Taxonomy and M-layer development: Why not *ISO 80000*?

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Measurement-Information Infrastructure

Section 1

Introduction

Today's Topics

1. Introduction
2. Interoperability—What does it mean?
3. *ISO-IEC 80000*
4. Digital Objectivity for Interoperability
5. Conclusion

Interoperability for DCCs and other measurement data

The goal: machine-actionable measurement data

At this stage, we will settle for FAIR machine-readable information.

FAIR: findable, accessible, interoperable, reusable

Hardest part of FAIR: interoperability

How do we achieve it?

Section 2

Interoperability—What does it mean?

Objective Communication

In human language, interoperability translates to objective communication—

- factual presentation
- with meaning and validity independent of the producer's consciousness
- tailored to the consumer's context.

How do we achieve it?

- clarity—definitions, no interpretation or clarification required from the source
- no subjective content
  - arbitrary statements
  - ambiguous, unclear, or misleading formulation
  - out-of-context placement

Objectivity, Subjectivity

Example

1. We calibrated the gage blocks with a multimeter.

Objective?

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3. We calibrated the reference standards, thermometers, and hygrometers.

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3. Still ambiguous—thermometers might or might not mean the same as reference standards.

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4. We calibrated the reference standards, plus the thermometers and hygrometers.

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4. Context: Whose reference standards?

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Objectivity requires care in reasoning, formulation (wording, punctuation), context

How do we achieve digital interoperability?

Machine reality:

- Allowing for measurement uncertainty, factual information comes given in the IQI.
- Machines have no consciousness to capture, but generated data has a source context.
- Consumer machines start with no context for interpreting incoming data.

Objective interoperability strategy:

- Source-independent meaning and validity—data transformed to a standardized context
- Reasoning—well designed data models and process models
- Formulation—standardized meanings, controlled syntax
- Context—standardized reference metadata

Dangers:

- Arbitrariness—undefined or free-form data fields
- Ambiguity—multipurpose data fields, missing unique identifiers, unclear definitions
- Out-of-context placement—essential elements falling outside the modeled framework

Section 3

ISO-IEC 80000

The Question

Does *ISO-IEC 80000* provide objective reference data for interoperability?

Examples:

Nice structure and data: name, symbol, concise definition, explanations, SI & non-SI units

not machine-readable in its current form

3-4 (*1-6*)	volume *fr volume* (m)		V	$V = \iiint \mathrm{d}x\,\mathrm{d}y\,\mathrm{d}z$ where x, y and z are cartesian coordinates (item 3-1.10)	$V = \int \mathrm{d}V$ For a volume element $\mathrm{d}V$, $\mathrm{d}\tau$ is sometimes also used.
3-4	volume	3-4.B.a	cubic inch: in^3	$1\ \mathrm{in}^3 = 16{,}387\,064\ \mathrm{cm}^3$	
		3-4.B.b	cubic foot: ft^3	$1\ \mathrm{ft}^3 \approx 28{,}316\,85\ \mathrm{dm}^3$	

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multiple terms for the same quantity

6-11.3 (*5-6.3*)	voltage, electric tension *fr* *tension* (f) *électrique* (The name "voltage", commonly used in the English language, is given in the IEV but is an exception from the principle that a quantity name should not refer to any name of unit.)	U, U_{ab}	in electric circuit theory, $U_{ab} = V_a - V_b$ where V_a and V_b are the electric potentials (item 6-11.1) at points a and b, respectively	For an electric field within a medium $U_{ab} = \int_{r_a\,(C)}^{r_b} \boldsymbol{E} \cdot \mathrm{d}\boldsymbol{r}$ where $\boldsymbol{E}$ is electric field strength (item 6-10) and $\boldsymbol{r}$ is position vector (ISO 80000-3, item 3-1.11) along a given curve C from point a to point b. For an irrotational electric field

The Question

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changing terminology over time (without unique identifiers)

6-36 (5-6.3)	source voltage, source tension *fr* *tension* (f) *de source*	U_s	voltage (item 6-11.3) between the two terminals of a voltage source when there is no electric current (item 6-1) through the source	The name "electromotive force" with the abbreviation EMF and the symbol E is deprecated. See IEC 60050-131, item 131-12-22.

ISO-IEC 80000 Interoperability-Issues Summary

A sample of issues

- Not currently machine-readable ⇒ Make it a Smart Document.
- Multiple terms for the same quantity ⇒ Settle on a single term.
- Changing terms ⇒ Implement formal deprecation for backward & forward compatibility.
- Historic quantity system ⇒ Refactor the quantities and units for machines??
- No measurand detail ⇒ Expand the document massively??
- Perhaps others–not thoroughly analyzed

We might enhance *ISO-IEC 80000* to solve all the interoperability problems.

The MII measurand taxonomy and M-layer does this already.

Section 4

Digital Objectivity for Interoperability

MII Taxonomy and M-layer—**modeling, formulations and context**

A taxonomy of measurands links to M-layer aspects that govern valid representations.

Expressions	M-layer Aspect ID	Taxon (`Measure...` or `Source...`)
		`Length.Circumference`
		`Length.Diameter`
		`Length.Form.Flatness`
1 ft		`Length.Form.Parallelism`
12 in		`Length.Form.Perpendicularity`
0.3048 m	$\Leftrightarrow \langle \text{length} \rangle \Leftrightarrow$	`Length.Form.Roughness`
30.48 cm		`Length.Form.Roundness`
304.8 mm		`Length.Form.Sphericity`
		`Length.Form.Straightness.Axis`
		`Length.Form.Straightness.Surface`
		`Length.Radius`

The M-layer for Quantities (Aspects) and Units (Scales)

Refactored quantities (aspects) support consistent transforms.

- separate aspects for thermodynamic temperature, temperature interval, ITS-90, ...
- separate quantity-ratio aspects: voltage ratio, length ratio, angle, ...
- combined aspect for log ratios of different bases (base 2, base e, base 10, ...)

Unique aspects and scales control representations.

Quantity	Valid & Invalid Expressions
frequency	$50\,\mathrm{Hz} \cong 50\,\mathrm{s}^{-1} \ncong 50\,\mathrm{Bq}$
activity	$50\,\mathrm{Bq} \cong 50\,\mathrm{s}^{-1} \ncong 50\,\mathrm{Hz}$
temperature interval	$12\,^{\circ}\mathrm{C} \cong 12\,\mathrm{K}$
abs. temperature	$12\,^{\circ}\mathrm{C} \cong 285.15\,\mathrm{K}$
gain	$1\,\mathrm{V}\cdot\mathrm{V}^{-1} \cong 1 \ncong 1\,\mathrm{m}\cdot\mathrm{m}^{-1}$
magnification	$1\,\mathrm{m}\cdot\mathrm{m}^{-1} \cong 1 \ncong 1\,\mathrm{V}\cdot\mathrm{V}^{-1}$

Aspects and scales control operations.

$t = (15,\ 25 \text{ and } 30)\,^{\circ}\mathrm{C} = (59,\ 77 \text{ and } 86)\,^{\circ}\mathrm{F}$

valid means	$23.33\,^{\circ}\mathrm{C} \cong 74\,^{\circ}\mathrm{F}$
but not ratios	$\max(t)/\min(t) = 2.0 \neq 1.46$

Force Examples

ISO-IEC 80000 defines only force and weight but measurands require more context:

- `Measure.Force.Tension`
- `Measure.Force.Compression`
- `Measure.Force.Weight`
- `Measure.Force.Friction`
- `Measure.Force.Gravitational`
- `Measure.Force.Electric`
- `Measure.Force.Magnetic`
- `...`
- `Source.Force...`

Abstract Taxon Definitions (XML)

. . . and much more modeling!

Source.MassFlowRate.Gas

This process sources a reference mass flow rate of gas for calibrating gas flow meters. The instantaneous mass flow rate q_m equals dm/dt, sometimes estimated as $\Delta m/\Delta t$ using the total mass Δm flowing through a defined space in time Δt.

- **Required Parameters (with ranges)**
  - Mass flow rate
- **Optional Parameters (with ranges)**
  - Gas Type
  - Gas Temperature
  - Gas Pressure
  - Gas Relative Humidity
  - Gas Compressibility
  - Reference Temperature
  - Reference Pressure
  - Reference Relative Humidity
  - Reference Compressibility
  - Ambient Temperature
  - Ambient Pressure
  - Ambient Relative Humidity
  - Outlet Pressure
  - Reynolds Number
  - Gas Velocity

Much work remains.

ISO-IEC 80000 provides

- a rich resource for quantity nomenclature;
- precise, concise, unambiguous definitions;
- symbols, units, explanations, etc.

ISO-IEC 80000 does not in itself provide FAIR digital functionality.

We should draw on *ISO-IEC 80000* and other sources to build reference metadata sources that support digital interoperability.

The identifiers should reference *ISO-IEC 80000* and other sources for their definitional value.

That work has begun.

Status and Strategy Updates

Add taxa to cover the KCDB CMCs.

- Covered now: photometry, most electromagnetic CMCs, a scattering in other areas
- Under development: radiometry
- Targeted: time and frequency

Add M-layer aspects and scales as required to support the new taxa.

NMIs and commercial entities have begun contributing.

Governance through NCSLI and GitHub—under development

High level control: *Governance of NCSLI's Measurement Information Infrastructure Products*

Collaboration Roles (modeled after Apache Software Foundation projects)

- Users—anyone may download and use the products per the license.
- Contributors—anyone may register suggestions, contribute material or otherwise help.
- Reviewers—designated members evaluate and comment on proposed contributions.
- Committers—designated members approve and commit contributions.
- Coordinators—designated members manage validations and publish releases.

Routine operations managed via GitHub per *GitHub Development Guide for NCSLI's Measurement Information Infrastructure Products*

Anyone may join the NCSL International 141 MII and Automation Committee.

Section 5

Conclusion

Objectivity –> Interoperability

The MII Measurand Taxonomy and M-layer provide objective interoperability.

- reasoning: source-independent models for present and future data
- formulation: controlled syntax and (linked) definitions
- context: unique identifiers and metadata

Together, they

- unambiguously differentiate, identify and qualify the measurand and its quantity values;
- work for DCCs, instrument specs—DCRs, accreditation statements, ...

Interoperability Proposal

1. Tag all measurement data with the measurand taxon (metadata).
2. Encode all quantity values via the M-layer.

Collaboration

- Open-source taxonomy open to collaboration under https://github.com/NCSLI-MII
- Prototype M-layer registry and API now available at https://www.mlayer.org/
- Will incorporate the M-layer into GitHub later
- Open M-layer and MII Taxonomy specification and governance documents coming soon
- Planning the first official taxonomy release
- Further MII info: http://miiknowledge.wikidot.com/

Collaboration opportunities? Please bring your expertise!

Acknowledgments

Please see the literature for further details.

Many thanks go to

- DTI, DFM, and Force Metrology for the kind invitation and hosting
- NCSL International for its MII support
- NCSL International Committee members for their MII development work
- Cherine-Marie Kuster
- *Objective Communication*, Leonard Peikoff, 2013.
- *Principles of Grammar*, Leonard Peikoff, 2020.

And Thank You for your time!

Questions?