Lecture 3: Measurement, concept, definition, fundamentals, representational theory of measurement

Measurement, concept, definition, fundamentals, representational theory of measurement

Content of the Lecture

- Introduction to measurements
- Theory of measurement in software
    - Representational condition
    - Measurement scales
    - Measurements and models

Introduction to Measurement (with an eye on Software Measures)

from Pressman Companion
Slides(chp 4)

Definition

Measurement is the process by which numbers or symbols are assigned to attributes of entities in the real world in such a way as to describe them according to clearly defined rules

N. Fenton and S. L. Pfleeger, 1997

Entities and Attributes

- Human being
- Apple
- Computer
- Computer
- Human being
- ...

- Name
- Weight
- Memory
- Hard Disk space
- Weight
- ...

Rules

- The LOC measure is obtained by counting all the lines that contain at least one character, and that do not contain comments.
- Interpretation: C Code?
- Visual BASIC 4 Code?

Why Measuring?

- Lack of measurable targets (Gilb's principle)
- Identification failure
- Lack of quality assurance
- Lack of consistent tool evaluation

The Measurement Advantage

Management

- Cost
- Productivity
- Quality
- User satisfaction
- Optimisation

Engineering

- Requirements testing
- Fault detection
- Meeting goals
- Forecasting

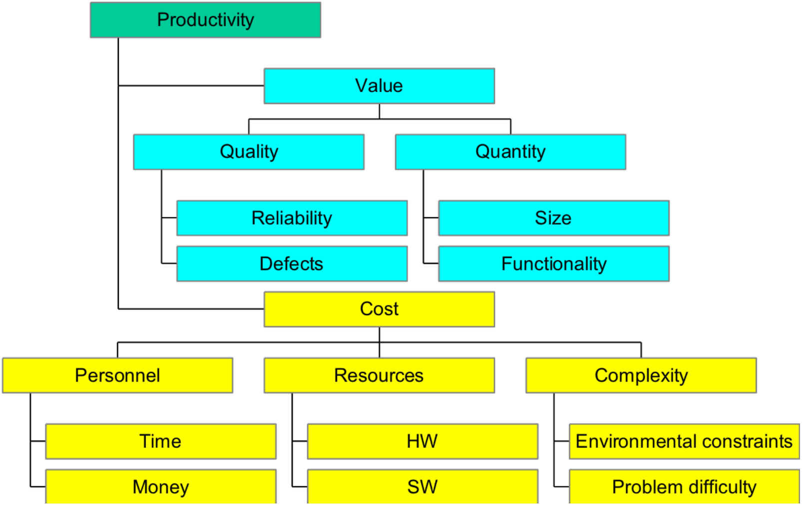
Scope of Measurement (partial list)

- Cost and effort estimation
- Productivity measures and models
- Data collection
- Quality models and measures
- Reliability models
- Performance evaluation and models
- Structural and complexity metrics
- Capability-maturity assessment
- Management by metrics
- Evaluation of methods and tools

Cost and Effort Estimation

- The aim is to predict project costs as early as possible
- Various models exist, expressing cost or effort as a function of size and/or other project attributes
- E.g., COCOMO (Boehm, 1981), COCOMO2 (Boehm, 1995), SLIM (Putnam, 1979), Function Points (Albrecht, 1979),

Productivity Model (Fig. 1.3 of FP, pag. 15)

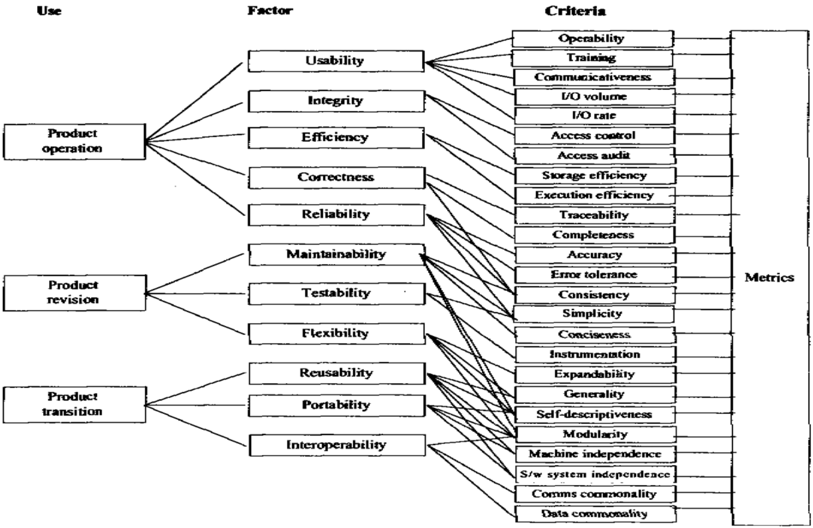


Data Collection

- Where
- How
- When

Should we collect software measurement data?

Quality Models and Measures



Reliability Models

- For how long will be our application up?
- Once we fix this failure, when the next failure will occur?

Performance Evaluation and Models

- Aspect of quality
- Include:
  - Response time
  - Average and worst case time complexity
  - Average and worst case space complexity
  - Required resources
  - ...

Structural and Complexity Metrics

- Describe inner properties of the system
- Examples include:
  - Weighted number of nested loops
  - Complexity of the program graph
  - Coupling between objects
  - ...

Management by Metrics

- Customers, developers, and managers can use software metrics to track the evolution of the project in terms of:
  - Hours spent
  - Required quality levels
  - Requests for new requirements
  - Work overtime
  - Quality of work

Evaluation of Methods and Tools

- New methods and tools can be very expensive for software companies both for:
  - Purchase / license
  - Training of employees
- It is therefore essential to have some systematic means to evaluate them (even if in most case this does not occur)
- Forms of experimental design help in defining proper structures for such studies

Capability Maturity Assessment

- Model of production maturity
- Ensures customers of capability of the development process (e.g., ISO 9000 uses the buzzwords "say what you do and do what you say")
- Provides paths for improvement
- Few exist ...

Proposed exercise (1/2)

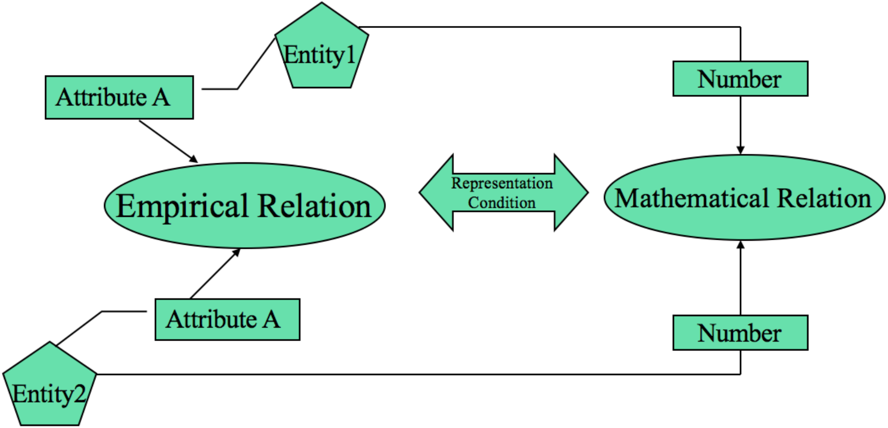
- Form groups of 3 people, with at least one data scientist and a software engineer in each group
- Send on Telegram your gmail account to the instructor
- For each category mentioned above, provide an example coming from your personal experience
- Write the results of the following spreadsheet: `http://tiny.cc/IU_EM_F20_L3`, in the tab: `GeneralExerciseOnMetrics`

Proposed exercise (2/2)

`http://tiny.cc/IU_EM_F20_L3`, tab: `GeneralExerciseOnMetrics`

Theory of Measurement

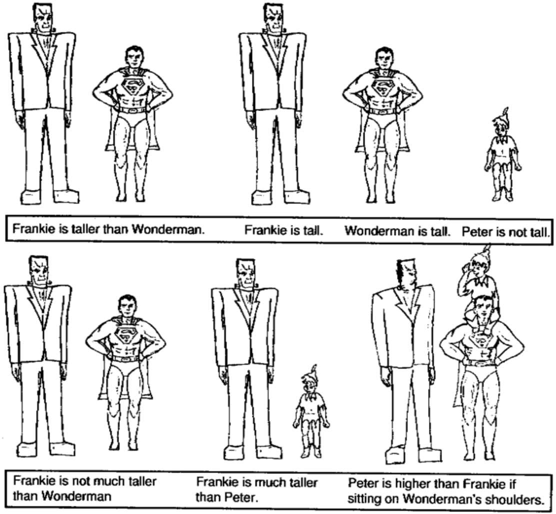
Set of rules to define measurement



Empirical Relations

- Links two entities by means of an attribute - e.g., Person (entity class) and height (attribute)
- Can be ambiguous - e.g., colour as perceived by human eye varies depending on subject measuring it
- Improves with the understanding of the attribute, and measures can foster improvement

Empirical Relations for the Attribute Height



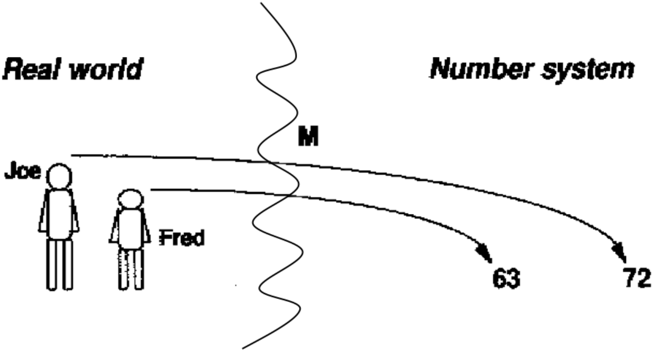
Measurement

To overcome these differences it is important to agree on:

- A **measurement** is a mapping from the empirical world to the formal, relational world
- A **measure** is the number or symbol assignment to an entity by this mapping in order to characterise an attribute

Fenton and Pfleeger, 1997

Measurement



from Fenton pg 31

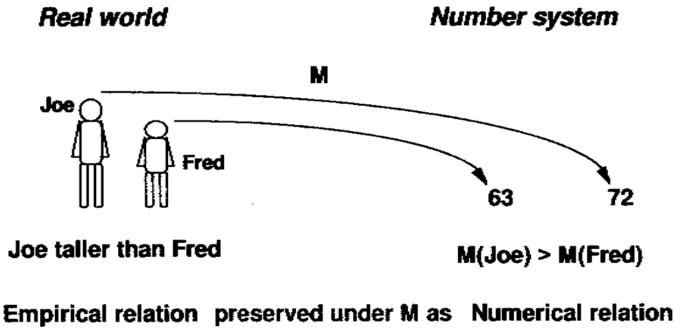
Representation Condition

- A measurement mapping must map entities into numbers and empirical relation into numerical relations that preserve them and vice-versa

Fenton and Pfleeger, 1997

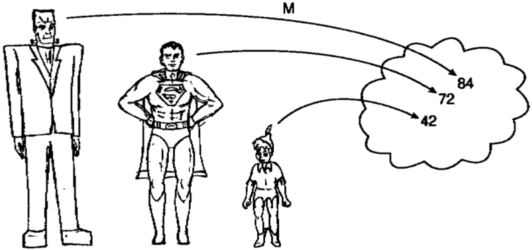
- **Valid** measure: satisfying the representation condition

Representation Condition



from Fenton pg 31

Measurement Mapping



from Fenton pg 32

A tall iff $M(A) > 70$
A taller than B iff $M(A) > M(B)$
A much taller than B iff $M(A) > M(B) + 20$

Role of the Representation Condition

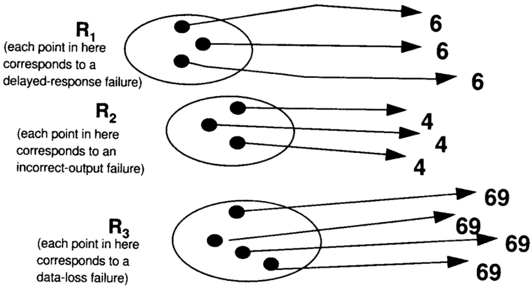


Figure 2.7: Measurement mapping

from Fenton pg 34

Alternative ...

$M(R1) = 3$

$M(R2) = 4$

$M(R3) = 5$

Your Example :)

Role of the Representation Condition

- Beware that properly defining the representational condition in true generality is far from easy
- Remember Gödel's Disjunction†: "Either the human mind (even within the realm of pure mathematics) can surpass the power of any finite computing machine, or there are absolutely undecidable mathematical problems"

† *Panu Raatikainen (2018) Gödel's Disjunction: The Scope and Limits of Mathematical Knowledge, History and Philosophy of Logic, DOI: 10.1080/01445340.2018.1495851*

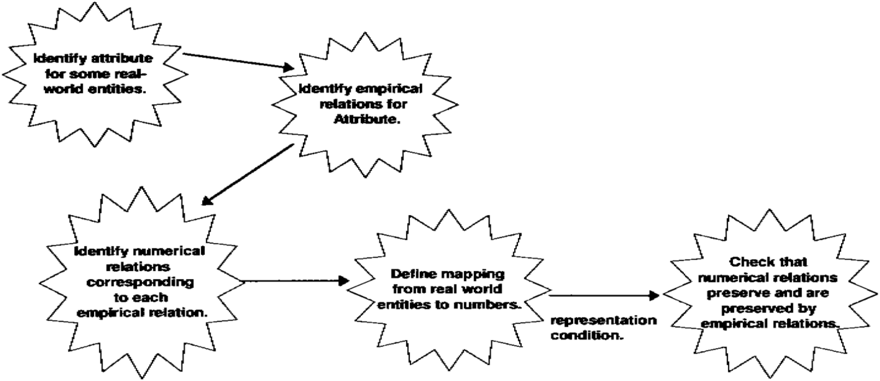
On the Representation Condition (1/2)

- The program started as a philosophical problem more than a century ago:
  - H. von Helmholtz, Zur Geschichte des Princips der kleinsten Action. Sitzungsberichte der Königlich Preussischen Akademie der Wissenschaften zu Berlin 14, 1887
  - O. Hölder, Die Axiome der Quantität und die Lehre vom Mass, Berichte über die Verhandlungen der Königliche Sachsischen Gesellschaft der Wissenschaften zu Leipzig, Matematisch-Physische Klasse 53, 1 – 64, 1901
- It has then evolved in a economical and mathematical problem:
  - R.D. Luce, Semiorders and a Theory of Utility Discrimination, Econometrica 24, 178 – 191, 1956
  - L. Fuchs, Partially Ordered Algebraic Systems, Addison Wesley, Reading, Massachusetts, 1963
  - D. Krantz, Extensive Measurement in Semiorders, Philosophy of Science 34, 348 – 62, 1967

On the Representation Condition (2/2)

- After, it has been considered in social sciences:
  - E.W. Holman, Strong and Weak Extensive Measurement, Journal of Mathematical Psychology 6, 286 – 293, 1969
  - A. Rutland, Measuring the zone of proximal development : studies of map-use in children with learning difficulties, PhD Dissertation, University of Stirling, 1993
  - F. Sani, J. Todman, Experimental Design and Statistics for Psychology: A First Course, John Wiley & Sons, Apr 15, 2008
- Fenton adopted it in Software Engineering more as a reference than as a full theory only much later

Key Stages of Formal Measurement



from Fenton pg 33

Questions ?

End of Lecture 3