

Digital Framework for Metrology (DF4M) +Digital Experts (DE4M)

2024,2025, Hugo Gasca Aragón

Spare time

Precedentes

- DCC (2019- 2025) centrado en certificados de calibracion ISO 17025 (*.xml, prefijos dcc:, si:)
- DRM (2023-2025) centrado en certificados de materiales de referencia ISO 17034 (*.xml, prefijos ?)
- Incertidumbre (NIST DataPlot 1982, Metrodata GUM Workbench 1999, NIST-UM 2020 #, CENAM-SEI 2017 #) centrado en evaluar la incertidumbre de un modelo de medida GUM (# *.txt, *.xlsx, estructurados, no intercambio)
- Consenso (NIST-NICOB 2020, CENAM-CCC 2017) centrado en evaluar comparaciones internacionales ISO 13528 (*.txt, *.xlsx, estructurados, no intercambio)
- Infinidad de Paquetes en C#, C++, Python, Fortran, R, Matlab, ...

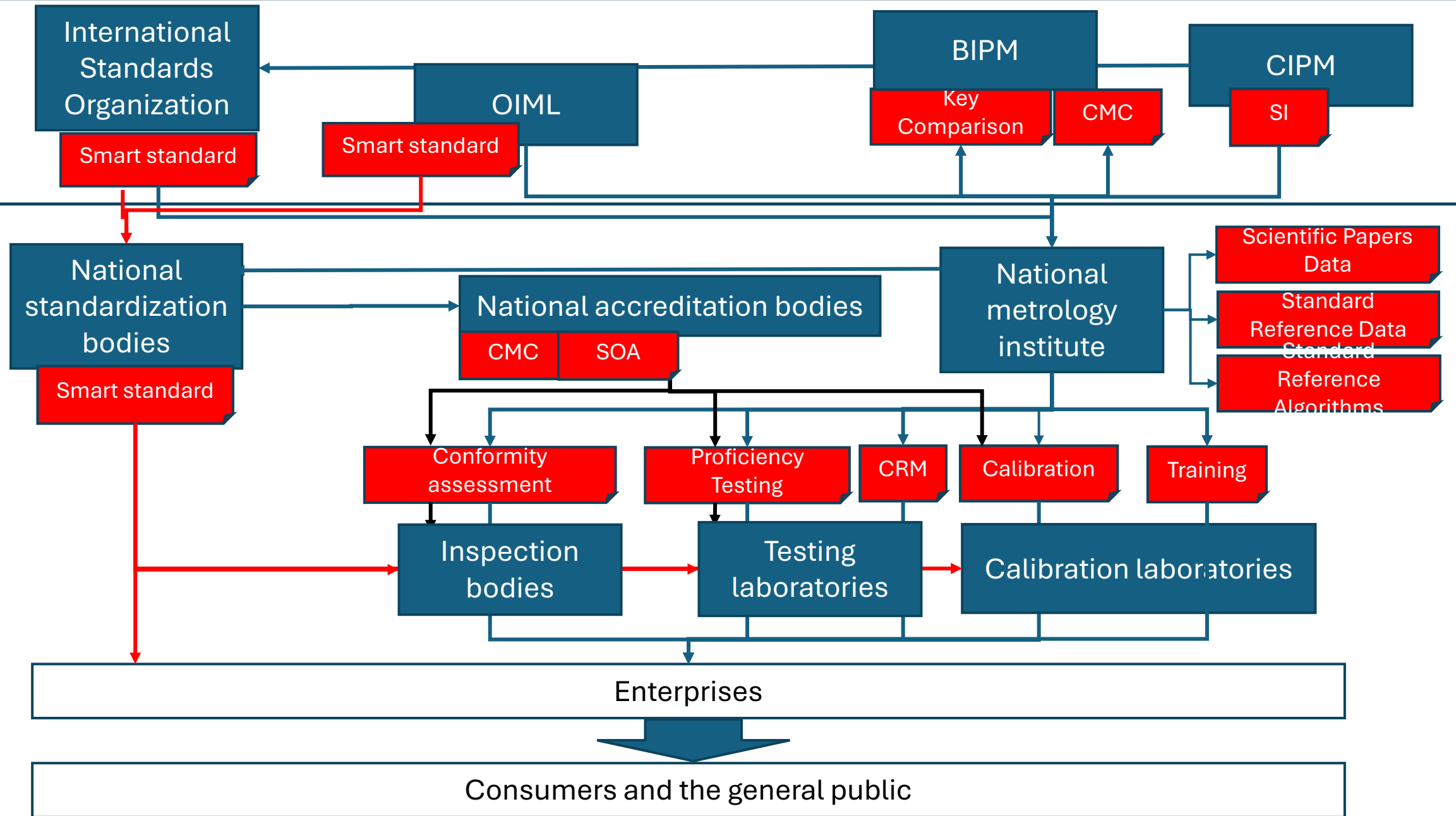
<https://cran.r-project.org/package=uncertainty>

<https://cran.r-project.org/package=gconsensus>

Precedentes

- DCC (2019- 2025), prefijos dcc:, si:, para términos “prestados” del vim y la gum. DCC es un concepto y el PTB tiene los derechos de autor bajo licencia GNU LGPL 3.0.
- ¿Deberíamos reconocer los prefijos vim:, gum:, si:? ¿Están protegidos?
- ¿Deberíamos alinearnos a la terminología de VIM, GUM y SIDF? Si
- ¿Necesitamos asesoría legal en derechos de autor? Yo si
- Vision SIM-M4DT @ Panama City

National Quality Infrastructure



Estructura de un resultado de medida

- measurementResult

- administrativeData

- Organization
 - Project
 - Software

- uncertaintyBudget

- inputQuantities
 - inputCorrelations

- outputQuantities

- outputCorrelations

- computationDetails

- methodName
 - methodReference

- InputQuantity

- QuantityKind

- Name

- Description

- Label (Symbol)

- Value

- MeasurementUnit

- DateTime

- MeasurementUncertainty

- StandardUncertainty
 - CoverageFactor
 - CoverageProbability
 - RelevantInformation
 - ProbabilityDensityFunction
 - Parameters (dof)
 - Evaluation type (A, B)

Estructura de un resultado de medida

- OutputQuantity

VIM

- QuantityKind

dSI

GUM

VIM

- Name

- Description

VIM

- Label

GUM

VIM

- Value

VIM

- Unit

dSI

- DateTime

GUM

VIM

- MeasurementUncertainty

- StandardUncertainty

- CoverageFactor

- CoverageProbability

- RelevantInformation

- ProbabilityDensityFunction

- Parameters (dof)

- Evaluation type

GUM

VIM

GUM

GUM

VIM

- measurementModel

GUM

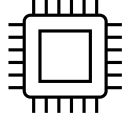
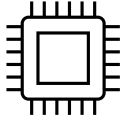
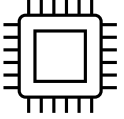
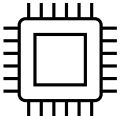
- Correlation

- Variable1

- Variable2

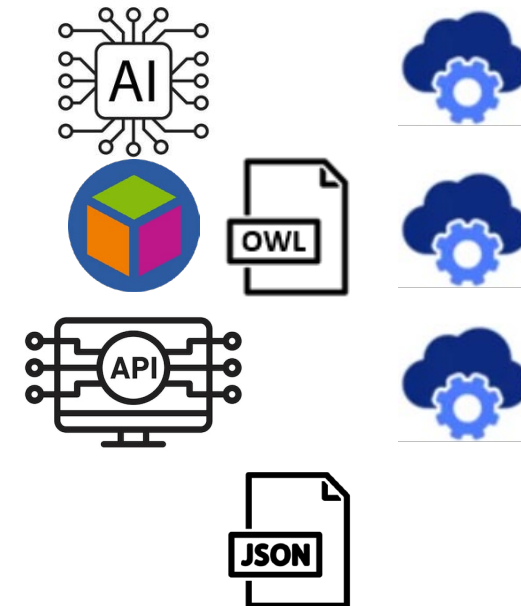
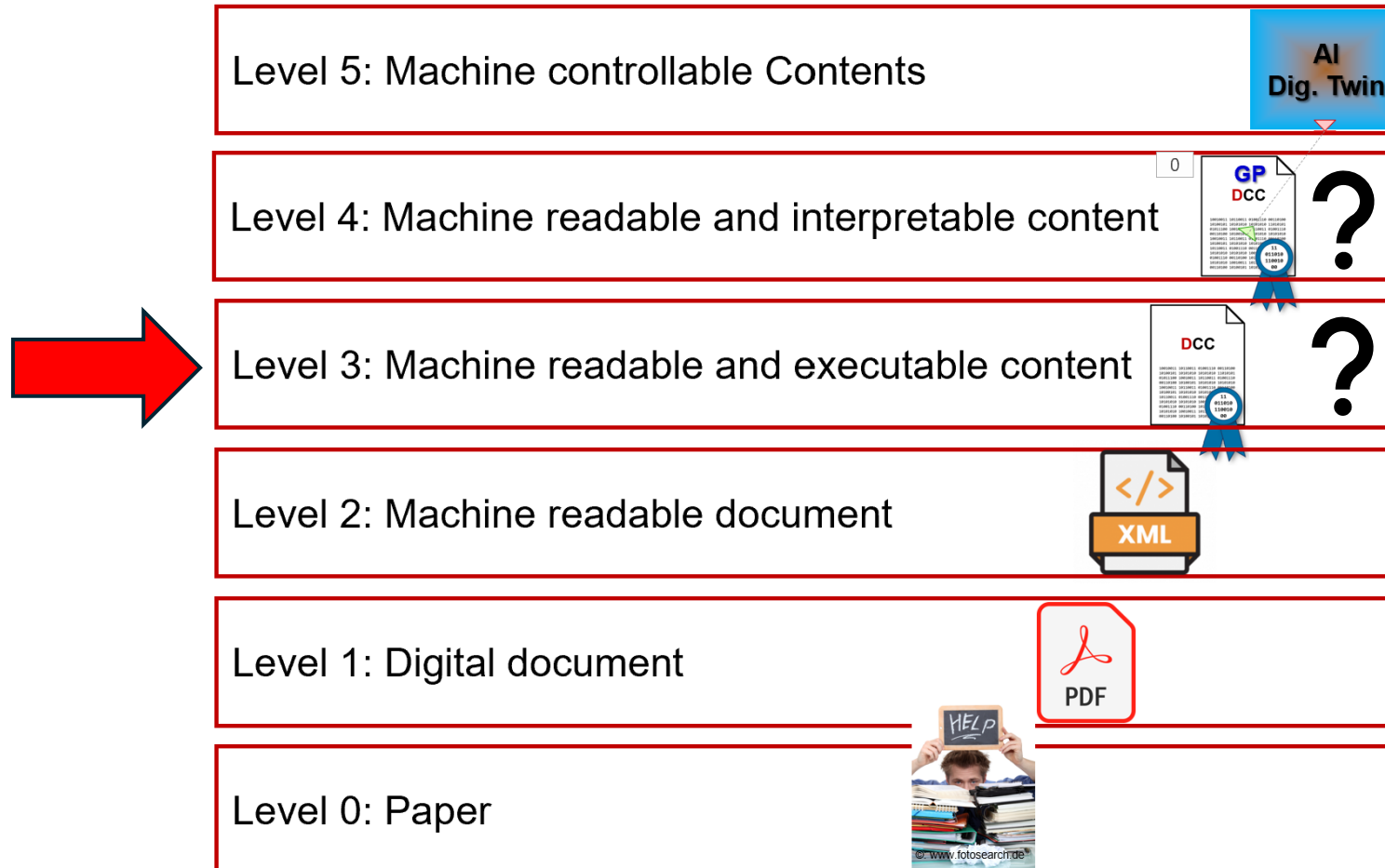
- Value

Bloques de Construcción

- Resultado de Medida 
 - uncertaintyBudget
 - outputQuantity\$measurementModel
- Consenso para Intercomparaciones y Proficiency Testing
 - Conjunto de (measurementResult from different sources) 
- Regresión Lineal
 - Predictor Conjunto de (measurementResult) 
 - Respuesta Conjunto de (measurementResult) 

Buenas Prácticas de Digitalización

Una “alternativa” de como implementarlo




Casos de Uso Metrológico

- | | |
|--|--|
| • single source -> single result -> multiple input quantities
{source, result, [inputQuantities]} | value assignment (Certified Reference Material), uncertainty evaluation, material measurement calibration (weight, resistor) |
| • single source -> multiple results -> single quantity
{source, [{result, inputQuantity}]} | regression/calibration (several calibration points) |
| • multiple sources -> single result -> single quantity
[{source, result, inputQuantity}] | comparison |
| • multiple sources -> multiple results -> single quantity
[{source, [result, inputQuantity]}] | comparison (different points) |
-
- | | |
|--|--|
| • multiple sources -> single result -> multiple quantities
[{source, result, [inputQuantity]}] | comparison << this is the next level in automation and analysis, participants providing the measurement model
+ detailed uncertainty budget |
| • multiple sources -> multiple results -> multiple quantity
[{source, [result, [inputQuantity]}]] | comparison (different measurands)
-> AI information-based decisions |

Swagger UI

localhost:5022/_docs_/

☆ | 📄 | ⬇️ | H | ⋮

 **Swagger**
Supported by SMARTBEAR

Explore

Digital Expert for Metrology DE4M

1.0.0 OAS3

<http://localhost:5022/openapi.json>

This API servers up data analysis for metrology based on the ISO guidelines.

Servers

⌵

default

⌵

POST

/measurement_result_GUMFO

Computes a measurement result object by the Gaussian First Order Method

⌵

POST

/measurement_result_GUMSO

Computes a measurement result object by the Gaussian Second Order Method

⌵

POST

/measurement_result_MCMC

Computes a measurement result object by the Markov Chain Monte Carlo Method

⌵

POST

/intercomparison

Computes a intercomparison object by the specified Method

⌵

Accesible via http o https

- Desde la línea de comandos del SO

```
curl --json @"filename.json" http://ip:5022/measurement_result...
```

```
curl --json @"filename.json" http://ip:5022/intercomparison
```

- Desde programas aplicativos (C#, Python, R, ...)

Ejemplo GUM-H1. Calibración de Bloque Patrón

```
"outputQuantities": [ {
  "name": "l",
  "label": "l",
  "value": 50000838,
  "valueType": "real",
  "unit": "null",
  "dateTime": "Mon Feb 03 13:16:37 2025",
  "stdUncertainty": 31.7106090984003,
  "coverageFactor": 2.90564732391098,
  "coverageProbability": 0.99,
  "distribution": "t",
  "dof": 16.6560641098668,
  "evaluationType": "B",
  "description": "length of the gauge block under calibration",
  "source": "DE4UM : Digital Expert for Uncertainty of Measurement version 1.0.0, a computational reference standard",
  "measurementModel": "d+l.s*(1 - delta.alpha*theta.s - alpha.s*delta.theta)"
} ],

"outputCorrelations": null,

"computationDetails": {
  "methodName": "Gaussian First Order Method",
  "methodReference": "JCGM 100:2008"
}
```


Ejemplo GUM-H1. Calibración de Bloque Patrón, aproximación de Segundo orden

```
"outputQuantities": [ {  
  "name": "l",  
  "label": "l",  
  "value": 50000838,  
  "valueType": "real",  
  "unit": "null",  
  "dateTime": "Mon Feb 03 13:16:37 2025",  
  "stdUncertainty": 33.9075067252739,  
  "coverageFactor": 2.90564732391098,  
  "coverageProbability": 0.99,  
  "distribution": "t",  
  "dof": 16.6560641098668,  
  "evaluationType": "B",  
  "description": "length of the gauge block under calibration",  
  "source": "DE4UM : Digital Expert for Uncertainty of Measurement version 1.0.0, a computational reference standard",  
  "measurementModel": "d+l.s*(1 - delta.alpha*theta.s - alpha.s*delta.theta)"  
} ],  
  
"outputCorrelations": null,  
  
"computationDetails": {  
  "methodName": "Gaussian Second Order Method",  
  "methodReference": "JCGM 100:2008"  
}
```

Ejemplo GUM-H1. Calibración de Bloque Patrón, estimación por MCMC

```
"outputQuantities": [ {  
    "name": "l",  
    "label": "l",  
    "value": 50000838.0362656,  
    "valueType": "real",  
    "unit": "null",  
    "dateTime": "Mon Feb 03 13:16:37 2025",  
    "stdUncertainty": 29.0029353753939,  
    "coverageFactor": 2.72701280364969,  
    "coverageProbability": 0.99,  
    "distribution": "t",  
    "dof": 34.2946915019618,  
    "evaluationType": "B",  
    "description": "length of the gauge block under calibration",  
    "source": "DE4UM : Digital Expert for Uncertainty of Measurement version 1.0.0, a computational reference standard",  
    "measurementModel": "d+l.s*(1 - delta.alpha*theta.s - alpha.s*delta.theta)"  
} ],  
  
"outputCorrelations": null,  
  
"computationDetails": {  
    "methodName": "Markov Chain Monte Carlo",  
    "methodReference": "JCGM 101:2008"  
}
```

Ejemplo desde el SO



The screenshot shows a Windows command prompt window with the title bar 'Símbolo del sistema'. The command entered is: `C:\Users\hgasca>curl --json @"E:/Workspace/Shiny/Apps/1Development/Consensus3.2/lib/CCQM.K127.input.json" http://localhost:5022/intercomparison`

```

1122         "measurementModel": "../inputQuantity/value - consensus)"
1123     }
1124 }
1125 ],
1126 },
1127 },
1128 "consensus": {
1129     "quantityKind": "Mass fraction",
1130     "sidfQuantityKind": "https://si-digital-framework.org/quantities/MASS.MASS-1",
1131     "name": "As.ref",
1132     "label": "As[ref]",
1133     "description": "Mass fraction of As in contaminated soil Reference Value",
1134     "value": 0,
1135     "measurementUnit": "ug/g",
1136     "sidfMeasurementUnit": "https://si-digital-framework.org/SI/units/microgram.gram-1",
1137     "dateTime": "Fri Jan 27 12:00:00 2017",
1138     "measurementUncertainty": {
1139         "stdUncertainty": 1,
1140         "coverageFactor": 2,
1141         "coverageProbability": 0.95,
1142         "distribution": "t",
1143         "dof": 17,
1144         "evaluationType": "B",
1145         "source": "computation"
1146     },
1147     "measurementModel": "consensus(../participants/inputQuantity/value)"
1148 }
1149 }
1150 }

```

Table 20. Values of the KCRV and respective standard uncertainties, with no multiple methods and with all data reported by NMIs/DIs for Contaminated soil.

Measurand	Median	MMADe	n
As (µg/g)	76.2	1.4	17
Cd (µg/g)	438.1	5.3	18
Fe (mg/g)	20.31	0.37	18
Pb (µg/g)	230.4	2.0	17

```
As in contaminated soil\", \"value\": 72, \"measurementUnit\": \"ug/g\", \"sidfMeasurementUnit\": \"https://si-digital-framework.org/SI/units/microgram.gram-1\", \"dateTime\": \"Fri Jan 27 12:00:00 2017\", \"measurementUncertainty\": { \"stdUncertainty\": 8.5, \"coverageFactor\": 2, \"coverageProbability\": 0.95, \"distribution\": \"t\", \"dof\": 4, \"evaluationType\": \"B\", \"source\": \"experiment\" }, \"quantityKind\": \"Mass fraction\", \"sidfQuantityKind\": \"https://si-digital-framework.org/quantities/MASS.MASS-1\", \"name\": \"d.As.IRMM\", \"label\": \"d[As[IRMM]]\", \"description\": \"Unilateral Degrees of Equivalence of Mass fraction of As in contaminated soil\", \"value\": 0, \"measurementUnit\": \"ug/g\", \"sidfMeasurementUnit\": \"https://si-digital-framework.org/SI/units/microgram.gram-1\", \"dateTime\": \"Fri Jan 27 12:00:00 2017\", \"measurementUncertainty\": { \"stdUncertainty\": 1, \"coverageFactor\": 2, \"coverageProbability\": 0.95, \"distribution\": \"t\", \"dof\": 4, \"evaluationType\": \"B\", \"source\": \"computation\" }, \"measurementModel\": \"./inputQuantity/value - consensus\", \"consensus\": { \"quantityKind\": \"Mass fraction\", \"sidfQuantityKind\": \"https://si-digital-framework.org/quantities/MASS.MASS-1\", \"name\": \"As.ref\", \"label\": \"As[ref]\", \"description\": \"Mass fraction of As in contaminated soil Reference Value\", \"value\": 76.24, \"measurementUnit\": \"ug/g\", \"sidfMeasurementUnit\": \"https://si-digital-framework.org/SI/units/microgram.gram-1\", \"dateTime\": \"Mon Feb 10 19:38:52 2025\", \"measurementUncertainty\": { \"stdUncertainty\": 1.38140922502717, \"coverageFactor\": 2.11990529922125, \"coverageProbability\": 0.95, \"distribution\": \"t\", \"dof\": 16, \"evaluationType\": \"B\", \"source\": \"computation\" }, \"measurementModel\": \"consensus(.../participants/inputQuantity/value)\" } } } }
```

Ejemplo CCQM-K127. As en suelo contaminado (2017)

```
...
  "consensus": {
    "quantityKind": "Mass fraction",
    "sidfQuantityKind": "https://si-digital-framework.org/quantities/MASS.MASS-1",
    "name": "As.ref",
    "label": "As[ref]",
    "description": "Mass fraction of As in contaminated soil Reference value",
    "value": 0,
    "measurementUnit": "ug/g",
    "sidfMeasurementUnit": "https://si-digital-framework.org/SI/units/microgram.gram-1",
    "dateTime": "Fri Jan 27 12:00:00 2017",
    "measurementUncertainty": {
      "stdUncertainty": 1,
      "coverageFactor": 2,
      "coverageProbability": 0.95,
      "distribution": "t",
      "dof": 17,
      "evaluationType": "B",
      "source": "computation"
    },
    "measurementModel": "consensus(..../participants/inputQuantity/value)"
  }
}
```


Demostración

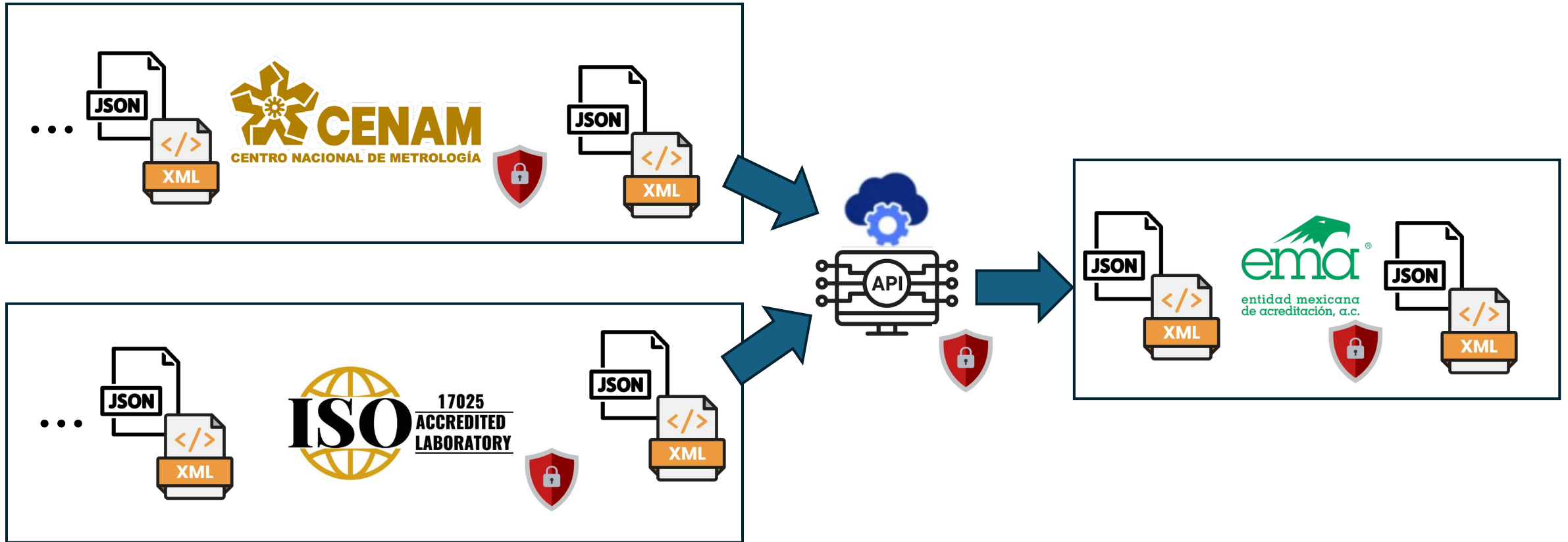
Próximos pasos

- Pruebas adicionales
- Corregir gaps:
 - Dof de la evaluación
 - Completar Protocolo de acuerdo a las ISO 17043 e ISO 13528
- Esquema de seguridad
- Integrar Otros Servicios Digitales:
 - Regresion (Estabilidad)
 - ANOVA (Homogeneidad)
 - ...

Desafio 1

- ¿Cual es la identidad del emisor de un resultado de medida? El usuario, el instituto, el Sistema de medida, el dispositivo IoT, el software que la proceso.
- ¿Cual es la identidad del emisor de una magnitud de entrada? Un documento, una base de datos de referencia, un certificado, una especificación técnica del instrumento, el metrologo que hace el registro, el instituto que emite el informe.
- Los resultados de medida son producidos por un sistema de medida, el sistema o instrumento de medida deberia administrar esta información, consultar, agregar información y monitorear su comportamiento.
- Firmas criptográficas para instrumentos, servicios digitales, personas, institutos.

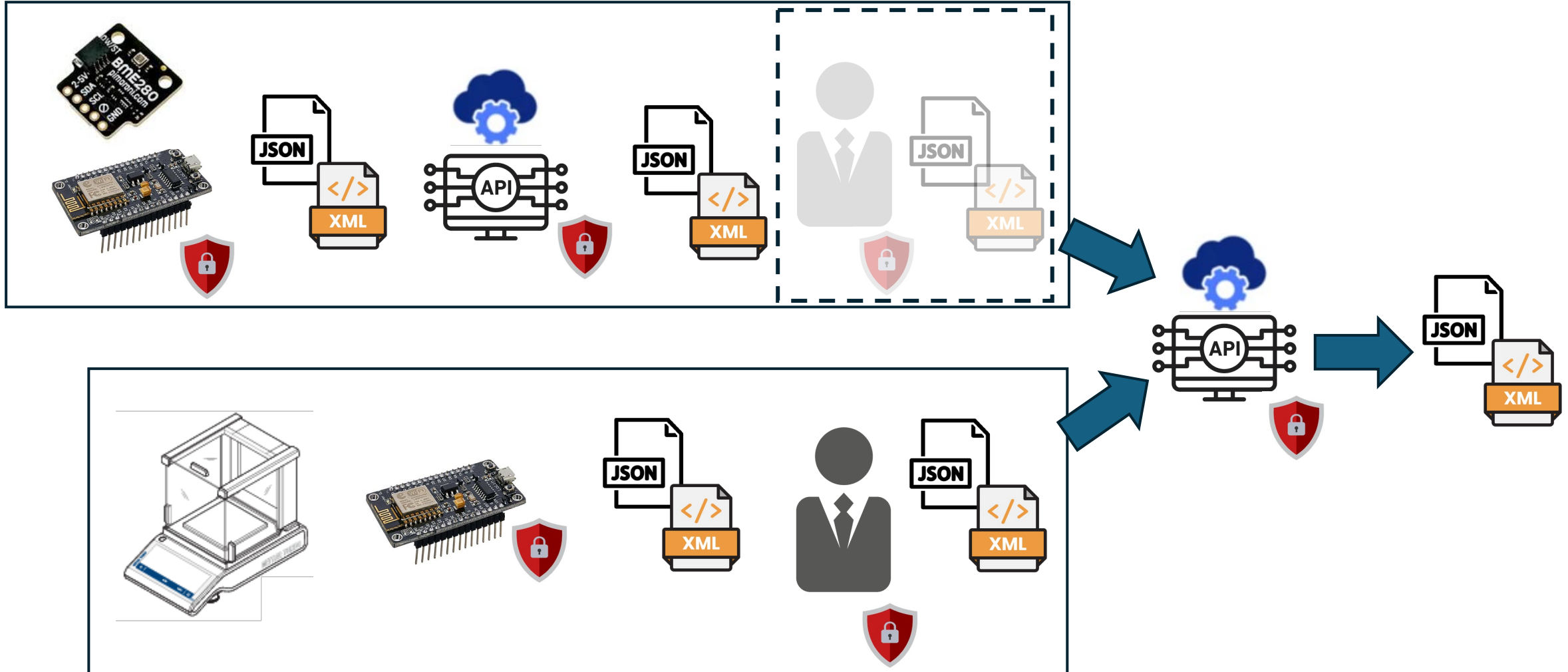
Ensayo de Aptitud + ciber seguridad firmas criptográficas para organizaciones ¿y servicios digitales?



Pesaje con corrección de empuje del aire

Firmas criptográficas para personas,

¿servicios digitales y sistemas de medida?

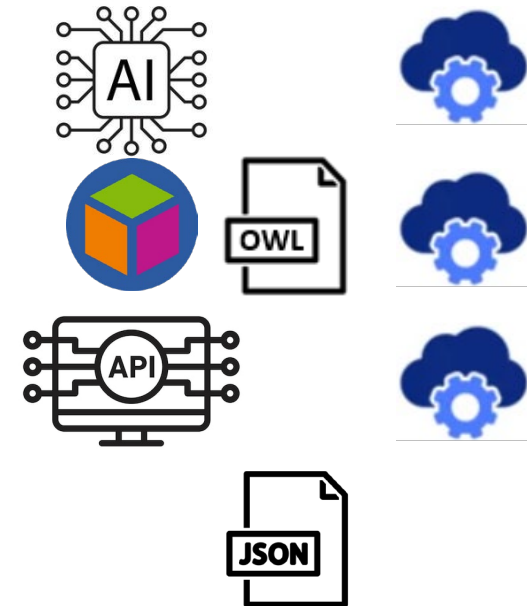
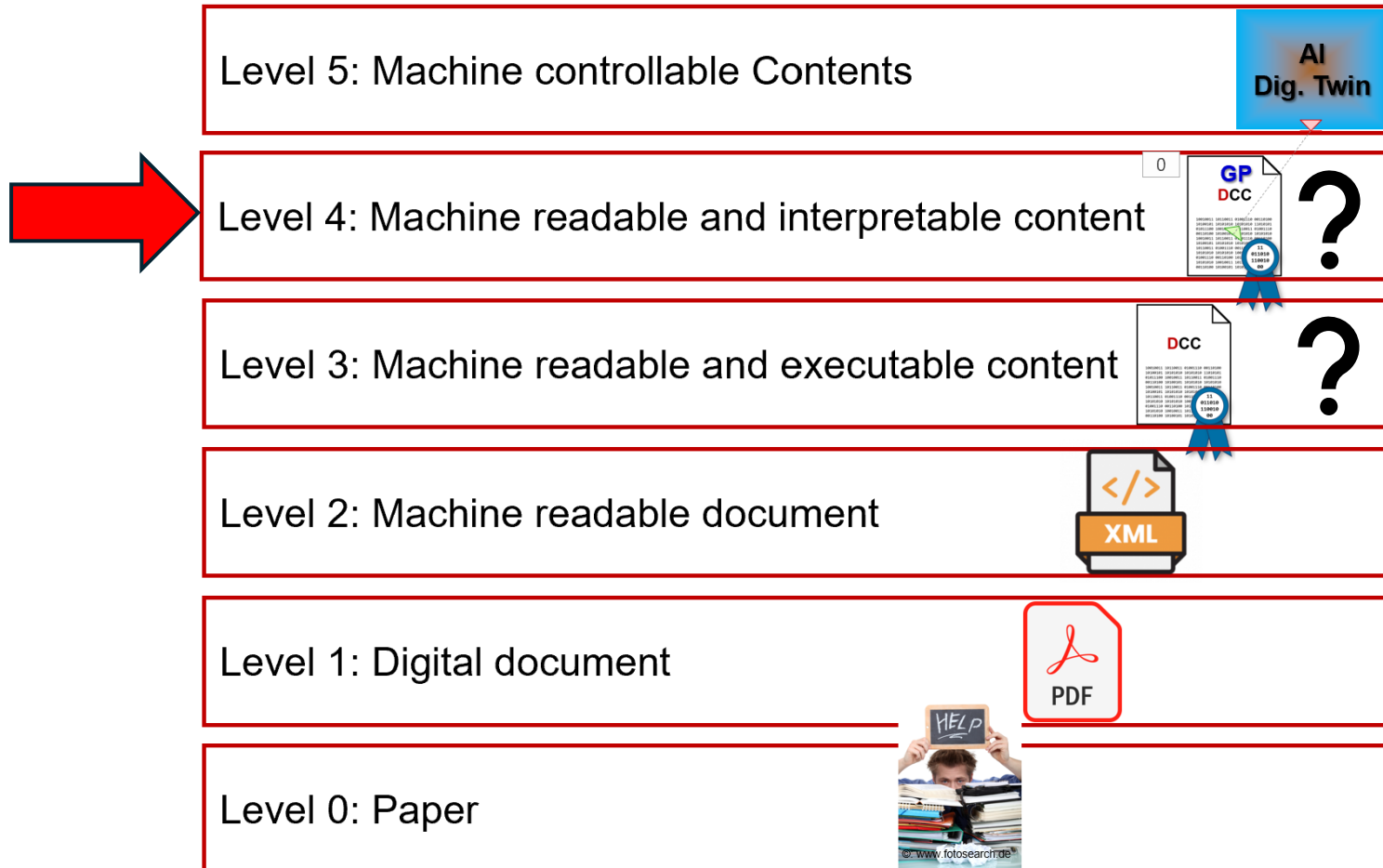


Desafio 2

- ¿Cómo declaramos la trazabilidad metrológica? ¿Qué necesitamos para que la declaración de trazabilidad metrológica sea machine actionable?
- Necesitamos herramientas de análisis semántico o de redes de objetos que naveguen para demostrar la trazabilidad metrológica y verifiquen numéricamente la incertidumbre de los modelos de medida.
- Esto se encuentra en el nivel 4 de las buenas practicas de digitalización (interpretación del significado), ontologias para inferir el significado.

Buenas Prácticas de Digitalización

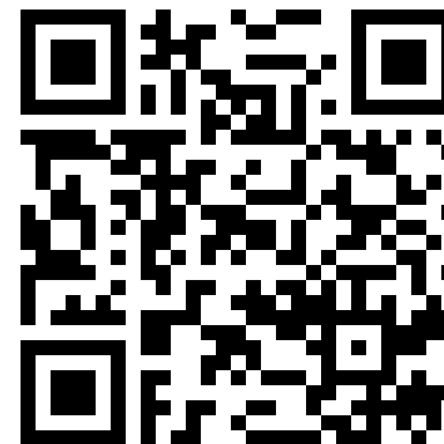
Una “alternativa” de como implementarlo



Referencias

- <https://www.itl.nist.gov/div898/software/dataplot/document.htm>
- http://www.metrodata.de/download_en.html
- <https://www.cenam.mx/incertidumbre>
- <https://uncertainty.nist.gov/>
- <https://consensus.nist.gov/app/nicob>
- https://gitlab.com/ptb/dcc/xsd-dcc/-/blob/master/dcc.xsd?ref_type=heads.
- <https://cran.r-project.org/package=uncertainty>
- <https://cran.r-project.org/package=gconsensus>
- <https://cran.r-project.org/package=dwlm>
- <https://cran.r-project.org/package=ggmr>

GRACIAS



<https://github.com/HugoGasca/MetrologicalDigitalFramework>