Security Metrics
- a brief introduction

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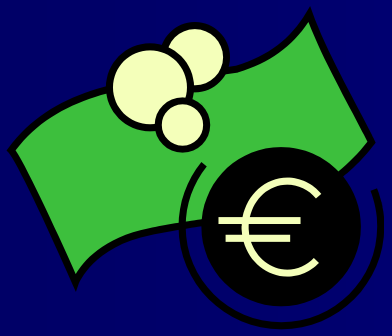
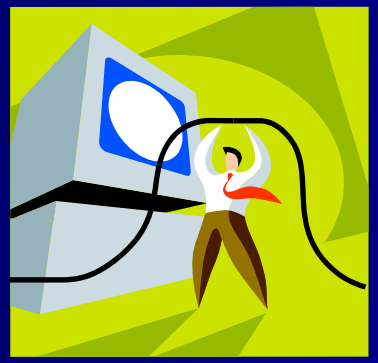
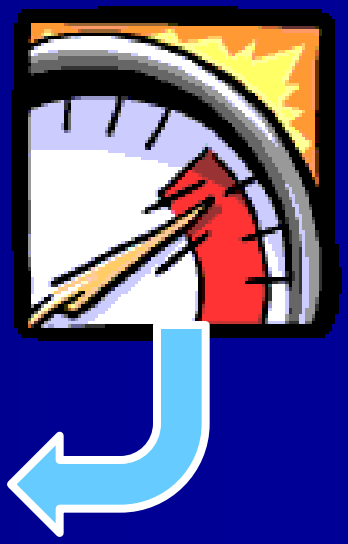
Motivation







Motivation

- Security is a major concern in computer-based systems, i.e. virtually ***all*** systems of today.
- It is good engineering practice to be able to verify/validate claimed performance. Obviously, this includes security performance.
- A number of standard bodies (e.g. ANSI 2008) require risk analysis
- Financial regulations (e.g. "Operational Risk" in Basel-III) also require precise risk management for technology

Why modelling?

- Quotation 1:
  - "Modelling is fundamental to measurement; without an empirical model or describing observations, measurement is not possible" (A. Kaposi 1991)

Why metrics?

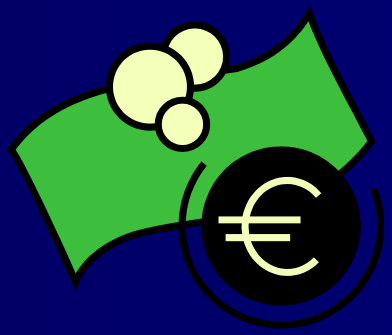
- Quotation 2:
  - "…if you can measure what you are speaking about and express it in numbers you know something about it; but when you cannot measure it, when you cannot express it in numbers, your knowledge of it is of meagre and unsatisfactory kind" (Lord Kelvin ~1870)

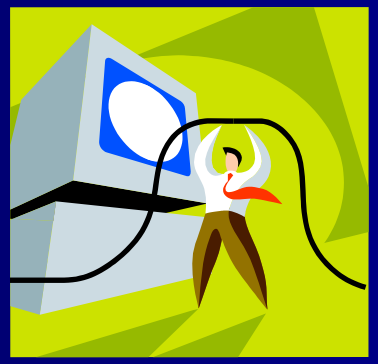
Why metrics?

Quotation 3:

- "The history of science has been, in good part, the story of quantification of initially qualitative concepts" (Bunge 1967)

What is Measurement ?





Definition of measurement

- **Definition:**
  - Measurement[1] is the process of empirical, objective encoding of some property of a selected class of entities in a formal system of symbols (A. Kaposi based on Finkelstein)
  - Cp Metrology is the field of knowledge concerned with measurement. Metrology can be split up into theoretical, methodology, technology and legal aspects.

1. We use the terms measurement and metrication interchangeably

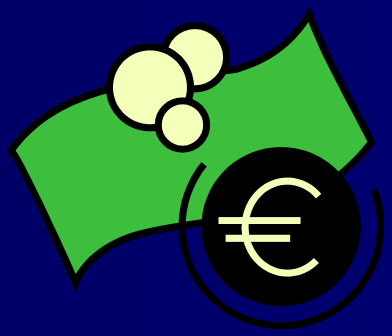
General requirements on measurement operations

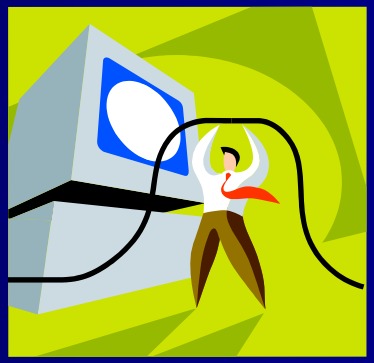
- Operations of measurement involve collecting and recording data from observation
- It means identifying the class of entities to which the measurement relates
- Measurements must be independent of the views and preferences of the measurerer
- Measurements must not be corrupted by an incidental, unrecorded circumstance, which might influence the outcome

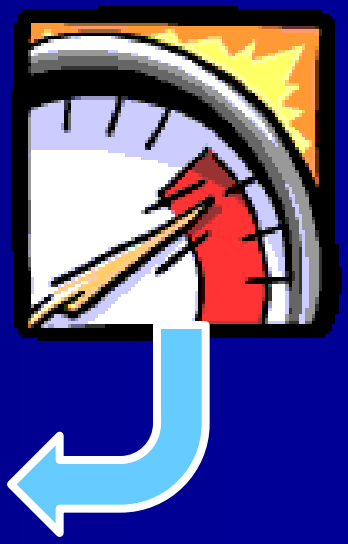
Specific requirements on measurement operations

- Measurement must be able to characterize abstract entities as well as to describe properties of real-world objects
- The result of measurement may be captured in terms of any well-defined formal system, i.e. not necessarily involving numbers

Measurement Scales







Measurement scales

- Mesurement theory distinguishes five types of scale:
  - nominal scale
  - ordinal scale
  - interval scale
  - ratio scale
  - absolute scale
- Here they are given in an ascending order of ”strength”, in the sense that each is permitting less freedom of choice and imposing stricter conditions than the previous one

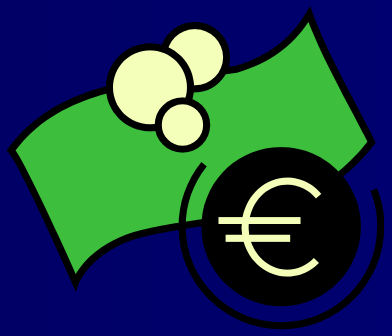
Measurement scales II

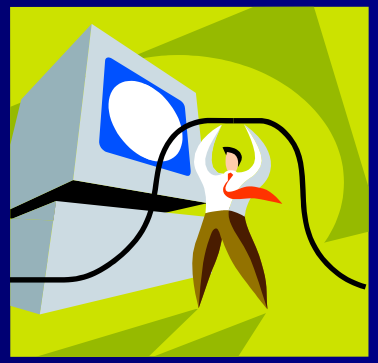
- The nominal scale can be used to denote membership of a class for purposes such as labelling or colour matching
- The ordinal scale is used when measurement expresses comparitive judgement
- The interval scale is used when measuring ”distance” between pairs of items of a class according to the chosen attribute
- The ratio scale denotes the degree in relation to a standard, i.e. a ratio. It must preserve the origin.
- The absolute scale used for counting the number of elements in an entity set

Meaningfulness

- Meaningfulness means that the scale measurement should be appropriate to the type of property measured, such that
  once measurement has been performed – and data expressed on some scale - sensible conclusions can be drawn from it
- Example 1: Point A is twice as far as point B (meaningless, since distance is a ratio scale, but position is not)
- Example 2: Point A is twice as far from point X as point B (is meaningful)

Security Metrication





What is Security?

- SECURITY *("prevention of unauthorized access and/or handling")*
  - A system is considered Secure if it is can protect itself against intrusions
  - There is no mathematical or formal definition of the Security of a system.
  - Security is normally defined by its three aspects: **confidentiality, integrity** and **availability** (*"CIA"*)
  - Security is not only technical. It is also a function of the environment, human behaviour, etc
  - In most languages the same word is used for security and safety (As a matter of curiosity.)

Problems with the security concept

- Security is not well-defined. There are different interpretations in different areas
- Security is multi-faceted. It consists of a number of diverse and sometimes even contradictory attributes. (For example: integrity and availability)
- Security as a concept denotes the absence of something (normally vulnerabilities) rather than the presence of somehing.
  (This raises some fundamental problems wrt verification and metrication.)

Why is measuring security hard?

- In order to measure something we must define what we measure. i.e. define the object system and its characteristics
- Security is a non-functional attribute – others are dependability, reliability, safety, etc
- A non-functional attribute defines to which extent a functional attribute is valid (e.g. a service is delivered)
- As of today, there are no scientifically solid metrics of security. Instead, there are a number of informal and/or subjective assessments or rankings.

The fundamental representation problem

When measuring security the following questions could be posed:

- What is my definition of security?
- Which aspects of security do I intend to measure? Or some composite?
- What is it that I am measuring? (That is, what kind of data do I gather?)
- How do I process these data? If at all?
- To which extent do the gathered and processed data represent the metric of security that I want to capture?

Methods for ”measuring” security I

- **Evaluation/Certification** (according to some standard):
  - *classification* of the system in classes based on design characteristics and security mechanisms.
  ”The ‘better’ the design is, the more secure the system”
- **Risk analysis**:
  - *estimation* of the probability for specific intrusions and their consequences and costs. Trade-off towards the corresponding costs for protection.
- **Penetration tests:**
  Finding vulnerabilities by using “Tiger teams”. (But you never find them all….)
- **Vulnerability assessment:**
  - includes methods for finding system vulnerabilities

Methods for ”measuring” security II

- **Effort-based approach** (based on “simulated” attacks):
  - a statistical metric of system security based on *the effort* it takes to make an intrusion.
  “The harder to make an intrusion, the more secure the system”
- **Weakest adversary**:
  - which is the weakest adversary that can compromise the system?
- **MTTC** (Mean Time To Compromise):
  - calculates the statistical mean time to an intrusion

Methods for "measuring" security III – special cases

- Cryptographic strength:

  - a statistical metric of the strength of a crypto system based on *the computational effort* for a successful cryptanalysis (FIPS 140-2[1]).
  "The harder to breach the crypto, the stronger it is"

- Privacy measures:

  - defines to which extent the system will leak personal information

- Fault trees, Worst Case Analyses, ….

1. Federal Information Processing Standard - used to accredit cryptographic modules

Methods for ”measuring” security IV - tools

- ISO/IEC 27004: Information security management - Measurement - measures the effectiveness of Information Security Management System processes and controls
- OCTAVE (Operationally Critical Threat, Asset, and Vulnerability Evaluation):

  - is a suite of tools, techniques, and methods for risk-based information security strategic assessment and planning. [CERT]
- OSSTMM (Open-Source Security Testing Methodology Manual):

  - is a document of security testing methodology and a set of rules and guidelines for which, what, and when events are tested [ISECOM]
- CVSS (Common Vulnerability Scoring System):

  - CVSS is an industry standard for assessing the severity of computer system security vulnerabilities

Security metrics research – suggested areas

- NIST suggests the following security metrics research areas:
  - Formal models related to security metrics ("the absence of formal models has hampered progress")
  - Historical data collection and analysis
  - AI assessment techniques
  - Praticable concrete measurement methods
  - Intrinsically measurable components ("developing components that are inherently attuned to measurement")

Summary

- An overall security metric is highly desirable by many actors
- As of today there are no scientifically solid metrics for security
- We have given a brief overview over the state of research and available methods