# *Softwaretechnik / Software-Engineering*

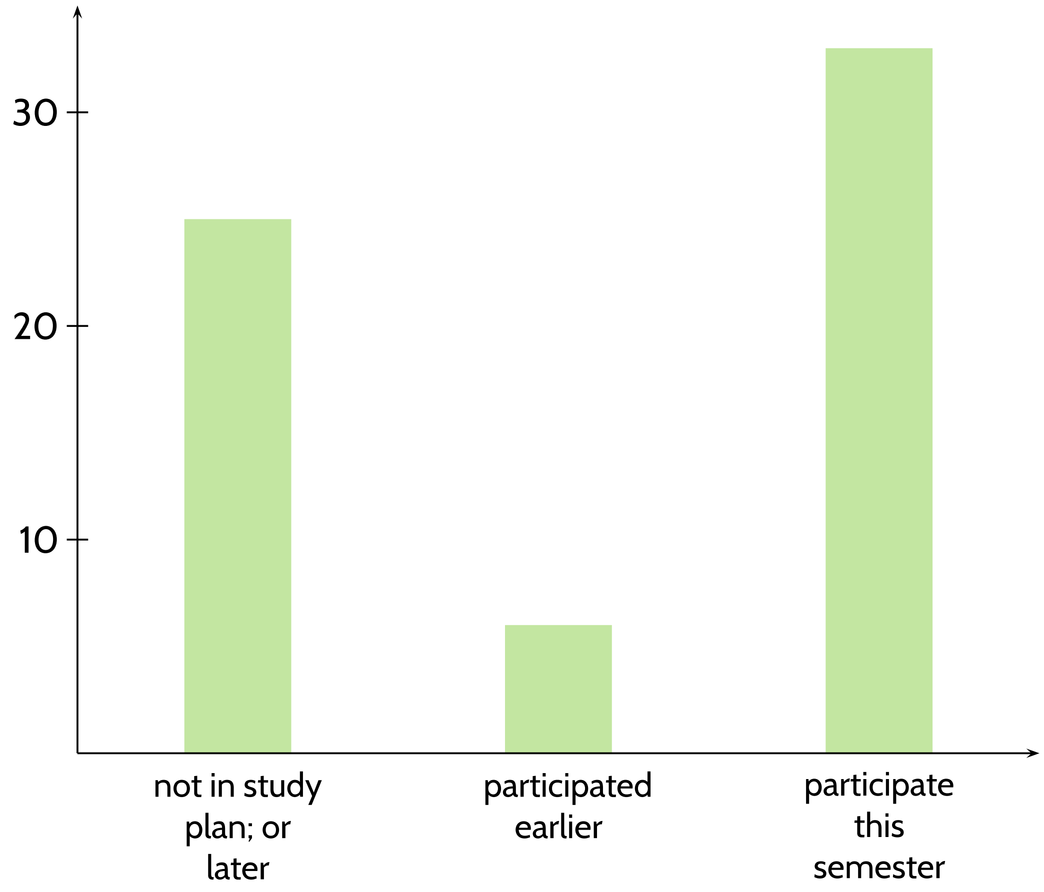
# *Lecture 3: More Metrics & Cost Estimation*

*2018-04-23*

Prof. Dr. Andreas Podelski, **Dr. Bernd Westphal**

Albert-Ludwigs-Universität Freiburg, Germany

# *Survey: Softwarepraktikum*



# Topic Area Project Management: Content

VL 2 ⋮ VL 3 ⋮ VL 4 ⋮ VL 5 ⋮

- **Software Metrics**
  - Properties of Metrics
  - Scales
  - Examples
- **Cost Estimation**
  - "(Software) Economics in a Nutshell"
  - Expert's Estimation
  - Algorithmic Estimation
- **Project Management**
  - Project
  - Process and Process Modelling
  - Procedure Models
  - Process Models
- **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*

| | objective metric | pseudo metric | subjective metric |
|---|---|---|---|
| **Procedure** | measurement, counting, possibly standardised | computation (based on measurements or assessment) | review by inspector, verbal or by given scale |
| **Example, general** | body height, air pressure | body mass index (BMI), weather forecast for the next day | health condition, weather condition ("bad weather") |
| **Example in Software Engineering** | size in LOC or NCSI; number of (known) bugs | productivity; cost estimation by COCOMO | usability; severeness of an error |
| **Usually used for** | collection of simple base measures | predictions (cost estimation); overall assessments | quality assessment; error weighting |
| **Advantages** | exact, reproducible, can be obtained automatically | yields relevant, directly usable statement on not directly visible characteristics | not subvertable, plausible results, applicable to complex characteristics |
| **Disadvantages** | not always relevant, often subvertable, no interpretation | hard to comprehend, pseudo-objective | assessment costly, quality of results depends on inspector |

(Ludewig and Lichter, 2013)

# *Pseudo-Metrics*

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:

| | differentiated | comparable | reproducible | available | relevant | economical | plausible | robust |
|---|---|---|---|---|---|---|---|---|
| **Expert review**, grading | (✔) | (✔) | (✘) | (✔) | ✔! | (✘) | ✔ | ✔ |
| **Pseudo-metrics**, derived measures | ✔ | ✔ | ✔ | ✔ | ✔! | ✔ | ✘ | ✘ |

**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).

# *Kinds of Metrics: by Measurement Procedure*

| | objective metric | pseudo metric | subjective metric |
|---|---|---|---|
| **Procedure** | measurement, counting, possibly standardised | computation (based on measurements or assessment) | review by inspector, verbal or by given scale |
| **Advantages** | exact, reproducible, can be obtained automatically | yields relevant, directly usable statement on not directly visible characteristics | not subvertable, plausible results, applicable to complex characteristics |
| **Disadvantages** | not always relevant, often subvertable, no interpretation | hard to comprehend, pseudo-objective | assessment costly, quality of results depends on inspector |
| **Example, general** | body height, air pressure | body mass index (BMI), weather forecast for the next day | health condition, weather condition ("bad weather") |
| **Example in Software Engineering** | size in LOC or NCSI; number of (known) bugs | productivity; cost estimation by COCOMO | usability; severeness of an error |
| **Usually used for** | collection of simple base measures | predictions (cost estimation); overall assessments | quality assessment; error weighting |

(Ludewig and Lichter, 2013)

# *Subjective Metrics*

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

(Ludewig and Lichter, 2013)

# *The Goal-Question-Metric Approach*

# *Information Overload!?*

Now we have mentioned **nearly** $60$ attributes one could measure…

Which ones **should** we measure?

**It depends**…

relevant plausible available differentiated economical comparable reproducible robust

One approach: **Goal-Question-Metric** (GQM).

# *Goal-Question-Metric (Basili and Weiss, 1984)*

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.

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 $S = \{0, \dots, 10\}$.

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

# Example: A Metric for Maintainability

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

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

**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.

- **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**
  - $t_2$: 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**: $m = \frac{n_1 + \dots + y_2}{20}$ (**with weights**: $m_g = \frac{g_1 \cdot n_1 + \dots + g_{20} \cdot y_2}{G}$, $G = \sum_{i=1}^{20} g_i$).
- **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)

# *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)

# *And Which Metrics Should One Use?*

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

- **size**…

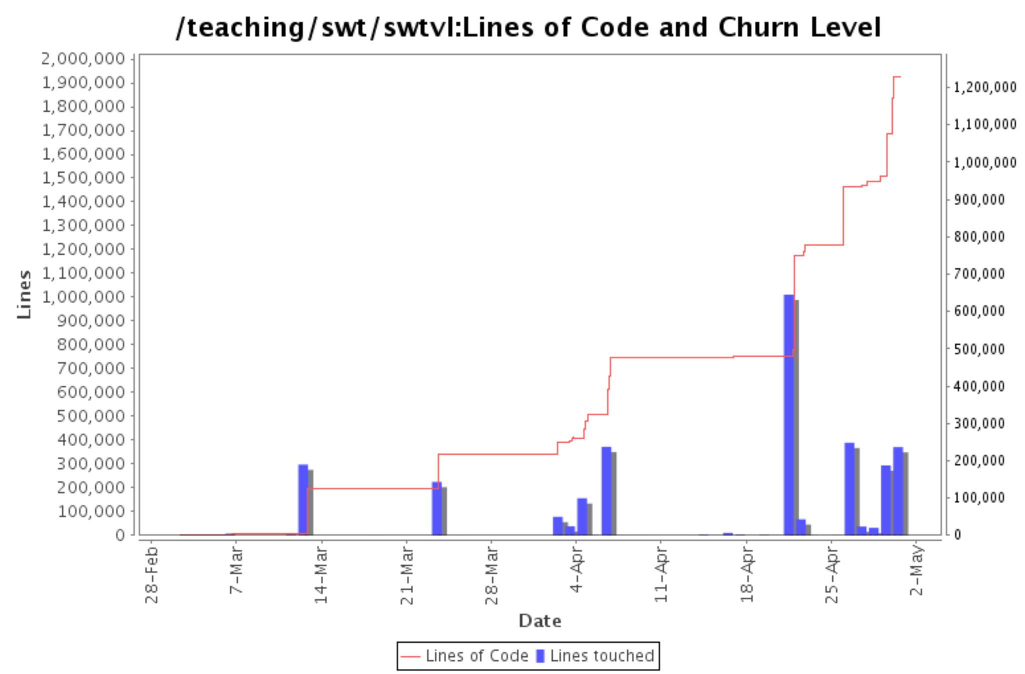
  … of newly **created** and **changed code**, etc.
  (automatically provided by revision control software),

- **effort**…

  … for **coding**, **review**, **testing**, **verificatio**

- **errors**…

  … at least errors **found** during quality ass
  (can be recorded via standardised revi




LOC and changed lines over time (obtained by `statsvn`(1)).

# *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)

**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).

# *And Which Metrics Should One Use?*

Often useful: collect some basic meas
(in particular if collection is cheap / aut

- **size**…

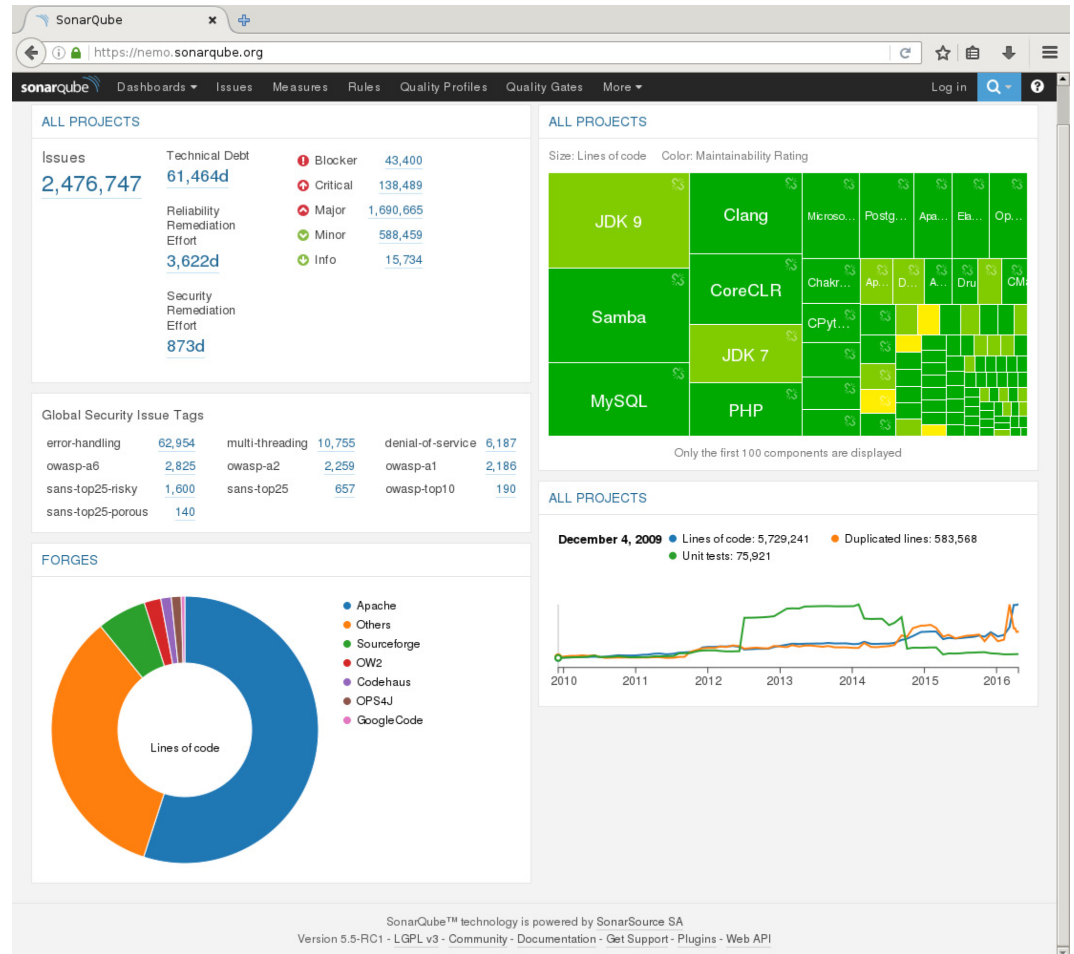
  … of newly **created** and **changed code**, e
  (automatically provided by revision co

- **effort**…

  … for **coding**, **review**, **testing**, **verificatio**

- **errors**…

  … at least errors **found** during quality ass
  (can be recorded via standardised revi




Tool support for software metrics, e.g., SonarCube.

**Measures derived** from such basic me
and buy time to take appropriate coun

- **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).

# Content

# 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 |
| VL 5 | Process Models |
| | **Process Metrics** |
| ⋮ | CMMI, Spice |

# Content

*“(Software) Economics in a Nutshell”*

# Costs

"Next to '**Software**', '**Costs**' is one of the terms occurring most often in this book."

Ludewig and Lichter (2013)

A first approximation:

| | |
|---|---|
| **cost** ('Kosten') | all disadvantages of a solution |
| **benefit** ('Nutzen')<br>(or: negative costs) | all benefits of a solution. |

**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.)

# *Costs vs. Benefits: A Closer Look*

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))

| Costs | Possible Benefits |
|---|---|
| Labor during development (e.g., develop new test machinery) | Use of result (e.g., faster testing) |
| New equipment (purchase, maintenance, depreciation) | Better equipment (maintenance; maybe revenue from selling old) |
| New software purchases | (Other) use of new software |
| Conversion from old system to new | Improvement of system, maybe easier maintenance |
| Increased data gathering | Increased control |
| Training for employees | Increased productivity |

# *Costs: Economics in a Nutshell*

Distinguish **current cost** ('laufende Kosten'), e.g.

- **wages**,
- (business) **management**, **marketing**,
- **rooms**,
- **computers**, **networks**, **software** as part of infrastructure,
- …

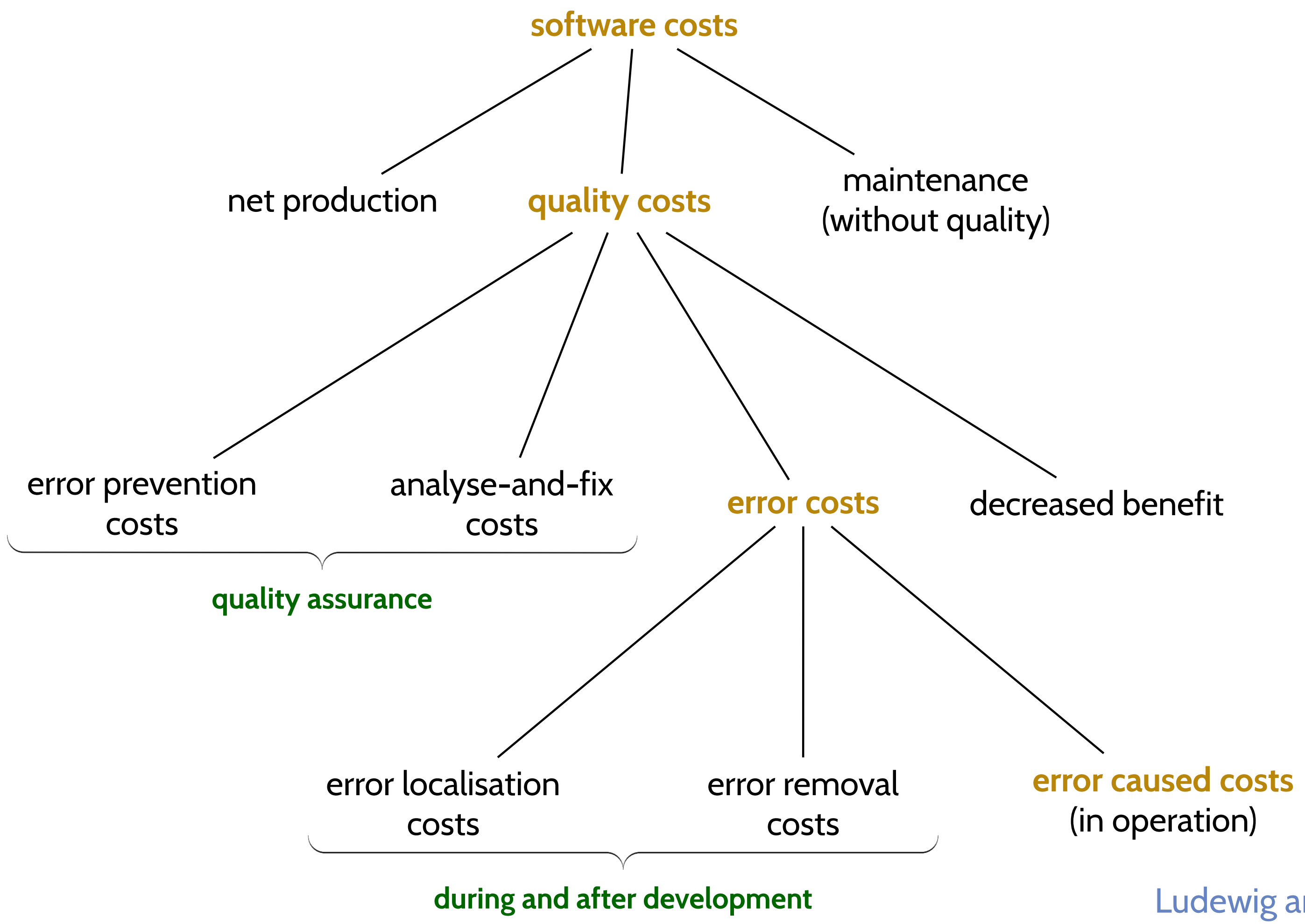
business administration

and **project-related cost** ('projektbezogene Kosten'), e.g.

- additional **temporary personnel**,
- **contract costs**,
- **expenses**,
- **hardware and software** as part of product or system,
- …

project leader involved

# *Software Costs in a Narrower Sense*




Ludewig and Lichter (2013)

**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)

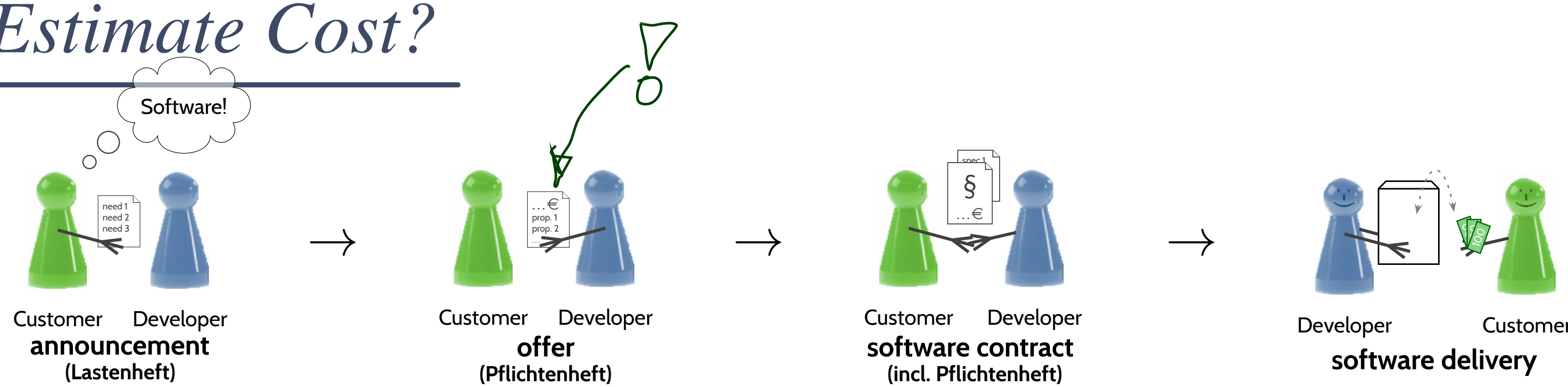
# *Cost Estimation*

# 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

# *Why Estimate Cost?*



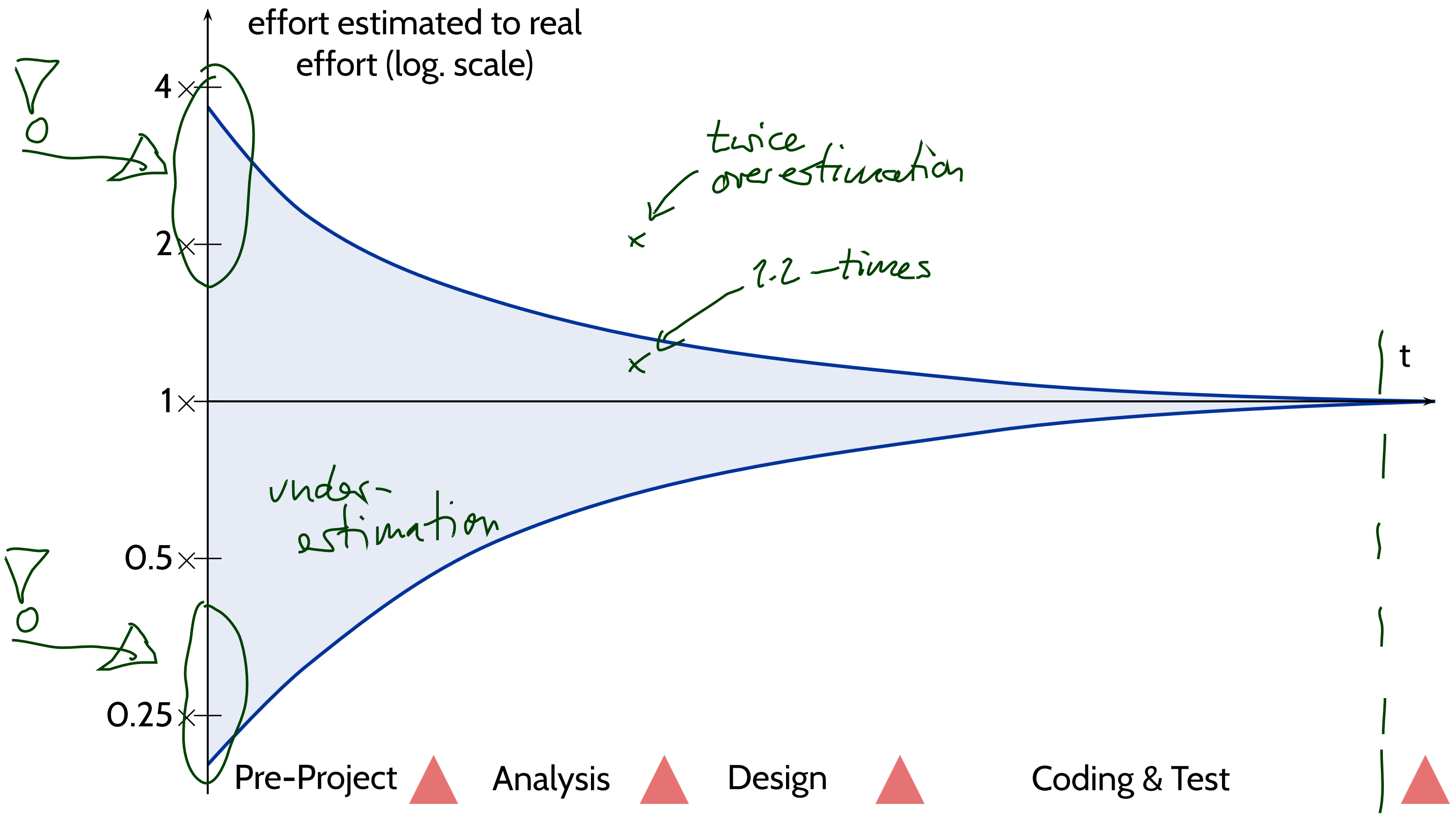

> **Lastenheft (Requirements Specification)** Vom Auftraggeber festgelegte Gesamtheit der Forderungen an die Lieferungen und Leistungen eines Auftragnehmers innerhalb eines Auftrages.
> (Entire demands on deliverables and services of a developer within a contracted development, created by the customer.)
> **DIN 69901-5 (2009)**

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

> **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.)
> **DIN 69901-5 (2009)**

- 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).

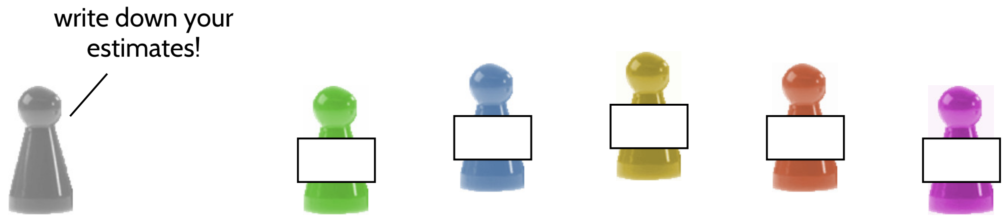
Visualisation: Ludewig and Lichter (2013)

*Expert's Estimation*

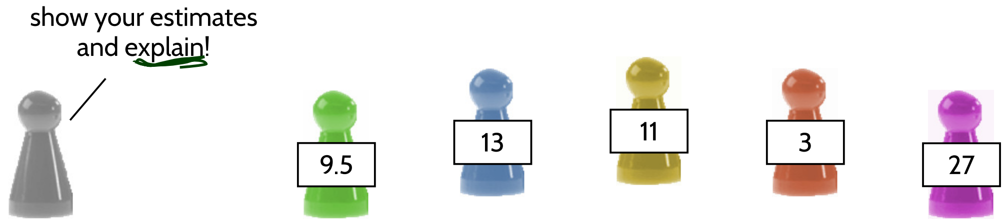
# *Expert's Estimation*

**One approach**: the **Delphi** method.

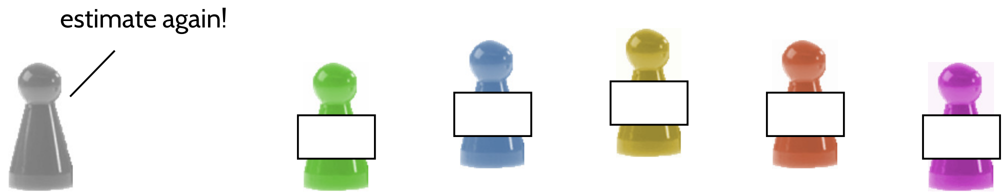
- Step 1:




- Step 2:



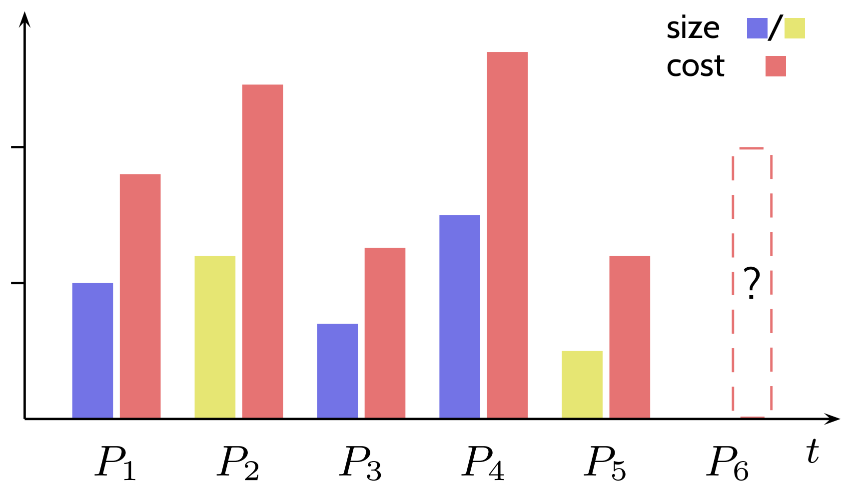

- Step 3:




- Then take the median, for example.

*Algorithmic Estimation*

# *Algorithmic Estimation: Principle*




**Assume**:

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

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

**Approach**:

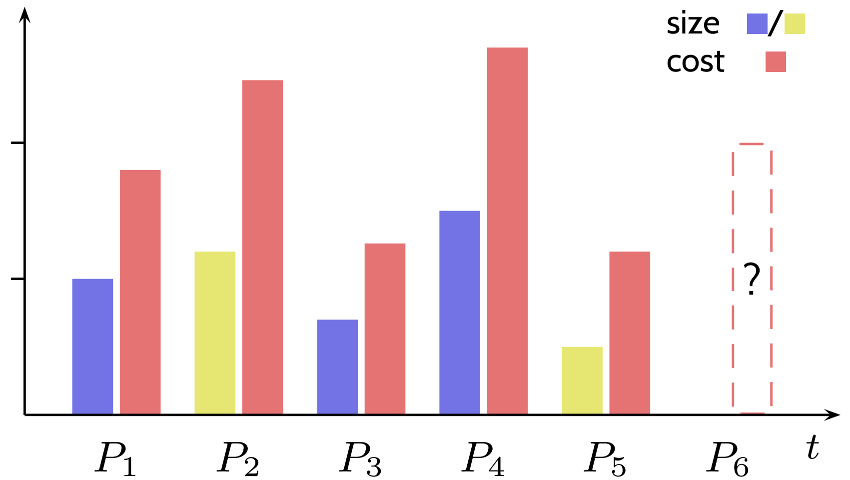
(i) Try to **find a function** $f$ such that $f(S_i, k_i) = C_i$, for $1 \leq i \leq 5$.

(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*

- **Co**nstructive **Co**st **Mo**del:

  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)

# COCOMO 81

| Characteristics of the Type | | | | a | b | Software Project Type |
|---|---|---|---|---|---|---|
| Size | Innovation | Deadlines/ Constraints | Dev. Environment | | | |
| Small (<50 KLOC) | Little | Not tight | Stable | 3.2 | 1.05 | Organic |
| Medium (<300 KLOC) | Medium | Medium | Medium | 3.0 | 1.12 | Semi-detached |
| Large | Greater | Tight | Complex HW/ Interfaces | 2.8 | 1.20 | Embedded |

**Basic COCOMO**:

estimated size

- **effort required**: $E = a \cdot (S/kDSI)^b$ [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**:

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

$$M = RELY \cdot CPLX \cdot TIME \cdot ACAP \cdot PCAP \cdot LEXP \cdot TOOL \cdot SCED$$

# COCOMO 81: Some Cost Drivers

$$M = RELY \cdot CPLX \cdot TIME \cdot ACAP \cdot PCAP \cdot LEXP \cdot TOOL \cdot SCED$$

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

- **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**: $S = (1 + REVL) \cdot (S_{new} + S_{equiv})$
  - **requirements volatility** $REVL$:
    e.g., if new requirements make 10% of code unusable, then $REVL = 0.1$
  - $S_{new}$: estimated size minus size $w$ of **re-used code**,
  - $S_{equiv} = w/q$, if writing new code takes $q$-times the effort of re-use.
- **Scaling factors**:
  $X = \delta + \omega, \quad \omega = 0.91, \quad \delta = \frac{1}{100} \cdot (PREC + FLEX + RESL + TEAM + PMAT)$

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

# COCOMO II: Post-Architecture Cont'd

$$M = RELY \cdot DATA \cdot \dots \cdot SCED$$

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

(also in COCOMO 81, new in COCOMO II)

# *Algorithmic Estimation: Function Points*

# *Algorithmic Estimation: Function Points*

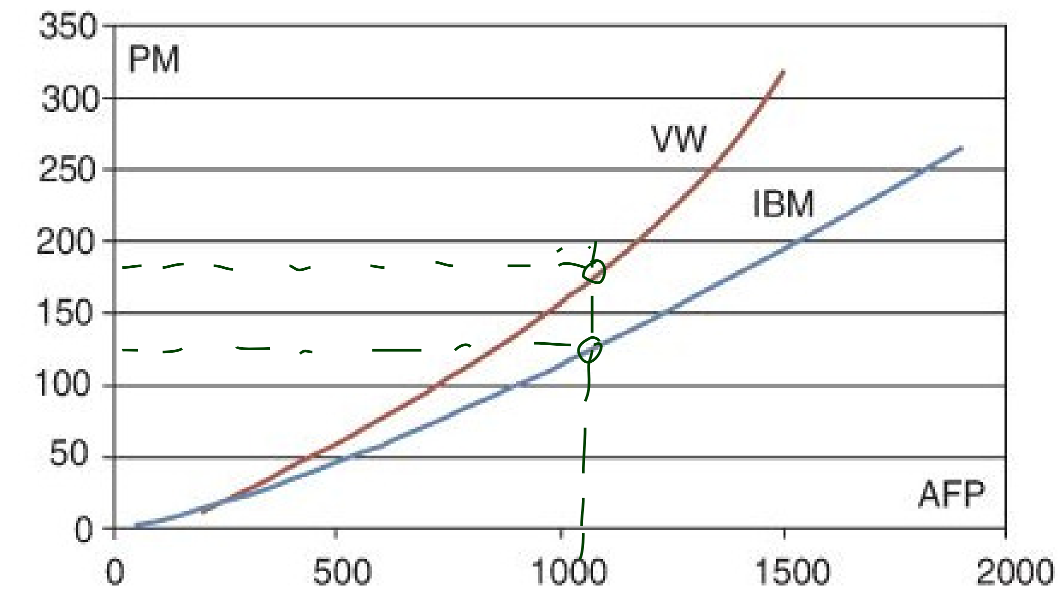
| Type | Complexity | | | Sum |
|---|---|---|---|---|
| | low | medium | high | |
| input | ____ $\cdot 3 =$ | ____ $\cdot 4 =$ | ____ $\cdot 6 =$ | |
| output | ____ $\cdot 4 =$ | ____ $\cdot 5 =$ | ____ $\cdot 7 =$ | |
| query | ____ $\cdot 3 =$ | ____ $\cdot 4 =$ | ____ $\cdot 6 =$ | |
| user data | ____ $\cdot 7 =$ | ____ $\cdot 10 =$ | ____ $\cdot 15 =$ | |
| reference data | ____ $\cdot 5 =$ | ____ $\cdot 7 =$ | ____ $\cdot 10 =$ | |
| Unadjusted function points | UFP | | | |
| Value adjustment factor | VAF | | | |
| Adjusted function points | AFP $=$ UFP $\cdot$ VAF | | | |

$$VAF = 0.65 + \frac{1}{100} \cdot \sum_{i=1}^{14} GSC_i,$$

$$0 \leq GSC_i \leq 5.$$

# *Algorithmic Estimation: Function Points*

| | Co | | | |
|---|---|---|---|---|
| **Type** | low | me | | |
| input | ____ $\cdot 3 =$ | ____ | | |
| output | ____ $\cdot 4 =$ | ____ | | |
| query | ____ $\cdot 3 =$ | ____ | | |
| user data | ____ $\cdot 7 =$ | ____ | | |
| reference data | ____ $\cdot 5 =$ | ____ $\cdot 7 =$ | ____ $\cdot 10 =$ | |
| Unadjusted function points | | UFP | | |
| Value adjustment factor | | VAF | | |
| Adjusted function points | | AFP $=$ UFP $\cdot$ VAF | | |




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

$$VAF = 0.65 + \frac{1}{100} \cdot \sum_{i=1}^{14} GSC_i,$$

$$0 \leq GSC_i \leq 5.$$

# *COCOMO vs. Function Points*

# *Discussion*

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
    $\rightarrow$ estimate cost **indirectly**, by estimating more **technical aspects**.

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

# *References*

# References


Basili, V. R. and Weiss, D. M. (1984). A methodology for collecting valid software engineering data. *IEEE Transactions of Software Engineering*, 10(6):728–738.

Bauer, F. L. (1971). Software engineering. In *IFIP Congress (1)*, pages 530–538.

Boehm, B. W. (1981). *Software Engineering Economics*. Prentice-Hall.

Boehm, B. W., Horowitz, E., Madachy, R., Reifer, D., Clark, B. K., Steece, B., Brown, A. W., Chulani, S., and Abts, C. (2000). *Software Cost Estimation with COCOMO II*. Prentice-Hall.

DIN (2009). *Projektmanagement; Projektmanagementsysteme*. DIN 69901-5.

Jones, G. W. (1990). *Software Engineering*. John Wiley & Sons.

Knöll, H.-D. and Busse, J. (1991). *Aufwandsschätzung von Software-Projekten in der Praxis: Methoden, Werkzeugeinsatz, Fallbeispiele*. Number 8 in Reihe Angewandte Informatik. BI Wissenschaftsverlag.

Ludewig, J. and Lichter, H. (2013). *Software Engineering*. dpunkt.verlag, 3. edition.

Noth, T. and Kretzschmar, M. (1984). *Aufwandsschätzung von DV-Projekten, Darstellung und Praxisvergleich der wichtigsten Verfahren*. Springer-Verlag.

Wheeler, D. A. (2006). Linux kernel 2.6: It's worth more!