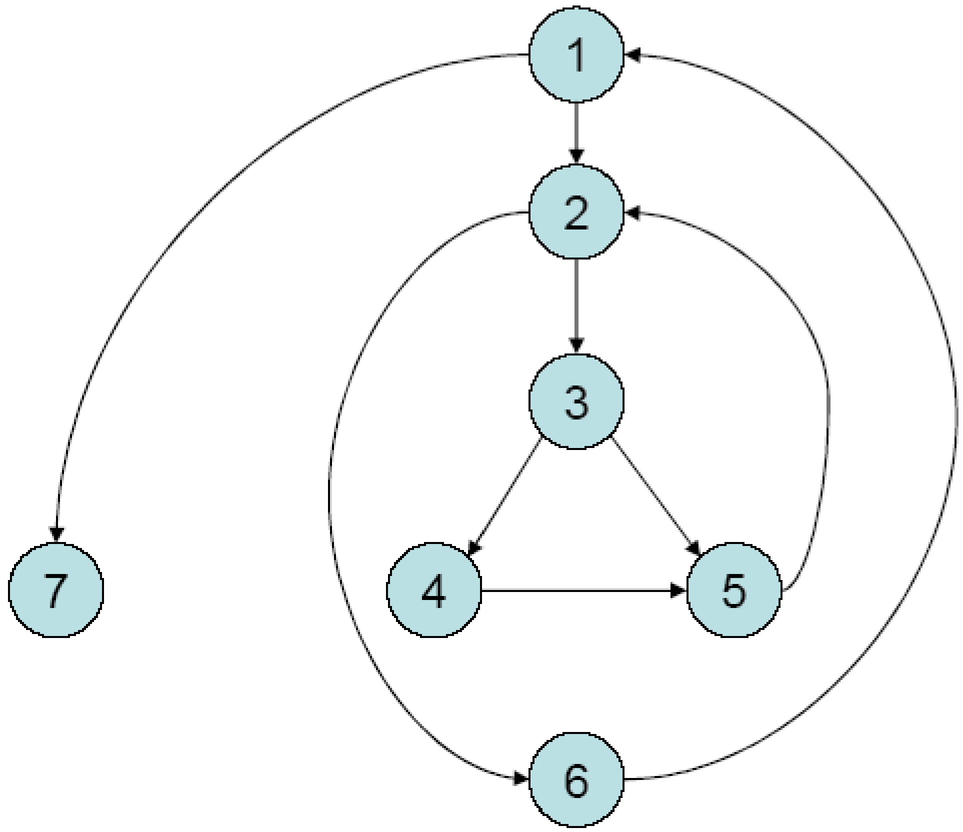
Cyclomatic Complexity

- Set of independent paths through the graph (basis set)
- $V(G) = E - N + 2$
  - E is the number of flow graph edges
  - N is the number of nodes
- $V(G) = P + 1$
  - P is the number of predicate nodes

Example

```
i = 0;
while (i<n-1) do
     j = i + 1;
     while (j<n) do
          if A[i]<A[j] then
               swap(A[i], A[j]);
     end do;
     i=i+1;
end do;
```

Flow Graph



Computing V(G)

- $V(G) = 9 - 7 + 2 = 4$
- $V(G) = 3 + 1 = 4$
- Basis Set
  - 1, 7
  - 1, 2, 6, 1, 7
  - 1, 2, 3, 4, 5, 2, 6, 1, 7
  - 1, 2, 3, 5, 2, 6, 1, 7

Meaning

- *V*(*G*) is the number of (enclosed) regions/areas of the planar graph
- Number of regions increases with the number of decision paths and loops.
- A quantitative measure of testing difficulty and an indication of ultimate reliability
- Experimental data shows value of *V*(*G*) should be no more then 10. Testing is very difficulty above this value.

McClure's Complexity Metric

- Complexity = $C + V$

  - C is the number of comparisons in a module

  - V is the number of control variables referenced in the module

- Similar to McCabe's but with regard to control variables.

High level Design Metrics

- Structural Complexity
- Data Complexity
- System Complexity
- Card & Glass '80
- Structural Complexity $S(i)$ of a module i.

  - $S(i) = f_{out}^2(i)$
  - Fan out is the number of modules immediately subordinate (directly invoked).

Design Metrics

- Data Complexity $D(i)$
  - $D(i) = v(i) / [\, f_{out}(i) + 1]$
  - $v(i)$ is the number of inputs and outputs passed to and from i.
- System Complexity $C(i)$
  - $C(i) = S(i) + D(i)$
  - As each increases the overall complexity of the architecture increases.

System Complexity Metric

- Another metric:
  - $length(i) * [\, f_{in}(i) + f_{out}(i)]^2$
  - Length is LOC
  - Fan in is the number of modules that invoke i.
- Graph based:
  - Nodes + edges
  - Modules + lines of control
  - Depth of tree, arc to node ratio

Component Level Metrics

- Cohesion (internal interaction)
- Coupling (external interaction)
- Complexity of program flow
- Cohesion

Coupling

- Data and control flow
  - d_i - input data parameters
  - c_i - input control parameters
  - d_o - output data parameters
  - c_o - output control parameters
- Global
  - g_d - global variables for data
  - g_c - global variables for control
- Environmental
  - w - fan in number of modules called
  - r - fan out number modules that call module

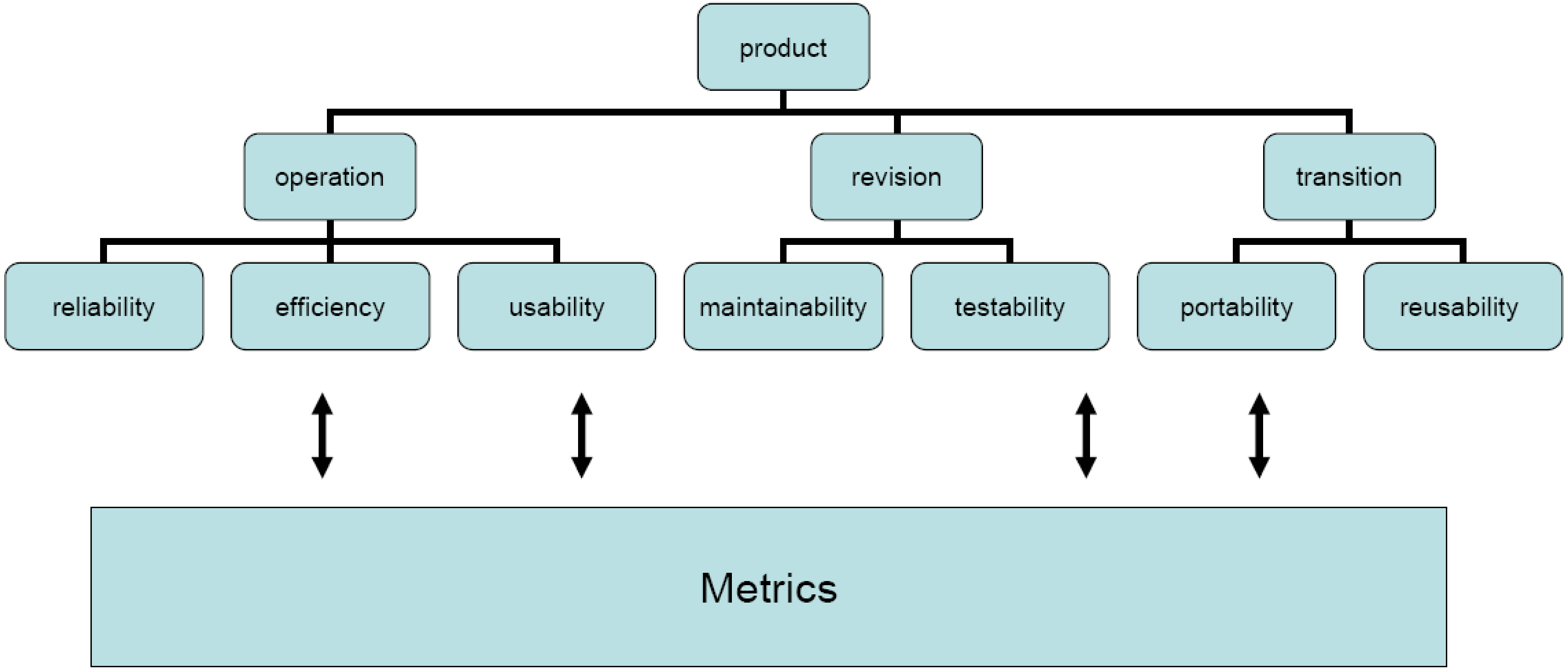
Metrics for Coupling

$M_c = k/m$, $k = 1$

$m = d_i + ac_i + d_o + bc_o + g_d + cg_c + w + r$

a, *b*, *c*, *k* can be adjusted based on actual data

Quality Model



FURPS

- Functionality - features of system
- Usability - aesthesis, documentation
- Reliability - frequency of failure, security
- Performance - speed, throughput
- Supportability - maintainability

Measures of Software Quality

- Correctness
  - Defects/KLOC
  - Defect is a verified lack of conformance to requirements
  - Failures/hours of operation
- Maintainability
  - Mean time to change
  - Change request to new version (Analyze, design etc)
  - Cost to correct
- Integrity
  - Fault tolerance, security & threats
- Usability
  - Training time, skill level necessary to use, Increase in productivity, subjective questionnaire or controlled experiment

Metrics for the Object Oriented

- Chidamber & Kemerer ’94 TSE 20(6)
- Metrics specifically designed to address object oriented software
- Class oriented metrics
- Direct measures

Class Size

- CS
  - Total number of operations (inherited, private, public)
  - Number of attributes (inherited, private, public)
- May be an indication of too much responsibility for a class.

Number of Operations Overridden

- NOO
- A large number for NOO indicates possible problems with the design.
- Poor abstraction in inheritance hierarchy.

Number of Operations Added

- NOA
- The number of operations added by a subclass.
- As operations are added it is farther away from super class.
- As depth increases NOA should decrease.

Specialization Index

- $SI = [NOO * L] / M_{total}$
- L is the level in class hierarchy.
- M_{total} is the total number of methods.
- Higher values indicate class in hierarchy that does not conform to the abstraction.

Method Inheritance Factor

$$MIF = \frac{\sum_{i=1}^{n} M_i(C_i)}{\sum_{i=1}^{n} M_a(C_i)}$$

- $M_i(C_i)$ is the number of methods inherited and not overridden in C_i
- $M_a(C_i)$ is the number of methods that can be invoked with C_i
- $M_d(C_i)$ is the number of methods declared in C_i

Method Inheritance Factor

- $M_a(C_i) = M_d(C_i) + M_i(C_i)$
- All that can be invoked = new or overloaded + things inherited

- MIF is [0,1]
- MIF near 1 means little specialization
- MIF near 0 means large change

Coupling Factor

$$CF = \frac{\sum_i \sum_j is\_client(C_i, C_j)}{\left(TC^2 - TC\right)}$$

- *is_client(x,y)* = 1 if a relationship exists between the client class and the server class. 0 otherwise.
- ($TC^2 - TC$) is the total number of relationships possible (Total Classes^2 – diagonal).
- *CF* is [0,1] with 1 meaning high coupling.

Using Metrics

- The Process
  - Select appropriate metrics for problem
  - Utilized metrics on problem
  - Assessment and feedback

- Formulate
- Collect
- Analysis
- Interpretation
- Feedback

Úkoly

- Pro svůj projekt navrhněte (vyberte) 3 různé metriky a okomentujte jejich význam.