Survey: Softwarepraktikum

- not in study plan; or later
- participated earlier
- participate this semester
Topic Area Project Management: Content

VL 2
- Software Metrics
  - Properties of Metrics
  - Scales
  - Examples

VL 3
- Cost Estimation
  - "(Software) Economics in a Nutshell"
  - Expert’s Estimation
  - Algorithmic Estimation

VL 4
- Project Management
  - Project
  - Process and Process Modelling
  - Procedure Models
  - Process Models

VL 5
- Process Metrics
  - CMMI, Spice
Content

- Software Metrics
  - Subjective Metrics
  - Goal-Question-Metric Approach

- Cost Estimation
  - "(Software) Economics in a Nutshell"
  - Cost Estimation
    - Expert’s Estimation
      - The Delphi Method
    - Algorithmic Estimation
      - COCOMO
      - Function Points
## Kinds of Metrics: by Measurement Procedure

<table>
<thead>
<tr>
<th></th>
<th>objective metric</th>
<th>pseudo metric</th>
<th>subjective metric</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Procedure</strong></td>
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<td>computation (based on measurements or assessment)</td>
<td>review by inspector, verbal or by given scale</td>
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<tr>
<td><strong>Example, general</strong></td>
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<td><strong>Example in Software Engineering</strong></td>
<td>size in LOC or NCSI: number of (known) bugs</td>
<td>productivity; cost estimation by COCOMO</td>
<td>usability; severeness of an error</td>
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<td><strong>Usually used for</strong></td>
<td>collection of simple base measures</td>
<td>predictions (cost estimation); overall assessments</td>
<td>quality assessment; error weighting</td>
</tr>
<tr>
<td><strong>Advantages</strong></td>
<td>exact, reproducible, can be obtained automatically</td>
<td>yields relevant, directly usable statement on not directly visible characteristics</td>
<td>not subvertable, plausible results, applicable to complex characteristics</td>
</tr>
<tr>
<td><strong>Disadvantages</strong></td>
<td>not always relevant, often subvertable, no interpretation</td>
<td>hard to comprehend, pseudo-objective</td>
<td>assessment costly, quality of results depends on inspector</td>
</tr>
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</table>

(Ludewig and Lichter, 2013)
Some of the most interesting aspects of software development projects are (today) hard or impossible to measure directly, e.g.:

- how maintainable is the software?
- how much effort is needed until completion?
- how is the productivity of my software people?
- do all modules do appropriate error handling?
- is the documentation sufficient and well usable?

Due to high relevance, people want to measure despite the difficulty in measuring. Two main approaches:

<table>
<thead>
<tr>
<th>Expert review, grading</th>
<th>differentiated</th>
<th>comparable</th>
<th>reproducible</th>
<th>available</th>
<th>relevant</th>
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</tr>
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<tr>
<td></td>
<td>✓</td>
<td>✓</td>
<td>(x)</td>
<td>✓</td>
<td>✓!</td>
<td>x</td>
<td>✓</td>
<td>✓</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Pseudo-metrics, derived measures</th>
<th>differentiated</th>
<th>comparable</th>
<th>reproducible</th>
<th>available</th>
<th>relevant</th>
<th>economical</th>
<th>plausible</th>
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<td></td>
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<td>✓!</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td></td>
</tr>
</tbody>
</table>

Note: not every derived measure is a pseudo-metric:

- average LOC per module: derived, not pseudo → we really measure average LOC per module.
- measure maintainability in average LOC per module: derived, pseudo
  → we don’t really measure maintainability; average-LOC is only interpreted as maintainability. Not robust if easily subvertible (see exercises).
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(Ludewig and Lichter, 2013)
## Subjective Metrics

<table>
<thead>
<tr>
<th></th>
<th>example</th>
<th>problems</th>
<th>countermeasures</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Statement</strong></td>
<td>“The specification is available.”</td>
<td>Terms may be ambiguous, conclusions are hardly possible.</td>
<td>Allow only certain statements, characterise them precisely.</td>
</tr>
<tr>
<td><strong>Assessment</strong></td>
<td>“The module is implemented in a clever way.”</td>
<td>Not necessarily comparable.</td>
<td>Only offer particular outcomes; put them on an (at least ordinal) scale.</td>
</tr>
<tr>
<td><strong>Grading</strong></td>
<td>“Readability is graded 4.0.”</td>
<td>Subjective; grading not reproducible.</td>
<td>Define criteria for grades; give examples how to grade; practice on existing artefacts</td>
</tr>
</tbody>
</table>

*(Ludewig and Lichter, 2013)*
The Goal-Question-Metric Approach
Now we have mentioned nearly 60 attributes one could measure…

Which ones **should** we measure?

**It depends**…

One approach: **Goal-Question-Metric (GQM)**.
The three steps of **GQM**:

(i) **Define** the **goals** relevant for a project or an organisation.

(ii) From each goal, **derive questions** which need to be answered to check whether the goal is reached.

(iii) For each question, **choose** (or develop) **metrics** which contribute to finding answers.

---

**Being good** wrt. to a certain metric is (in general) not an asset on its own. We usually want to optimise wrt. **goals**, not wrt. **metrics**.

In particular critical: pseudo-metrics for quality.

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Software and process measurements may yield **personal data** (“personenbezogene Daten”). Their collection may be regulated by laws.
Example: A Metric for Maintainability

- **Goal:** assess **maintainability**.
- **One approach:** grade the following aspects, e.g., with scale $S = \{0, \ldots, 10\}$.

(Some aspects may be objective, some subjective (conduct review))

**Norm Conformance**
- $n_1$: size of units (modules etc.)
- $n_2$: labelling
- $n_3$: naming of identifiers
- $n_4$: design (layout)
- $n_5$: separation of literals
- $n_6$: style of comments

**Locality**
- $l_1$: use of parameters
- $l_2$: information hiding
- $l_3$: local flow of control
- $l_4$: design of interfaces

**Readability**
- $r_1$: data types
- $r_2$: structure of control flow
- $r_3$: comments

**Testability**
- $t_1$: test driver
- $t_2$: test data
- $t_3$: preparation for test evaluation
- $t_4$: diagnostic components
- $t_5$: dynamic consistency checks

**Typing**
- $y_1$: type differentiation
- $y_2$: type restriction

**Define:** $m = \frac{n_1 + \ldots + y_2}{20}$ (with weights: $m_g = \frac{g_1 \cdot n_1 + \ldots + g_20 \cdot y_2}{G}$, $G = \sum_{i=1}^{20} g_i$).

**Procedure:**
- Train reviewers on existing examples.
- Do not over-interpret results of first applications.
- Evaluate and adjust before putting to use, adjust regularly.

(Ludewig and Lichter, 2013)
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**Development of a pseudo-metrics:**

(i) Identify **aspect** to be represented.
(ii) Devise a **model** of the aspect.
(iii) Fix a **scale** for the metric.
(iv) Develop a **definition** of the pseudo-metric, i.e., how to compute the metric.
(v) Develop **base measures** for all parameters of the definition.
(vi) **Apply and improve** the metric.

**Define:**
\[
m = \frac{n_1 + \cdots + n_k + y_2}{20}
\]
(with weights: \( m_g = \frac{g_1 \cdot n_1 + \cdots + g_{20} \cdot y_2}{G} \), \( G = \sum_{i=1}^{20} g_i \)).

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(Ludewig and Lichter, 2013)
And Which Metrics Should One Use?

Often useful: collect some basic measures **in advance** (in particular if collection is cheap / automatic), e.g.:

- **size**…
  - … of newly **created** and **changed code**, etc.
    - (automatically provided by revision control software),

- **effort**…
  - … for **coding**, **review**, **testing**, **verification**, **fixing**, **maintenance**, etc.

- **errors**…
  - … at least errors **found** during quality assurance, and errors **reported** by customer
    - (can be recorded via standardised revision control messages)
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LOC and changed lines over time (obtained by `statsvn`):

```
/teaching/swt/swtvl:Lines of Code and Churn Level

LOC and changed lines over time (obtained by `statsvn`).
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*Measures derived* from such basic measures may indicate problems ahead early enough and buy time to take appropriate counter-measures. E.g., track

- error rate per release, error density (errors per LOC),
- average effort for error detection and correction,
- etc.

over time. In case of unusual values: investigate further (maybe using additional metrics).
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“(Software) Economics in a Nutshell”
“Next to ‘Software’, ‘Costs’ is one of the terms occurring most often in this book.”

Ludewig and Lichter (2013)

A first approximation:

<table>
<thead>
<tr>
<th>cost ('Kosten')</th>
<th>all disadvantages of a solution</th>
</tr>
</thead>
<tbody>
<tr>
<td>benefit ('Nutzen') (or: negative costs)</td>
<td>all benefits of a solution.</td>
</tr>
</tbody>
</table>

Note: costs / benefits can be subjective – and not necessarily quantifiable in terms of money...

Super-ordinate goal of many projects:

- **Minimize overall costs**, i.e. maximise difference between benefits and costs.
  (Equivalent: minimize sum of positive and negative costs.)
The benefit of a software is determined by the advantages achievable using the software; it is influenced by:

- the degree of coincidence between product and requirements,
- additional services, comfort, flexibility etc.

Some other examples of cost/benefit pairs: (inspired by Jones (1990))

<table>
<thead>
<tr>
<th>Costs</th>
<th>Possible Benefits</th>
</tr>
</thead>
<tbody>
<tr>
<td>Labor during development (e.g., develop new test machinery)</td>
<td>Use of result (e.g., faster testing)</td>
</tr>
<tr>
<td>New equipment (purchase, maintenance, depreciation)</td>
<td>Better equipment (maintenance; maybe revenue from selling old)</td>
</tr>
<tr>
<td>New software purchases</td>
<td>(Other) use of new software</td>
</tr>
<tr>
<td>Conversion from old system to new</td>
<td>Improvement of system, maybe easier maintenance</td>
</tr>
<tr>
<td>Increased data gathering</td>
<td>Increased control</td>
</tr>
<tr>
<td>Training for employees</td>
<td>Increased productivity</td>
</tr>
</tbody>
</table>
Distinguish **current cost** (‘laufende Kosten’), e.g.
- wages,
- (business) **management**, **marketing**,
- **rooms**,
- **computers, networks, software** as part of infrastructure,
- ...

and **project-related cost** (‘projektbezogene Kosten’), e.g.
- additional **temporary personnel**,
- **contract costs**,
- **expenses**,
- **hardware and software** as part of product or system,
- ...

\[ egin{align*}
\text{business administration} \\
\text{project leader involved}
\end{align*} \]
Software Costs in a Narrower Sense

- **Software costs**
  - net production
  - quality costs
    - error prevention costs
    - analyse-and-fix costs
      - quality assurance
    - error costs
      - error localisation costs
      - error removal costs
        - during and after development
      - error caused costs (in operation)
    - maintenance (without quality)
  - decreased benefit

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**Software Engineering** — the establishment and use of sound engineering principles to obtain economically software that is reliable and works efficiently on real machines.

*F. L. Bauer (1971)*
Cost Estimation
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**Lastenheft (Requirements Specification)** Vom Auftraggeber festgelegte Gesamtheit der Forderungen an die Lieferungen und Leistungen eines Auftragnehmers innerhalb eines Auftrages.
(Entire demands on deliverables and services of a developer within a contracted development, created by the customer.)

**Pflichtenheft (Feature Specification)** Vom Auftragnehmer erarbeitete Realisierungsvorgaben aufgrund der Umsetzung des vom Auftraggeber vorgegebenen Lastenhefts.
(Specification of how to realise a given requirements specification, created by the developer.)

**Developer can help with writing** the requirements specification, in particular if customer is lacking technical background.

**One way of getting the feature specification:** a pre-project (may be subject of a designated contract).

*Tricky* one and the same content can serve both purposes; then only the title defines the purpose.
The “Estimation Funnel”

Uncertainty with estimations (following (Boehm et al., 2000), p. 10).

Visualisation: Ludewig and Lichter (2013)
Expert’s Estimation
One approach: the Delphi method.

- Step 1: write down your estimates!

- Step 2: show your estimates and explain!

- Step 3: estimate again!

- Then take the median, for example.
Algorithmic Estimation
Assume:

- Projects $P_1, \ldots, P_5$ took place in the past,
- Sizes $S_i$, costs $C_i$, and kinds $k_i$ ($0 = \text{blue-ish}, 1 = \text{yellow-ish}$) have been measured and recorded.

Question: What is the cost of the new project $P_6$?

Approach:

(i) Try to find a function $f$ such that $f(S_i, k_i) = C_i$, for $1 \leq i \leq 5$.
(ii) Estimate size $\tilde{S}_6$ and kind $\tilde{k}_6$.
(iii) Estimate cost $C_6$ as $\tilde{C}_6 = f(\tilde{S}_6, \tilde{k}_6)$.

(In the artificial example above, $f(S, k) = S \cdot 1.8 + k \cdot 0.3$ would work, i.e. if $P_6$ is of kind yellow (thus $\tilde{k}_6 = 1$) and size estimate is $\tilde{S}_6 = 2.7$ then estimate $C_6$ as $f(\tilde{S}_6, \tilde{k}_6) = 5.16$.)
**Algorithmic Estimation: Principle**

**Approach, more general:**

(i) **Identify** (measurable) factors $F_1, \ldots, F_n$ which influence overall cost, like size in LOC.

(ii) Take a big sample of data from previous projects.

(iii) Try to **come up with a formula** $f$ such that $f(F_1, \ldots, F_n)$ matches previous costs.

(iv) **Estimate** values for $F_1, \ldots, F_n$ for a new project.

(v) **Take** $f(\tilde{F}_1, \ldots, \tilde{F}_n)$ as cost estimate $\tilde{C}$ for the new project.

(vi) Conduct new project, **measure** $F_1, \ldots, F_n$ and cost $C$.

(vii) **Adjust** $f$ if $C$ is too different from $\tilde{C}$.

**Note:**

- The need for (expert’s) estimation does not go away: one needs to estimate $\tilde{F}_1, \ldots, \tilde{F}_n$.
- Rationale: it is often easier to estimate **technical aspects** than to estimate cost directly.
Algorithmic Estimation: COCOMO
Algorithmic Estimation: COCOMO

- **Constructive Cost Model:**
  Formulae which fit a huge set of archived project data (from the late 70’s).

- **Flavours:**
  - COCOMO 81 (Boehm, 1981): variants **basic, intermediate, detailed**
  - COCOMO II (Boehm et al., 2000)

- All flavours are based on estimated program size $S$ measured in DSI (Delivered Source Instructions) or kDSI (1000 DSI).

- Factors like security requirements or experience of the project team are mapped to values for parameters of the formulae.

- COCOMO examples:
  - textbooks like Ludewig and Lichter (2013) (most probably made up)
  - an exceptionally large example: COCOMO 81 for the Linux kernel (Wheeler, 2006) (and follow-ups)
## Characteristics of the Type

<table>
<thead>
<tr>
<th>Size</th>
<th>Innovation</th>
<th>Deadlines/Constraints</th>
<th>Dev. Environment</th>
<th>a</th>
<th>b</th>
<th>Software Project Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Small (&lt;50 KLOC)</td>
<td>Little</td>
<td>Not tight</td>
<td>Stable</td>
<td>3.2</td>
<td>1.05</td>
<td>Organic</td>
</tr>
<tr>
<td>Medium (&lt;300 KLOC)</td>
<td>Medium</td>
<td>Medium</td>
<td>Medium</td>
<td>3.0</td>
<td>1.12</td>
<td>Semi-detached</td>
</tr>
<tr>
<td>Large</td>
<td>Greater</td>
<td>Tight</td>
<td>Complex HW/Interfaces</td>
<td>2.8</td>
<td>1.20</td>
<td>Embedded</td>
</tr>
</tbody>
</table>

### Basic COCOMO:

- **effort required:** \( E = a \cdot \left(\frac{S}{kDSI}\right)^b \) [PM (person-months)]
- **time to develop:** \( T = c \cdot E^d \) [months]
- **headcount:** \( H = E/T \) [FTE (full time employee)]
- **productivity:** \( P = S/E \) [DSI per PM] (← use to check for plausibility)

### Intermediate COCOMO:

\[
E = M \cdot a \cdot \left(\frac{S}{kDSI}\right)^b \quad \text{[person-months]}
\]

\[
M = \text{RELY} \cdot \text{CPLX} \cdot \text{TIME} \cdot \text{ACAP} \cdot \text{PCAP} \cdot \text{LEXP} \cdot \text{TOOL} \cdot \text{SCED}
\]
COCOMO 81: Some Cost Drivers

\[ M = \text{RELY} \cdot \text{CPLX} \cdot \text{TIME} \cdot \text{ACAP} \cdot \text{PCAP} \cdot \text{LEXP} \cdot \text{TOOL} \cdot \text{SCED} \]

<table>
<thead>
<tr>
<th>factor</th>
<th>very low</th>
<th>low</th>
<th>normal</th>
<th>high</th>
<th>very high</th>
<th>extra high</th>
</tr>
</thead>
<tbody>
<tr>
<td>RELY required software reliability</td>
<td>0.75</td>
<td>0.88</td>
<td>1</td>
<td>1.15</td>
<td>1.40</td>
<td></td>
</tr>
<tr>
<td>CPLX product complexity</td>
<td>0.70</td>
<td>0.85</td>
<td>1</td>
<td>1.15</td>
<td>1.30</td>
<td>1.65</td>
</tr>
<tr>
<td>TIME execution time constraint</td>
<td></td>
<td></td>
<td>1</td>
<td>1.11</td>
<td>1.30</td>
<td>1.66</td>
</tr>
<tr>
<td>ACAP analyst capability</td>
<td>1.46</td>
<td>1.19</td>
<td>1</td>
<td>0.86</td>
<td>0.71</td>
<td></td>
</tr>
<tr>
<td>PCAP programmer capability</td>
<td>1.42</td>
<td>1.17</td>
<td>1</td>
<td>0.86</td>
<td>0.7</td>
<td></td>
</tr>
<tr>
<td>LEXP programming language experience</td>
<td>1.14</td>
<td>1.07</td>
<td>1</td>
<td>0.95</td>
<td></td>
<td></td>
</tr>
<tr>
<td>TOOL use of software tools</td>
<td>1.24</td>
<td>1.10</td>
<td>1</td>
<td>0.91</td>
<td>0.83</td>
<td></td>
</tr>
<tr>
<td>SCED required development schedule</td>
<td>1.23</td>
<td>1.08</td>
<td>1</td>
<td>1.04</td>
<td>1.10</td>
<td></td>
</tr>
</tbody>
</table>

- **Note:** what, e.g., “extra high” TIME means, may depend on project context. (Consider data from previous projects.)
COCOMO II (Boehm et al., 2000)

Consists of

- **Application Composition Model** — project work is configuring components, rather than programming
- **Early Design Model**  — adaption of Function Point approach (in a minute); does not need completed architecture design
- **Post-Architecture Model** — improvement of COCOMO 81; needs completed architecture design, and size of components estimatable
COCOMO II: Post-Architecture

\[ E = 2.94 \cdot S^X \cdot M \]

- **Program size**: \( S = (1 + REVL) \cdot (S_{\text{new}} + S_{\text{equiv}}) \)

- **requirements volatility** \( REVL \):
  e.g., if new requirements make 10% of code unusable, then \( REVL = 0.1 \)

- \( S_{\text{new}} \): estimated size minus size \( w \) of re-used code,

- \( S_{\text{equiv}} = w/q \), if writing new code takes \( q \)-times the effort of re-use.

- **Scaling factors**:
  \[ X = \delta + \omega, \quad \omega = 0.91, \quad \delta = \frac{1}{100} \cdot (\text{PREC} + \text{FLEX} + \text{RESL} + \text{TEAM} + \text{PMAT}) \]

<table>
<thead>
<tr>
<th>factor</th>
<th>very low</th>
<th>low</th>
<th>normal</th>
<th>high</th>
<th>very high</th>
<th>extra high</th>
</tr>
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<tbody>
<tr>
<td>PREC</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>precedentness (experience with similar projects)</td>
<td>6.20</td>
<td>4.96</td>
<td>3.72</td>
<td>2.48</td>
<td>1.24</td>
<td>0.00</td>
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<tr>
<td>FLEX</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>development flexibility (development process fixed by customer)</td>
<td>5.07</td>
<td>4.05</td>
<td>3.04</td>
<td>2.03</td>
<td>1.01</td>
<td>0.00</td>
</tr>
<tr>
<td>RESL</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Architecture/risk resolution (risk management, architecture size)</td>
<td>7.07</td>
<td>5.65</td>
<td>4.24</td>
<td>2.83</td>
<td>1.41</td>
<td>0.00</td>
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<tr>
<td>TEAM</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Team cohesion (communication effort in team)</td>
<td>5.48</td>
<td>4.38</td>
<td>3.29</td>
<td>2.19</td>
<td>1.10</td>
<td>0.00</td>
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<tr>
<td>PMAT</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Process maturity (see CMMI)</td>
<td>7.80</td>
<td>6.24</td>
<td>4.69</td>
<td>3.12</td>
<td>1.56</td>
<td>0.00</td>
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</table>
**COCOMO II: Post-Architecture Cont’d**

\[ M = RELY \cdot DATA \cdot \cdots \cdot SCED \]

<table>
<thead>
<tr>
<th>group</th>
<th>factor</th>
<th>description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Product factors</strong></td>
<td>RELY</td>
<td>required software reliability</td>
</tr>
<tr>
<td></td>
<td>DATA</td>
<td>size of database</td>
</tr>
<tr>
<td></td>
<td>CPLX</td>
<td>complexity of system</td>
</tr>
<tr>
<td></td>
<td>RUSE</td>
<td>degree of development of reusable components</td>
</tr>
<tr>
<td></td>
<td>DOCU</td>
<td>amount of required documentation</td>
</tr>
<tr>
<td><strong>Platform factors</strong></td>
<td>TIME</td>
<td>execution time constraint</td>
</tr>
<tr>
<td></td>
<td>STOR</td>
<td>memory consumption constraint</td>
</tr>
<tr>
<td></td>
<td>PVOL</td>
<td>stability of development environment</td>
</tr>
<tr>
<td><strong>Team factors</strong></td>
<td>ACAP</td>
<td>analyst capability</td>
</tr>
<tr>
<td></td>
<td>PCAP</td>
<td>programmer capability</td>
</tr>
<tr>
<td></td>
<td>PCON</td>
<td>continuity of involved personnel</td>
</tr>
<tr>
<td></td>
<td>APEX</td>
<td>experience with application domain</td>
</tr>
<tr>
<td></td>
<td>PLEX</td>
<td>experience with development environment</td>
</tr>
<tr>
<td></td>
<td>LTEX</td>
<td>experience with programming language(s) and tools</td>
</tr>
<tr>
<td><strong>Project factors</strong></td>
<td>TOOL</td>
<td>use of software tools</td>
</tr>
<tr>
<td></td>
<td>SITE</td>
<td>degree of distributedness</td>
</tr>
<tr>
<td></td>
<td>SCED</td>
<td>required development schedule</td>
</tr>
</tbody>
</table>

(Also in COCOMO 81, new in COCOMO II)
Algorithmic Estimation: Function Points
## Algorithmic Estimation: Function Points

### Complexity Sum

<table>
<thead>
<tr>
<th>Type</th>
<th>Complexity</th>
<th>Sum</th>
</tr>
</thead>
<tbody>
<tr>
<td>input</td>
<td>low</td>
<td>medium</td>
</tr>
<tr>
<td>output</td>
<td></td>
<td></td>
</tr>
<tr>
<td>query</td>
<td></td>
<td></td>
</tr>
<tr>
<td>user data</td>
<td></td>
<td></td>
</tr>
<tr>
<td>reference data</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Type</th>
<th>Complexity</th>
<th>Sum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unadjusted function points</td>
<td>UFP</td>
<td></td>
</tr>
<tr>
<td>Value adjustment factor</td>
<td>VAF</td>
<td></td>
</tr>
<tr>
<td>Adjusted function points</td>
<td>AFP = UFP · VAF</td>
<td></td>
</tr>
</tbody>
</table>

\[
VAF = 0.65 + \frac{1}{100} \cdot \sum_{i=1}^{14} GSC_i, \\
0 \leq GSC_i \leq 5.
\]
Algorithmic Estimation: Function Points

<table>
<thead>
<tr>
<th>Type</th>
<th>Complexity</th>
<th>Value adjustment factor</th>
<th>Unadjusted function points</th>
<th>Value adjustment factor</th>
<th>Adjusted function points</th>
</tr>
</thead>
<tbody>
<tr>
<td>input</td>
<td>low</td>
<td>·3 =</td>
<td>·10 =</td>
<td></td>
<td>AFP = UFP · VAF</td>
</tr>
<tr>
<td>output</td>
<td>medium</td>
<td>·4 =</td>
<td>·10 =</td>
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</tr>
<tr>
<td>query</td>
<td>medium</td>
<td>·3 =</td>
<td>·4 =</td>
<td></td>
<td></td>
</tr>
<tr>
<td>user data</td>
<td>high</td>
<td>·7 =</td>
<td>·10 =</td>
<td></td>
<td></td>
</tr>
<tr>
<td>reference data</td>
<td>high</td>
<td>·5 =</td>
<td>·7 =</td>
<td>·10 =</td>
<td></td>
</tr>
</tbody>
</table>

IBM and VW curve for the conversion from AFPs to PM according to (Noth and Kretzschmar, 1984) and (Knöll and Busse, 1991).

\[
VAF = 0.65 + \frac{1}{100} \cdot \sum_{i=1}^{14} GSC_i, \quad 0 \leq GSC_i \leq 5.
\]
COCOMO vs. Function Points
Ludewig and Lichter (2013) says:

- **Function Point** approach used in practice, in particular for **commercial software** (business software?).

- **COCOMO** tends to **overestimate** in this domain; needs to be adjusted by corresponding factors.

In the end, it’s **experience, experience, experience:**

“Estimate, document, estimate better.” (Ludewig and Lichter, 2013)

**Suggestion:** start to explicate your experience **now**.

- **Take notes on your projects:**
  (e.g., Softwarepraktikum, Bachelor Projekt, Master Bacherlor’s Thesis, Master Projekt, Master’s Thesis, …)
  - timestamps, size of program created, number of errors found, number of pages written, …

- **Try to identify factors:** what hindered productivity, what boosted productivity, …

- Which **detours and mistakes** were **avoidable** in hindsight? How?
Tell Them What You’ve Told Them…

- **Goal-Question-Metric** approach:
  - Define goals, derive questions, choose metrics.
  - Evaluate and adjust.

  Recall: It's about the **goal**, not the metrics.

- For **software costs**, we can distinguish
  - net production, quality costs, maintenance.

  **Software engineering** is about being **economic** in all three aspects.

- Why estimate?
  - **Requirements specification** (‘Lastenheft’)
  - **Feature specification** (‘Pflichtenheft’)

  The latter (plus budget) is usually part of **software contracts**.

- Approaches:
  - **Expert’s Estimation**
  - **Algorithmic Estimation**: COCOMO, Function Points
    → estimate cost **indirectly**, by estimating more **technical aspects**.

  In the end, it’s **experience** (and **experience** (and **experience**)).
References
References


