Software Measurement & Lessons from the Masters: Benefits for Industry

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Egyptian Pyramids
Egyptian Measurement & Tools

New Kingdom Dynasty XVIII-XX (1550-1070 B.C.)

New Kingdom

Architect Kha

Amenhotec II

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Golden étalon

Folding étalon
Late Dynasty Tool (712-332 BC)

Bronze

Green limestone

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Measurement of Time

Evolution of Time Perceptions, & Measurement Concepts & Tools
Time Museum in Besançon (France)
The communal local time

Sun shadow

The house sun dial

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Time measurement: The “horloge”

Communal Time – XVII Century

Personal time – XVIII century
Personal clock - Minituarization

Mechanical

Quartz

Atomic

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Lack of universally accepted references & Impact
Masters from the Past

Reference:


Musée des sciences de Genève –
Current Masters

- Front page of the ISO VIM document
- picture
Current Masters

Joint Committee for the Guide in Metrology:

- International Bureau of Weights and Measures,
- International Electrotechnical Commission,
- International Federation of Clinical Chemistry & Laboratory Medicine,
- International Organization for Standardization (ISO),
- International Union of Pure & Applied Chemistry,
- International Union of Pure & Applied Physics,
- International Organization of Legal Metrology,
- International Laboratory Accreditation Cooperation.
Current Masters

Guidelines for setting up structures in metrology & proposed articles for the law:

3.1 Definitions
3.2 National metrology
3.3 Traceability and uncertainties
3.4 Legal units of measurement
3.5 Transparency of metrological information.
3.6 Legal metrology
3.7 Application of the Law
3.8 Offences
3.9 Responsibilities and duties
3.10 Conformity assessment procedures

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Key Lessons from the Masters

1. Evolutionary societal understanding of measurement concepts
   - Perfection is not expected first: the search for precision – when necessary only!

2. Development of Measuring Instruments

3. Establishment of measurement ‘etalons’

4. Specialized measurement training & certification:
   - Land surveyors
   - Accountants,
   - Engineers, etc.

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Measurement in Metrology
Table 3: Description of the measurement elements

<table>
<thead>
<tr>
<th>Measurement result</th>
<th>Measurement procedure</th>
<th>Measuring device</th>
<th>Measurement conditions</th>
<th>Measurement error</th>
</tr>
</thead>
<tbody>
<tr>
<td>Measured quantity value</td>
<td>Reference measurement procedure</td>
<td>Measuring system</td>
<td>Repeatability condition of measurement</td>
<td>Systematic measurement error</td>
</tr>
<tr>
<td>True quantity value</td>
<td>Primary reference measurement</td>
<td></td>
<td>Intermediate precision condition of measurement</td>
<td>Measurement bias</td>
</tr>
<tr>
<td>Conventional quantity value</td>
<td>measurement procedure</td>
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<td>Reproducibility condition of measurement</td>
<td>Random measurement error</td>
</tr>
</tbody>
</table>

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Table 6: Detailed quality criteria for a measurement result

<table>
<thead>
<tr>
<th>Measurement Precision</th>
<th>Measurement Uncertainty</th>
<th>Calibration</th>
<th>Metrological traceability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Measurement accuracy</td>
<td>Definitional uncertainty</td>
<td>Calibration hierarchy</td>
<td>Metrological traceability chain</td>
</tr>
<tr>
<td>Measurement trueness</td>
<td>Type A evaluation of measurement uncertainty</td>
<td>Verification</td>
<td>Metrological traceability to a measurement unit</td>
</tr>
<tr>
<td>Measurement repeatability</td>
<td>Type B evaluation of measurement uncertainty</td>
<td>Validation</td>
<td>Metrological comparability of measurement results</td>
</tr>
<tr>
<td>Intermediate measurement precision</td>
<td>Standard measurement uncertainty</td>
<td>Correction</td>
<td>Metrological compatibility of measurement results</td>
</tr>
<tr>
<td>Measurement Reproducibility</td>
<td>Combined standard measurement uncertainty</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>Relative standard measurement uncertainty</td>
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<tr>
<td></td>
<td>Uncertainty budget</td>
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<td></td>
<td>Target measurement uncertainty</td>
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<td></td>
<td>Expanded measurement uncertainty</td>
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<td></td>
<td>Coverage interval</td>
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<tr>
<td></td>
<td>Coverage probability</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Coverage factor</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Measurement in Software

• The academic view & achievements

• The software industry needs & track record
Measurement in Software

Enduring Software Measurement Myths:

- **Software is different:**
  - It is an intellectual product & it is not material
- **Software metrics = an algorithm**
  - Foundation = measurement theory! (limited to maths)
- **Innovation in metrics = again, another proposal**

**Impact - Examples:**

- In the 1990s: already +100 proposals on software complexity
- The vast majority of software metrics from academia not used in industry.....
Measurement in Software

• A typical new software metrics:
  – A modified algorithm
  – Additions of conditions to the algorithms
  – Automatically extracted-calculated from code-files

• Typical empirical analyses:
  – No hypothesis to be tested!
  – As many metrics as can be extracted automatically
  – ..........

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Software Industry & Measurement

Which ‘software metrics’ have reached some maturity with respect to industry needs?

- How do you recognize maturity in measurement?
Software Measurement

Measurement Maturity = Standardization

• Which ‘software metrics’ are recognized as ISO standards?

• ‘Quality Metrics’: ????

• …..
Software Measurement

What is common in their design process?

- ISO 20926 : IFPUG (1979)
- ISO 24570 : NESMA (1985)
- ISO 29881 : FISMA (198?)
- ISO14143 Parts 1 to 6

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Software Measurement

ISO 14143 meta-standard on Functional Size Measurement:
Part 1: Definitions & Concepts
Part 2: Conformity Evaluation of FSM methods
Part 3: Verification Guide of FSM methods
Part 4: Reference Model (but only samples of FUR!)
Part 5: Determination of Functional Domains for of FSM methods
Part 6: Guide for the use of ISO 14143!

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Software Measurement & Industry

• For industry, measurement has little to do with maths!

• Measurement is not maths, but a technology with considerable consensual knowledge on the concepts to be measured, credible references for measurement, & expected measurement errors
Measurement is a Technology

- **Technology** is defined as:
  - the set of methods & materials used to achieve industrial or commercial objectives.

- **Not limited to materials alone:**
  - It also includes processes and the knowledge related to them, referred to as "know-how".
Measurement as a Technology

• What does it take for software measurement to be adopted as a new technology?
  – Software measurement must already have been proven to work well in a large variety of contexts:
    • i.e. it must be mature as a technology, or maturing rapidly).
  – Software measurement must become integrated into the technological environment of the software industry.
  – It must become integrated into the business context (which includes its legal and regulatory aspects).
Measurement as a Technology

What does it take for software measurement to be adopted as a new technology?

• On the part of a software organization:
  – Software measurement must promise enough benefits to overcome the pain of changing to an initially unknown technology.
  – The organization must have the technological know-how in software measurement to make it work.
  – The organization must be clever enough, and enthusiastic enough, to harvest the benefits, which takes time.
Measurement as a Technology

- What does it take for an industry to promote software measurement as a new technology?
  - Software measurement must have been proven to work in similar contexts.
  - Current software measurement practices must be ‘good enough’.
  - The industry must recognize that the players will not, by themselves, submit to the pain of change (unless the environmental-regulatory context forces such a change).
  - It should want to speed up the transition to quantitative support for decision making.
Measurement is a Technology

• Out of the +1,000s of software metrics proposed in the literature, only 5 have been adopted as ISO standards!

• What has been done differently?
Quality Criteria for Software Measurement

The criteria for the design of measurement are already defined in Metrology:

- The components of a measurement system
- The quality criteria for measurement
Measurement in Metrology

Devices for Measurement

Measurand

Measurement

Measurement Result

Quantities and Units
Measurement Standards, Etalons
Properties of Measuring Devices

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Measurement in Metrology

Measurement Model

- Input quantity in a measurement model
- Measurement Function
- Output quantity in a measurement model
- Measured quantity value

Operator

Measurement
- Uncertainty
- Value

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<td>Systematic measurement error</td>
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Measurement Infrastructure

• To increase consensus to ensure repeatability, a measurement practice committee that sets detailed measurement procedures for typical contexts
• When a ‘measurement étalon’ does not yet exist:
  – Case studies for various topics-contexts
• Outside recognition, through standardization channels (ISO xxx and ISO 90003, ISO 19760, etc)
• Certification process
• Training, specialized guides, etc.
Initial design stage: criteria

- Relevance: must be perceived by practitioners (within a functional domain) as adequately measuring the functional size of the applications in their domain.
- Measurement instrumentation:
  - Automated, or
  - is in the form of a measurement standard which documents & clarifies the measurement objectives & perspective, and defines the measurement procedures adopted by a user group.
- Repeatability:
  - different individuals, in different contexts, at different times, and following the same measurement procedures will obtain the same measurement results.
- Measurement results obtained with minimal judgment.
- Measurement results auditable.
- Measurement method in the public domain.
• Field tests in industry
TOOLDOM

K. R. Jayakumar
Director, Amitysoft Technologies
Advisor, International Advisory Council, COSMIC
Simple Tools
Sophisticated Tools
Usage
<table>
<thead>
<tr>
<th></th>
<th>Simple</th>
<th>Feel Good</th>
<th>Real Good</th>
</tr>
</thead>
<tbody>
<tr>
<td>Basic</td>
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<td>✓</td>
<td>×</td>
</tr>
<tr>
<td>Political</td>
<td>×</td>
<td>✓</td>
<td>×</td>
</tr>
<tr>
<td>Real</td>
<td>✓</td>
<td>✓</td>
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**VALUE**

**TOOL SOPHISTICATION**

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</thead>
<tbody>
<tr>
<td>Craft Use</td>
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<td>✓</td>
</tr>
<tr>
<td>Factory Use</td>
<td>✓</td>
<td>✓</td>
</tr>
</tbody>
</table>

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Tooldom

VALUE

Real

Political

Basic

Simple

Feel Good

Real Good

Craft Use

Factory Use

FP / UCP

/ COCOMO

WORK BREAKDOWN

TOOL SOPHISTICATION

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1st Generation FSM Methods

Weights-like FSM methods:

- Not aligned with the terminology in other fields of measurement (engineering, sciences, etc).
- A number of structural weaknesses pointed out in the literature over the past 30 years:
  - discredited it in academia for almost 20 years.
- Not fully aligned with the ISO criteria in ISO 14143 series (which, for instance, rejected the VAF)
1st Generation FSM Key Contributions

User Groups built the essential metrology support infrastructure:

– Procedural Measurement Manuals
– Central technical authority:
  • Measurement Practice Committee
– Certification criteria & exams
– Case studies for reference materials
1\textsuperscript{st} Generation FSM Key Weakness

1- A structure with weights to integrate multi variables:
   - An end number with a symbol (FP) but without a well defined measurement unit!

2- User groups:
   - The initial designs considered as a ‘bible’ by many: ‘bible-type’ designs cannot be changed, by definition!

3- Researchers:
   - Tweaking the structure, rather that radical re-design.
2nd Generation FSM criteria

1. Adoption-Addition of the concepts from ISO Metrology
   - measurement method,
   - measurement procedure,
   - base quantity,
   - derived quantity
   - measurement unit, etc.
   - Many of the ISO definitions explicitly quoted ‘as is’ in the COSMIC glossary.
2nd Generation FSM criteria

2- Correction of all known structural weaknesses:
   • adopting a clear & unique ‘measurement unit’:
     – ‘a data movement of a single data group’ to which a size unit of 1 is assigned, together with the 1CFP as its measurement symbol.
   • Making sure that it did not included any valid mathematical operations.
   • Similarly, the CFP represents a single measurable concept, size of a FUR, making it a true ‘base quantity’.

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2\textsuperscript{nd} Generation FSM criteria

3- Designed to entirely meet the ISO 14143-1 FSM requirements:
   
   – Measurement of FUR
   
   – No reference to technical & quality characteristics, &
   
   – No reference to effort
2\textsuperscript{nd} Generation FSM criteria

4- A collective effort with practitioners, including:
   - Fields trials in industry
     - Ensuring relevance of measurement results: Does it capture quantitatively well the expected functionality?
     - Measurement procedures to ensure repeatability & reproducibility of measurement results
   - ‘Good enough’ criteria met
     - In estimation models, the other major variable (effort) typically has a much larger range of variation!
2nd Generation FSM criteria

5- Design to be application domain independent

6- Open access
ISO/IEC 19761:2002 COSMIC - A functional size measurement method

Method Overview
Measurement Manual
Advanced & Related Topics

Beginners
Practitioners
Experienced Practitioners

DOMAIN-SPECIFIC SUPPORT DOCUMENTS:

Guidelines
- Business V1.0
- Real-time

Case Studies
- Business
- Real-time

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Conclusions

Do you have your golden measurement étalon for software design & control?
Questions?