Implementing an M-Layer data model

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Measurement-Information Infrastructure

Section 1

Introduction

Acronyms

- DOI—digital object identifier
- DX—digital transformation
- FAIR—findable, accessible, interoperable, reusable
- MA—machine-actionable
- MathML—math markup language
- MII—measurement information infrastructure
- M-Layer—metrology information layer to support measurement systems
- NCSLI—NCSL International
- PID—persistent identifier

Today's Topics

1. Introduction
2. Problems, M-Layer Solution
3. M-Layer Data Models
4. Demo
5. Conclusion

Section 2

Problems, M-Layer Solution

Motivation

The following points motivate a new measurement-unit solution:

- Metrology's DX requires a digital quantities and units system.
- However, simple digitization does not suffice for digital transformation.
- For true DX metrology should rethink itself from the ground up.
  - Identify and eliminate suboptimum pragmatic practices that, if propagated into automated systems, undercut the full gains that digital transformation promises.
- Quantities and units lie at the ground level so we start there.

Without such innovations, measurement producers will inevitably encounter measurements that require some ad hoc data in digital documents that consumers' software will not consume automatically.

Realities

Digital quantity-unit systems face multiple realities—that we should consider now to smooth and enhance metrology's DX—including

1. a plethora of edge cases;
    - non-SI measurement units,
    - nonlinear unit conversions,
    - non-ratio measurement scales,
    - restricted operations by scale type.
2. quantity and measurand ambiguity that challenges automated data consumption.

The M-Layer as a Solution

M-Layer Goals and Concepts:

- Generalize quantities and units to include all measurement types.
    - Generalize “quantity kind” to “aspect” to include all scale types.
    - Generalize measurement “unit” (VIM “reference”) to “scale”.
    - Transparently digitalize the data model:
        - Replace free text quantity descriptions with a unique aspect ID $\langle q \rangle$.
        - $q\ [Q] \mapsto q\ [Q]\ \langle q \rangle$
- Establish FAIR authorized registries to contain the essential information.

The M-Layer will force no changes; it merely offers improvements in processing quantities and their values.

The Measurement-Information Infrastructure and the M-Layer

- M-Layer aspect IDs disambiguate quantities for digital processing: calculations, uncertainty propagation, etc.
  - $q\ [Q]\ \langle\mathrm{voltage}\rangle$
  - $q\ [Q]\ \langle\mathrm{pressure}\rangle$
- MII taxons disambiguate full measurands for communicating measurement information in digitalized documents.
  - Source.Voltage.AC.Sinewave[.RearOutput]
  - Measure.Pressure.Pneumatic.Differential.Static[.Port1]
- Each MII taxon's quantity token uniquely maps to an M-Layer aspect ID.

Section 3

M-Layer Data Models

A Basic Aspect Data Model (DRAFT)

Data Element	Description	Example
AspectID	unique identifier-index representing the aspect $\langle q \rangle$ in MA documents and data	$\langle \mathrm{length} \rangle$
Name	registered name	length
Symbol	mathematical symbol markup (e.g., LaTeX, MathML	l
Definition	textual description or external pointer	PID to an ontology's length definition?
ScaleTypeID	index to the aspect's scale type	RatioScaleID

Other data elements regarding aspects may reside here or in linked ontologies.

Ancillary Datasets

Other datasets within or outside the M-Layer

- Scales—relates references (units) and scale types
- Units—specific measurement units
- Scale Types—ratio, nominal, ordinal, interval, logarithmic, . . .
- Conversions—symbolic equations $(x\pi/180)$
- Aspect-Scales—relates aspects to compatible scales and units
- Locally specific or other datasets?
  - Quantity and Unit Systems—SI9, SI8, . . . , US Customary, . . .
  - Valid Scale Operations—add, subtract, multiply, . . . ?
  - Aspect Name Aliases—voltage = electric tension, local languages
  - Dimensions—$\mathsf{T}, \mathsf{L}, \mathsf{M}, \mathsf{I}, \Theta, \mathsf{N}, \mathsf{J} \ldots$
  - Apsect Relations—$f = ma$

Distributed Data?

The current M-Layer work does not prescribe hosting details. Global and local authoritative registries may exist. For example:

- The core M-Layer and SI definitions at BIPM?
- National, legacy, or local units at NMIs?
- Industry-association definitions
- Feature-specific data extensions with applications
- MII taxons hosted by digital-document standards bodies?
- . . .

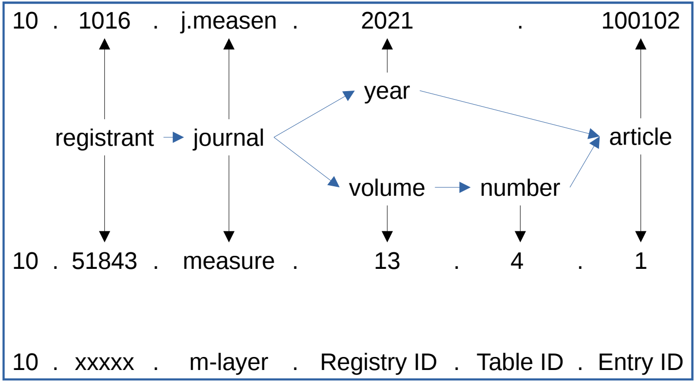
Unique Identifiers

The M-Layer requires unique IDs throughout.

Potential unique identifers

- URIs (URLs, URNs)
- UUIDs (universally unique IDs) in place of URNs
- DOIs
- . . .
- PIDs preferable for locations

A DOI Example



Given an application's context, `AspectID` might shorten to as little as `EntryID`.

Section 4

Demo

Demo

M-Layer Prototype Demonstration

Section 5

Conclusion

Features for Digital Processes without Pragmatisms

- Machine actionable
  - No problems disambiguating dimensionless or other quantities
  - No free-text quantity or measurand descriptions to interpret
  - Symbolics for arbitrary precision numerics
- Simple, light-weight interface and processing
  - One and only one (implicit) measurement unit
  - No prefixes or complications like the kg
  - No data-type restrictions
- FAIR, comprehesive, authoritative conversions
  - Any unit: . . . , SI9, SI10, . . . , US Customary, locally or industry-defined, . . .
  - Any scale: ITS-XX, conventional voltage and resistance, modular scales, hardness, . . .
  - Extensible and adaptable to future definitions

Conclusions

Metrology in the Digital Era:

- Rethink our processes from the ground up.
- Digitally transform, not simply digitize, manual processes!
- Discard pragmatic practices for extensible replacements.

The M-Layer as a foundation

- disambiguates quantities for machine processing,
- generalizes quantities for all scale types and unit references,
- provides a reference for all further unit redefinitions.

MII taxons

- tie uniquely to M-Layer aspect IDs,
- fully qualify measurands for interoperable digital documents.

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