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From Data to Decisions and Back

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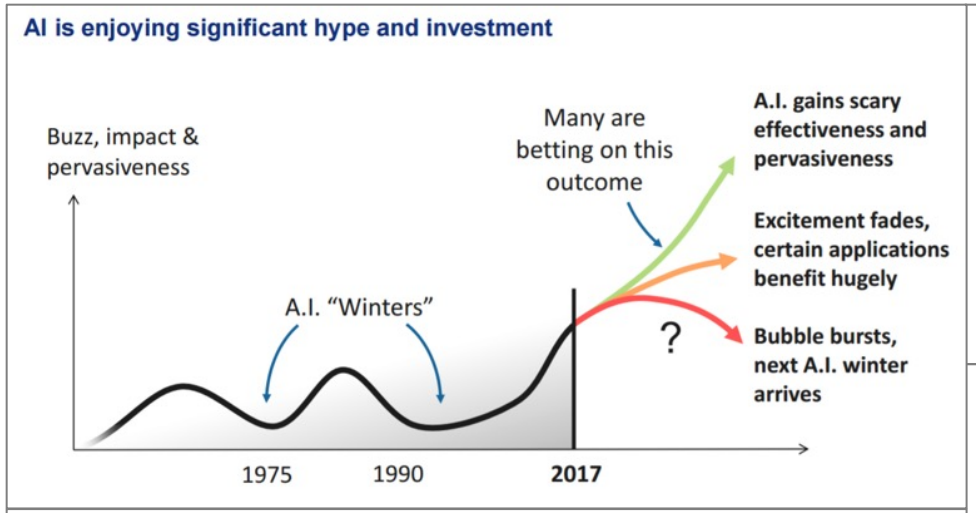
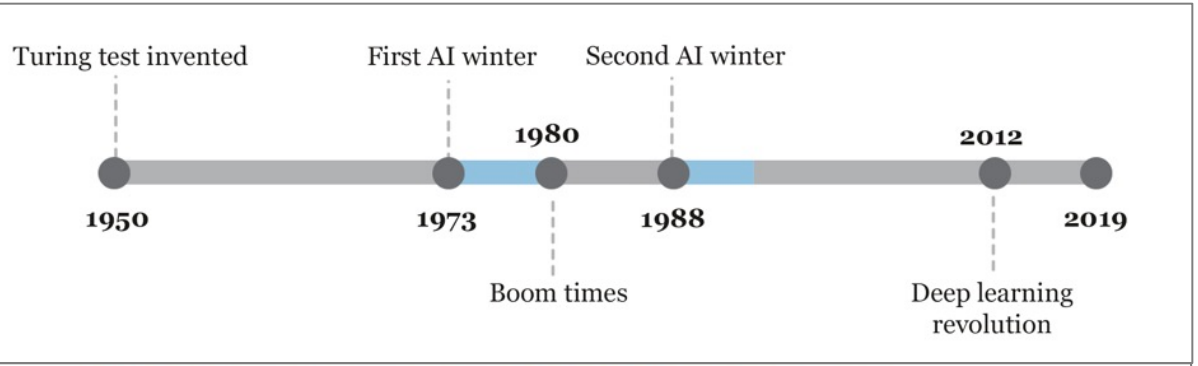
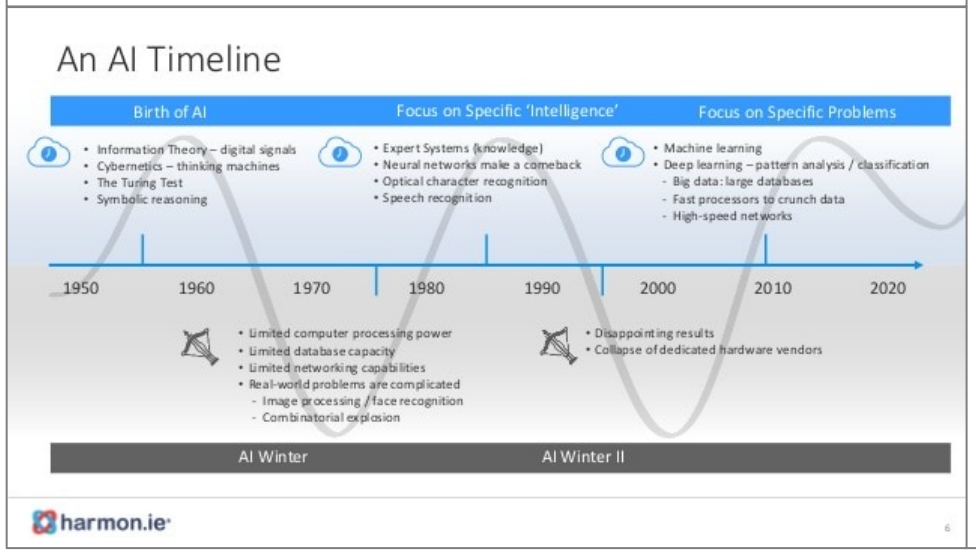
CTO-AI

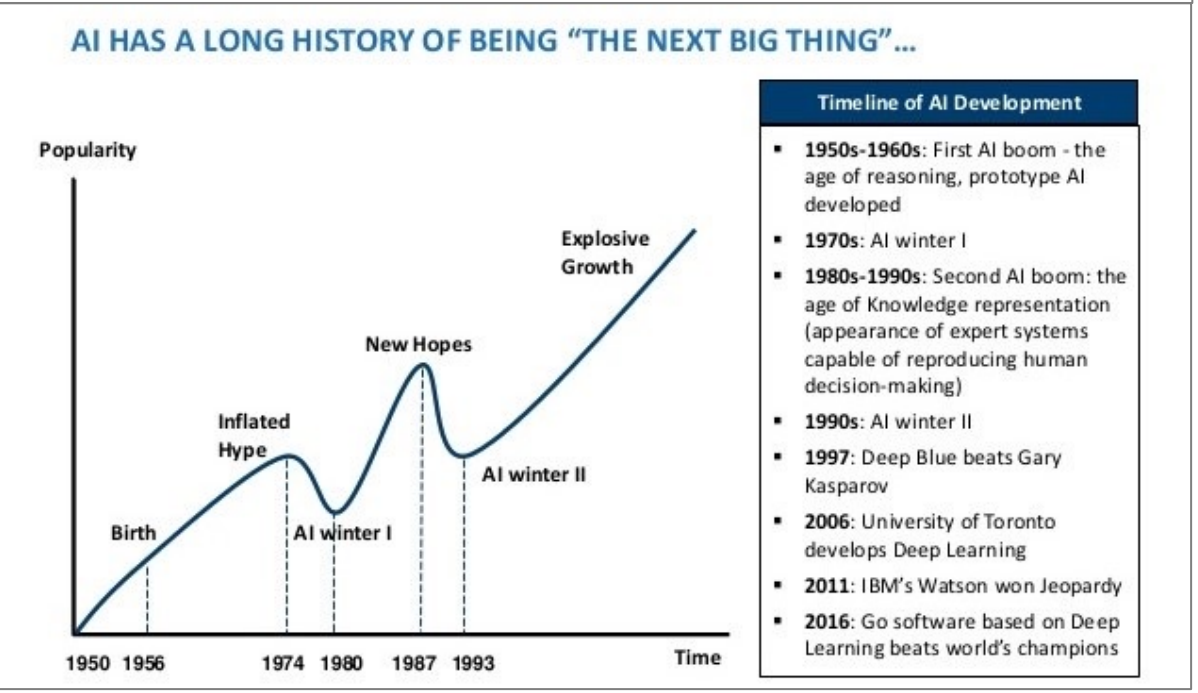
May 24th, 2022

Another AI Winter?









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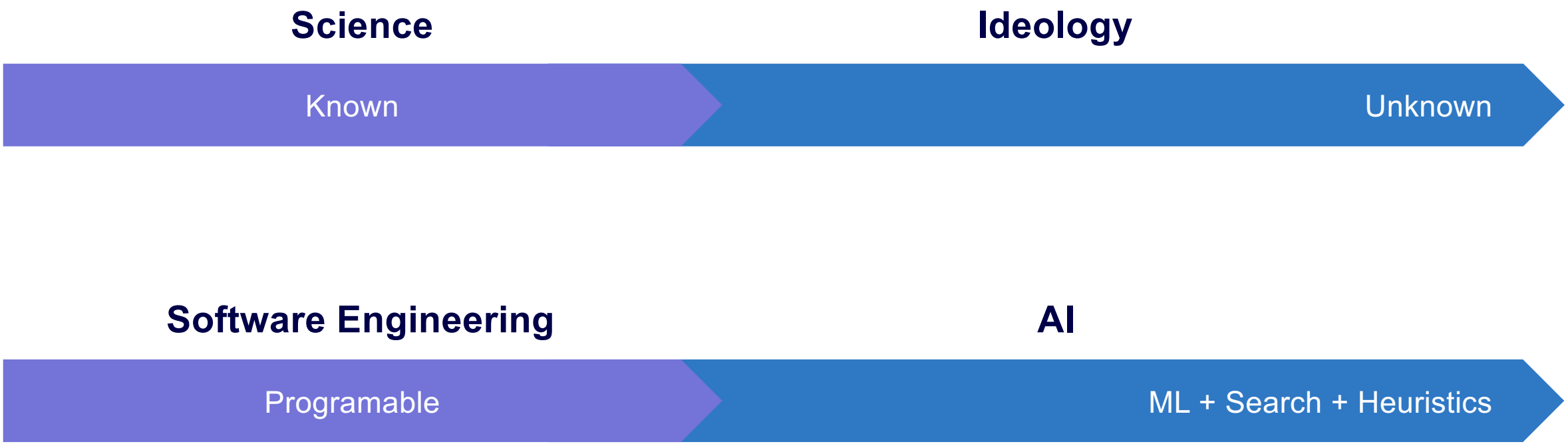
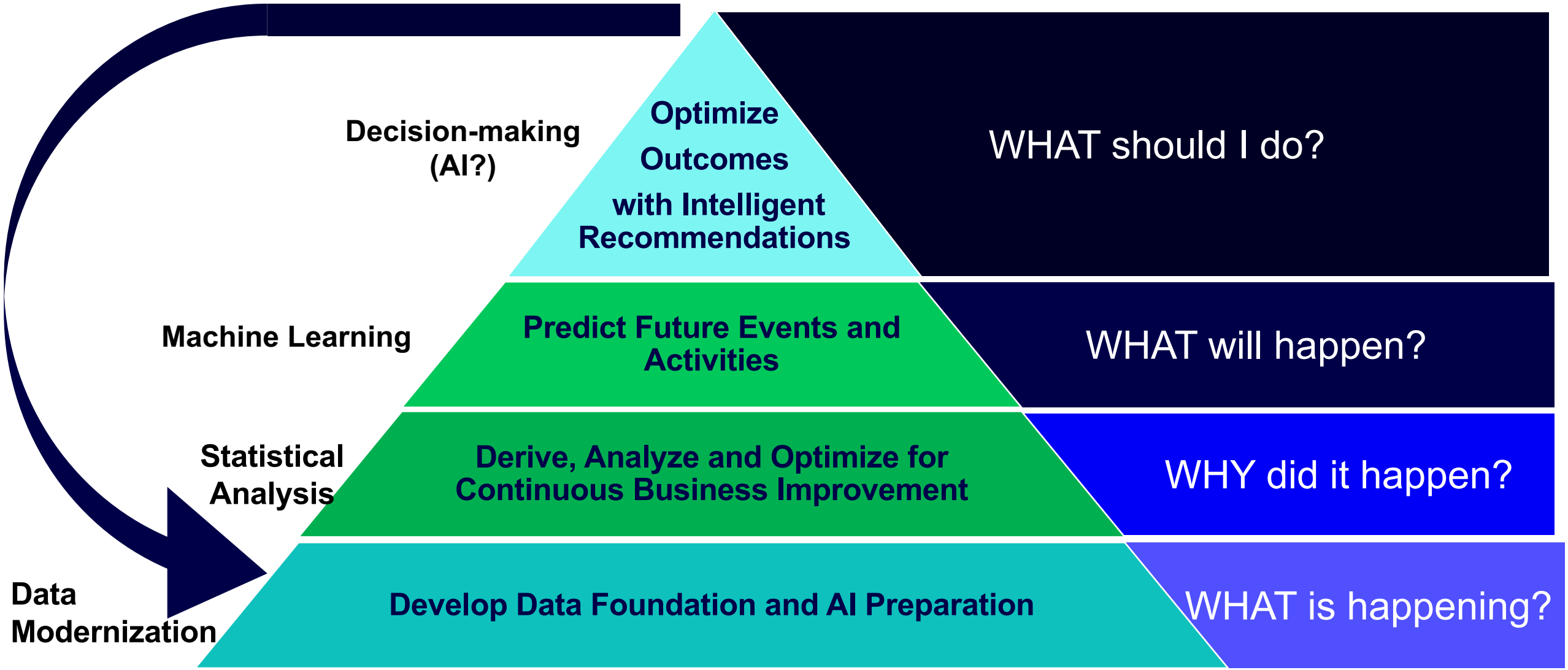
There is Always Room For AI



What Should we Expect from an AI System?
AI Should Tell Us:

- What to do
- When to do it
- What would happen if we do it
- How much should we trust it
- What would happen if we do something else…

The AI Journey Should come Full Circle



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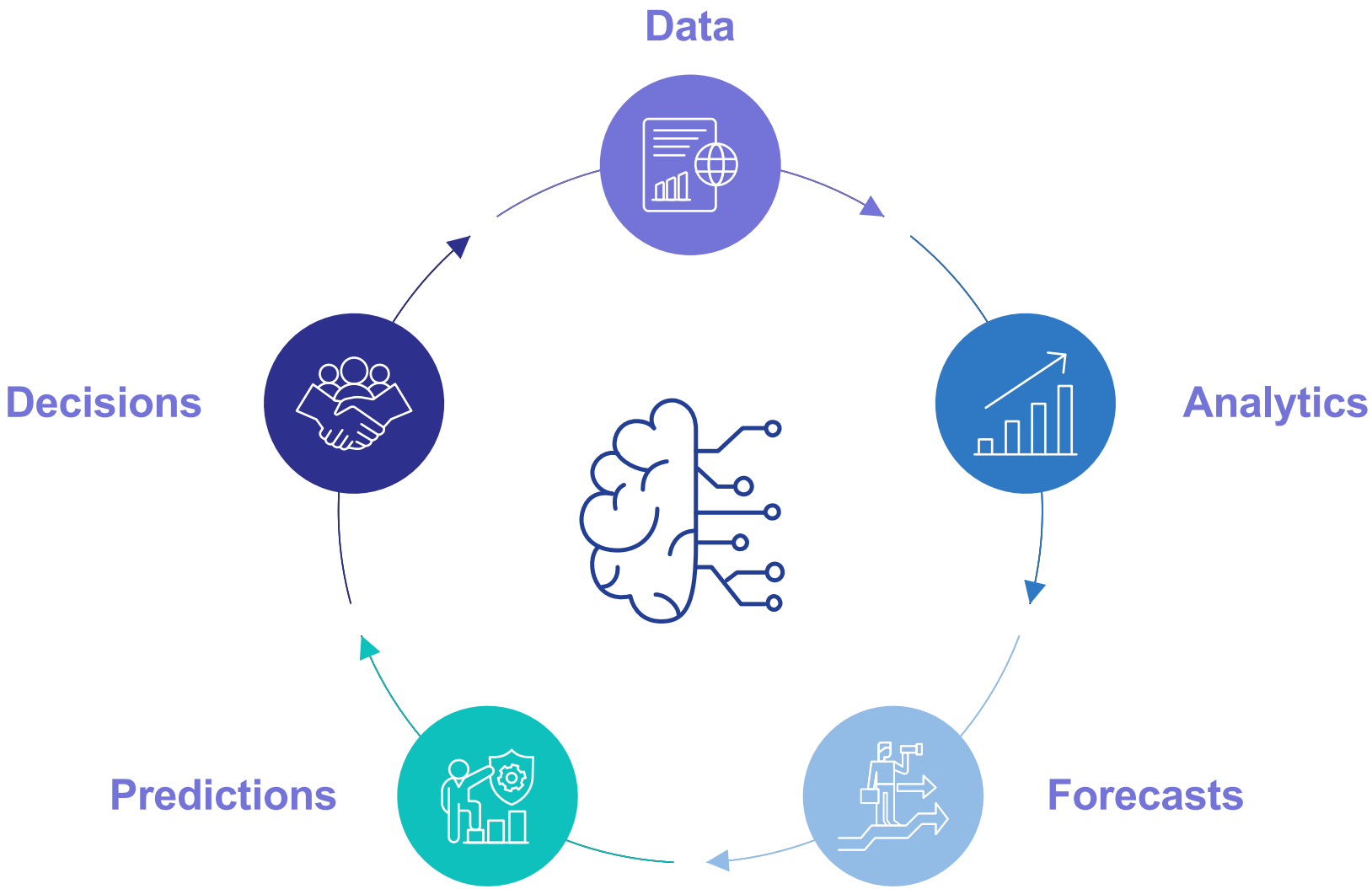
The Scope of AI Enablement: Step-by-step vs Wholistic



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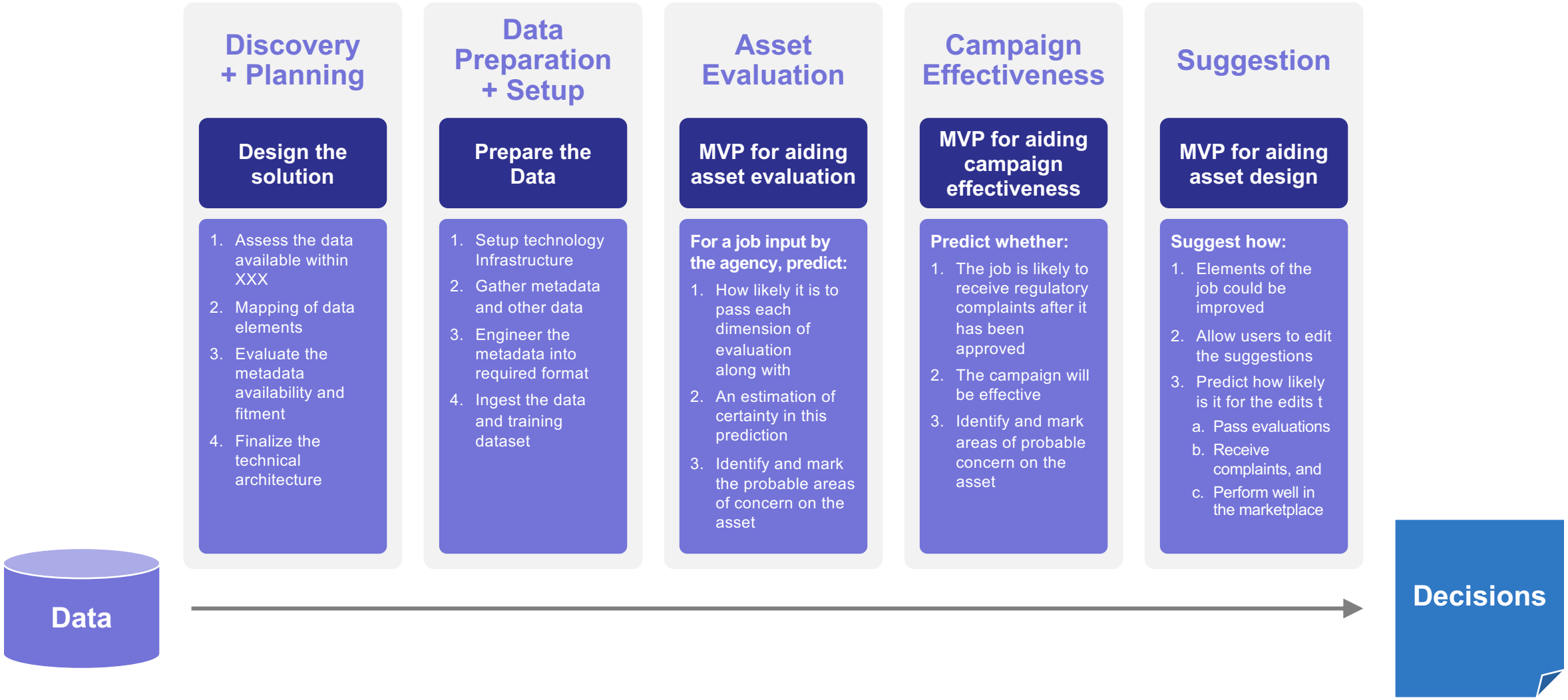
What is wrong with this picture?



AI Hesitancy

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Our data is a mess/not ready

Timestamp	Rank 1	Rank 2	Rank 3	Rank 4	Rank 5
12/5/2016 13:18:46	Chris Staples, Golden Age	Kaytranada, 99.9%	Michael Kiwanuka, Love & Ha	Arkells, Morning Report	Hannah Georgas, For Evelyn
12/5/2016 13:19:50	Radiohead, A Moon Shaped	James Blake, The Colour in A	Bon Iver, 22, A Million	Chance the Rapper, Coloring	Anderson .Paak, Malibu
12/5/2016 13:19:51	Frightened Rabbit, Painting	Wilco, Schmilco	Weezer, White Album	Drive-By Truckers, American	Band of Horses, Why Are You
12/5/2016 13:19:55	Childish Gambino, "Awaken,	Basia Bulat, Good Advice	Kanye West, The Life of Pabl	Frank Ocean, Blonde	Tacocat, Lost Time
12/5/2016 13:20:09	Nada Surf, You Know Who Yo	The Jayhawks, Paging Mr. Pr	The Posies, Solid States	Purusa, Soundtrack	
12/5/2016 13:20:10	William Tyler, Modern Countr	Hiss Golden Messenger, Hea	BJ Barnham, Rockingham	Mandolin Orange, Blindfaller	The Avett Brothers, True Sad
12/5/2016 13:20:15	22 A Million, Bon Iver	Coloring Book, Chance the R	We've Got It From Here, Thx	Moon Shaped Pop, Radiohea	The Polyphonic Anything, Jame
12/5/2016 13:20:19	The Posies, Solid States				
12/5/2016 13:20:28					
12/5/2016 13:20:31	ZAYN, Mind of Mine	Ariana Grande, Dangerous W	Solange, A Seat at the Table	Chance the Rapper, Coloring	dvsn, SEPT. 5TH
12/5/2016 13:21:01					
12/5/2016 13:21:07	BTS, Wings	Agust D, Agust D	Lindsey Stirling, Brave Enoug	Babymetal, Metal Resistance	Red Velvet, Russian Roulette
12/5/2016 13:21:11	Hope Sandoval, Until the Hur	Madness, Can't Touch Us No	Suzanne Vega, Lover, Belove	Poliça, United Crushers	Underworld, Barbara Barbara
12/5/2016 13:21:40	Beyonce, Lemonade	Radiohead, A Moon Shaped	Parquet Courts, Human Perfo	Cate Le Bon, Crab Day	Nels Cline, Lovers
12/5/2016 13:21:43	Zayn, Mind of Mine	Banks, The Altar	Beyonce, Formation	Rihanna, Anti	Jojo, Mad Love.
12/5/2016 13:21:59	Josh Ritter, Sermon on the R	Lori McKenna, The Bird &	Sara Watkins, Young In All the Wrong Ways		
12/5/2016 13:23:06	Tancred, Out of the Garden	Jimmy Eat World, Integrity Bl	Sam Beam & Jesca Hoop, Lo	The Gumdrops, Cleopatra	Sara Watkins, Young In All Th
12/5/2016 13:23:21	Anderson .Paak, Malibu	Toro y moi, Live from Ohia	Kendrick Lamar, untitled unm	Frank Ocean, Blonde	Chance the Rapper, Coloring
12/5/2016 13:23:59	Weezer, Weezer	Death Grips, Bottomless Pit	Jon Bellion, The Human Cond	David Bowie, Blackstar	Explosions in the Sky, The W
12/5/2016 13:24:09	RVRB, FADED	Views, Drake	Latigo, Wilderado	TLOP, Kanye West	22 a million, Bon Iver
12/5/2016 13:24:16	Teenage Fanclub, Here	The Posies, Solid States	Phantogram, Three	Wilco, Shmilco	Monkees, good times
12/5/2016 13:25:10	RVRB, FADED	RVRB, FADED	RVRB, FADED	RVRB, FADED	RVRB, FADED
12/5/2016 13:25:11	AJJ, The Bible 2	Jeff Rosenstock, WORRY	Eric Bachmann, S/T	Joyce Manor, Cody	Kanye West, Life of Pablo
12/5/2016 13:25:26	Care Le Bon, Crab Day	David Bowie, Blackstar	Weaves, Weaves	Trentmøller, Fixion	Solange, a Seat at te Table
12/5/2016 13:25:26	RVRB, FADED	RVRB, FADED	RVRB, FADED	RVRB, FADED	RVRB, FADED
12/5/2016 13:25:28	Carseat Headrest, Teens of D	Beyonce, Lemonade	Radiohead, Moon Shaped Po	Margaret Glaspy, Emotions a	Dawes, We're All Gonna Die

DIFFERENT SPELLING

EMPTY ROWS

ONE PERSON, MULTIPLE ENTRIES

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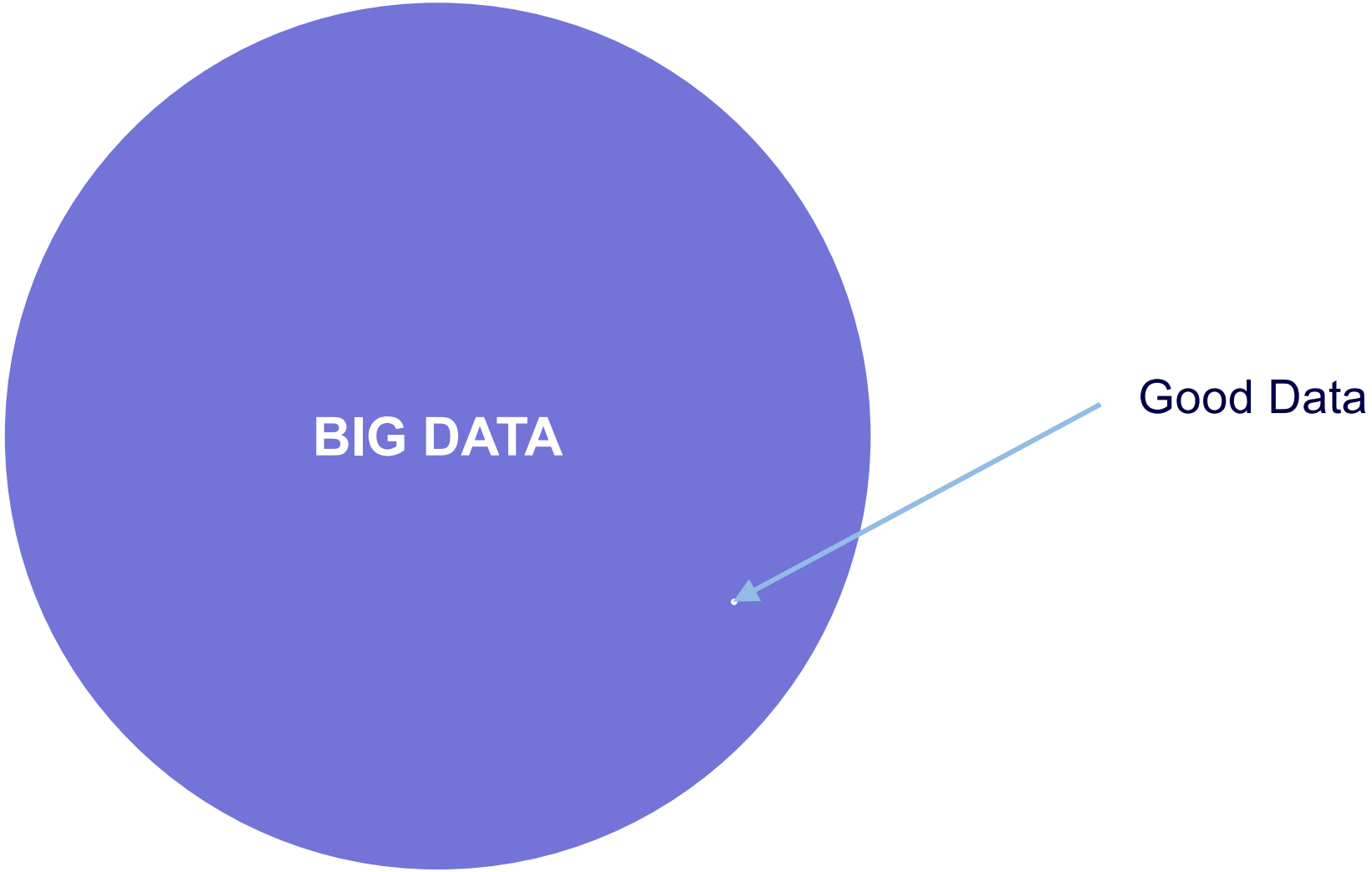
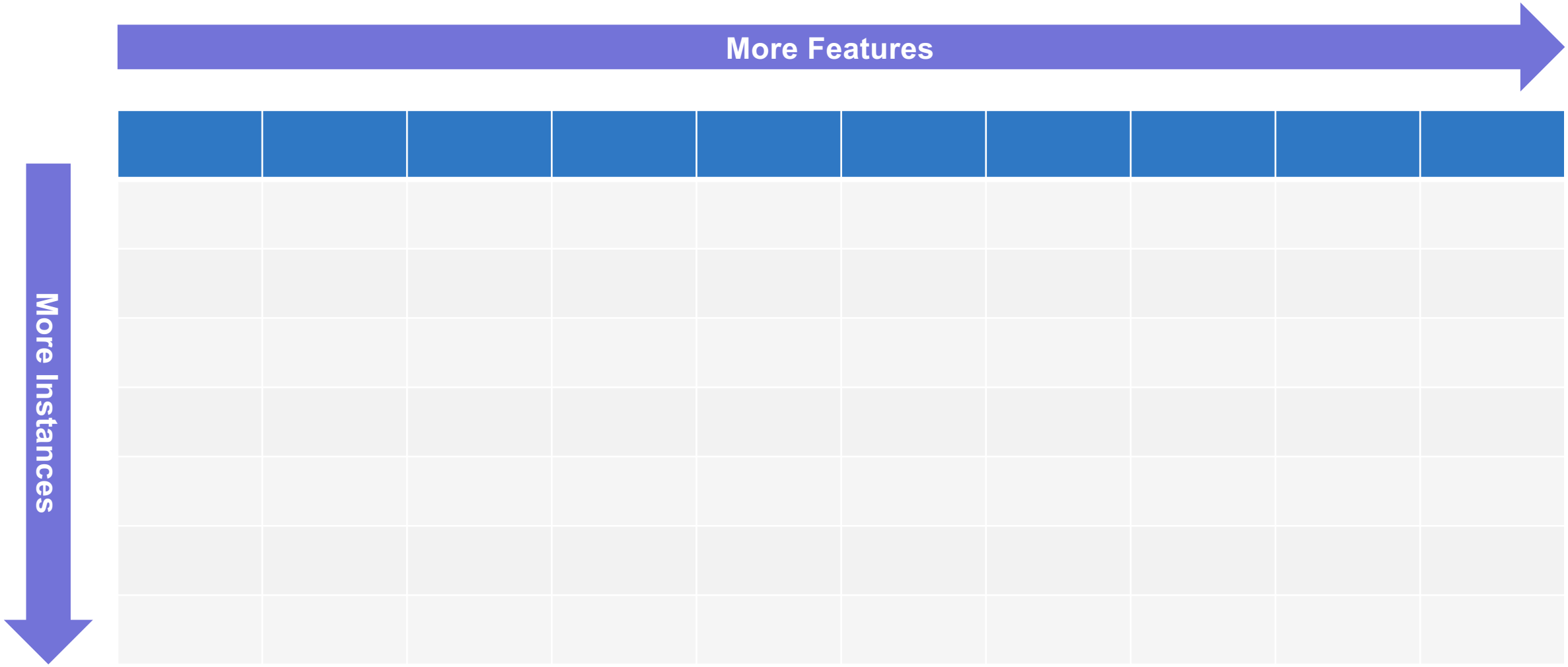
We don’t have enough Data

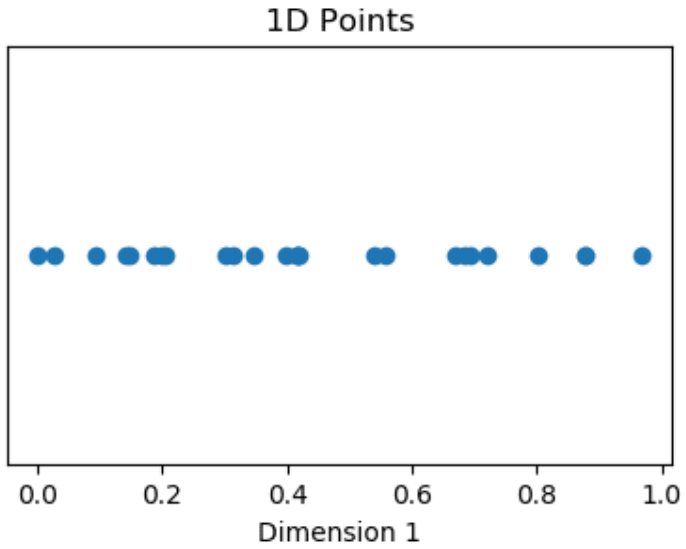


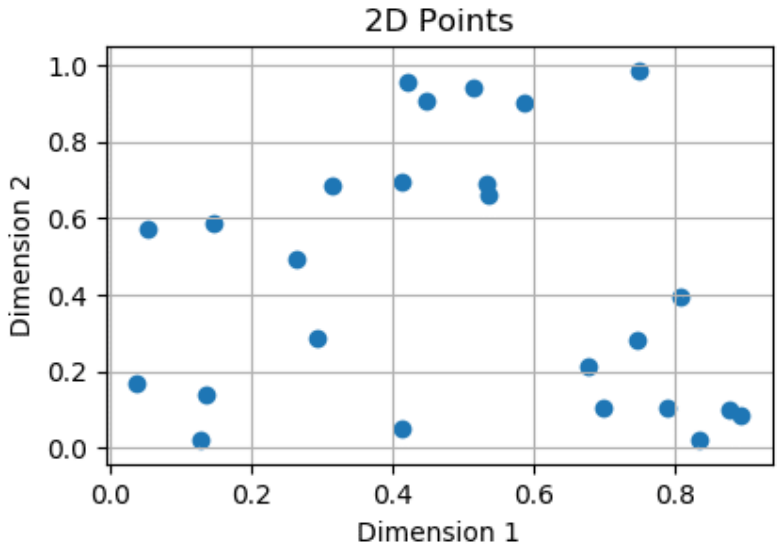
More data does not mean, more features!

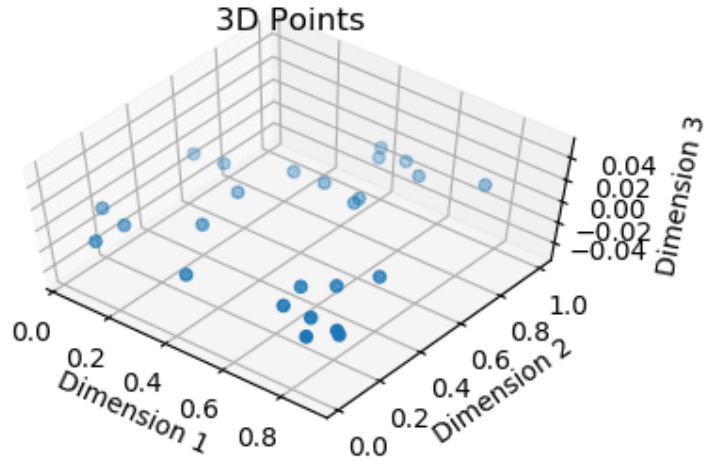


The Curse of Dimensionality

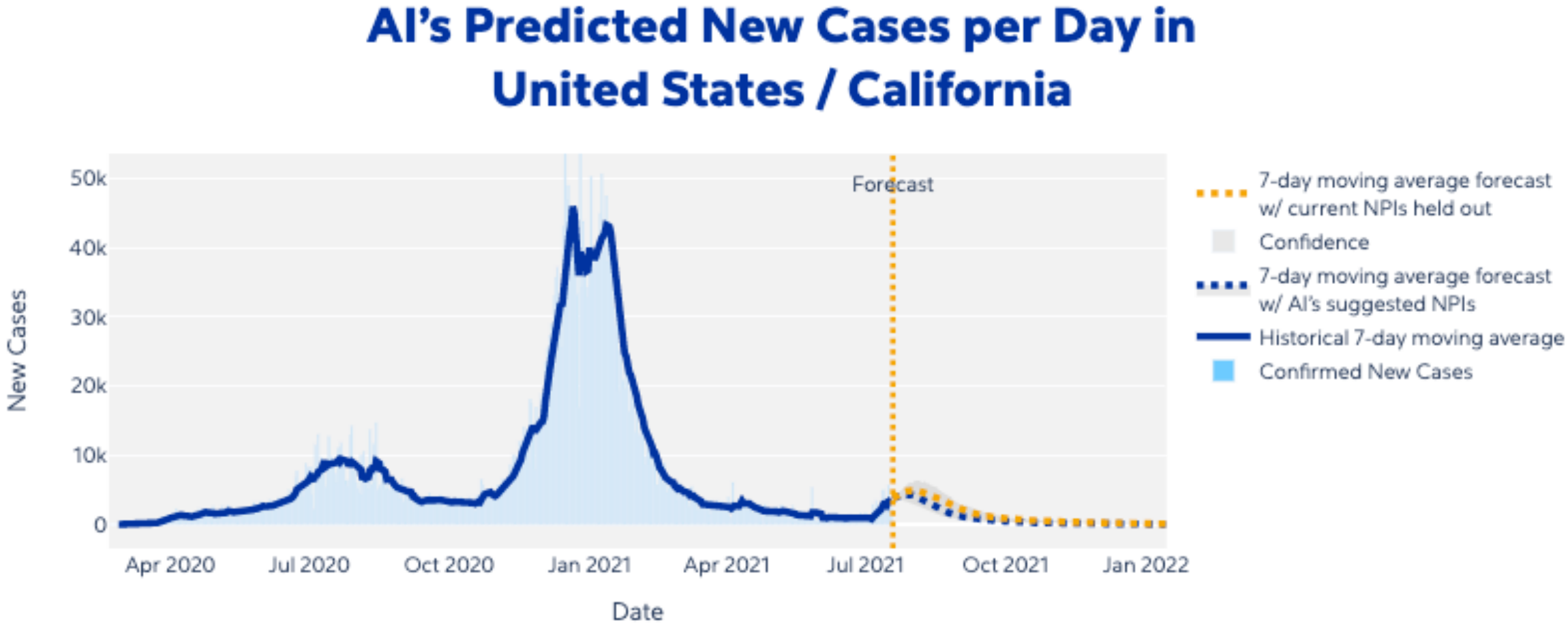
More features means exponentially more observations to avoid overfitting







Outcomes Timeseries Captures Effect of Missing Features



No One-Size-Fits-All AI

Domain Specific Models are the new IP

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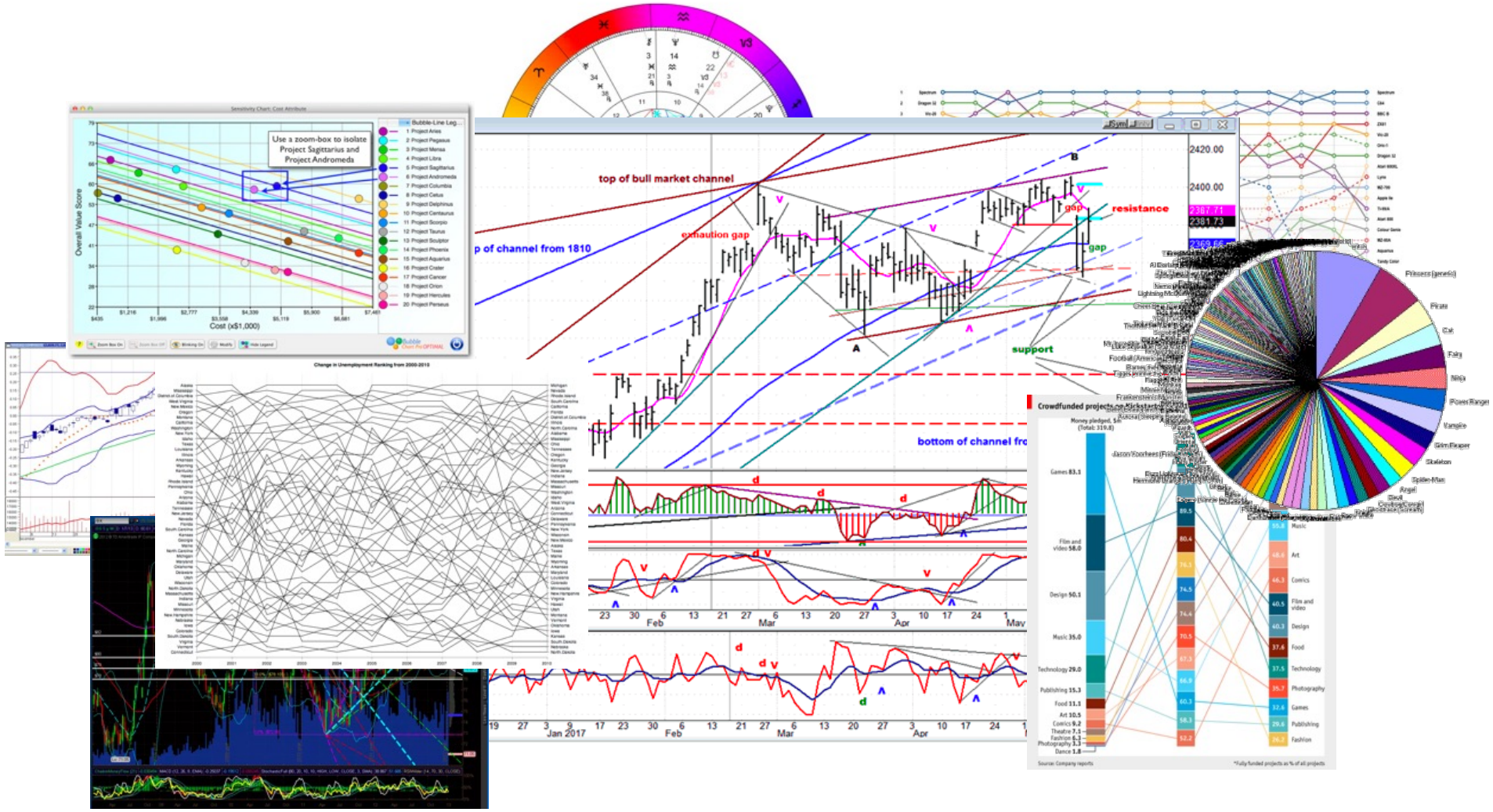
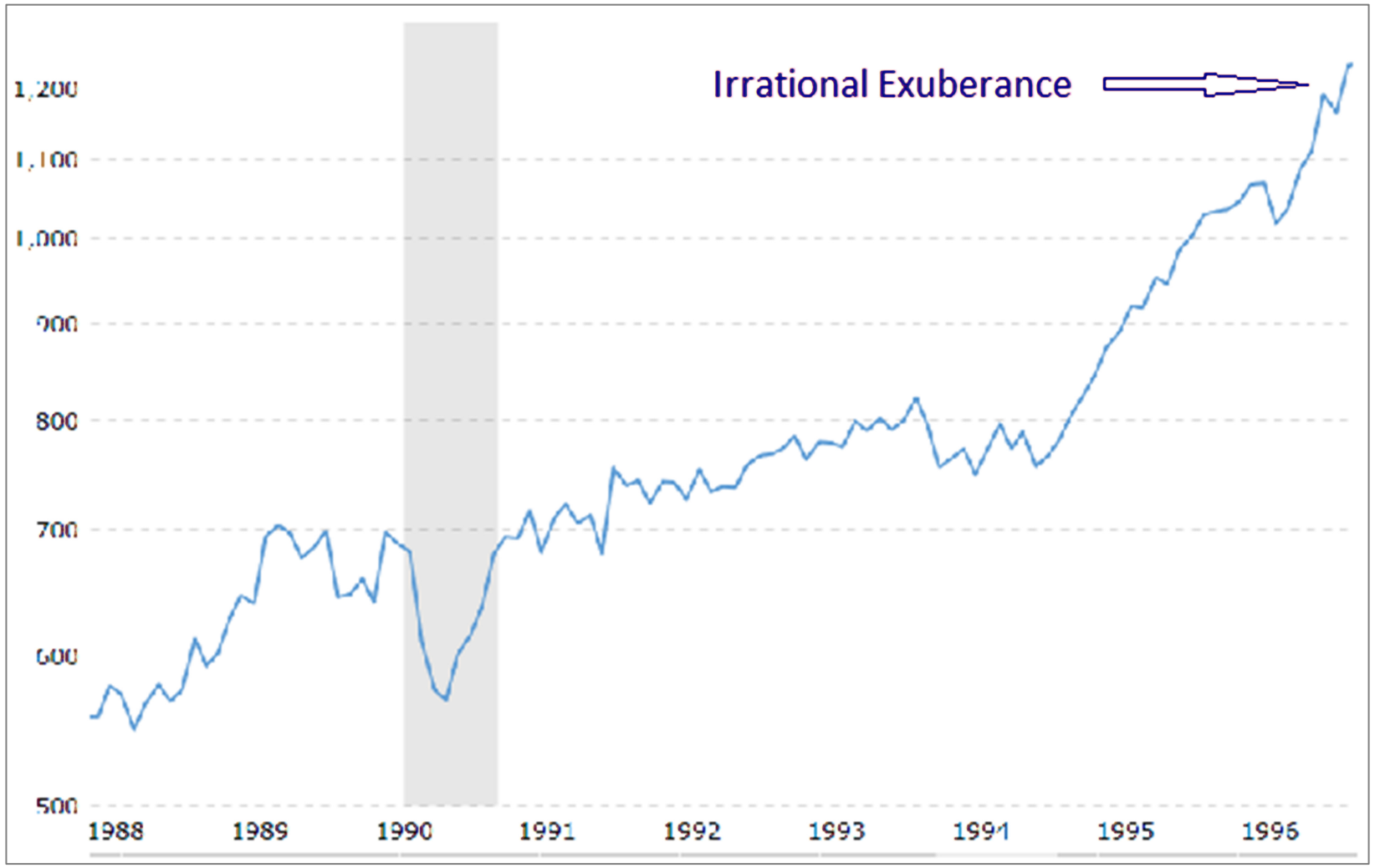
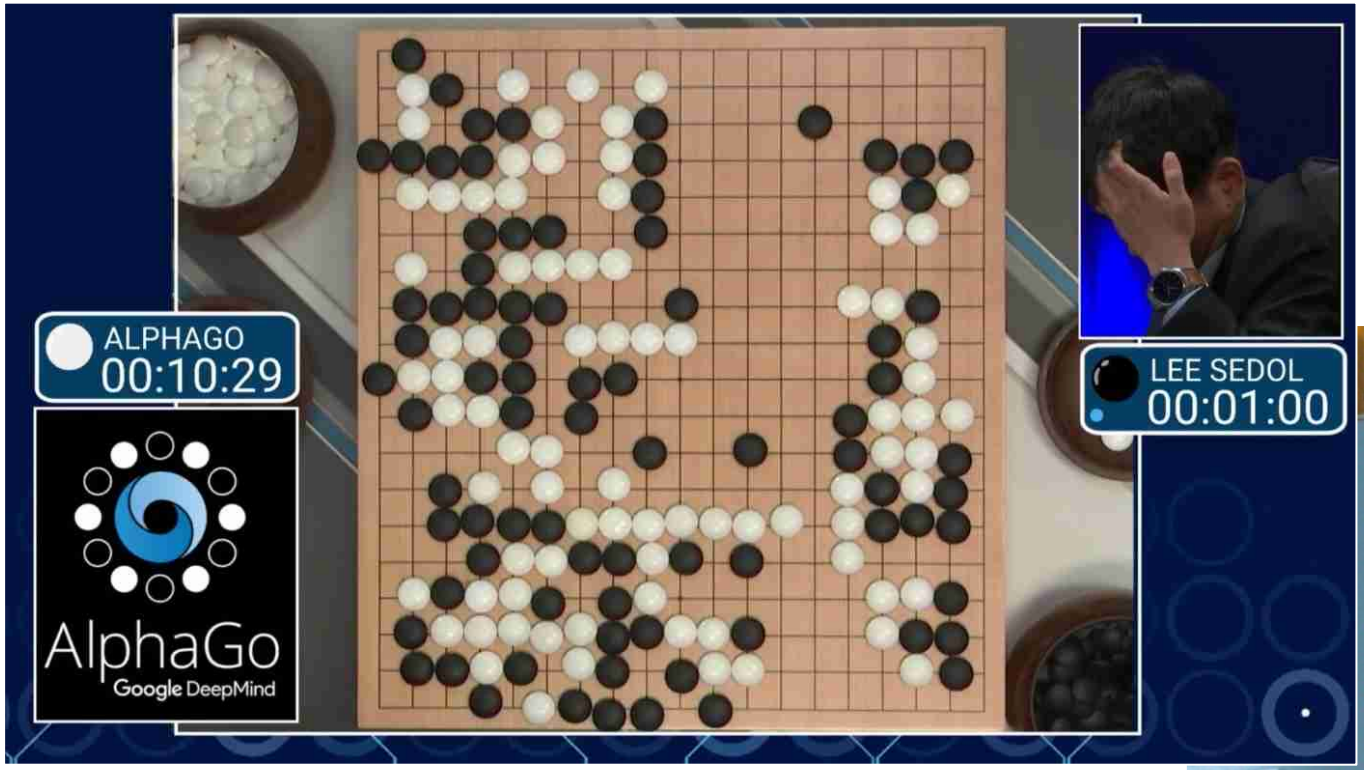
Need to get Insights First



What if Insights Show we are Good Already?



Human Decision-Making is Better



All we need is better insights - we can make the decisions

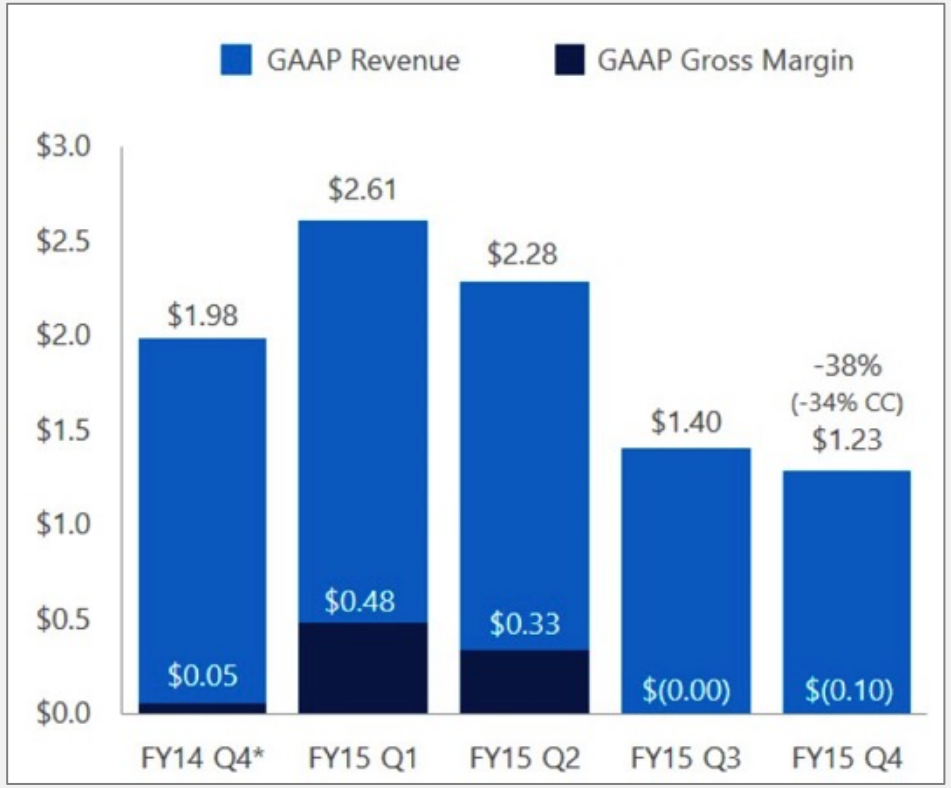
Projections Show we're Missing Revenue Targets!

Should we cut costs?

Sell at a discount?

Retarget sales?

Invest in growth?



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We care about sales – Cost is for a different department

There is never a single objective!

We often want to:

- Maximize revenue, and
- Maximize sales, while
- Minimizing cost, and,
- Minimizing risk

Worried about bias and ethics of using AI

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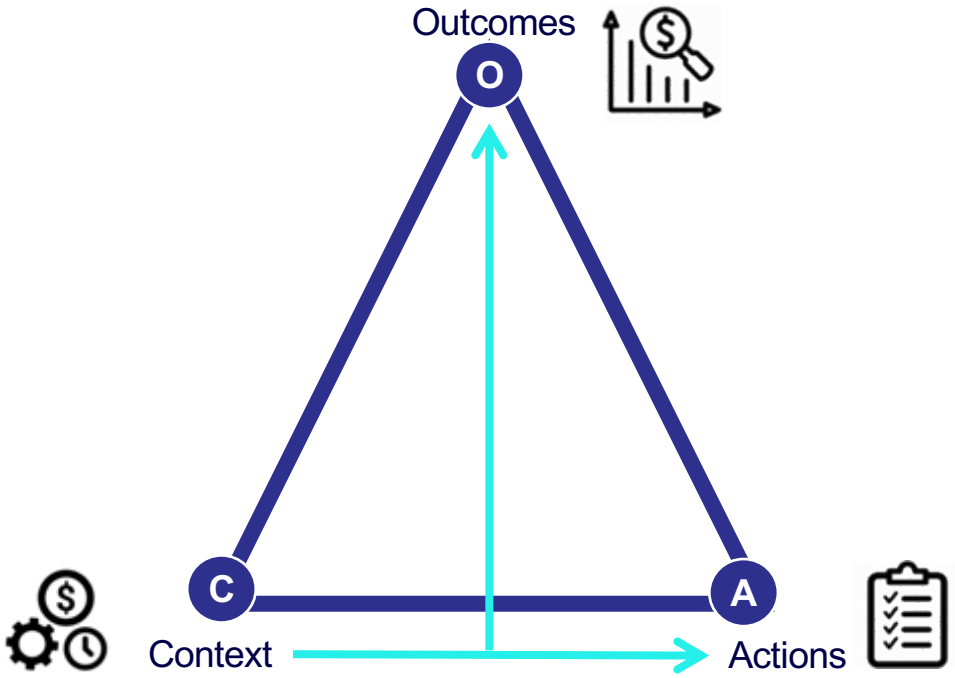
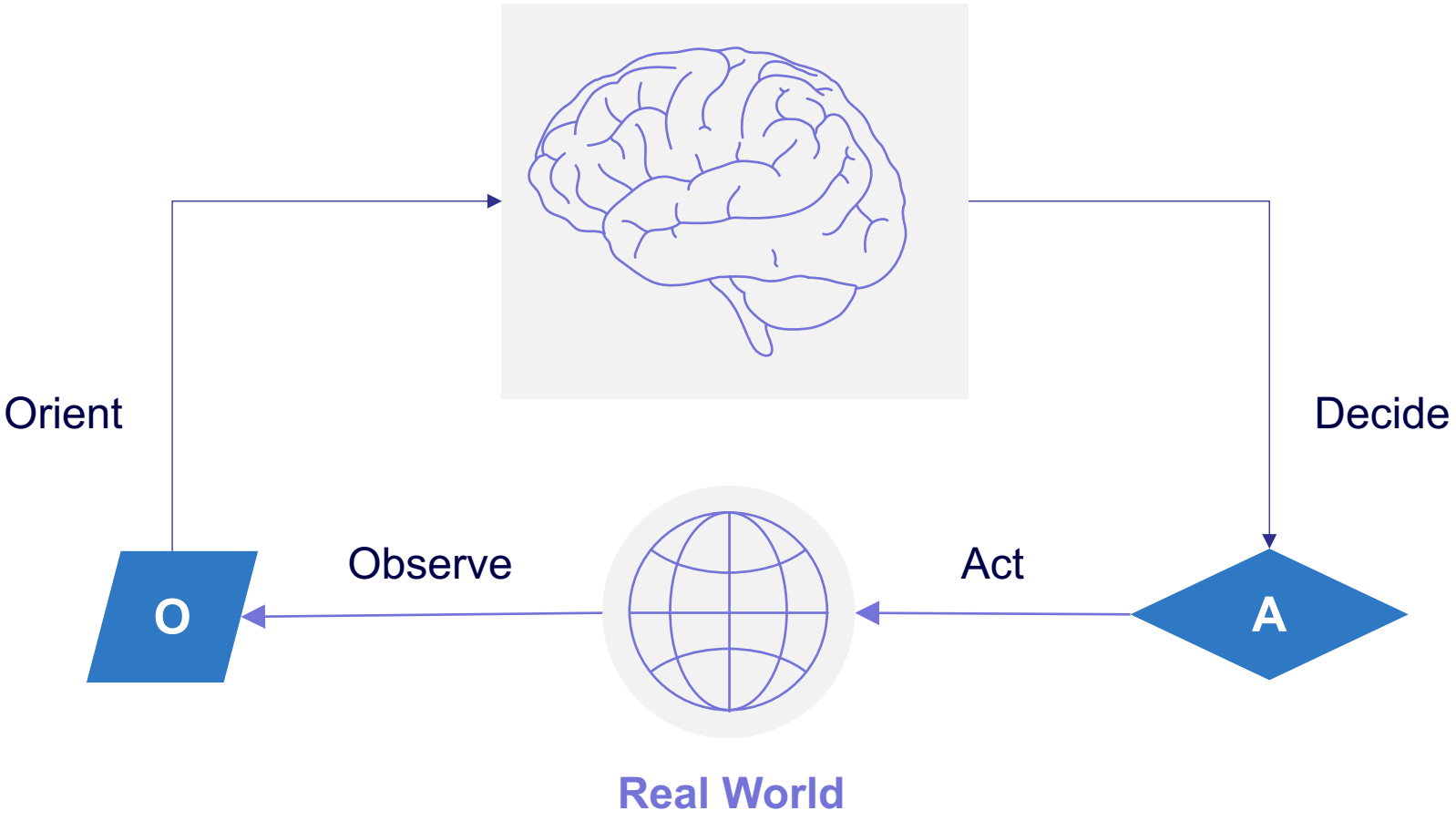
We make Decisions all the time



- Given a **context** (C)
- Which **actions** should I take (A)
- To optimize some **outcomes** (O)?

Adaptive Decision-Making: The OODA Loop



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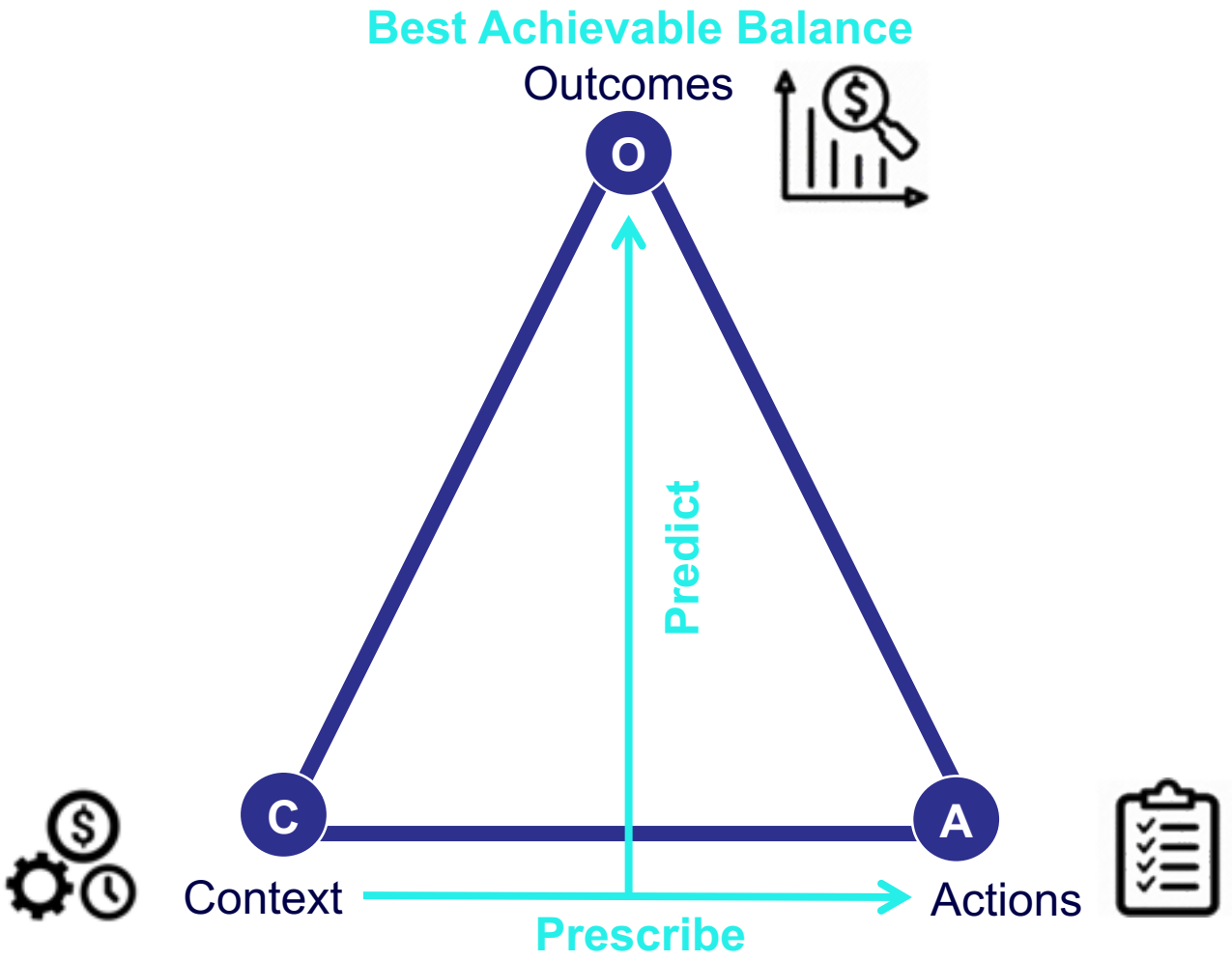
How do we make decisions?



- Given a **context** (C)
- Which **actions** should I take (A)
- To optimize some **outcomes** (O)?

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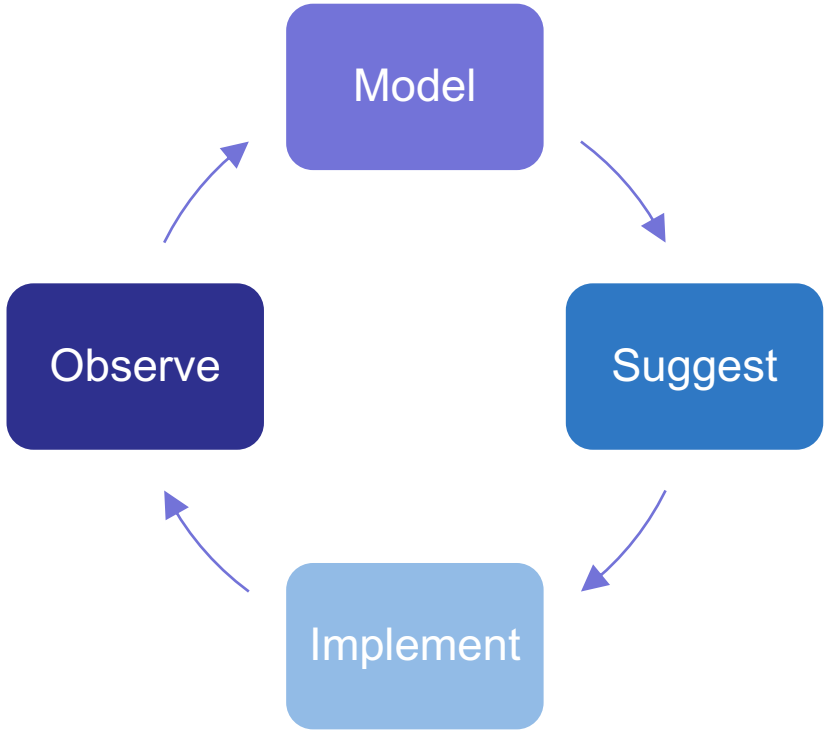
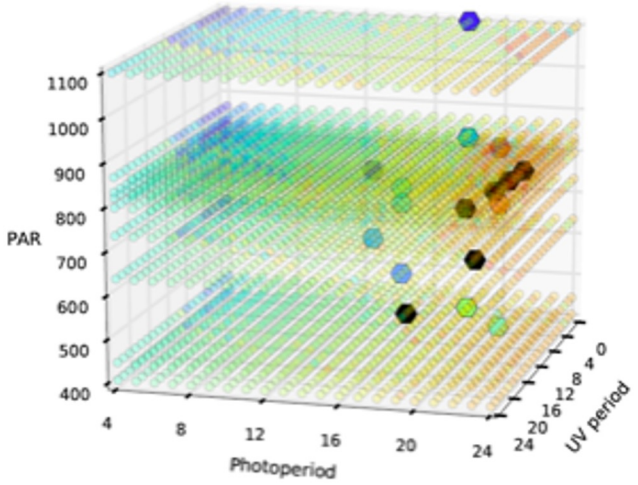
AI-Enabled Decisioning (and Data Collection)





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Important Questions AI can Answer

Predictor:

What will happen?

Prescriptor:

What should we do?

Uncertainty:

How much can we trust it?

Scratchpad:

What-if we do something else?

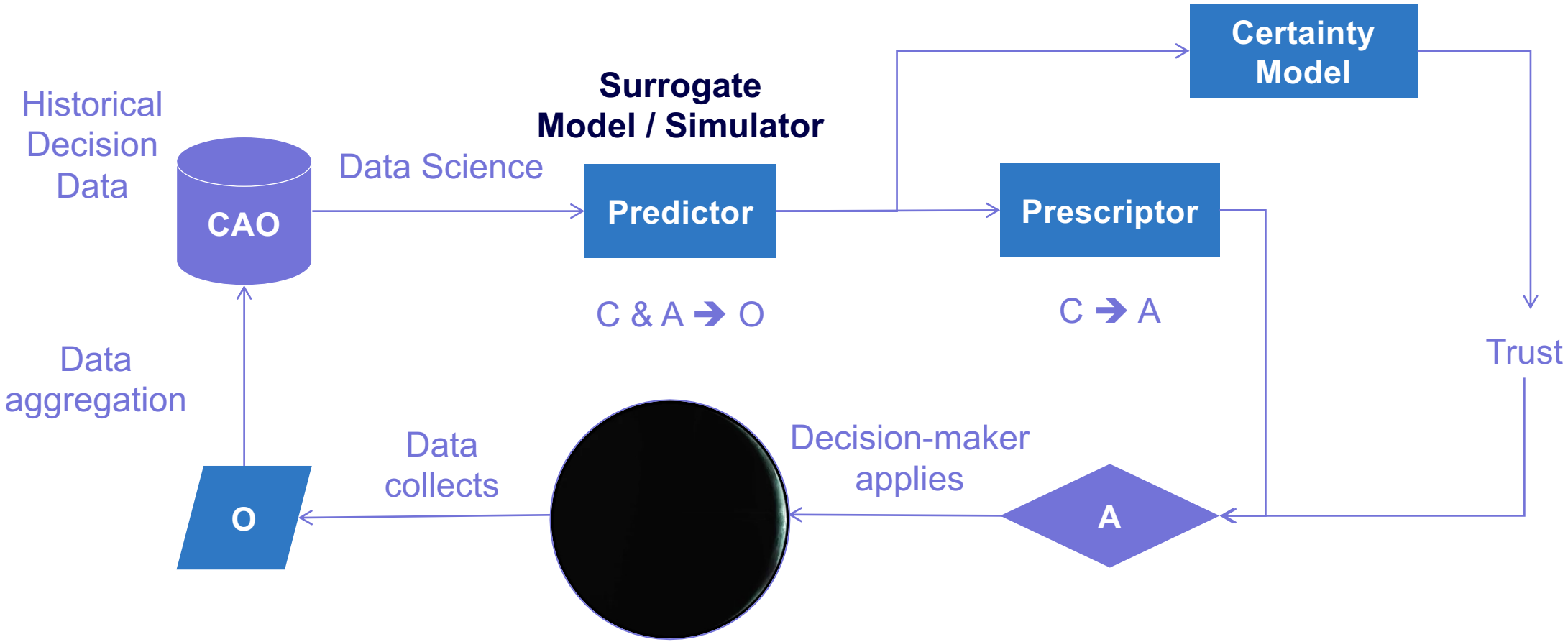
Impact Estimation (Retrospective):

What if we had done something else?

Multiple-Objectives:

What if we want a different balance of outcomes?

How it all comes together



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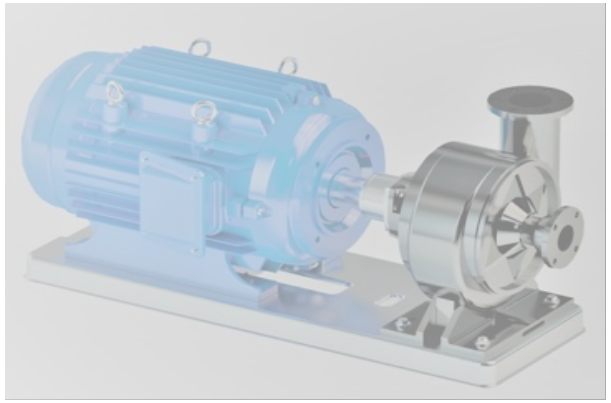
Digital Twins

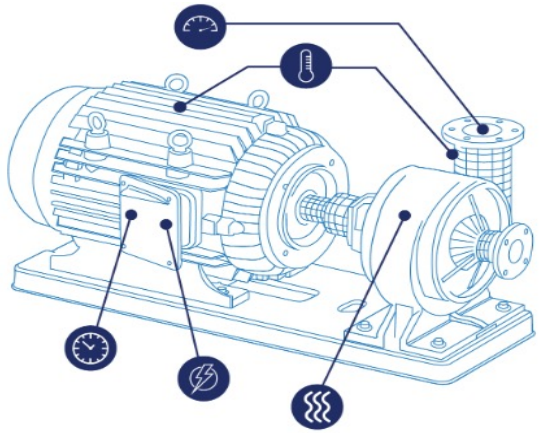
Physical environment



- Design Systems
- Enterprise Data
- Sensor Data
- Historical data
- Image data
- Acoustic data

……

Digital Twin Instance



- Vibration
- Heating Temperature
- Flow Speed
- Viscosity
- Vapor pressure
- Power Consumption monitor
- Chamber humidity
- Current and voltage

……

Prediction and Optimization

- Simulation
- What-if scenarios
- Prediction and prescription
- Optimization
- Predictive maintenance
- Remaining useful life

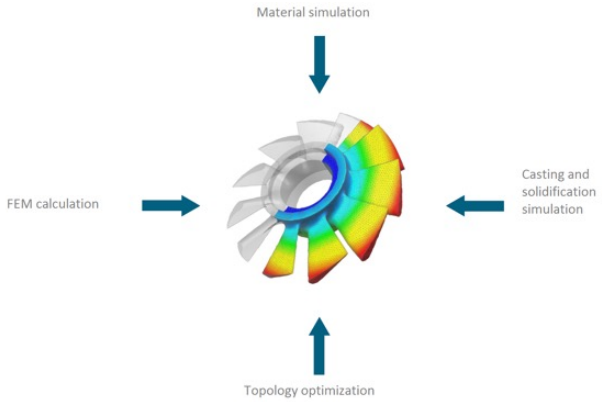
Rigid Simulations

Make Assumptions
- May be unavailable
- May be wrong
- May be inaccurate
- May be insufficient

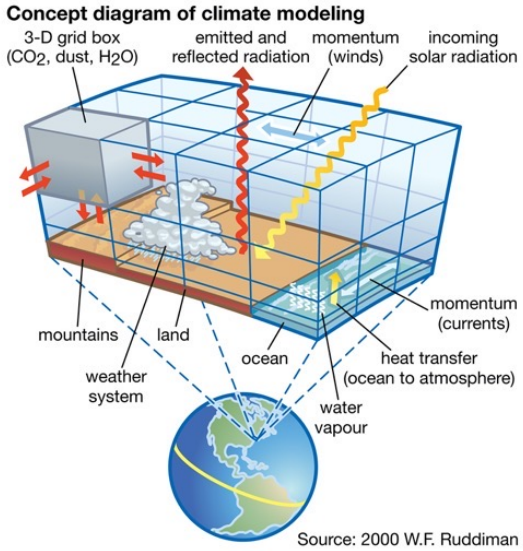
Create Model
- Requires knowledge of mechanisms and dynamics

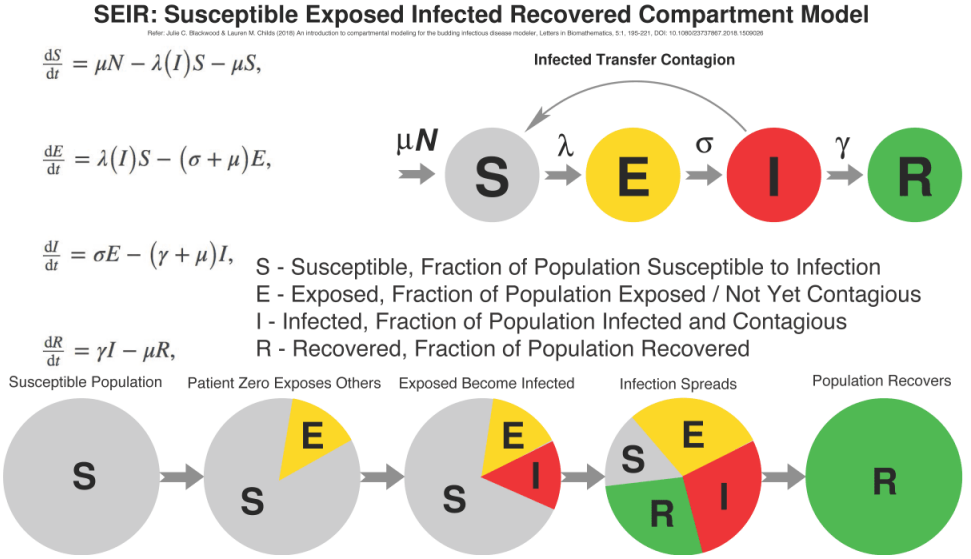
Run Model
- Often Expensive at scale
- Often inaccurate in miniature

Interrogate Model
- Rigid



Digital Twin





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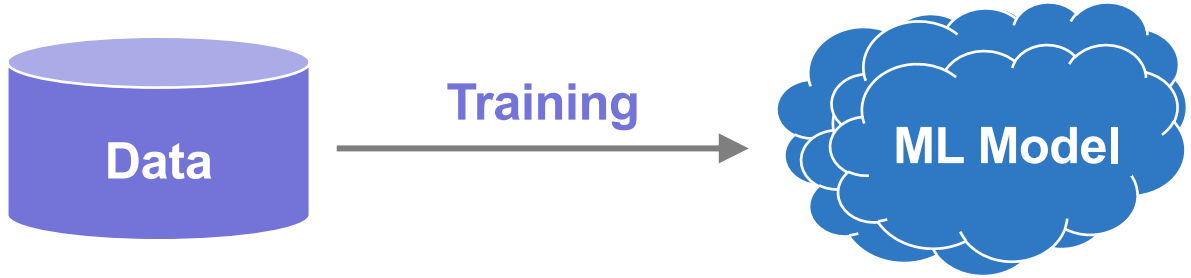
ML Models



Robust

Data Driven

Does not require (as much) knowledge of the domain

Can be applied at scale

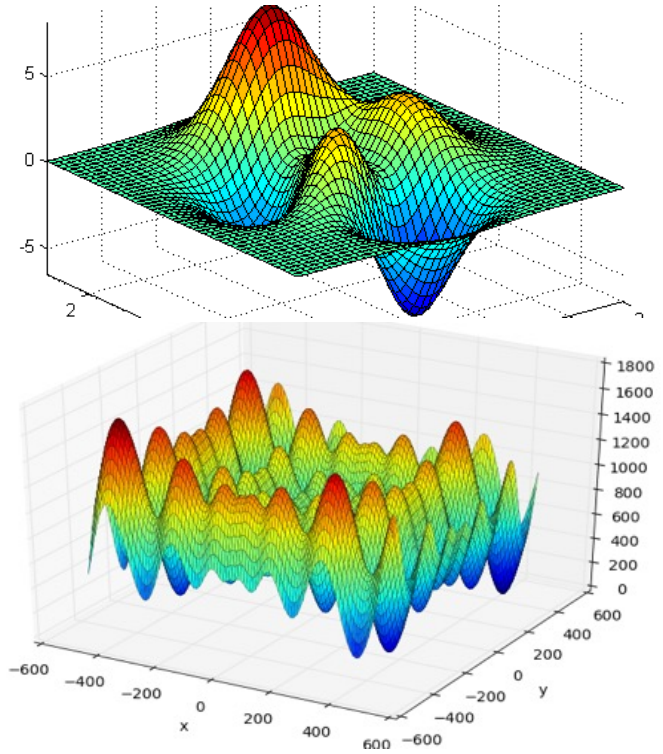
<u>BUT</u> **not enough**

Data-hungry

Training could be expensive/time consuming

Not adaptive

Gradient Descent is not good at large, deceptive, multi-objective search spaces



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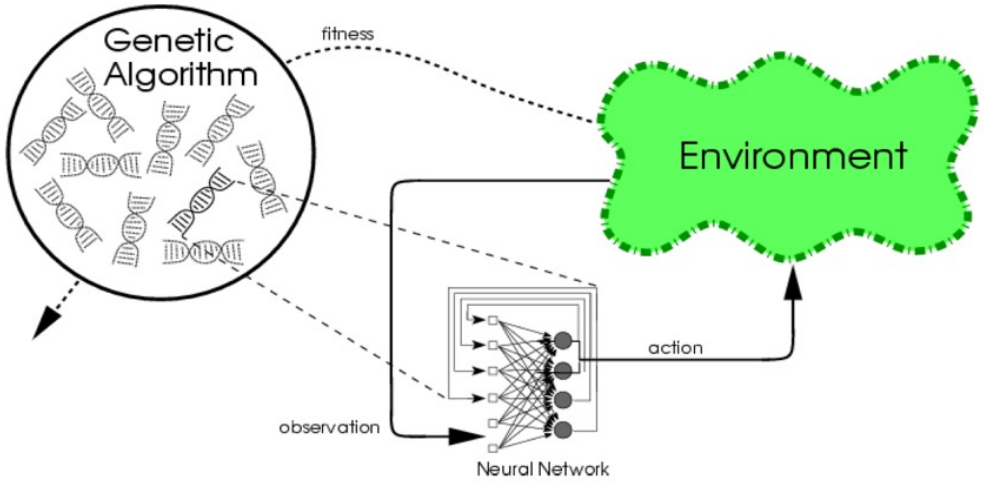
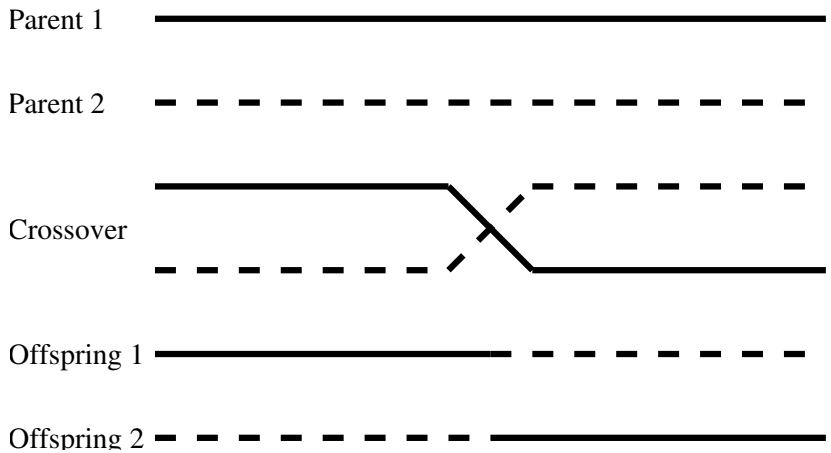
Why use Evolutionary AI?



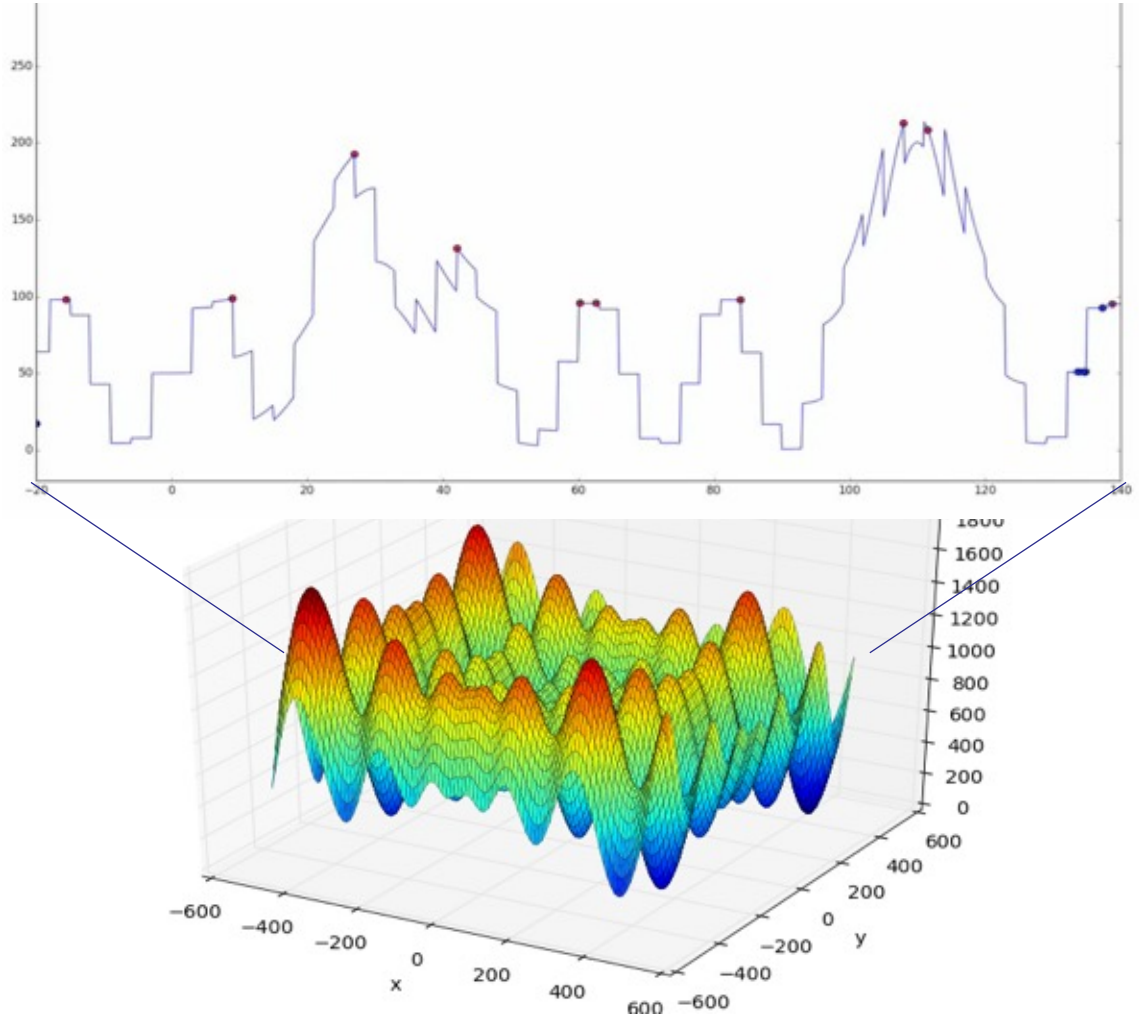


- A population of encodings (e.g., lists or trees)
- Decoded into individuals that are tested
- Good individuals retained, bad thrown away

- New individuals generated from the parent encodings
  - Crossover: Combine building blocks from two parents
  - Mutation: Create new building blocks

Evolution is Efficient

- Works in large spaces (e.g., 2^2^70)
- Multiple variables optimized at once (e.g., up to 1B)
- Multiple objectives and novelty get around deception



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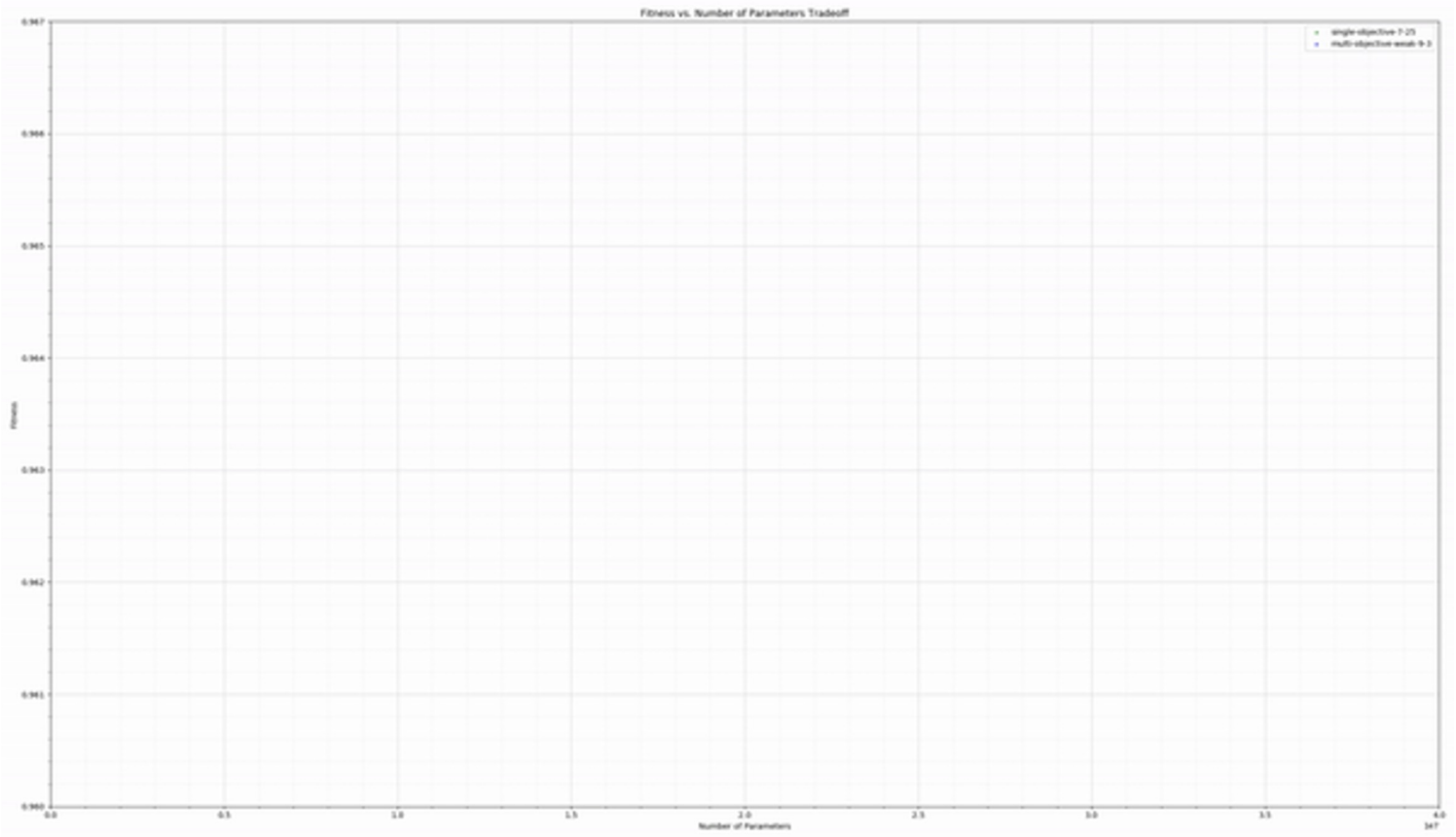
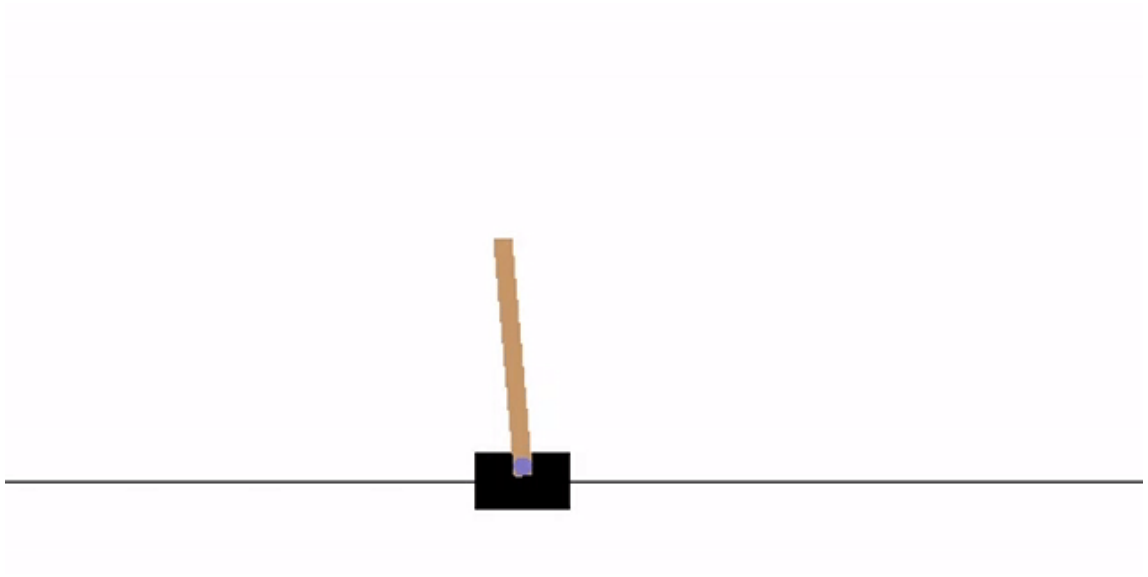
Evolution can handle Multiple Objectives

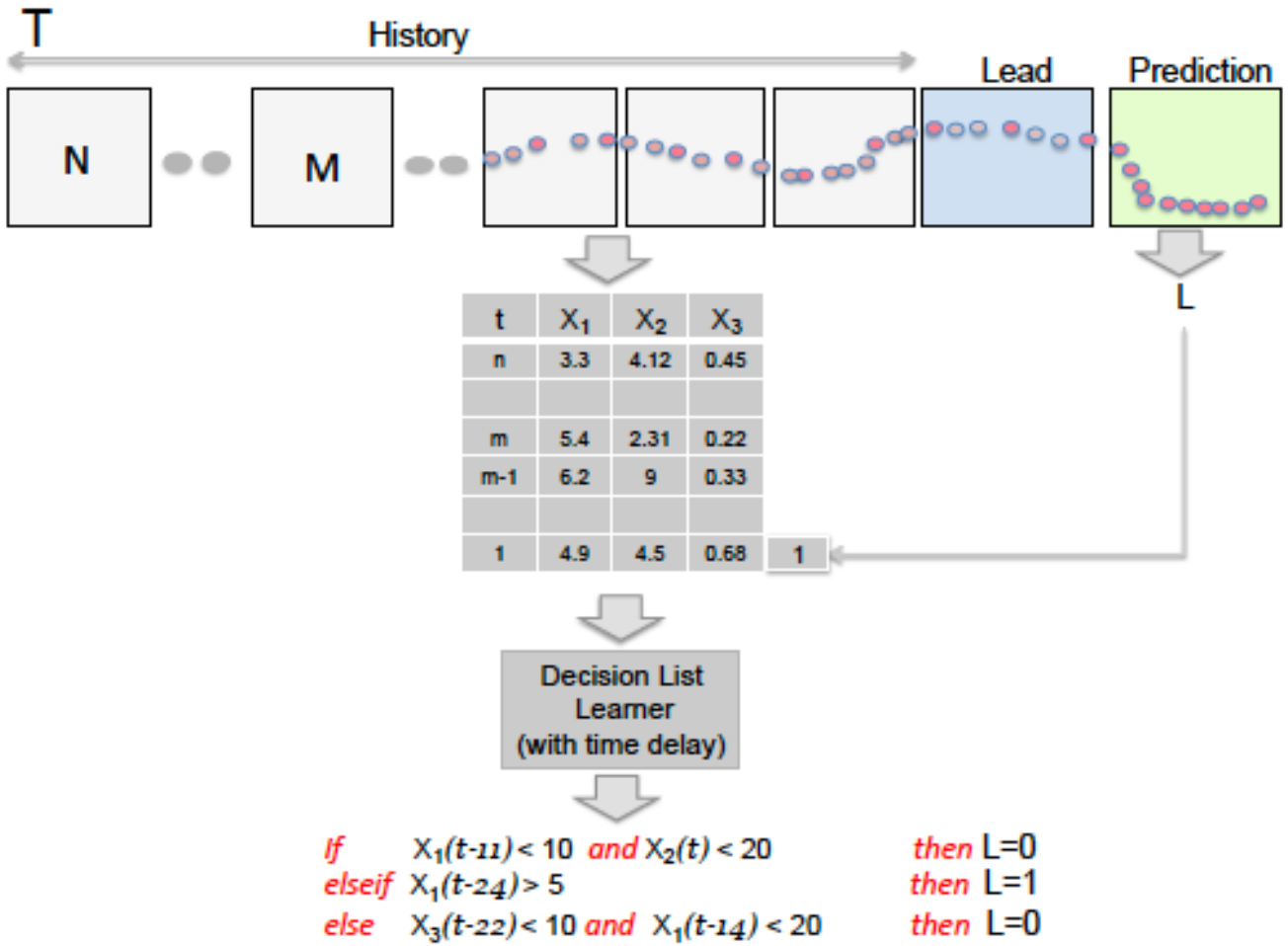


- Animation: Pareto front by generation for single-objective (green) vs. multi-objective (blue)
- Single-objective focuses on improving **largest networks**
- Multi-objective focuses on improving the **entire curve**
- Result: Multi-objective finds much smaller models for the majority of performance values.

Evolution Can Create Explainable Solutions



- 3_53 Rules agent:
- <22978> (0.11*S_1^3 < 0.87*S_2) ---> **LEFT**
- <23022> Default Action: **RIGHT**



Each rule is a variable length conjunction of conditions with an associated class prediction. In the evaluation each condition compares a lagged value or the current value of the time series to a threshold (decision boundary). Decision lists in LEAF have a variable number of rules and conjunctive clauses in each rule.

This representation is different from many other classifiers e.g. Decision Trees, simple Decision Lists, Support Vector Machines and Logistic Regression, which requires every time lagged value or an aggregate to be explicitly presented as a different feature.

Diabetes Rules

1. (diag_1_injury <= 2.2*diag_1_respiratory) and (diag_2_neoplasms > 33) —> 18
2. (age_[60-70) >= 1.2*age_[10-20)) --> 7
3. (diag_2_diabetes >= 0.82*diag_1_digestive) --> 17
4. (admission_source_id_Court/Law Enforcemenct >= 1.045*diag_3_circulatory) --> 9
5. (age_[80-90) >= 2.29*admission_type_id_Newborn) --> 14
6. (age_[30-40) <= 0.47*age_[50-60)) and
   (admission_type_id_Newborn <= 0.47*age_[50-60)) and
   (diag_2_respiratory >= 1.86*diag_3_musculoskeletal) and
   (diag_1_diabetes >= 1.42*age_[30-40)) and
   (0.18*gender >= 0.38*race_Asian) and
   (0.12*race_AfricanAmerican >= 0.15*admission_source_id_Court/Law Enforcement) and
   (0.03*race_Hispanic <= 0.76*admission_source_id_Emergency Room) --> 15
7. Default 8

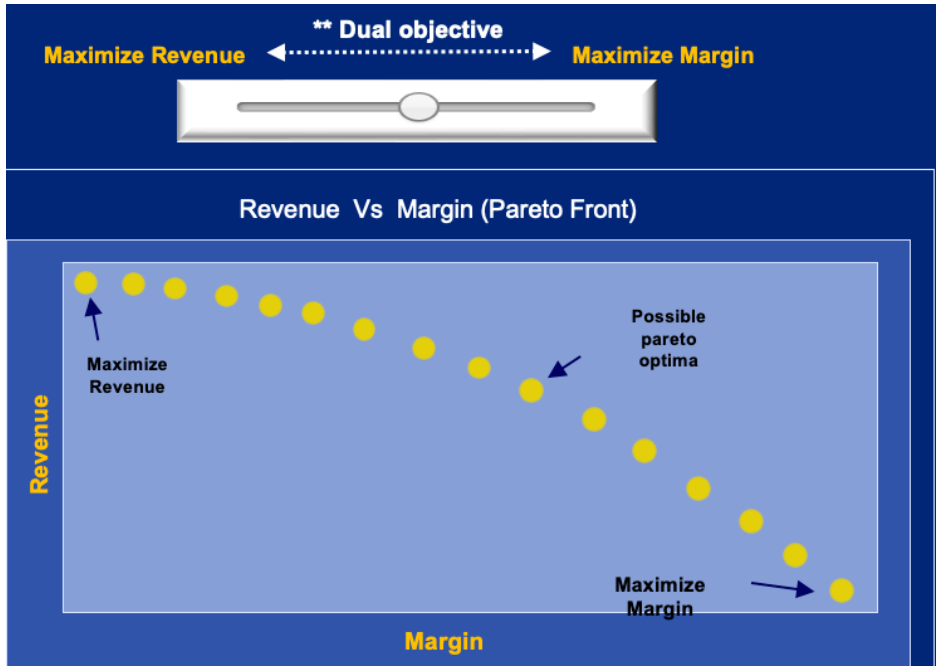
Examples

Diabetes Rules Interpretation

1. If Patient has a respiratory problem but not a neoplasms problem prescribe **metformin-pioglitazone**
2. If the person any age except 60-70 prescribe **glyburide**
3. If the person has Diabetic Diagnostic result as positive prescribe **glipizide-metformin**
4. If the person has a positive circulatory diagnosis prescribe **pioglitazone**
5. If the admission type is Newborn prescribe **tolazamide**
6. If the person is between 30 and 60 years old and has a positive musculoskeletal diagnosis and is Asian and was sent by court/law enforcement and was admitted in emergency, prescribe **insulin**
7. If none of the above, prescribe **glipizide**

Some Examples

Pricing Optimization



	LEAF Recommendation	Scenario Planning
Price	$608 **	$397
Quantity	3942 **	8990
Revenue	$1,600,000 **	$2,300,000
Margin	$440,000 **	-$300,000

Improving pricing strategy for a leading home appliance manufacturer

- Using historical data, build an adaptive digital twin of the market
- With evolutionary optimization, maximize conflicting objectives of revenue and margin

Result: A Pareto front of the best possible tradeoffs

- The user can select a desired tradeoff from it
- RIO indicates uncertainty in the predictions

Scratchpad allows adjusting the price by hand

- The digital twin predicts the resulting revenue and margin

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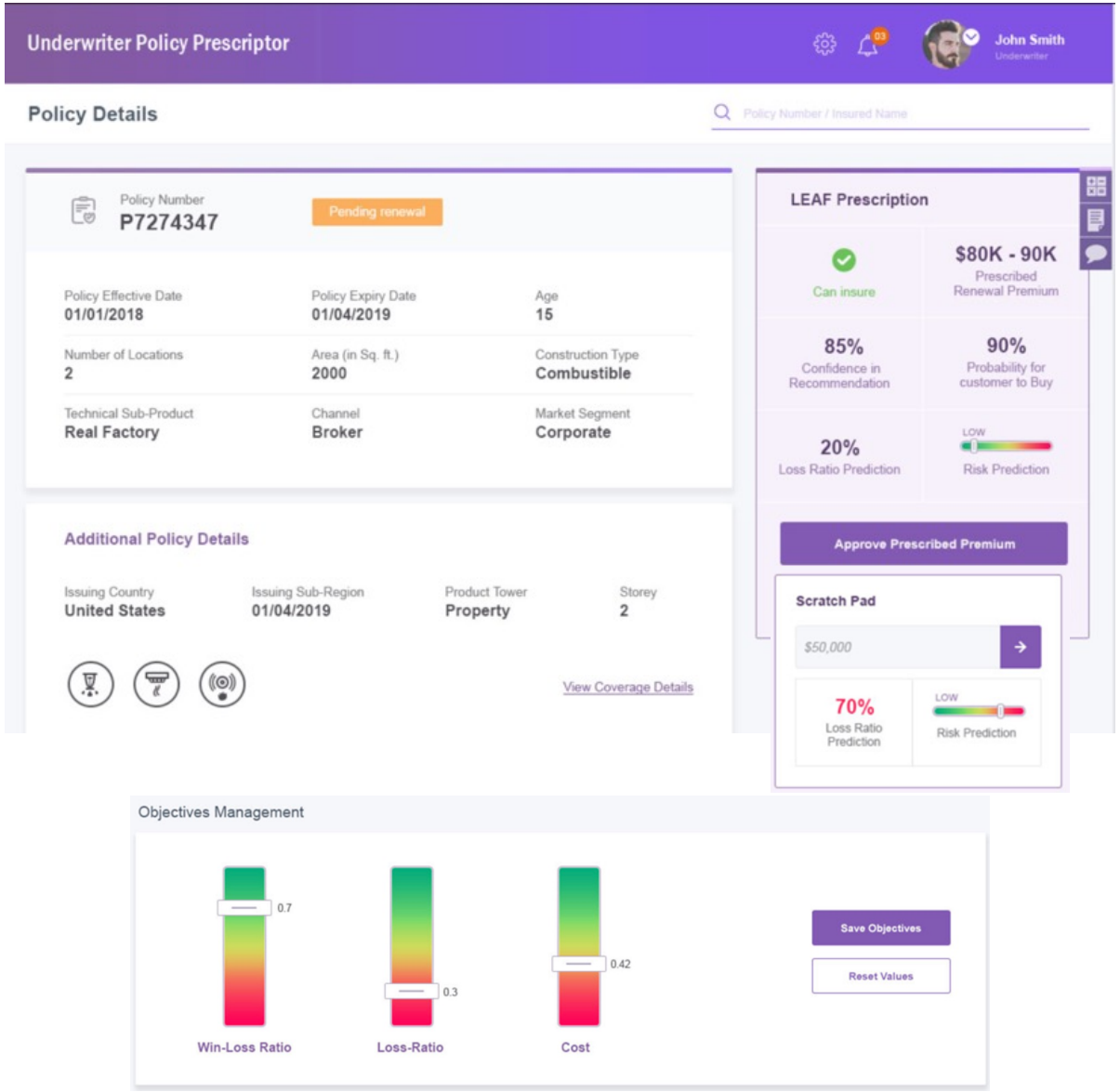
Insurance Underwriting



Improving pricing strategy for a leading property insurance company

- Using historical data, build an adaptive digital twin of the properties
- With evolutionary optimization, maximize conflicting objectives of win/loss, risk, and cost

Result: A Pareto front of the best possible tradeoffs

- The user can select a desired tradeoff from it
- RIO indicates uncertainty in the predictions

Scratchpad allows adjusting the premiums by hand

- The digital twin predicts the resulting risk and win/loss

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Ship Trim Optimization

Improving ship speed/fuel efficiency for a shipping company

- Using historical data, build an adaptive digital twin of the ship
- With evolutionary optimization, maximize conflicting objectives of speed and fuel consumption

Result: A Pareto front of the best possible tradeoffs

- The user can select a desired tradeoff from it
- RIO indicates uncertainty in the predictions

Scratchpad allows adjusting the premiums by hand

- The digital twin predicts the resulting speed and fuel consumption

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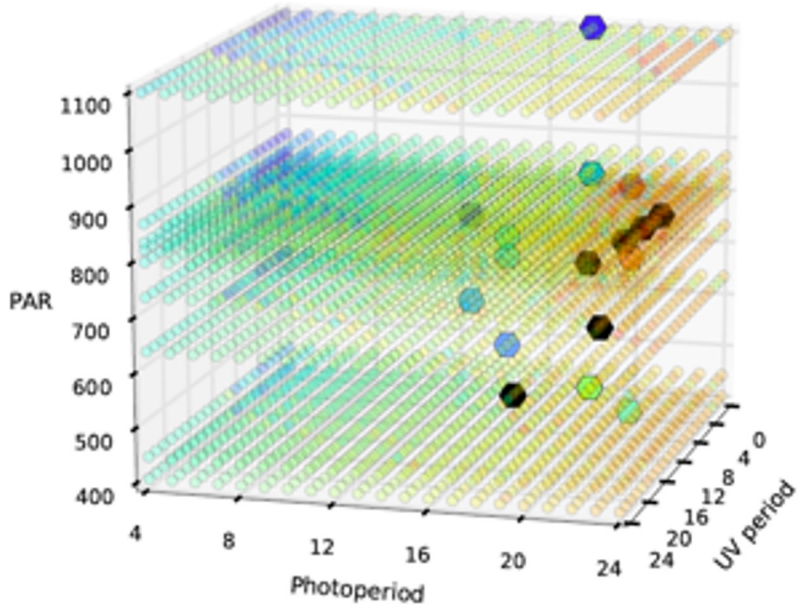
Optimizing Growth Recipes for Agriculture

Environments at the OpenAg Lab of MIT Media Lab



Recipes discovered for light (darker is better)

- Build an adaptive digital twin of how plants grow in hydroponic growth environments
  - Light, temperature, water, nutrients etc. computer controlled
- Evolve growth recipes against the twin
  - Millions new recipes created and evaluated; only a few hundred actually planted
- Discovered that basil does not need to sleep!
  - Grows best when lights are on 24hrs/day
  - An insight that surprised domain experts

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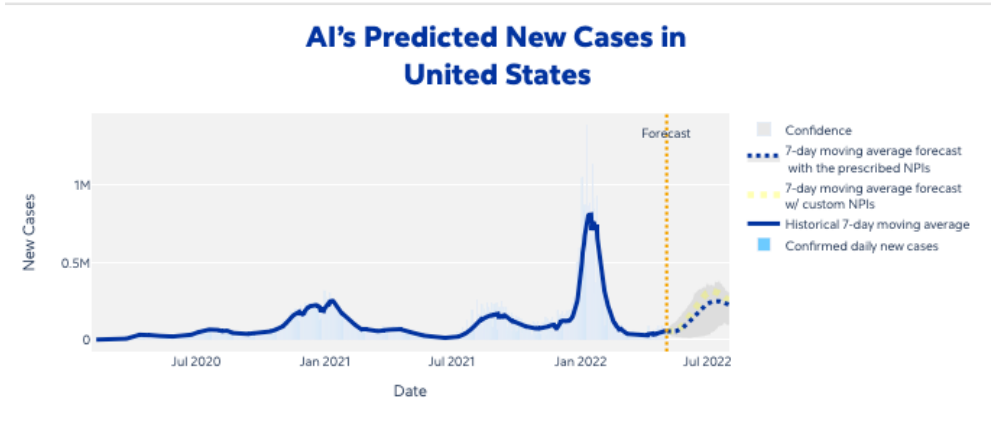
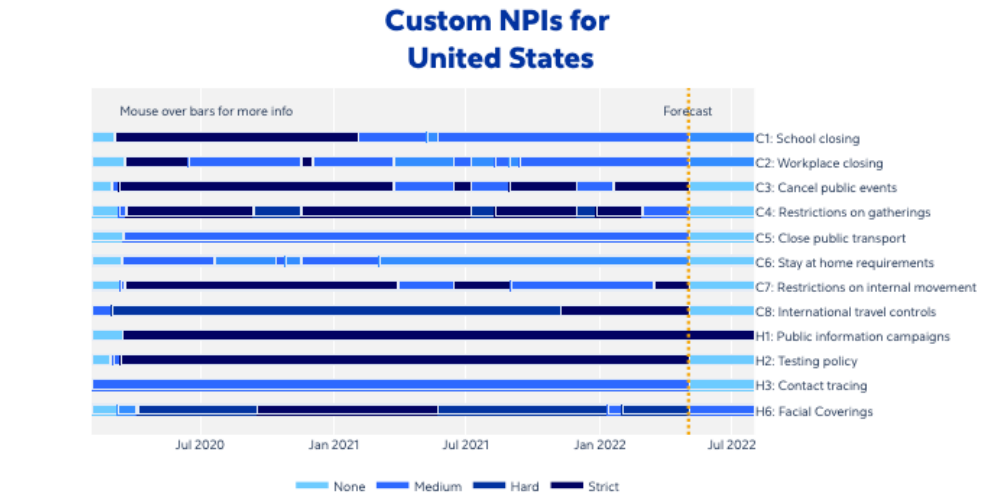
Optimizing COVID-19 Response





Interactive demo: https://evolution.ml/demos/npidashboard

Build an adaptive digital twin of COVID-19 cases over time
- Predict number of cases in different countries
- In response to non-pharmaceutical interventions (NPIs)

Discover best interventions against the twin
- Resulting in smallest number of cases
- With minimal economic cost

Not just what will happen, but what we should do about it!
- Scratchpad, uncertainty to help explore alternatives

Retrained continuously since May 2020
- Adapting to the different stages of the pandemic
- Generalizing from experiences across the world

Recommendations about two weeks in advance, e.g.
- May 2020: Focus on schools and workplaces (i.e. indoors)
- Sept 2020: Focus on gatherings, travel restrictions
- March 2021: India lockdown
- July 2021: Delta surge on countries with low rates so far
- March 2022: Masking to avoid a second Omicron surge

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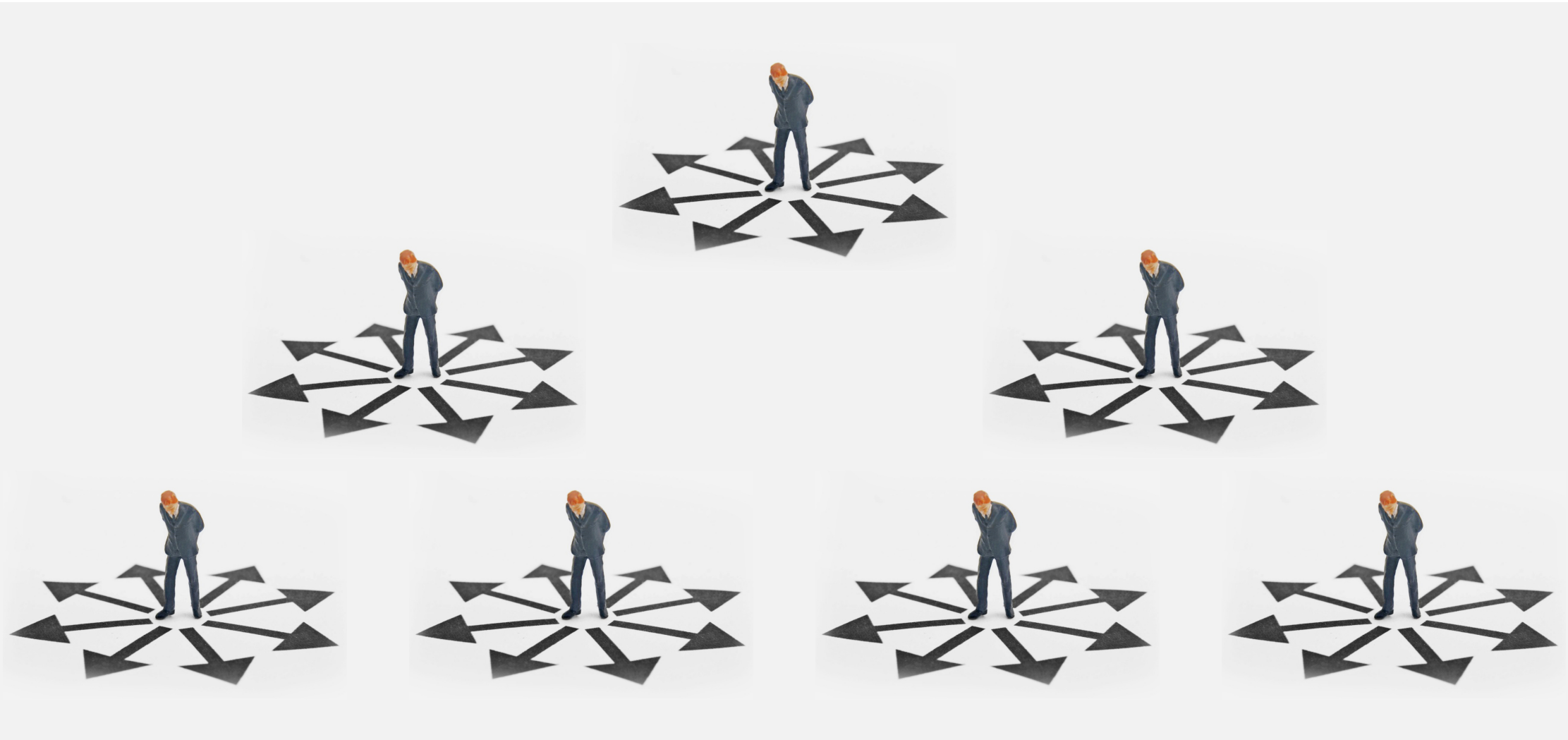
An Organization Consists of Many Decision Makers



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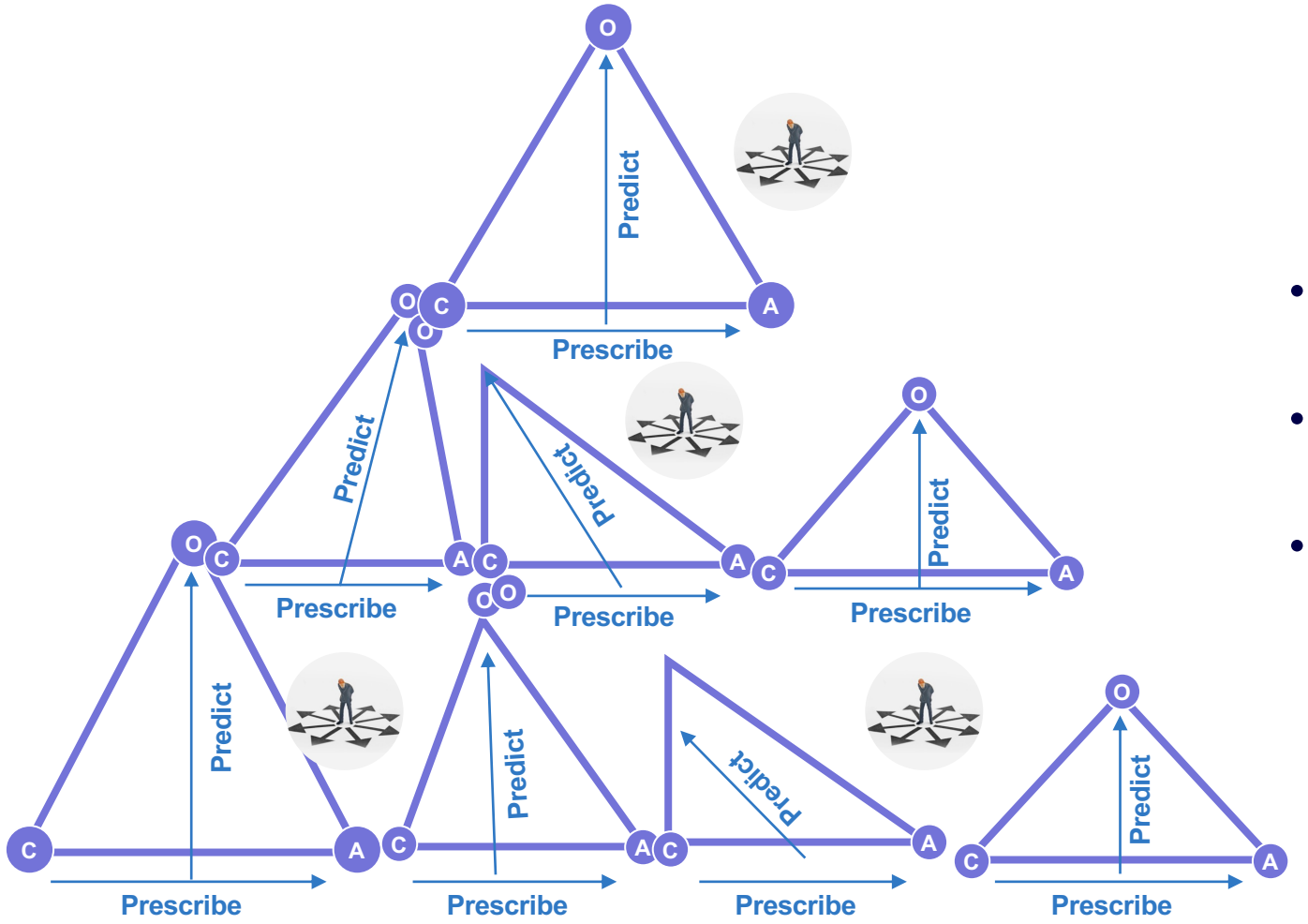
Scale in Entangled Decision-Loops



- More Accurate Decision
- More Efficient Decision-making
- Better Outcomes

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Thank You