The M-layer – overview

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Ambiguity is a problem for interoperability

- SI notation has evolved beyond the 19th century Maxwell / Fourier formalism (which applied to certain types of data).

- Traditional notation
  1. assumes the kind of quantity is known
  2. assumes the (numerical) structure of data

Interoperability ⇔ legitimate conversion

". . . so that we may be able at once to transform our results from one system to another" – J C Maxwell

SI notation leads to difficulties interpreting data:

1. Special unit names *vs* products of powers of base unit names
2. Multiple meanings for some unit names

$$0.555\dot{5}\ \text{Hz} \rightarrow 0.555\dot{5}\ \text{s}^{-1} \leftarrow 0.555\dot{5}\ \text{Bq}$$

$$1.5\,\text{N m} \rightarrow 1.5\,\text{kg m}^2\,\text{s}^{-2} \leftarrow 1.5\,\text{J}$$

$$12\,^\circ\text{C} = 12\,\text{K} \qquad (\Delta t/^\circ\text{C} = \Delta T/\text{K})$$
$$(\text{or}) \ = 285.13\,\text{K} \qquad (T/\text{K} = t/^\circ\text{C} + 273.13)$$

M-layer expressions have three components

$$\textit{(traditional) expression} = \{x\}\,[x]$$

$$\textit{(M-layer) expression} = \{x\}\,[\![x]\!]\,\langle x\rangle$$

$\{x\}$:value
$[\![x]\!]$:scale (combines $[x]$ with scale structure)
$\langle x\rangle$:aspect (*kind of quantity* in traditional systems)

$$\{12\}\,[\![\text{[°C], interval}]\!]\,\langle T\rangle \quad \nleftrightarrow \quad \{12\}\,[\![\text{[°C], ratio}]\!]\,\langle \Delta T\rangle$$

$$\{0.55\dot{5}\}\,[\![\text{[Hz], ratio}]\!]\,\langle \text{frequency}\rangle \quad \nleftrightarrow \quad \{0.55\dot{5}\}\,[\![\text{[Bq], ratio}]\!]\,\langle \text{activity}\rangle$$

The M-layer is register-based

- The client metadata is succinct unique digital identifiers (***UIDs***) for M-layer scales and aspects
- A ***register*** holds detailed information about scales and aspects, and underlying units, etc., and moderates conversion and transformation
- The UIDs index information and register services

M-layer components support interoperability

- Expression equivalence is rule-based
  (may be unidirectional, conditional on aspect)

$$1\ [\![[\mathrm{Hz}], \mathrm{ratio}]\!] \rightarrow 1\ [\![[\mathrm{s}^{-1}], \mathrm{ratio}]\!]$$
$$1\ [\![[\mathrm{s}^{-1}], \mathrm{ratio}]\!]\ \langle \mathrm{frequency} \rangle \leftrightarrow 1\ [\![[\mathrm{Hz}], \mathrm{ratio}]\!]\ \langle \mathrm{frequency} \rangle$$

- Conversion remains possible without knowing kind of quantity (aspect)
  (when appropriate – to support current practice)

- Dimensions (SI) and dimensional expressions will be supported*
- Unit / scale arithmetic will be supported*

- Scale-aspect transformations are supported (think: *change of variable* –rule-based and unidirectional, conditioned on the scale-aspect pairs)

$$\text{photon-energy:} \quad E = h\nu = hc/\lambda = hc\bar{\nu}$$

(* where appropriate, i.e., ratio scales and recognised unit systems)

Opportunities

- ***Overcomes*** difficulties with SI notation
- ***Smooth transition*** path from current practice to digital interoperability
- ***Modular*** => can combine with *ad hoc* user-community notation (e.g., spectroscopy)
- Represents more ***types of data*** (e.g., method-defined measurands, categorical measurements, ITS-90, etc.) with a sound scientific formalism.

Thank you ☺

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