Machine Learning @

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Don’t Blink.
AI in Industry and Future Opportunities

ARPA-e Workshop

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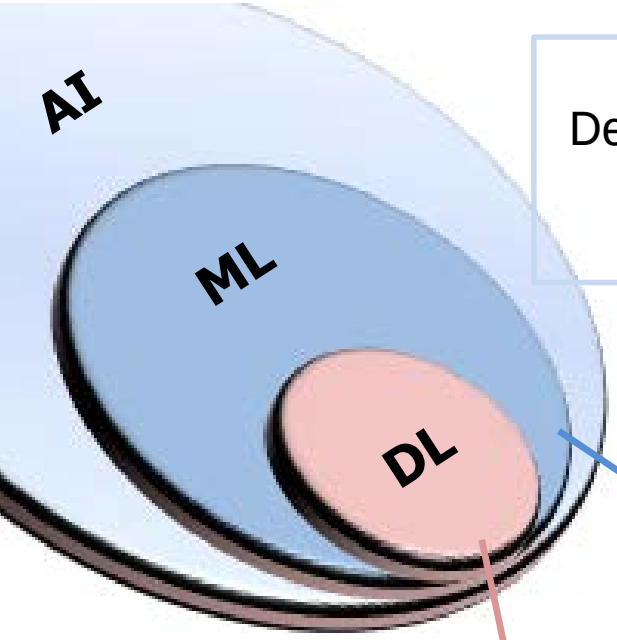
AI in Industry and Future Opportunities

DL - Deep Learning
ML - Machine Learning
AI – Artificial Intelligence

Outline

- Machine Learning
  - What is it
  - Recent progress
- Current State of DL for Engineering
- Industry Challenges for Design & Manufacturing
- Design and Manufacturing Opportunities for ML
- Conclusions

Machine Learning : “Learning Programs From Data”



AI
Decision making via rule based and expert systems

Machine Learning
Probabilistic methods that improve with more data

Deep Learning
Creates the best data representations to date for learning and querying.

2012
- Speech Recognition
- Object Recognition

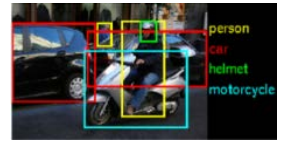
2014
- Information Fusion

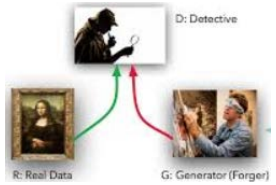
2015
- Sequential Decision Making
- Attention Models

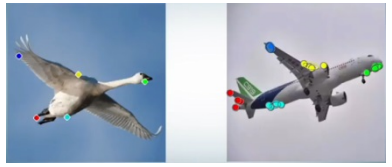
2016
- Generative Adversarial Networks
- Text <-> Image

2017
- Unsupervised Generative Models
- Meta-Learning

2018
- Self Attention
- Cross Domain Modeling



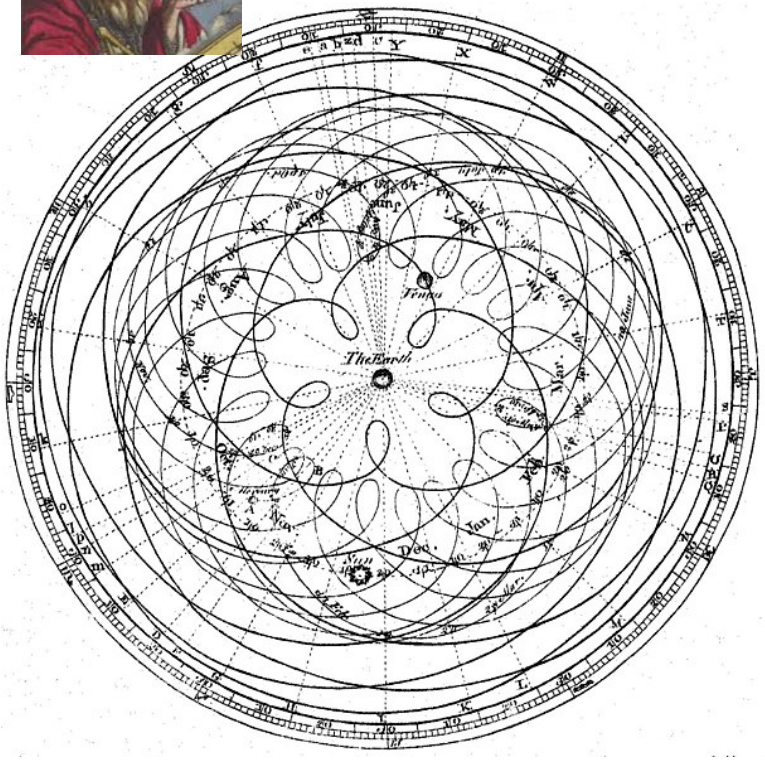




Current State of Deep Learning for Engineering

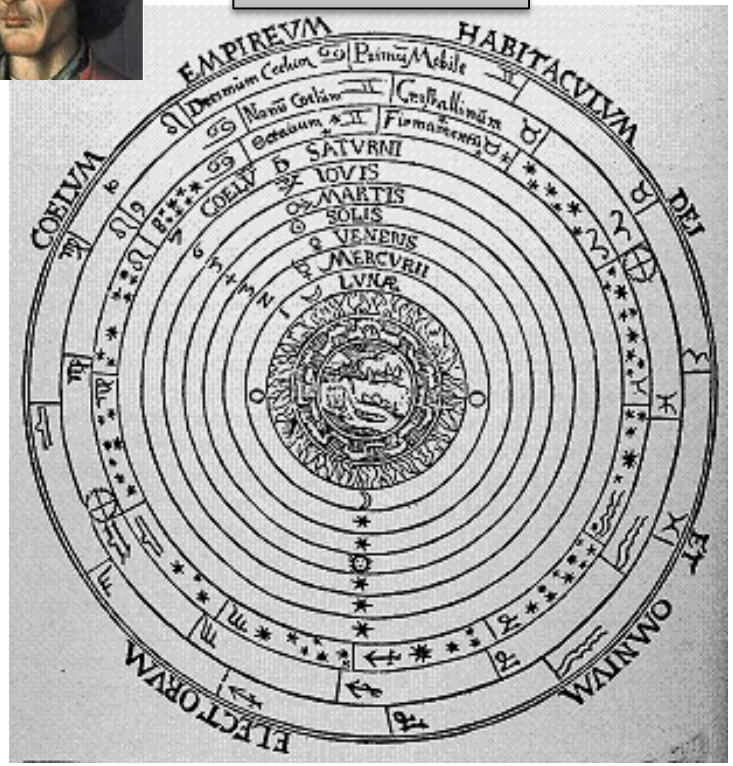
Awaiting Newton, though Copernicus would do

Ptolemy



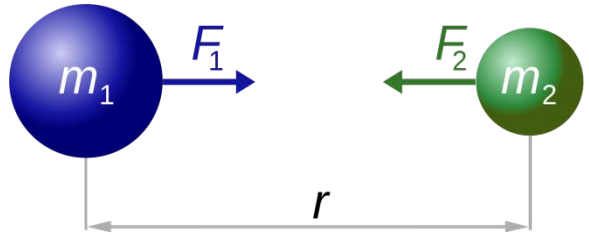
1. This is what the data tells us.
2. Best available predictions.

Copernicus



1. Also consistent with the data.
2. Explainable. Comforting.

Newton



$$F_1 = F_2 = G\frac{m_1 \times m_2}{r^2}$$

1. Also consistent with the data.
2. The underlying principle.

Industry Challenges for Design & Manufacturing

Common Industry Practices

- Physics based engineering
- Reliance on extreme scale simulations
- Heuristic, incremental design methods
- Expert based decision making

Pace

The rate of ML innovation is several times the rate of non-software product innovation.

Competitive advantage is fleeting.

Machine Learning Shortcomings

- Difficulty incorporating explicit constraints
  - Physics, manufacturing & engineering specs

Risk and Bottlenecks

- Many expert based tasks:
  - Produce highly variable results.
  - Are repetitive, time consuming and unscalable.
  - Are difficult to codify.

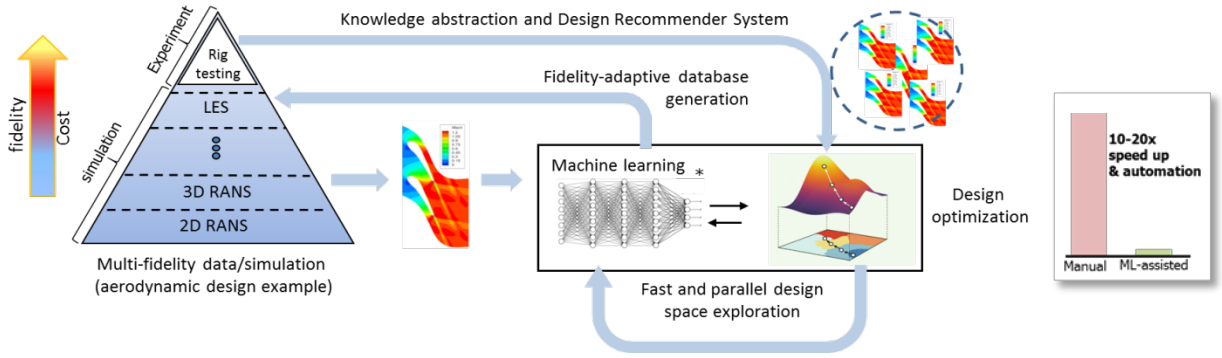
Organizational

- Often suboptimal:
  - Data collection and management.
  - Analytics planning and pipeline standardization.
  - Data collection and feedback loop for design.

Design and Manufacturing Opportunities for Machine Learning

Learning from Prior Design & ML-enabled Multi-fidelity Design Optimization

Detect when massively parallel simulations can be modeled at lower fidelity and switch.



Material Design and Characterization

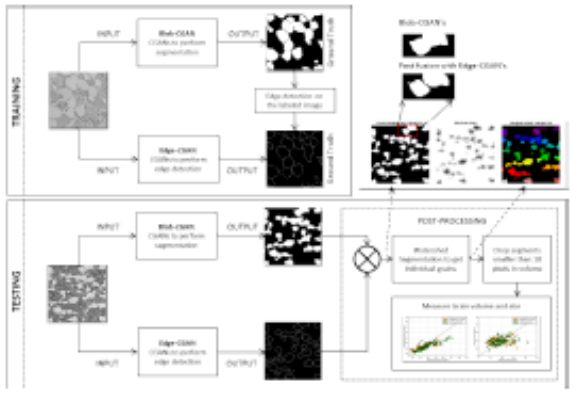


Figure 5: Flowchart of the coupled cGAN inspection system.

Deep Learning for Image-based Material Characterization

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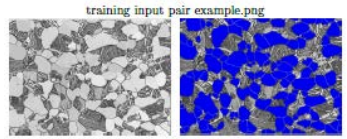

Modeling Structure-Property Relationships in Materials Using Deep Convolutional Neural Networks

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Design of Complex Energy System Components

Unsupervised & Supervised Learning

Advanced Manufacturing Constraints

Representation Learning

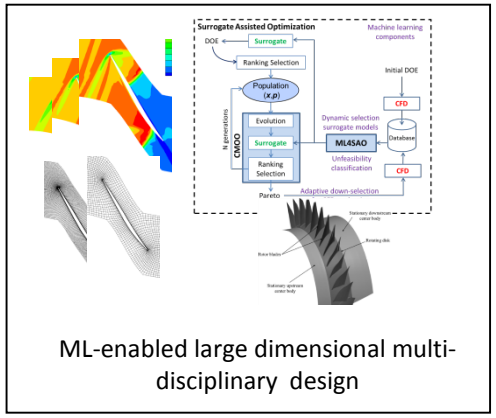
Heat exchanger design recommendations, fabrication and validation

Spec Consistent Automated High-dimensional Design

The power of ML

Constrained to:

Physics, Engineering and Manufacturing specs



ML-enabled large dimensional multi-disciplinary design

Bridging the Engineering – Machine Learning Gap

Conclusions

The greatest barrier to realizing the value of ML is the absence of bridges from existing deterministic, rule based practices to highly non-linear probabilistic methods.

- Trust by experts
- Performance confidence and explainability
- Validation methods
- Specification practices
- Commissioning practices

- Cutting edge DL methods are becoming more explainable.
- Generative models are enabling better and more generalizable models.
- Unsupervised learning has begun and is the key to exploration of design and manufacturing product spaces.

Thank You

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