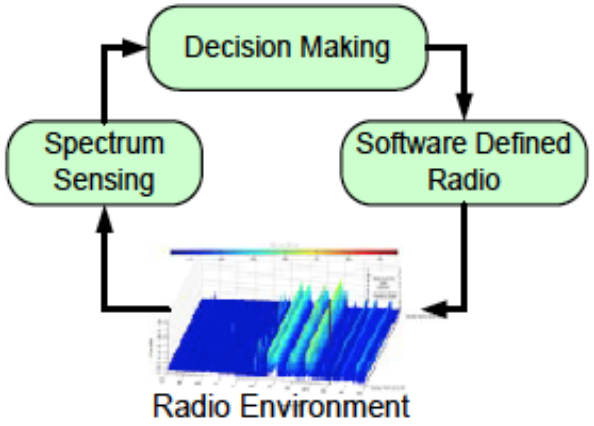
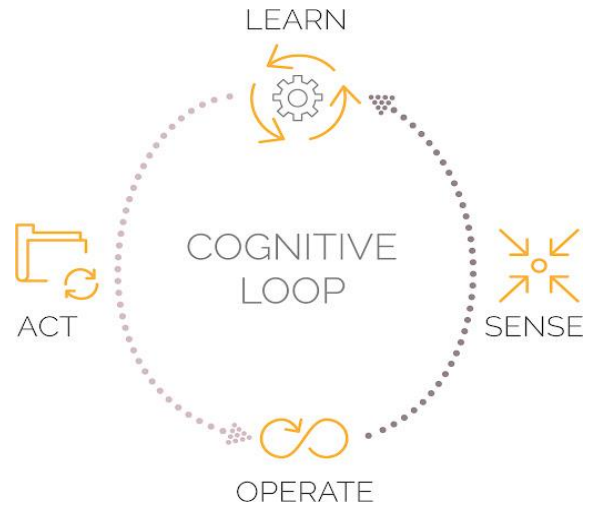
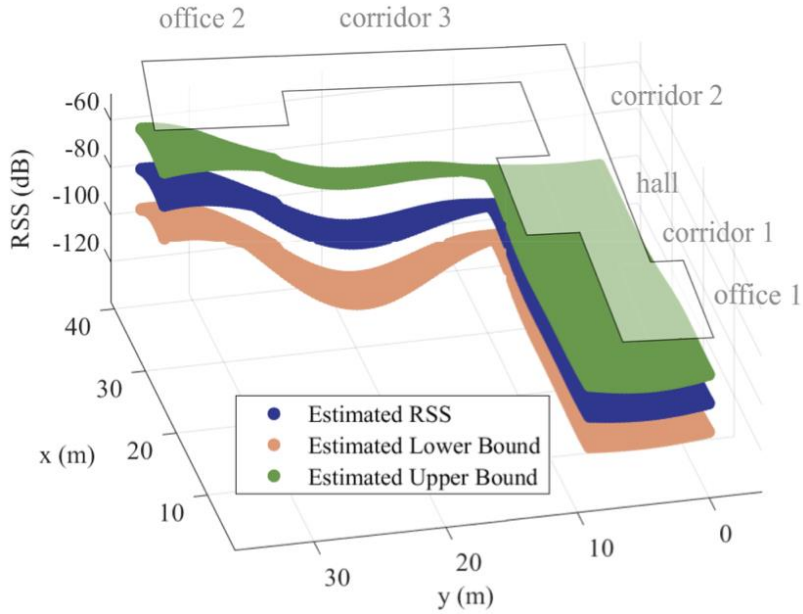
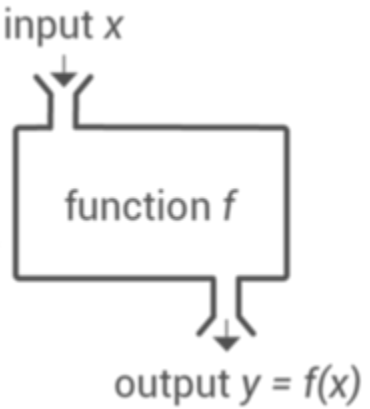
Rely on Domain Knowledge or Handoff to Machine Learning Models?

- **My answer**: not to choose one over the other, but to **synergizing the two**
  - ➔ Traditional models, though limited, have brought us to where we are today
  - ➔ Potentials of ML has already been demonstrated and widely recognized
- Success stories
  - ➔ Cognitive radio vs. reinforcement learning
  - ➔ Also: congestion control, distributed power control
  - ➔ Deep learning-empowered fingerprinting
  - ➔ Construction of radio maps/confidence maps
- If a problem is well defined and sufficient data is available, ML can effectively find a mapping: $y = f(x)$
  - ➔ Domain knowledge is essential to define the problem in the first place
  - ➔ Machine learning is then simply a class of computational algorithms—evolving over time with different models to meet different needs



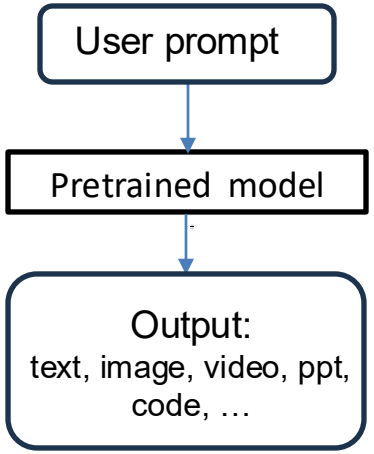




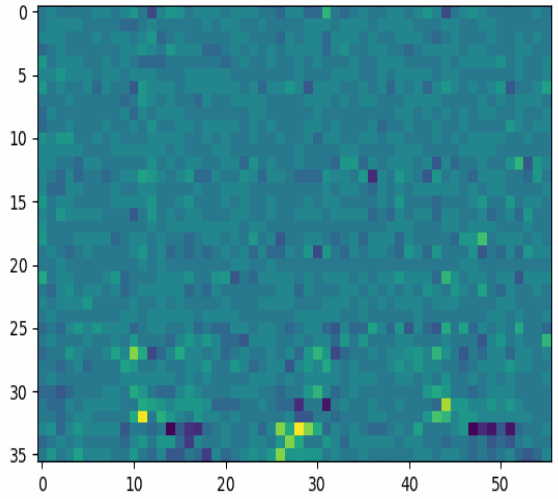


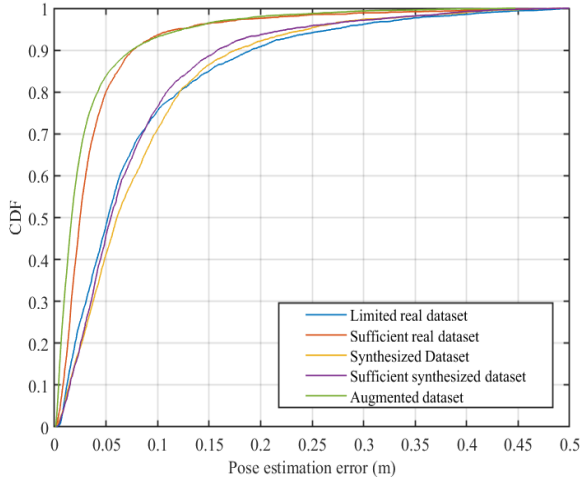
Data Augmentation

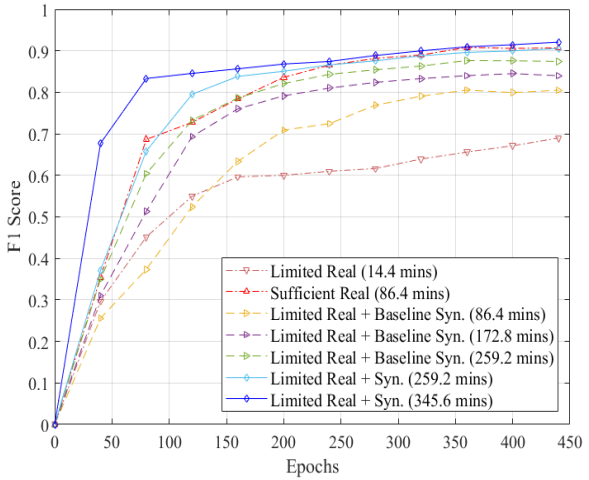
- Deep learning is powerful, but fundamentally limited by the availability, quality, and diversity of data
- Unlike CV and NLP, RF data collection is time-consuming and costly, and
  - ➔ Collected data is often noisy and sparse,
  - ➔ … spans spectral, temporal, and spatial dimensions
  - ➔ Diversity of environment is often limited
  - ➔ Variability in the RF signal representations across different types of devices
  - ➔ Difficult with generalization beyond training data
- A promising approach is to leverage AIGC for synthesizing RF data, with
  - ➔ Conditional GAN models
  - ➔ Diffusion and stable diffusion models
  - ➔ Domain knowledge remains crucial for model design and for assessing the quality of the synthesized datasets







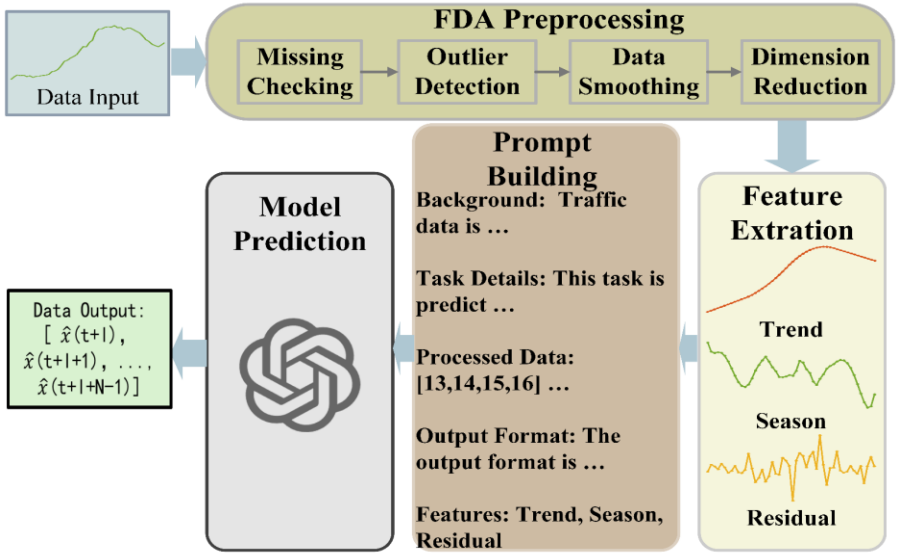




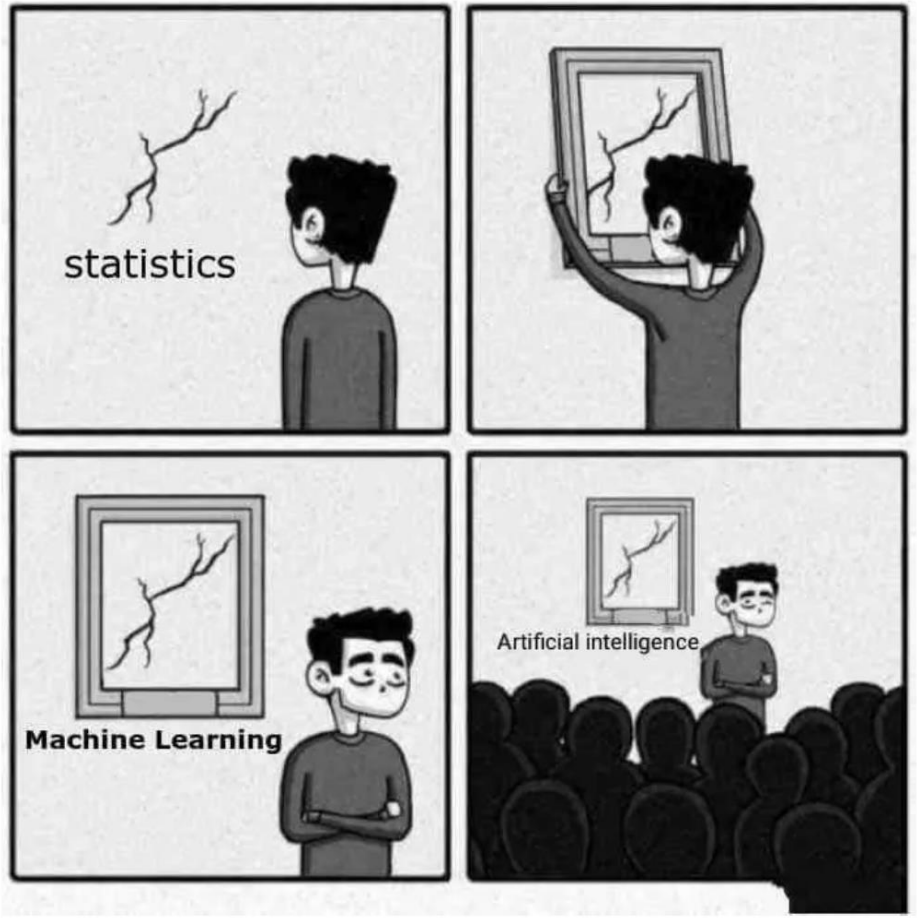
Leverage Advances in Other Fields

- **Example**: Functional Data Analysis (FDA)
- Wireless data belong to the class of functional data, which can be represented by curves or functions
  - ➔ The process that generates wireless data naturally follows a stochastic function
  - ➔ Many spectrum-related problems can be more effectively addressed when the data are treated as functions
  - ➔ Unlike black-box approaches, FDA can provide interpretable results, such as performance guarantees

FDA+LLM for wireless network traffic prediction



Machine Learning is not just glorified Statistics



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