DARPA Overview
&
Data Driven Discovery of Models (D^3M)

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- Gene Editing & Synthetic Biology

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- Physical Systems
- Human-Machine Systems
- Social Systems

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- Analytics: Understand the World
- Symbiosis: Partner with Machines

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- EM Spectrum
- Tactical Information Extraction
- Globalization

Strategic Technology

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- Win In Any Environment via Composable Kill Chains
  - Sensing
  - Comms, Command, Control
  - Effects

Tactical Technology

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- System Focus Areas
  - Ground, Maritime, Air, Space
- Crosscutting Themes
  - Agile Development
  - Cooperative Autonomy
  - Unmanned Systems
  - Power and Propulsion

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Example Program

D^3M: Data-driven discovery of models

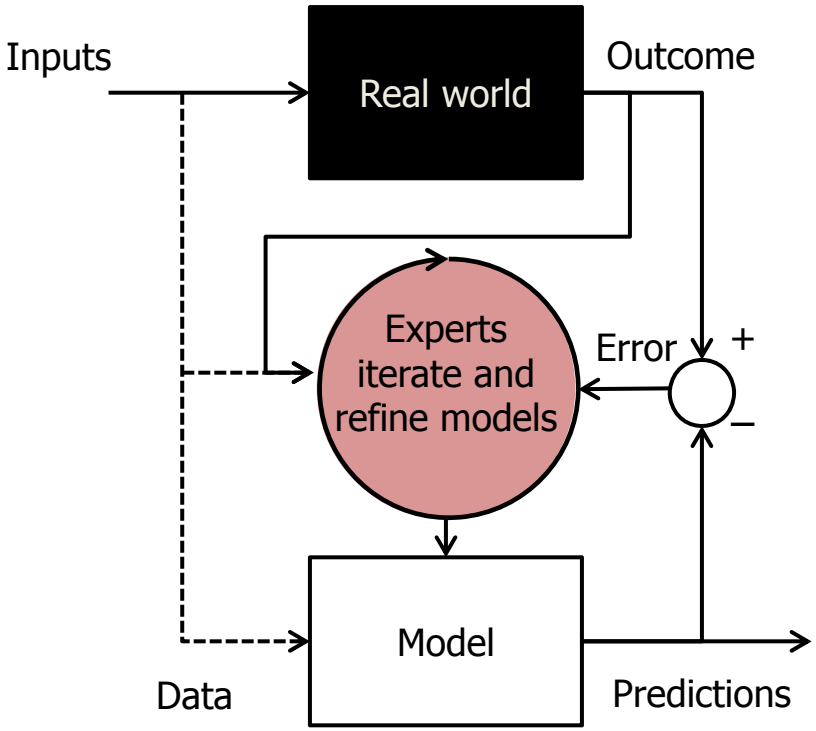
Goal:

Automate (many of) the methods in data science to create empirical models of real, complex processes

- Enable non-expert users to make predictions from data without the need for data scientists
- Provide expert data scientists with automation that allow them to focus on the hard parts of the problem

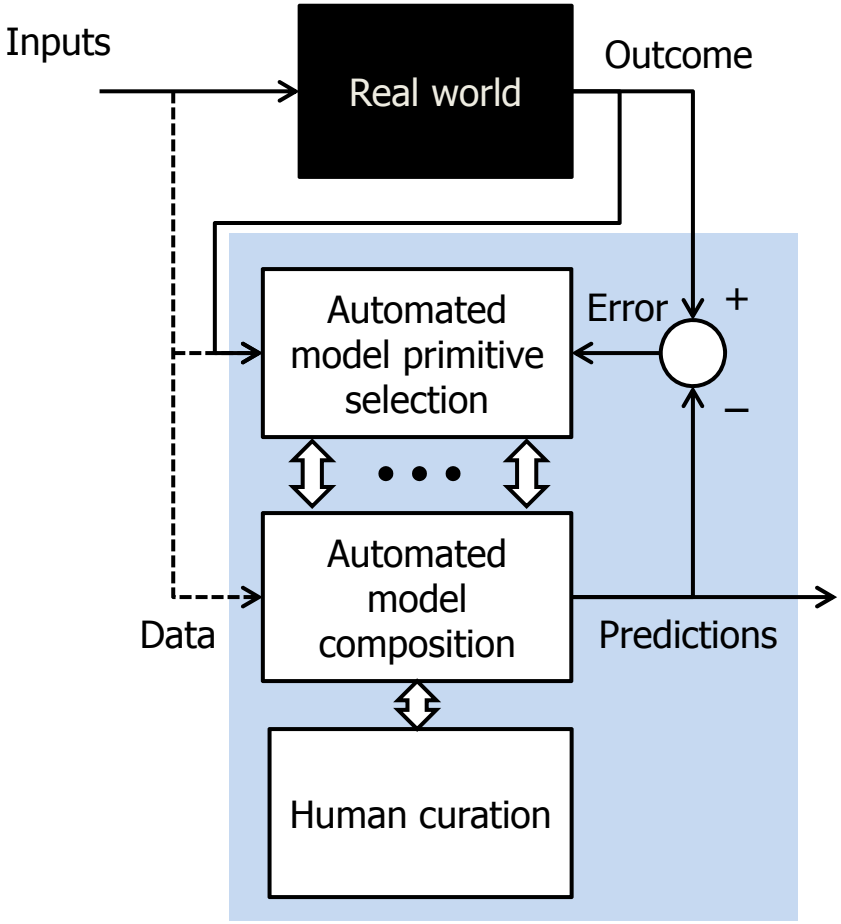
D³M: Data-driven discovery of models

Today: Manual



- Model: representation of a real-world system
  - Examples
    - Inferring locations of images
    - Prediction of election outcomes
    - Estimation model for disease outbreaks
- Manual process: 10-1000s of person-years
- Teams of experts required to develop the model

Tomorrow: Automated



- Automatically select problem-specific model primitives
  - Extend the library of modeling primitives
- Automatically compose complex models from primitives
- Facilitate user interaction with composed models

D³M: Accelerate scientific discovery and intelligence analysis

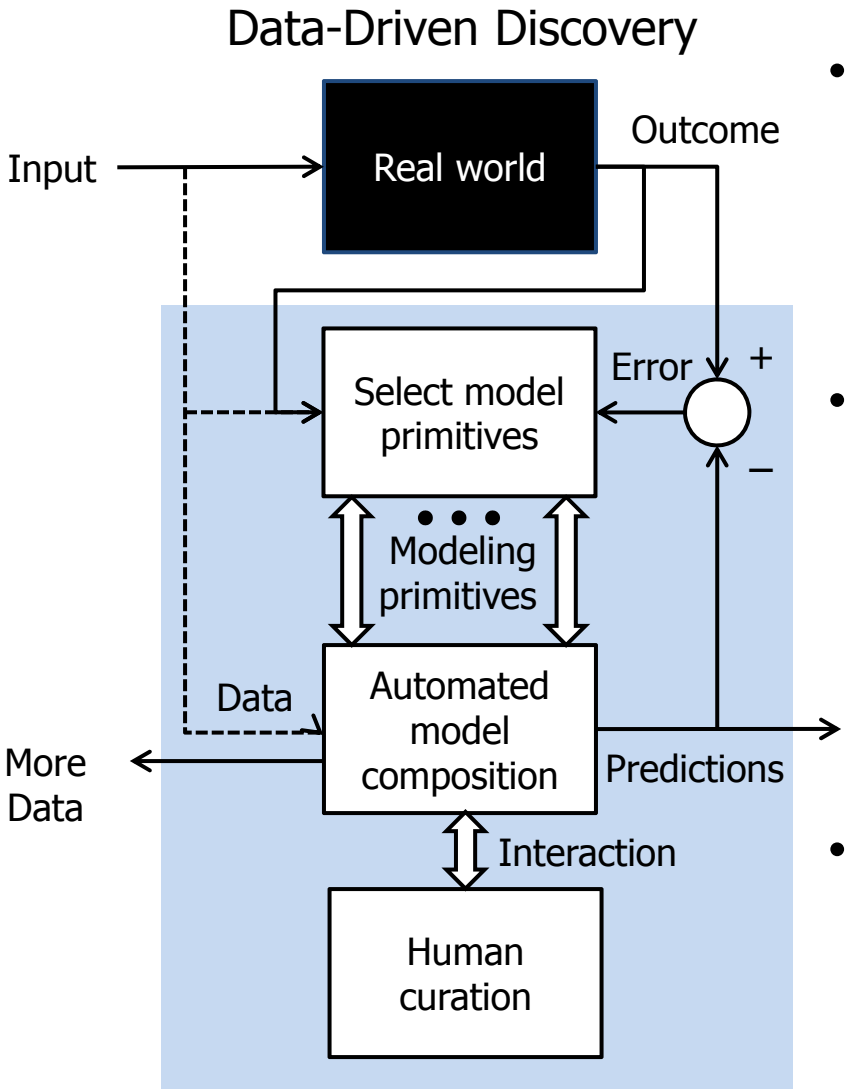
- Discover empirical models having complexity beyond current human comprehension
  - Humans can search only a tiny fraction of model space
  - Machines can search a much larger fraction much more rapidly

- Fast, automated model discovery enables:
  - Accelerated scientific discovery
  - Rapid intelligence analysis w/o embedded data scientists

Year	Cost (Person-months)		Avg. time to solution (Months)	
	As-performed	with D³M (estimated)	As-performed	with D³M (estimated)
2009	432	4	24	0.5
2009-2011	126	5	18	0.25
2014-2015	102	3	6	0.25
2015-2016	83	4	5	1

Average cost of model construction per analytical problem posed to Nexus 7, XDATA, Memex and QCR

Automated discovery of complex models with non-expert curation



- TA1: Discover and develop model primitives
  - Create a "vocabulary" of modeling primitives
  - Make primitives automatically discoverable
- TA2: Automatically compose complex models
  - Mine corpora of complex models to learn the "syntax" of primitive composition
  - Find optimal compositions
  - Predict additional data requirements
- TA3: Curation of models by non-experts
  - Decompose questions
  - Explain data and models to enable selection and editing

Evaluation metrics

TA1: Measure efficiency of predicting primitives

Protocol	Metric
Predict primitives; experts compose	Δ error of predicted primitives vs. optimal

TA2: Measure (re)discovery of optimal analyses/models

Protocol	Metric
Synthesize models compare to experts	Δ error of D^3M model vs. expert models

TA3: Human curation of models

Protocol	Metric
Decompose questions, compare with experts	P_d/P_{fa} of automated vs. expert (ROC)
Compare decisions made by experts with lay users	Δ error of analyst vs. data scientist in-the-loop

Program-level evaluation (annual integration and evaluation)

Protocol	Metric
TA1-3 form team, work with non-experts to build model, compare with experts	Δ error of D^3M model vs. expert model

Program goals

Phase 1: Reproduce/improve models for existing problems without a data scientist

Problem	Example	Pre-D^{3}M Effort (1st – Opt.)	D^{3}M Effort
1. Simple social/bio-med problems *Linear/categorical models, flat hierarchy, structured data*	*Smoking Factors, genetic species classification*	2-200 hrs (data science)	0.5-2 hrs (SME)
2. Multi-source prediction problems *Multi-fused models, complex hierarchy, mixed data*	*Netflix Prize, Kaggle-PTSD, XDATA problems*	2000-15000 hrs (data science)	1-10 hrs (SME)

Phase 2: Synthesize models for unsolved problems, propose data augmentation

Problem classes	Examples	D^{3}M Effort
1. Multi-modal predictive models with supplied data	*Predict political instability or uprising, riot, conflict, donations to terrorist groups; predict causors/spread of disease; capabilities prediction from designs; optimize manufacturing process (OM)*	5-40 hrs (SME)
2. Multi-modal predictive models with automated data collection	*Multi-player games predict strategy/team formation, market/GDP forecasting, weather/ecology/environmental interaction, genetic factors for disease, predict mass shooting events*	30-100 hrs (SME)

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