METROLOGIA 2025 – M4DT

Uncertainty in the Age of AI: Challenges for Metrology

Agustina Viaggio

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INTI Instituto Nacional de Tecnología Industrial

Secretaría de Industria y Comercio
Ministerio de Economía

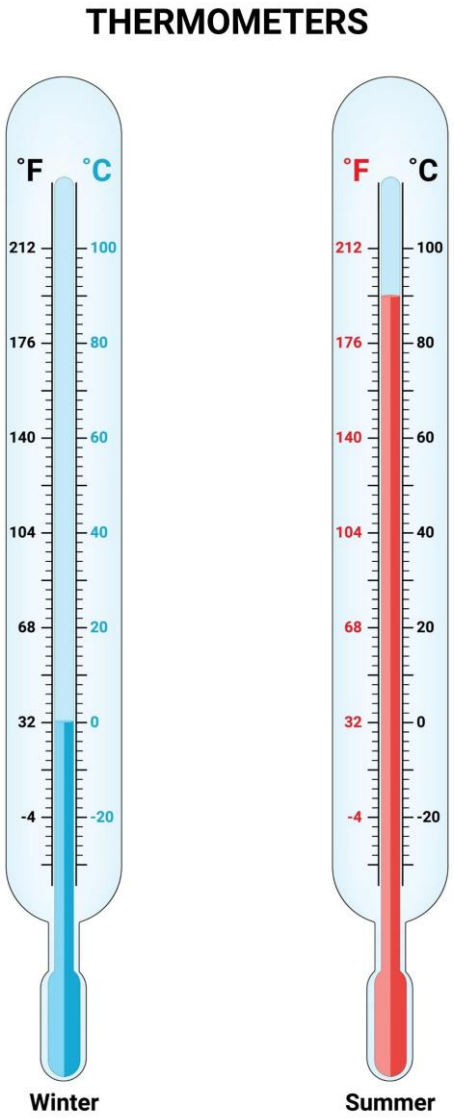
A fundamental tension between two paradigms

METROLOGY

Grounded in first-principle models.

ARTIFITIAL INTELLIGENCE

Based on data-driven moels.



Metrology

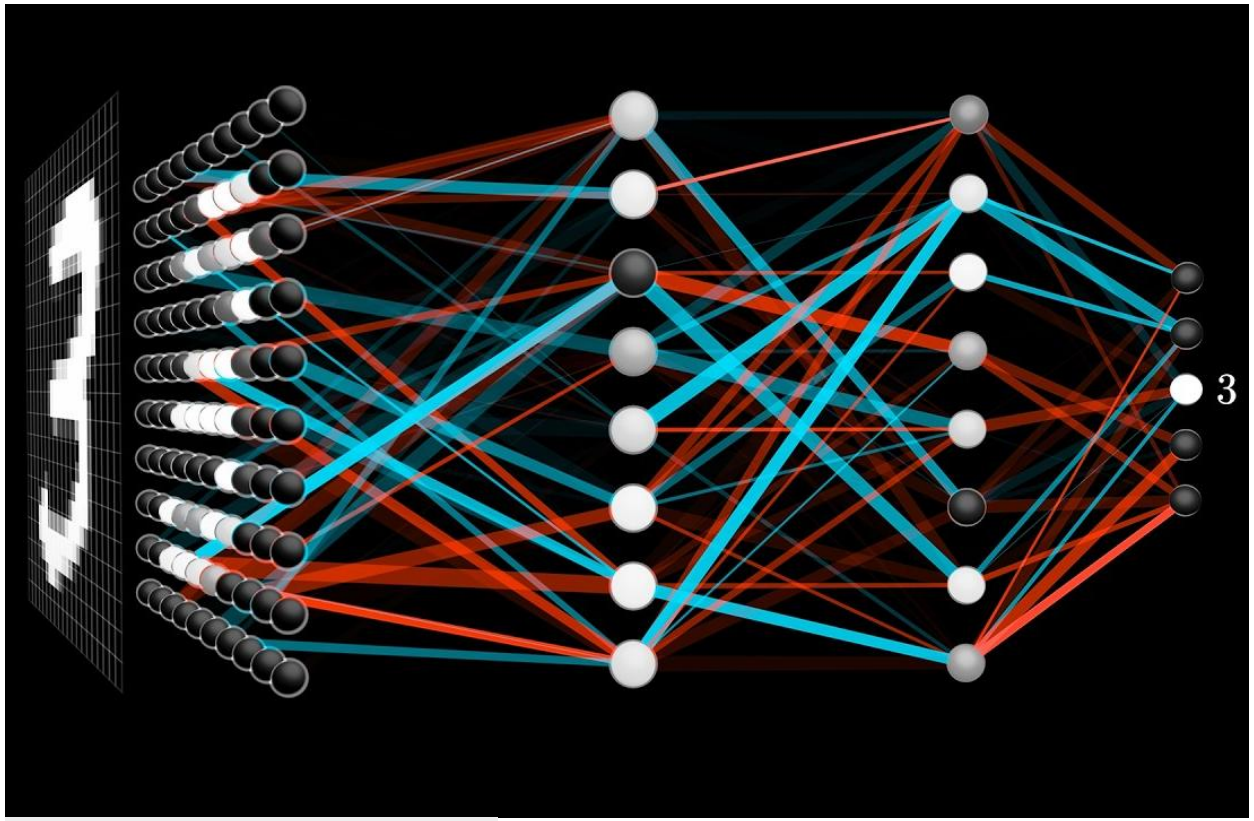
Relies on a deep understanding of the physical world.

When we measure a temperature, we aply the laws of thermodynamics.

We know **why** the sensor yields a specific value.

The model is transparent, allowing us to propagate uncertainty through stablished mathematical frameworks.

AI



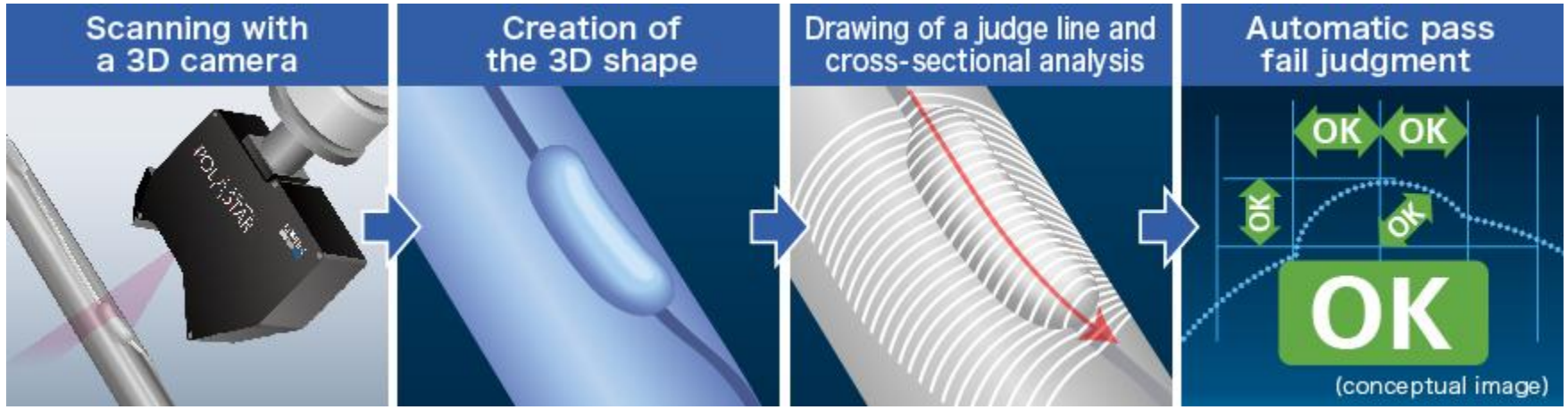
https://www.youtube.com/watch?v=aircAruvnKk

It learns independently from massive datasets, without explicit programming.

They are powerful because they create complex, hierarchical representations to map inputs to outputs.

However, they do not explicitly model physical laws. They are engines of pattern discovery.

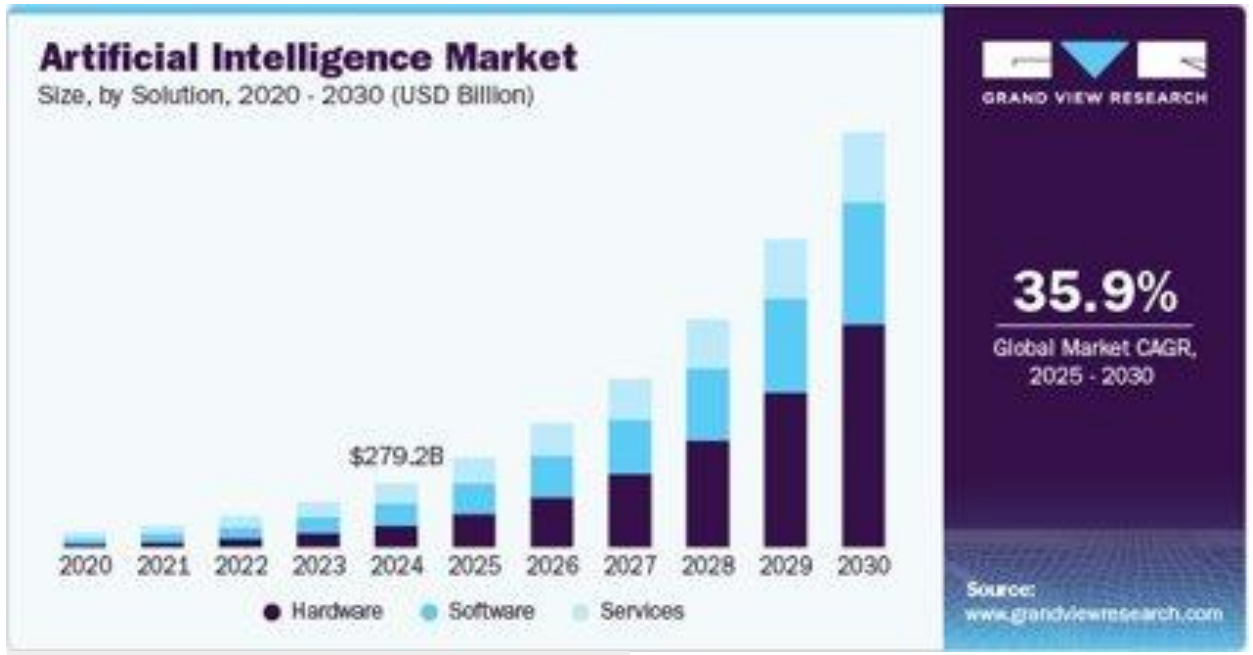
The Black-Box Challenge



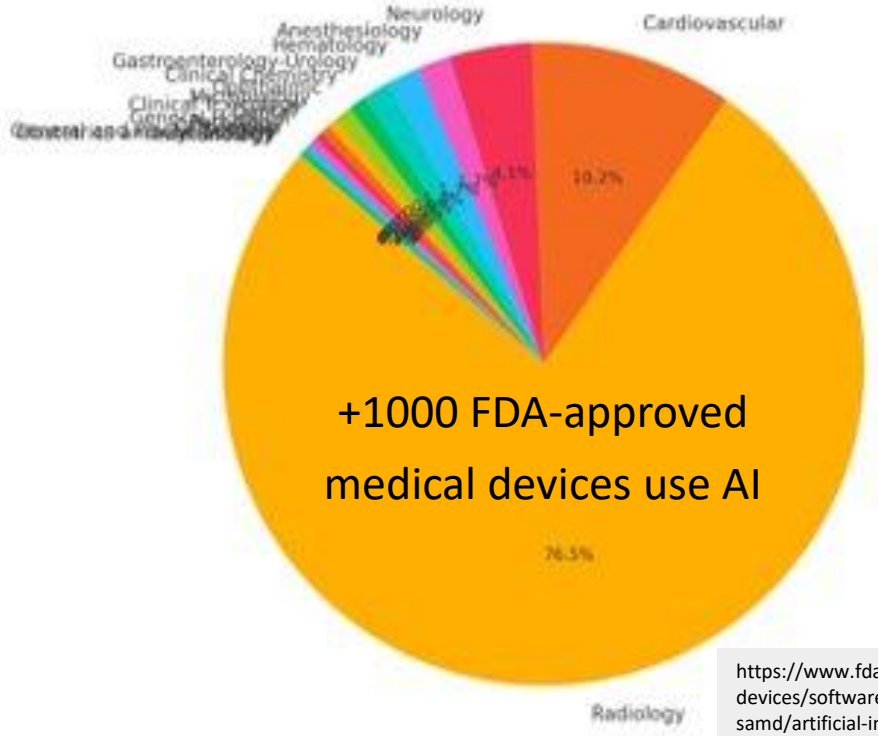
https://www.coretec.co.jp/en/products/vision/v400/

- What is the uncertainty of that decision?
- How do we express it?
- How do we validate it?

AI is here to stay



https://explodingtopics.com/blog/companies-using-ai



https://www.fda.gov/medical-devices/software-medical-device-samd/artificial-intelligence-and-machine-learning-aiml-enabled-medical-devices

AI is no longer a tool --- It is an engine of economic growth and innovation

The Metrological Objective

Its necessary AI systems adhere to core metrological principles:

Reliable

Traceable

Auditable

Limits of the current VIM

The actual definition

> “ Non-negative **parameter** characterizing the dispersion of the **quantity values** being attributed to a measurand, based on the information used. ”

- Works perfectly for continuous quantities and well-behaved models.
- Fails when the result is a **category**.
- AI often produces nominal results, not physical quantities. We cannot associate a standard numerical "parameter" with a non-linear classification model.

Redefining Uncertainty

The proposed new definition

> “ **Doubt** about the value of the measurand that remains after a measurement has been performed. ”

- Opens the conceptual space.
- Not longer a numerical parameter.
- Enables multiples valid forms of expression:
  - Intervals
  - Discrete distributions
  - Covariance matrices
  - Credibility regions
  - Probabilities for categories

JCGM Webinar: Have Your Say on the Future Definition of ‘Measurement Uncertainty’
https://www.youtube.com/watch?v=iHivi6UC5Uk

A broader scope: expanding, not replacing

- Covers everything from traditional measurements to AI-based methods.
- Does not change the day-to-day practice of laboratories.
- It is essential for AI in regulated contexts and conformity assessment.

¡Muito Obrigada!

Agustina Viaggio (aviaggio@inti.gob.ar)
INSTITUTO NACIONAL DE TECNOLOGÍA INDUSTRIAL

Departamento de Inteligencia Artificial
Subgerencia de Electrónica y Energía

INTI Instituto Nacional de Tecnología Industrial

Secretaría de Industria y Comercio
Ministerio de Economía

| protocolo@inti.gob.ar | **www.inti.gob.ar**