Cost Estimating Maturity and a Vision for the Future

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Agenda

- INTRODUCTION
- PRE-MODERN AND PRE-INDUSTRIAL ESTIMATING
- EARLY MODERN ESTIMATING (INDUSTRIAL REVOLUTIONS 1 AND 2)
- MODERN ANALYSIS (EARLY INDUSTRIAL REVOLUTION 3)
- POST MODERN (LATE INDUSTRIAL REVOLUTION 3)
- META-MODERNISM (INDUSTRIAL REVOLUTION 4 AND BEYOND)
- A VISION FOR THE FUTURE
- FUTURE RESEARCH AND TRENDS

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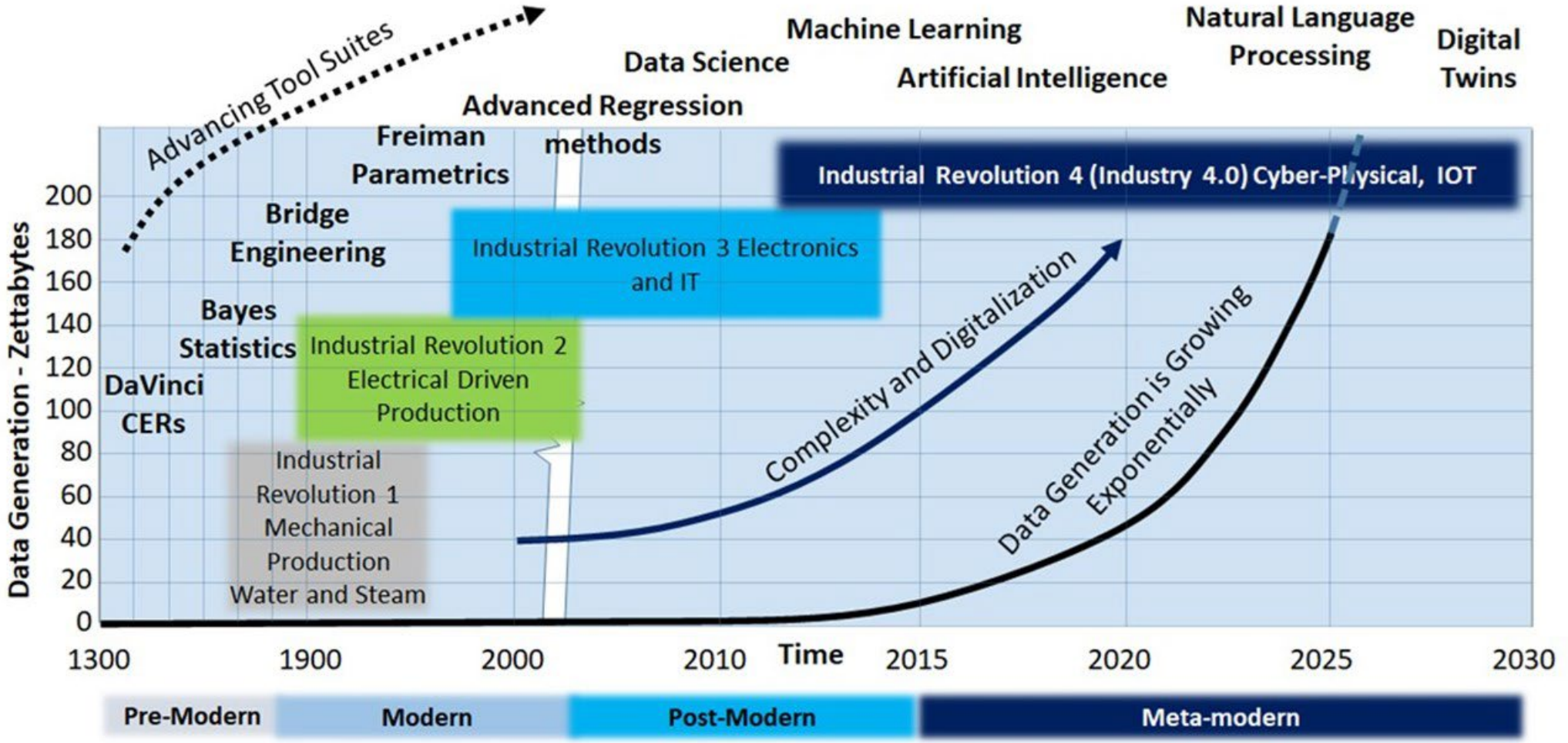
Introduction



Explosive Growth of Data and Computing Power and Advances in Analysis Techniques Enable the Meta-Modern Period.

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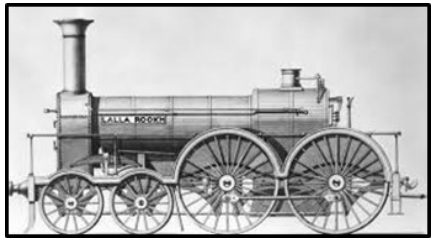
Pre-Modern and Pre-Industrial Estimating

- Who were these Pre-modern estimators?
  - Archimedes (287 – 212 BC)
  - Diophantus (cir 275 BC)
  - Leonardo da Vinci (1452 – 1519)
  - Isaac Newton (1642 – 1727)
  - Thomas Bayes (1702 – 1761)
  - Carl Gauss (1777 – 1855)
  - Charles Babbage (1792 – 1871)
  - Isambard Brunel (1806 – 1859)



- What were their contributions?
  - Quantitative measurement
  - Advancements in algebra
  - Cost Estimating Relationships
  - Binominal mathematics and calculus
  - Advancements in probability theory
  - Least squares, CER best fit
  - Programmable computer
  - Railroad/General purpose CERs

Early estimating pioneers provided the foundation to modern and Meta-modern analytical methods.

An Early Example to Modern Day

- French Cathedral Builders (1300's)
  - Developed a "standard unit"
    - Element of work
    - Performed in ten-man days including material
  - Chartres Cathedral had 7,448 units
    - One Unit today is $81,500 (BY 2018 US)
    - Todays Cost - $607M
- Modern Day – Washington Cathedral (1907 – 1990)
  - 83,000 Square Feet - $65M and a $34M underground garage
  - Today's cost - $665M or $8,010/sqft

Early estimating methods are still valid and support current day forecasting.

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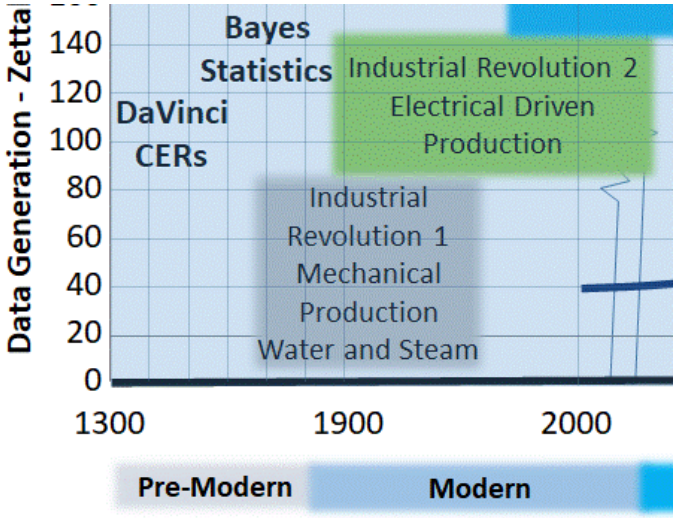
Industrial Revolutions 1 and 2

- Industrial Revolution 1
  - Mechanization and mechanical advantage
  - Materials and productionization
  - Migration from Farm to City
  - Water and Steam power for commerce
  - Analytical method maturity



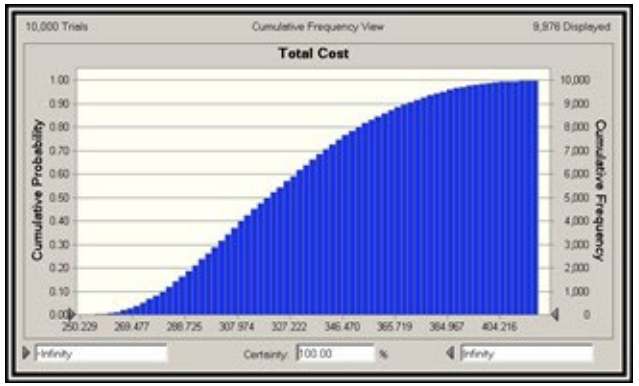
- Industrial Revolution 2
  - Migration to electrical driven industrial model
  - Machine advancements
  - Computer fundamentals
  - Programming Languages
  - Logical process implementation
  - Emergence of modeling approaches of physical products

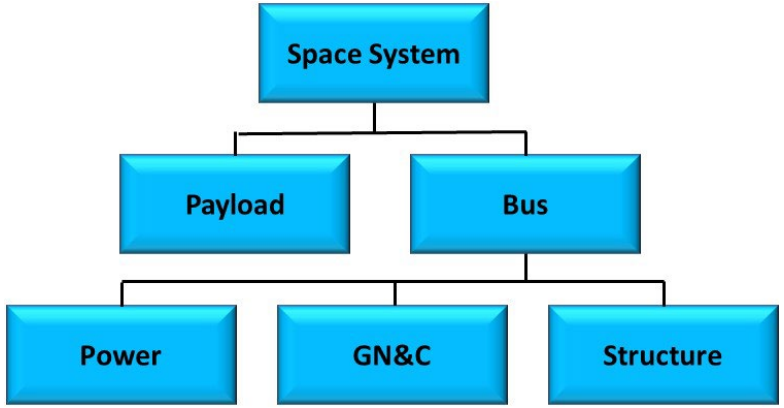
Estimating technology driven by evolving manufacturing and scientific advancements.

Early Modern Contributions to Cost Estimating

- Who were these modern pioneers?
  - Frank Freiman (1962 – Present)
  - David Novick (1930s – 1960s)
  - RAND Corporation
  - Los Alamos National Labs (LANL)
  - Aerospace Corporation (Steve Book)

- What were their contributions?
  - Parametric Analysis
  - Statistical Estimating
  - Precursor to the WBS
  - Monte Carlo Simulations
  - Cost Driver Identification

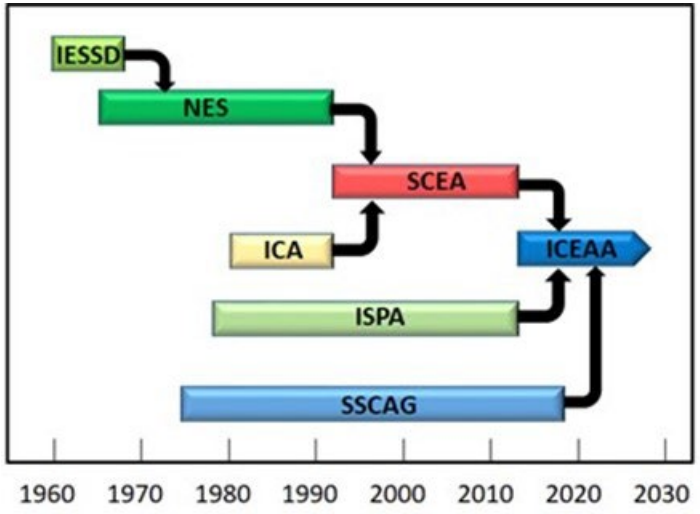


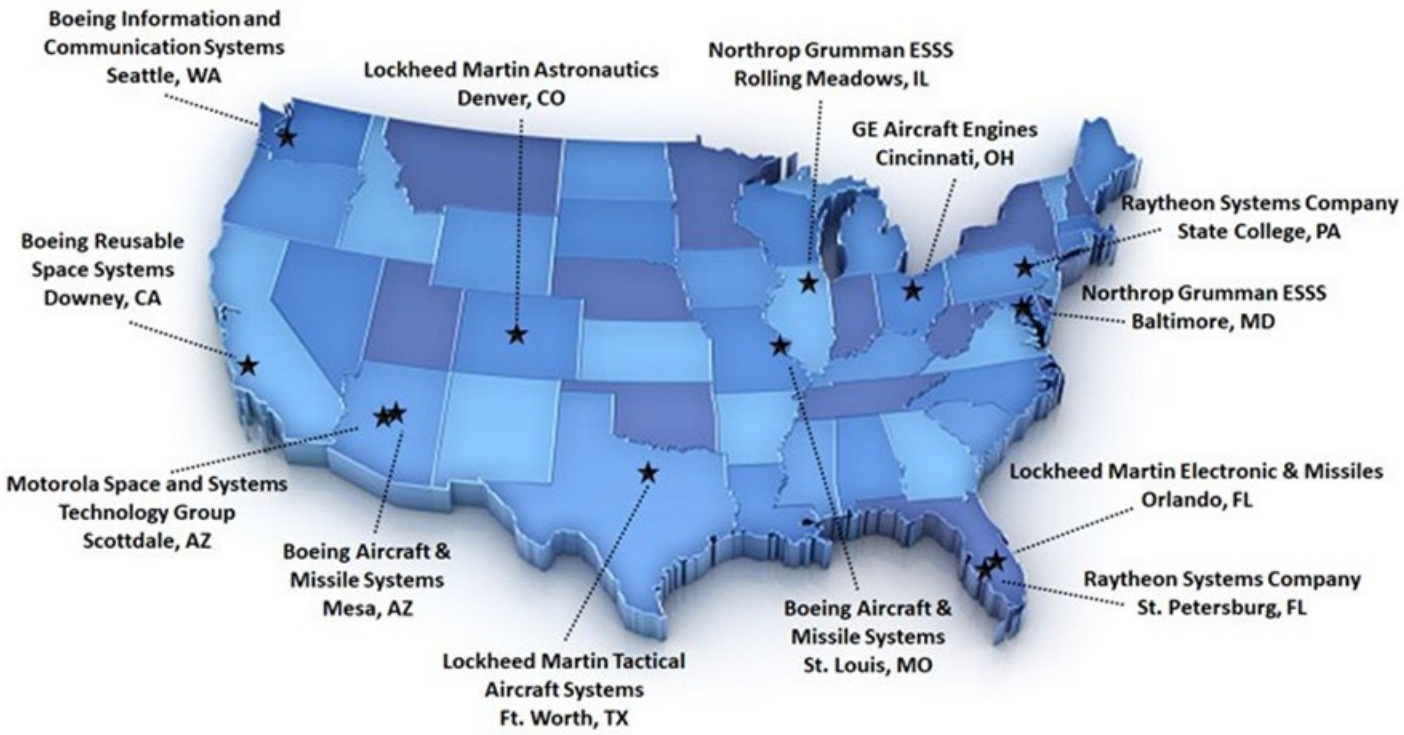


Increased availability of estimating tools across industry.

Data Collection and Professional Maturity

- Joint Government – Industry Initiative
- Parametric Reinvention Laboratory
- Professional Societies





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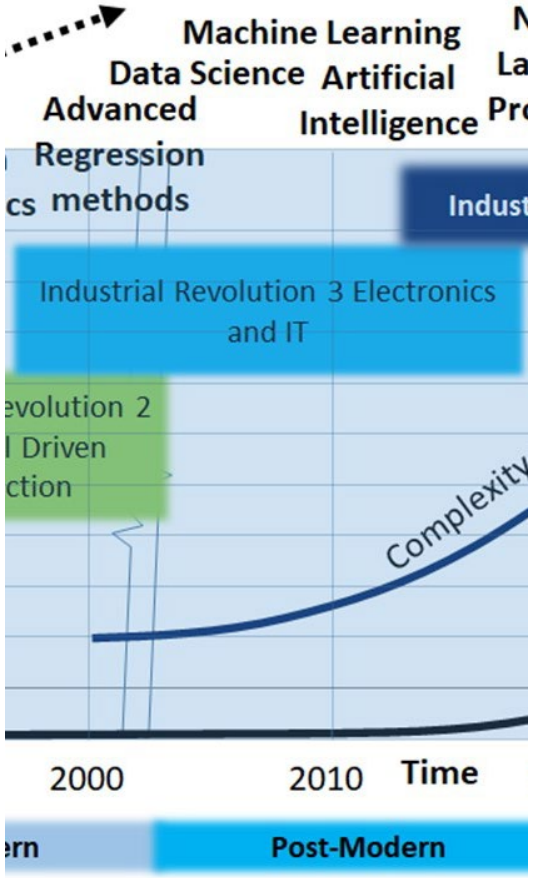
Early Industrial Revolution 3

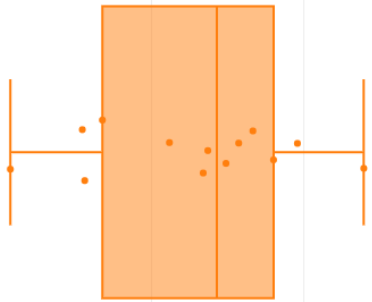
- From mainframe to desktop to portable computers
- Connectivity, networks and WiFi
- Beginning of Data Generation revolution
- Basic Automation
- Advancement of modeling and simulation



The tool of the century (computers) drive applications of the century (business and defense).

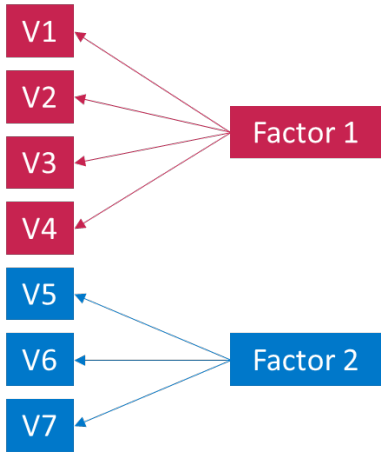
Modern Tools and Methods

Descriptive Statistics

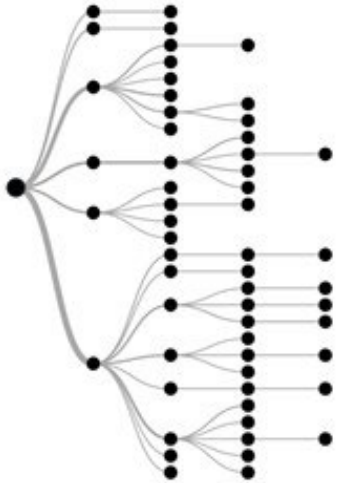


Regression

Factor Analysis



Decision Tree



- Descriptive Statistics and Statistical Inference
- Regression Models
- Factors
- Discriminant Analysis
- Time Series
- Decision Trees

Modern tools and methods provide robust solutions in cost estimating.

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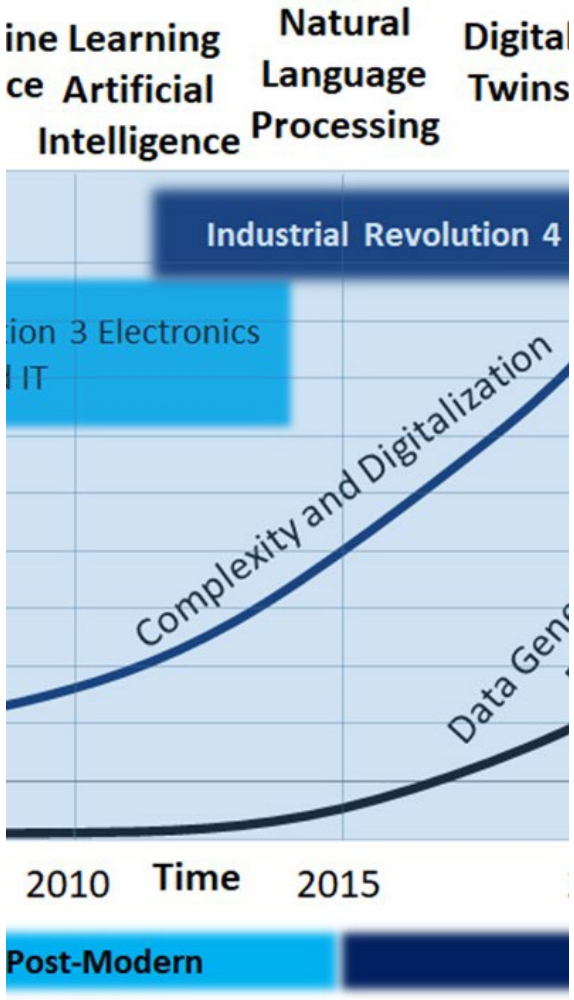
Later Industrial Revolution 3

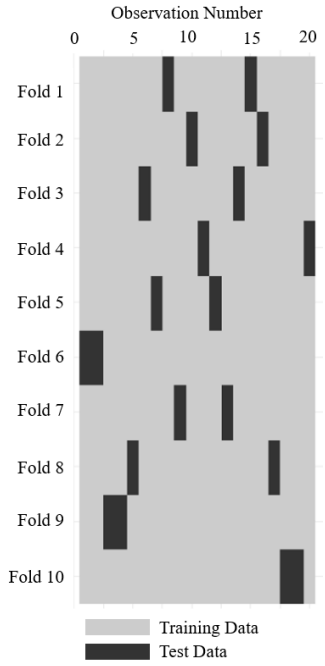


- Technology has caught up with the estimators imagination
- Advanced computing power to process algorithms efficiently is realized
- Means available to demonstrate repeatability and credibility

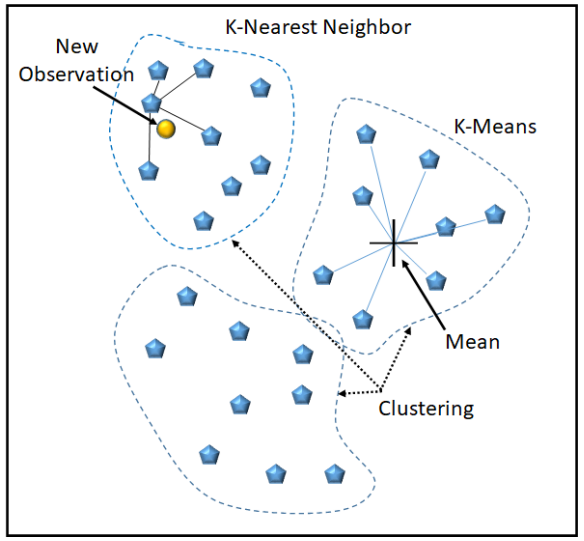
How Advancements are Accelerating

- Cross- Validation
- Clustering
- Neural Networks
- Fuzzy Logic
- Evolutionary Programming

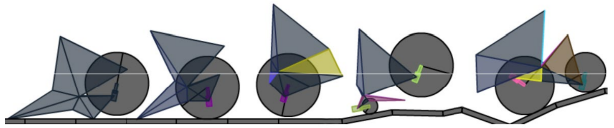
Cross-Validation



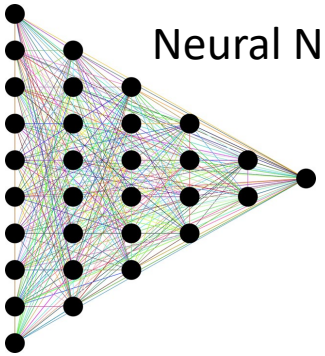
K-NN, K-Means Clustering



Evolutionary Programming



Neural Networks



Inexpensive computing power enables multiple methods that enhance cost estimating.

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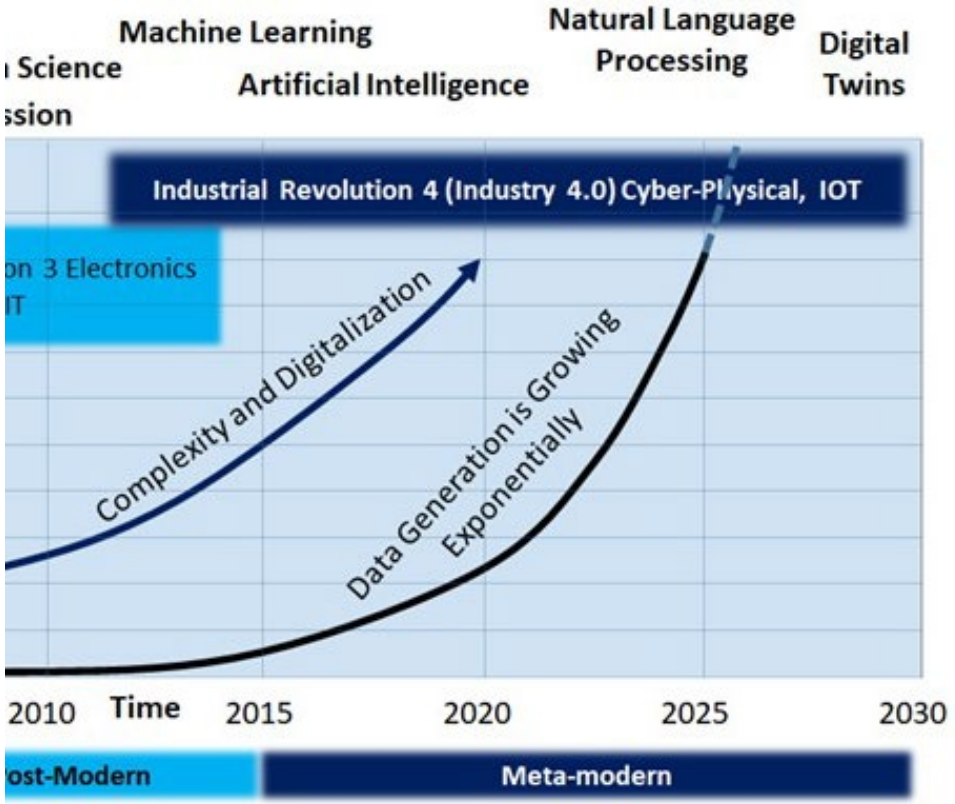
Industrial Revolution 4 and beyond



- Advanced methods
- Automating Modeling and Simulation
- Internet of Things/Connectivity
- Complexity and processes
- Speed

More accessibility tools, methods and information results in higher productivity.

Meta-Modern and Beyond

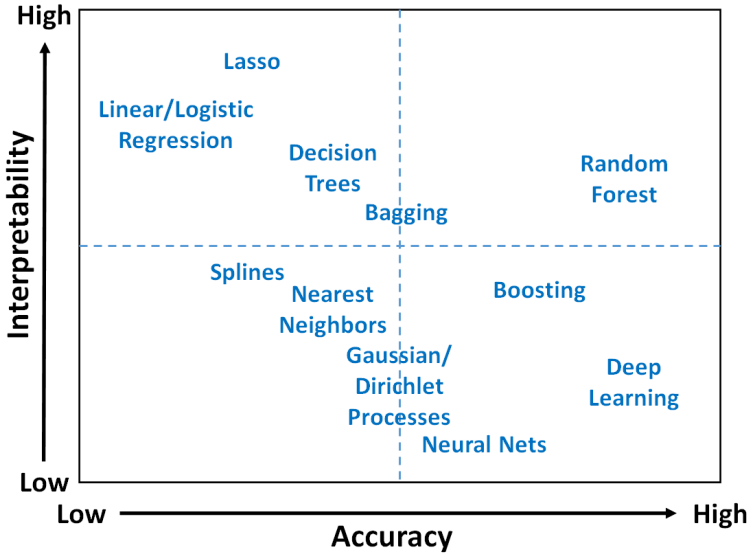
- Data Science
- Artificial Intelligence and Machine Learning
- Natural Language Processing
- Digital Twins

Types	Supervised	Unsupervised
What does it do?	Learn a mapping from inputs to outputs (i.e., how to predicts outcomes)	Identify clusters, association or anomalous data and reduce dimensionality
What does it require?	Labeled training data (i.e., a response variable in addition to predictors)	Training data (a response variable is not required)
What kinds of Algorithms?	Linear, non-linear and logistic regression, LDA, Decision Trees, Random Forests and Gradient Boosted Trees, Support Vector Machines, and ANNs	K-Means and Hierarchical Clustering, Gaussian Mixture Models, Principal Components Analysis (PCA) and Autoencoders
Key Limitations	Needing to balance the Bias-Variance tradeoff (Underfitting and Overfitting)	Interpreting clusters requires human intervention and no guarantee of meaning

(a) Husky classified as wolf (b) Explanation

Figure from LIME paper [1]: The husky was mistakenly classified as wolf, because the classifier learned to use snow as feature.

Source: https://arxiv.org/pdf/1602.04938.pdf



There is an appropriate method for every organizational level.

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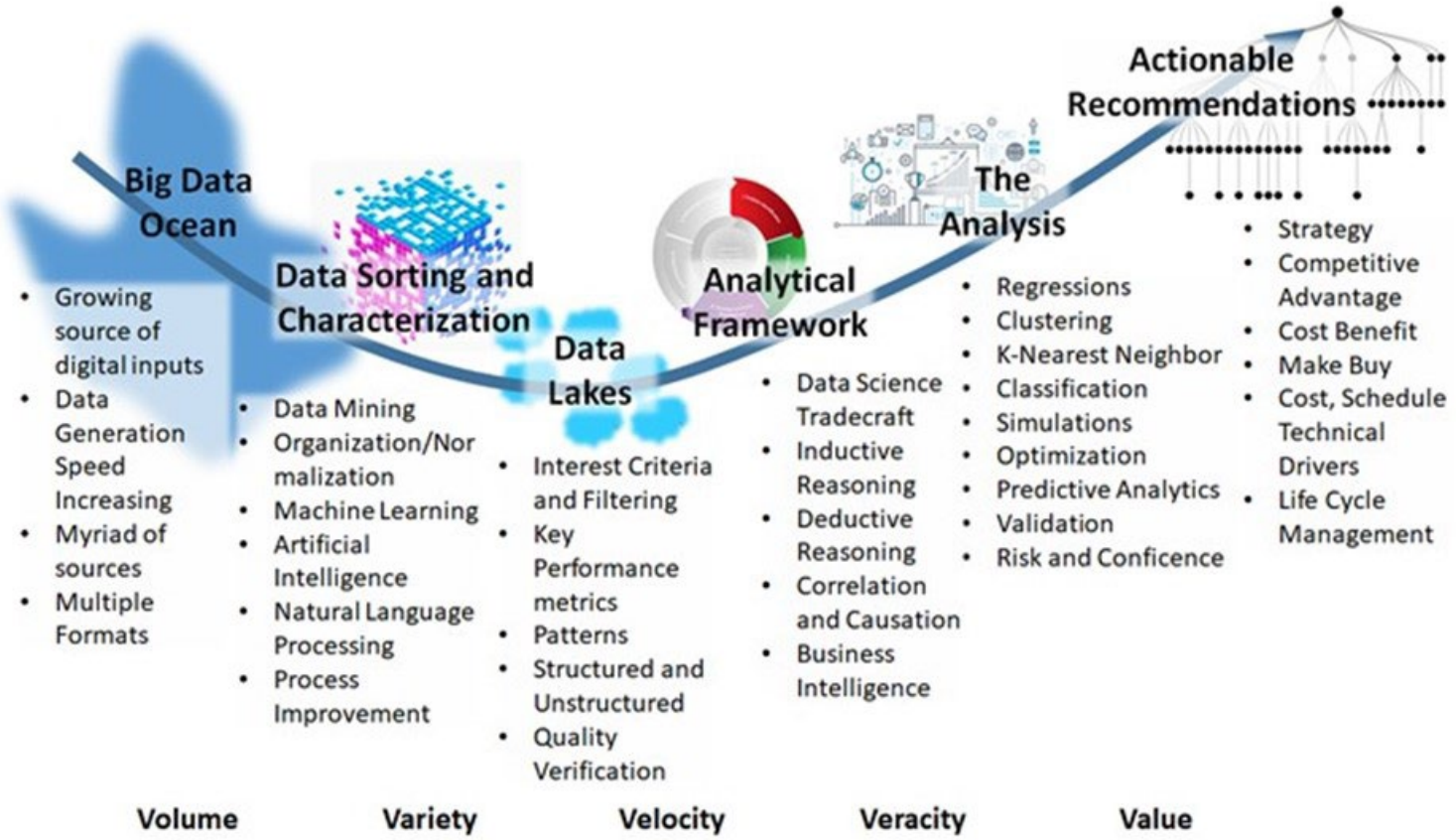
Vision for the Future

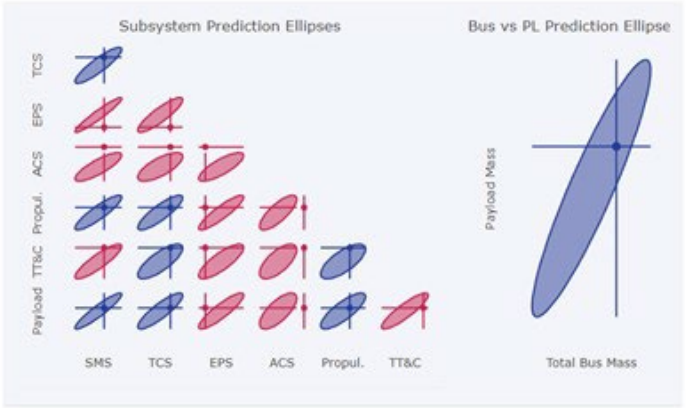
- Digital data is growing
- Advanced tools enable rich analytical methods
- Modeling and simulation is growing
- All lead to higher fidelity actionable decision making

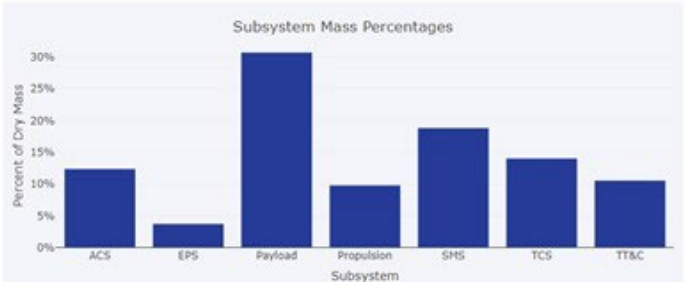


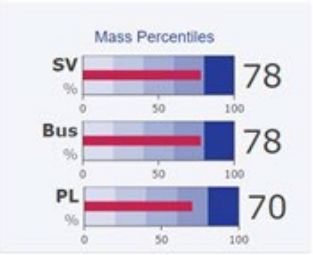
Understanding past methods enables enhanced forecasting and decision making.

Example

- Visionary Methods are here today
- Technical Baseline Assessment Tool (TBAT)
- “No-code” tools
- Benefits
- Future Capability







No-Code tools provide access to the community without understanding how to code.

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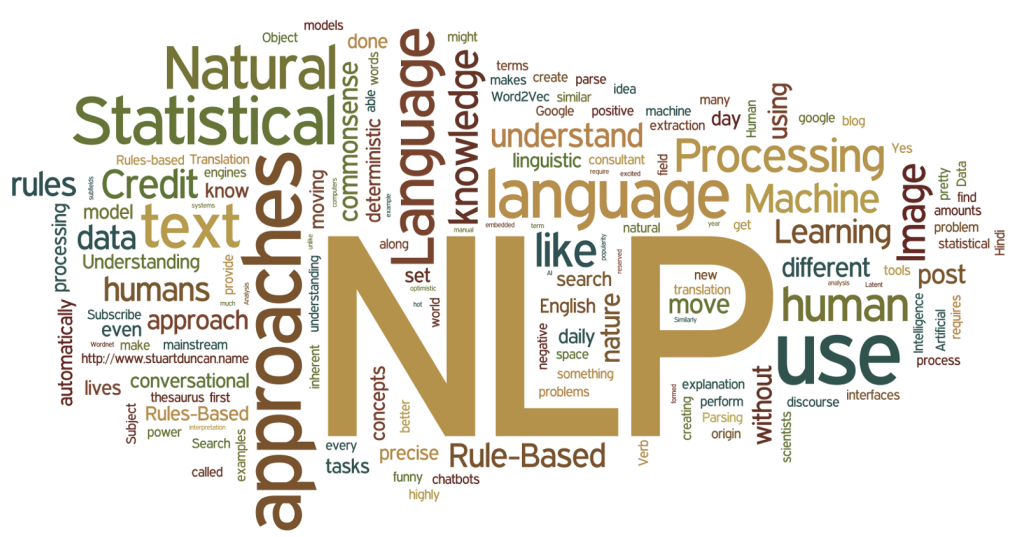
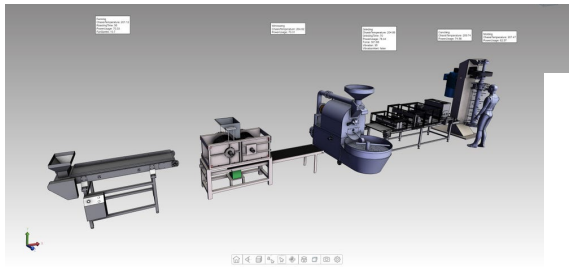
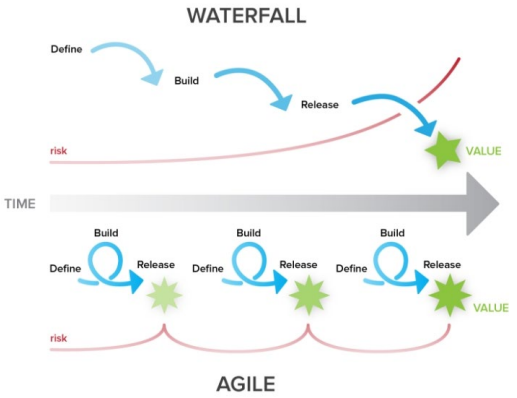
Future Research

- Data Visualization
  - When to Apply
  - How to Implement
- Advancing
  - Artificial Intelligence
  - Machine Learning
- Natural Language Processing
- Digital Twins
- Data Sorting and Quality
- Agile versus Waterfall approach





Digital Twins



Questions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