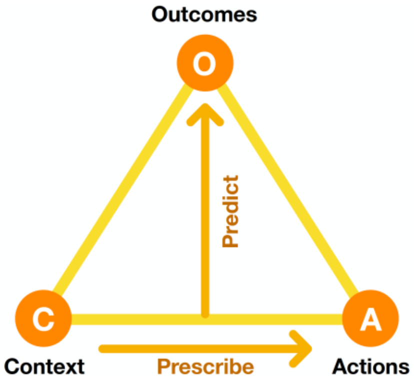
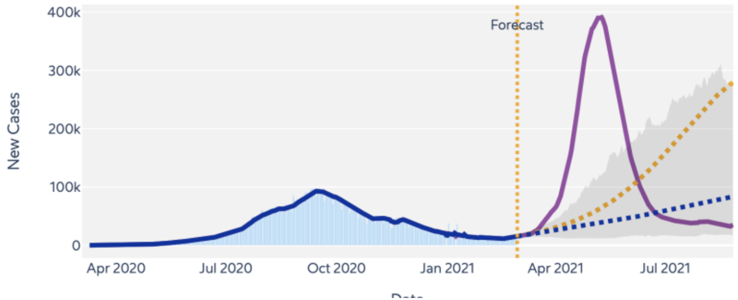
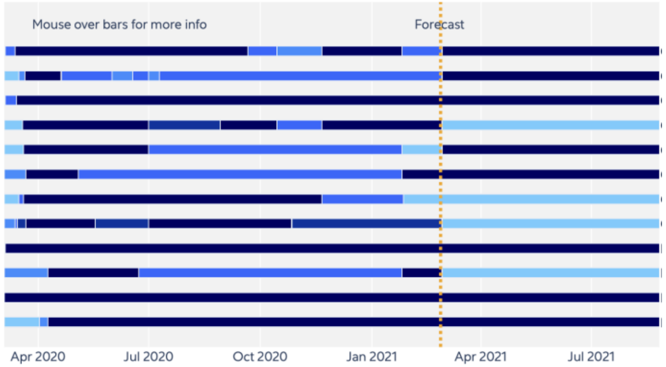
Pandemic Resilience Use Case







Developed at Cognizant AI Labs 2020-2022

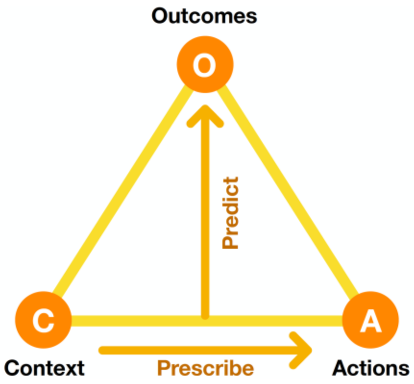
- Risto Miikkulainen, Elliot Meyerson, Olivier Francon, Elisa Canzani, Darren Sargent, Babak Hodjat

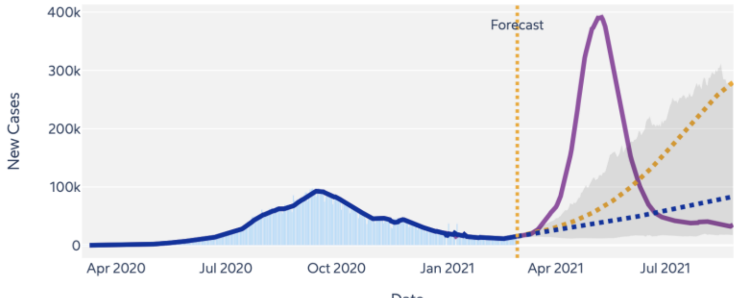
Extended to an XPRIZE competition 2020-2021

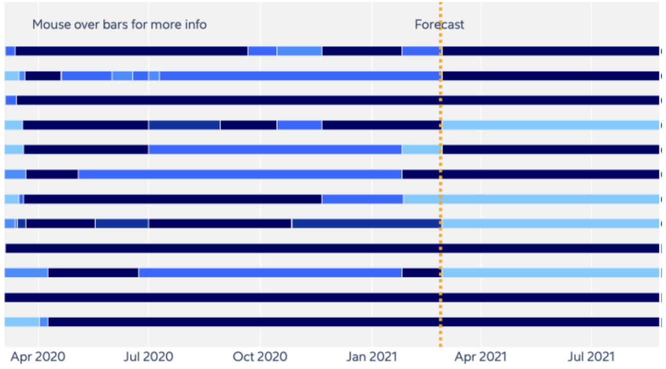
- With Amir Banifatemi, Haneen Khalaf, Andrew Tauhert…

Motivation for Project Resilience

A data-driven approach to COVID-19 modeling







Based on two models:

1. A predictive model
- Given a history of cases and NPIs
- Predict number of cases daily

2. A prescriptive model
- Given a history of cases and NPIs
- Prescribe NPIs daily

The predictive model is a surrogate for the world
- Makes it possible to evaluate prescriptor candidates

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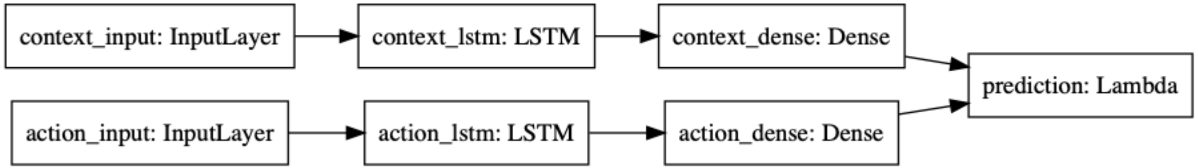
First build a predictor with available data



SEIR, network, agent-based models do not work well as a surrogate

- Too slow: need to create millions of predictions daily
- Too specific: hundreds of countries, millions of NPI settings

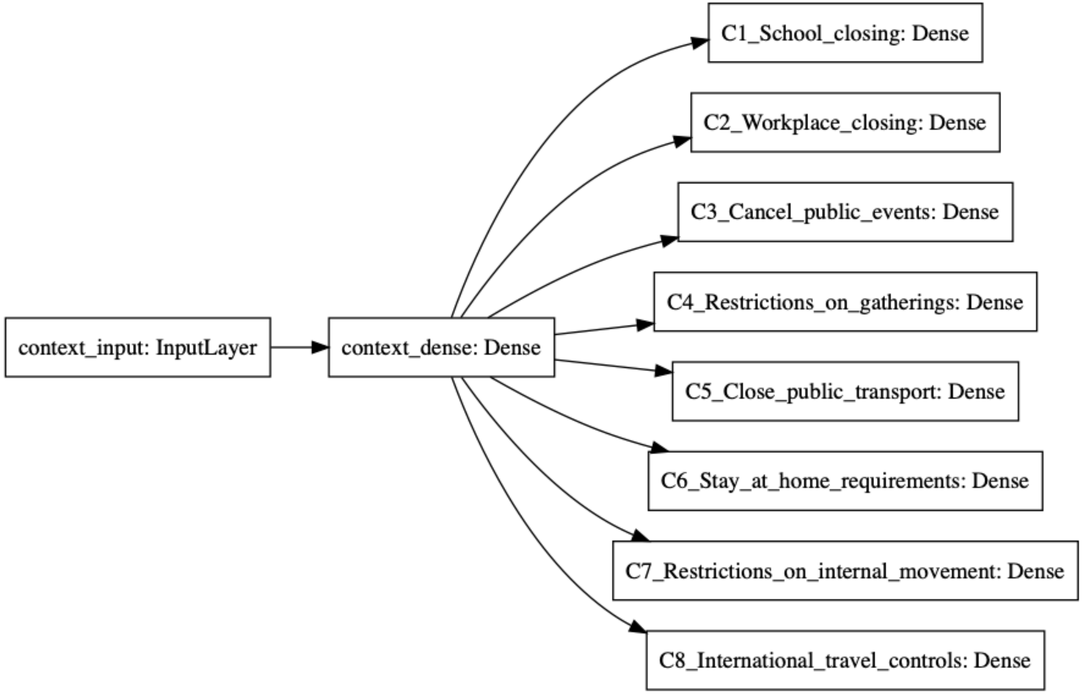
Instead, train a neural network with historical data

- Maps cases and NPIs directly to predictions
- Phenomenological model: Requires no estimation of epidemiological parameters
- Data includes all interactions between parameters! (if enough good data)

Such data was available for COVID19

- Oxford COVID-19 Government Response Tracker (Toby!)
- Daily case numbers and NPIs for most countries

Then evolve a Prescriptor with the Predictor as a surrogate



etc.

No gradients!

- Need to search for a good model

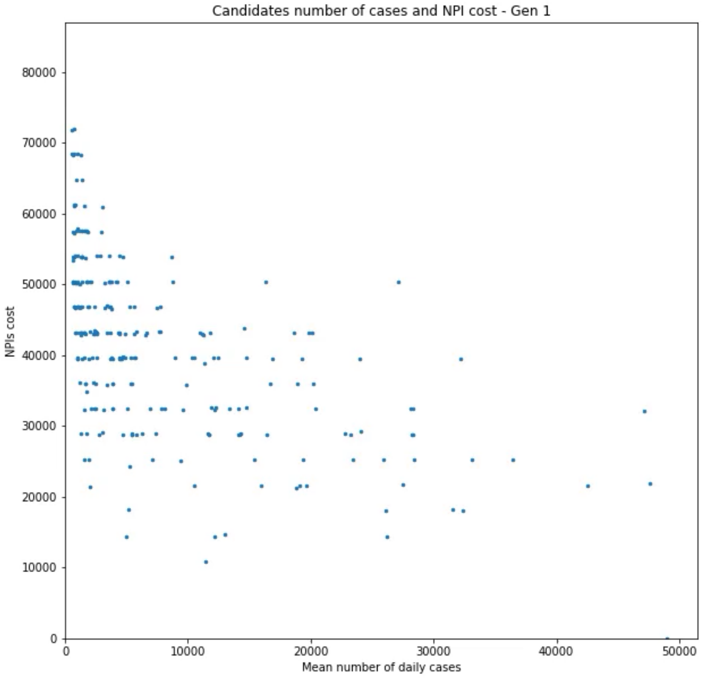
Evolve neural network prescriptors

- Population-based search
- Use Predictor to evaluate each one

Multiobjective

- Minimize future cases
- Minimize stringency of NPIs
  (a proxy for economic cost)

Solutions represent different tradeoffs



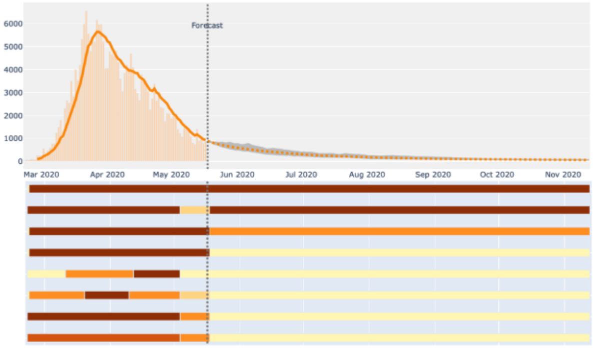
Evolution minimizes both objectives

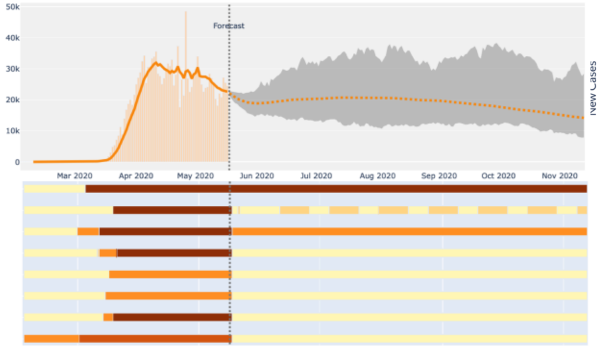
Results in a Pareto front:

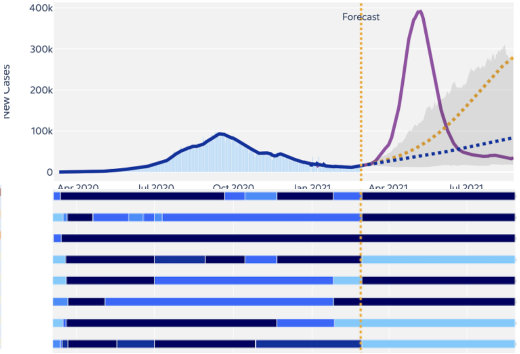
- Some minimize cases
- Some minimize cost
- Others balance the two to different degrees

Given a desired balance, best possible solutions

Discoveries on Prediction and Prescription







Highlights (often 2 weeks in advance):

- May 2020: Focus on schools and workplaces (i.e. indoors); alternation
- Sept 2020: Focus on gatherings, travel restrictions; open schools
- Delta surge: India (March 2021); others with low rates (July 2021)
- August 2021: Recommendations for schools (Iceland)
- Dec 2021: Missed omicron surge; it happened everywhere at once
- March 2022: Impact of masking

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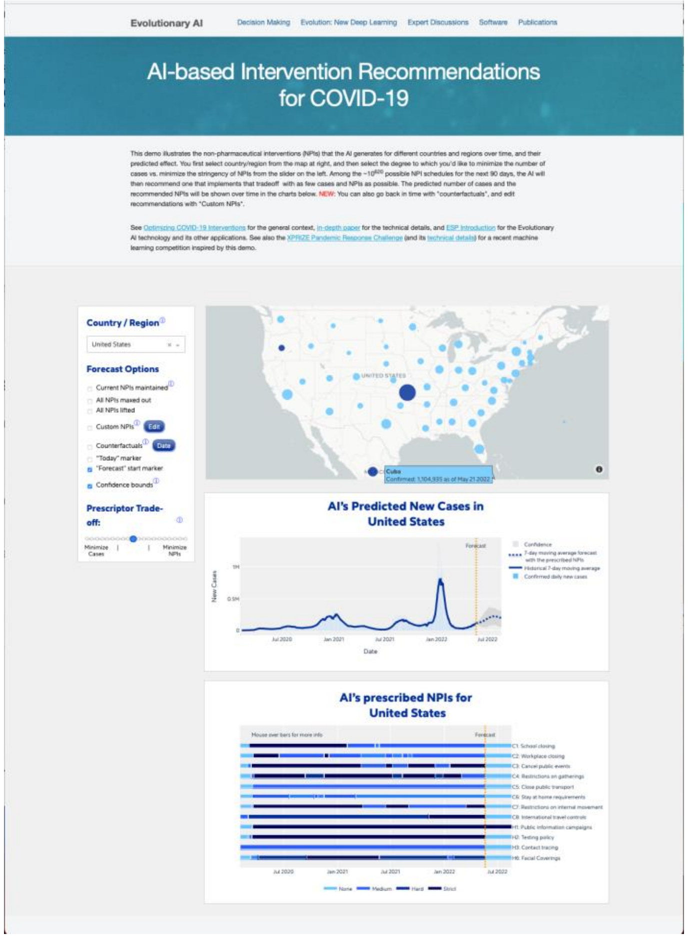


Interactive Demo

https://evolution.ml/demos/npidashboard

Updated daily May 2020 – Dec 2022

Can be used to obtain data-based recommendations

- Select country
- Select date (current, or past)
- Select health/economy tradeoff (cases vs. NPIs)
- Obtain NPI recommendations and case predictions

Trustworthiness:

- Obtain confidence bounds
- Design custom NPIs with a scratchpad
- Evolve explainable rulesets (instead of neural networks)

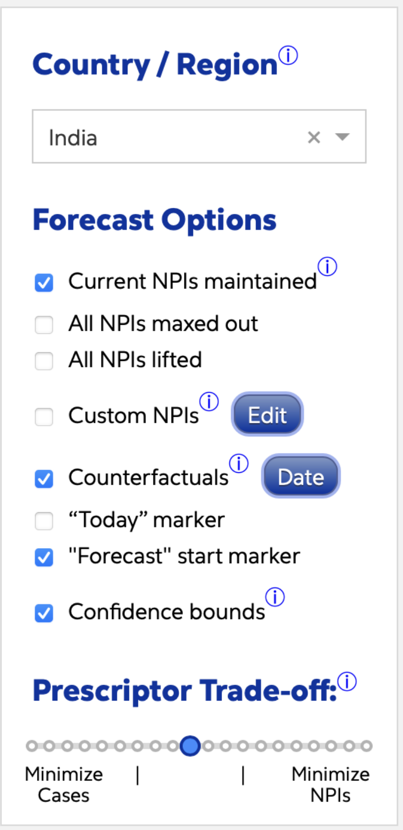
Obtaining Recommendations

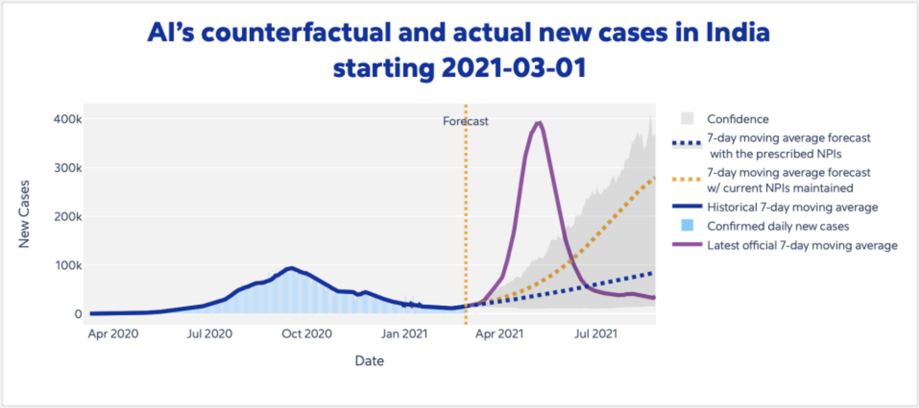
Select
- Country
- Date (current/past)
- Tradeoff

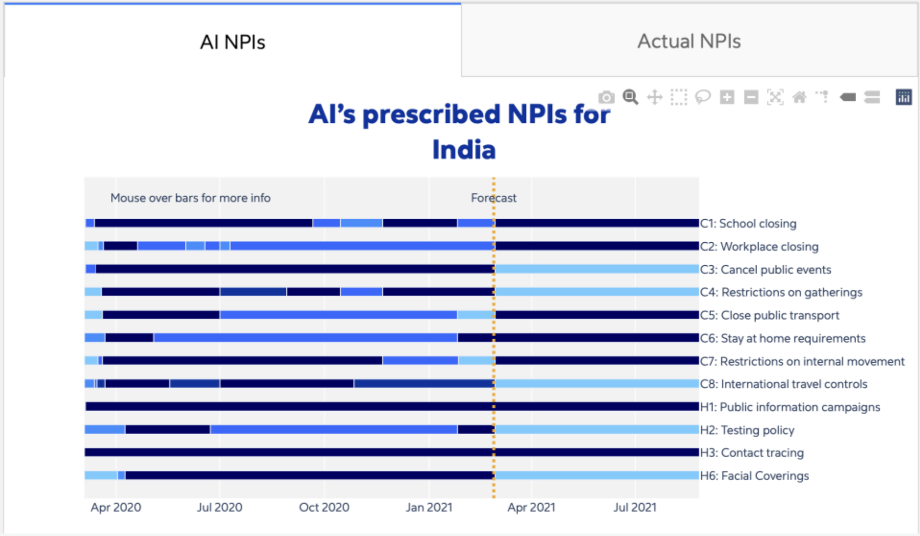
Observe cases
- Actual
- With current NPIs
- With AI NPIs

And confidence bounds
- GP model
- Multiple rollouts

Observe NPIs
- Actual
- Prescribed







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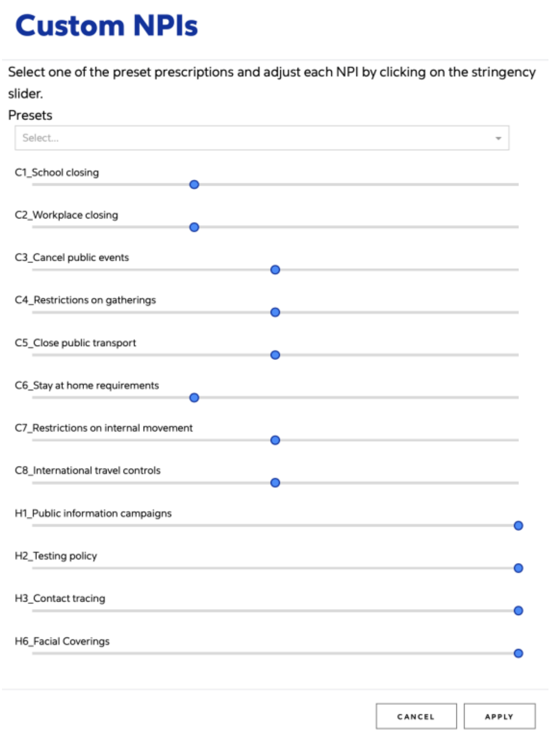
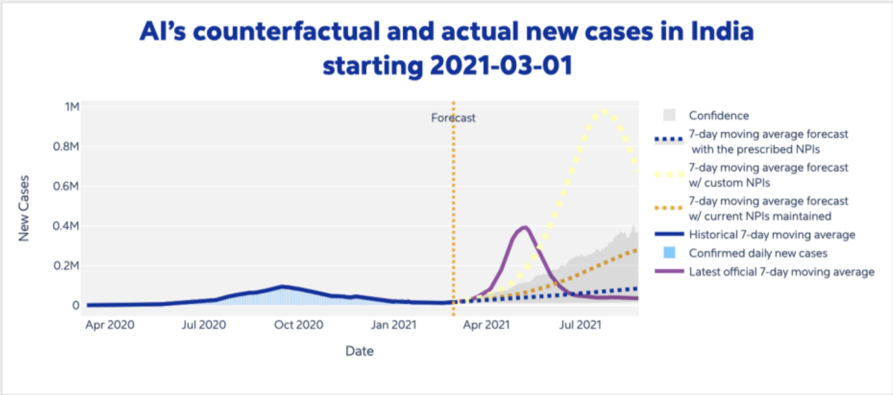
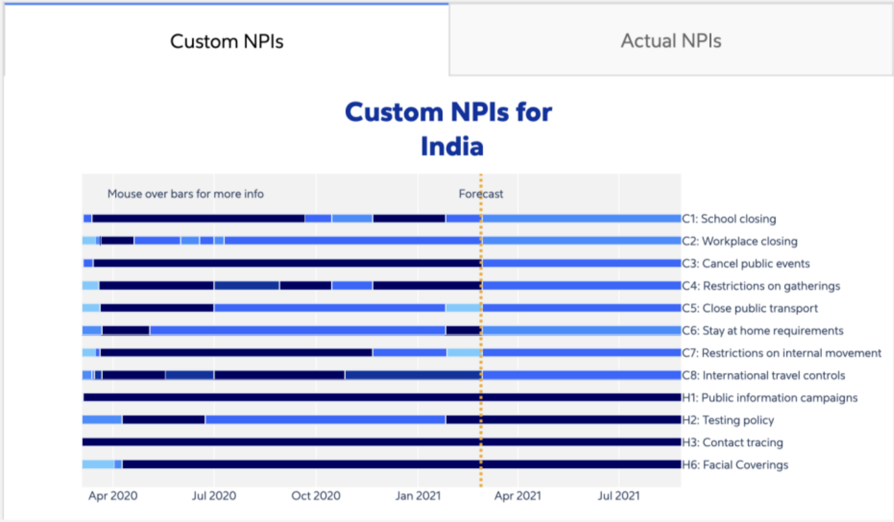
Explore alternative NPIs

Start from
- AI's prescriptions
- Current
- Maxed-out
- No NPIs





For instance
- Less school, work, home, transport
- More masks, tests, internatl. travel



Observe results
- A different way to achieve the same result?
- Not quite ☹

Making recommendations explainable: Evolve rulesets

< > (0.07*context_12 < 0.16*context_6) --> 0.92*C2_Workplace closing
< > (0.54*context_17 >= 0.03*context_16) (0.46*context_3 >= 0.48*context_11) --> 0.15*C6_Stay at home requirements
< > (0.93*context_16 > 0.46*context_19) (0.82*context_2 > 0.42*context_4) (0.54*context_17 >= 0.03*context_16) (0.47*context_9 <= 0.72*context_11) (0.46*context_3 >= 0.48*context_11) (0.46*context_17^2 >= 0.48*context_11) (0.46*context_17 >= 0.48*context_11) (0.30*context_7 >= 0.29*context_4) (0.16*context_4^3 > 0.15*context_18) (0.16*context_4 > 0.15*context_18) (0.16*context_13 > 0.15*context_18) (0.10*context_6^2 <= 0.95*context_16) (0.10*context_6 <= 0.95*context_16) (0.10*context_6 <= 0.95*context_16) --> 0.15*C6_Stay at home requirements
< > (0.54*context_17 >= 0.03*context_16) (0.46*context_3 >= 0.48*context_11) (0.46*context_17 >= 0.48*context_11) (0.38*context_12 <= 0.22*context_1) (0.38*context_12 <= 0.22*context_1) (0.16*context_4 > 0.15*context_18) (0.10*context_6^2 <= 0.95*context_16) (0.10*context_6 <= 0.95*context_16) (0.10*context_6 <= 0.95*context_16) (0.10*context_6 <= 0.95*context_16) --> 0.75*C6_Stay at home requirements
< > (0.18*context_18 <= 0.62*context_12) --> 0.95*C4_Restrictions on gatherings
< > (0.38*context_4 >= 0.26*context_16) (0.18*context_18 > 0.62*context_12) --> 0.95*C4_Restrictions on gatherings
< > (0.07*context_12^2 < 0.16*context_6) --> 0.92*C2_Workplace closing
< > (0.46*context_3 >= 0.48*context_11) (0.16*context_4 > 0.15*context_18) --> 0.71*C6_Stay at home requirements
< > (0.16*context_4 > 0.15*context_18) --> 0.71*C6_Stay at home requirements
< > (0.33*context_10 < 0.27*context_5) (0.00*context_2 < 0.24*context_16) --> 0.72*C5_Close public transport
< > (0.71*context_12 >= 0.57*context_7) (0.63*context_11 >= 0.60*context_8) (0.29*context_16 >= 0.26) (0.27*context_4 > 0.14*con
< > (0.75*context_13 > 1.00*context_1) (0.07*context_12 < 0.16*context_6) --> 0.92*C2_Workplace closing
< > (0.58*context_17 <= 0.89*context_19) (0.39*context_10 > 1.00*context_12) --> 0.82*C7_Restrictions on internal movement
< > (0.71*context_12 >= 0.57*context_7) (0.63*context_11 >= 0.60*context_8) (0.29*context_16 >= 0.26) (0.24*context_3 >= 0.63*cc
< > (0.71*context_12 >= 0.57*context_7) (0.63*context_11 >= 0.60*context_8) --> 0.36*H3_Contact tracing
< > (0.54*context_17 >= 0.03*context_16) (0.46*context_3 >= 0.48*context_11) (0.16*context_4 > 0.15*context_18) --> 0.71*C6_St
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< > (0.29*context_16 >= 0.26) --> 0.36*H3_Contact tracing
< > (0.07*context_12 < 0.16*context_6) --> 0.92*C2_Workplace closing
< > (0.54*context_17 >= 0.03*context_16) --> 0.71*C6_Stay at home requirements
< > (0.56*context_17 >= 0.49*context_18) (0.49*context_0 > 0.90*context_10) (0.01*context_16 >= 0.31*context_1) --> 0.42*C3_Ca
< > (0.71*context_12 >= 0.57*context_7) (0.63*context_11 >= 0.60*context_8) (0.29*context_16 >= 0.26) --> 0.36*H3_Contact traci
< > (0.45*context_4 < 0.13*context_0) (0.04*context_19 < 0.54) --> 0.95*H1_Public information campaigns
< > (0.71*context_16 >= 0.00) (0.07*context_12 < 0.16*context_6) --> 0.92*C2_Workplace closing
< > (0.21*context_4 <= 0.23*context_7) (0.07*context_12 < 0.16*context_6) (0.07*context_12 < 0.16*context_6) --> 0.92*C2_Workp
< > (0.33*context_10 < 0.27*context_5) (0.03*context_17 > 0.82*context_14) --> 0.72*C5_Close public transport
< > (0.58*context_17 <= 0.89*context_19) --> 0.82*C7_Restrictions on internal movement
< > (0.58*context_9 > 0.74*context_2) (0.25*context_2 < 0.84*context_3) --> 0.34*H2_Testing policy
< > (0.49*context_0 > 0.90*context_10) --> 0.42*C3_Cancel public events
< > (0.04*context_19 < 0.54) --> 0.95*H1_Public information campaigns
< > (0.33*context_10^2 < 0.27*context_5) (0.03*context_17 > 0.82*context_14) --> 0.72*C5_Close public transport
< > (0.54*context_17 >= 0.03*context_16) (0.46*context_3 >= 0.48*context_11) (0.46*context_3 < 0.48*context_11) (0.16*context_4
0.99*context_6) --> 0.15*C6_Stay at home requirements
< > (0.54*context_17 >= 0.03*context_16) (0.46*context_3 < 0.48*context_11) (0.16*context_4 > 0.15*context_18) (0.10*context_6 <
< > (0.54*context_17 >= 0.03*context_16) (0.46*context_3 >= 0.48*context_11) (0.46*context_3 < 0.48*context_11) (0.38*context_12
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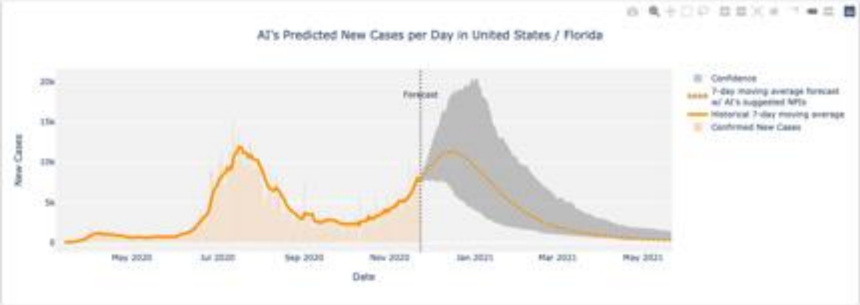
<= 0.95*context_16) (0.06*context_0 <= 0.99*context_6) --> 0.75*C6_Stay at home requirements
< > (0.54*context_17 >= 0.03*context_16) (0.46*context_3 >= 0.48*context_11) (0.46*context_3 < 0.48*context_11) (0.38*context_12
<= 0.99*context_6) --> 0.71*C6_Stay at home requirements
< > (0.54*context_17 >= 0.03*context_16) (0.46*context_3 >= 0.48*context_11) (0.46*context_3 < 0.48*context_11) (0.30*context_7 >= 0.29*context_4) (0.16*context_4 > 0.15*context_18) (0.10*context_6 <= 0.95*context_16) --> 0.71*C6_Stay at home requirements
< > (0.54*context_17 >= 0.03*context_16) (0.46*context_3 >= 0.48*context_11) (0.46*context_3 < 0.48*context_11) (0.46*context_17 >= 0.48*context_11) (0.30*context_7 >= 0.29*context_4) (0.16*context_4 > 0.15*context_18) (0.10*context_6 <= 0.95*context_16) (0.10*context_6 <= 0.95*context_16) --> 0.00*C6_Stay at home requirements
< > (0.18*context_18 > 0.62*context_12) --> 0.95*C4_Restrictions on gatherings
< > (0.46*context_3 >= 0.48*context_11) (0.10*context_6 <= 0.95*context_16) --> 0.00*C6_Stay at home requirements
< > (0.46*context_17 >= 0.48*context_11) (0.16*context_4 > 0.15*context_18) (0.10*context_6 <= 0.95*context_16) (0.10*context_6 <= 0.95*context_16) --> 0.15*C6_Stay at home requirements
<> Default Action: 0.12*C7_Restrictions on internal movement



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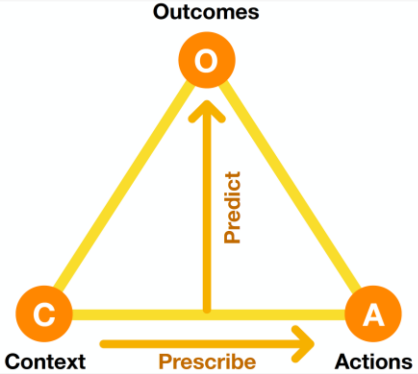
Scaling up: XPRIZE Pandemic Response Challenge



XPRIZE

November 2020-March 2021
- Phase 1: Prediction Accuracy; 100 teams narrowed down to 50 finalists
- Phase 2: Prescription Effectiveness; 2 winners (Valencia, Slovenia) and 8 runner-ups

Many Machine Learning approaches as well as conventional ones
- Evaluation and analysis: https://evolution.ml/xprize

Informing government policy
- E.g. Team Valencia doing that already during the competition
- Embedded a government representative into the science team

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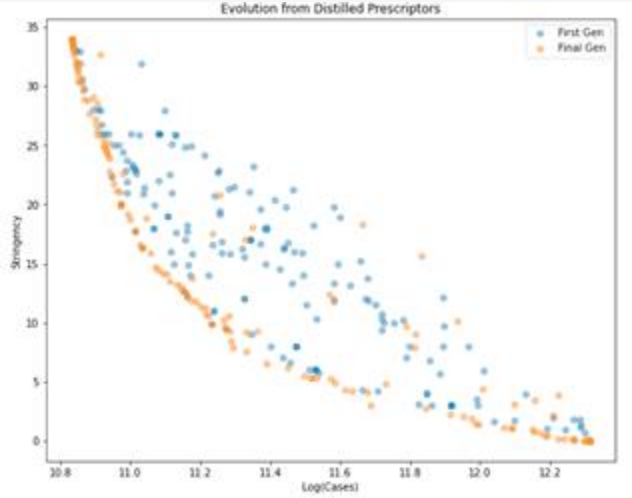
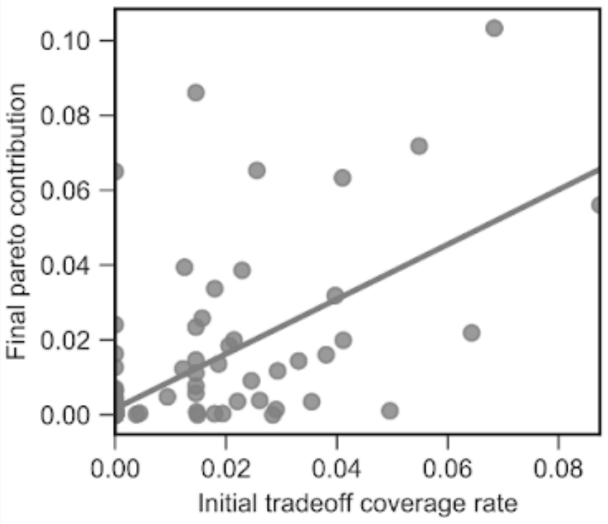
Using AI to Leverage Human Insights





XPRIZE entries have many useful, diverse ideas

Evolutionary AI (RHEA) can be used to build on them

- Improve upon XPRIZE entries
- Improve upon evolution from scratch

Can realize latent potential hidden in poor entries

Technology to bring the community effort together

The Story Continues

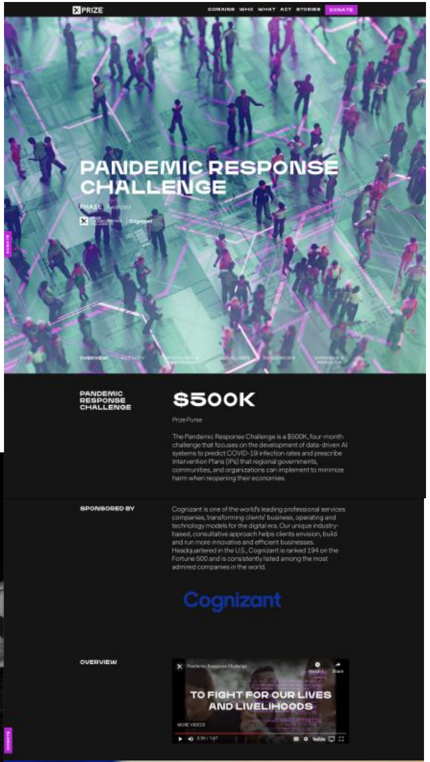
Built the original demo to draw attention to science
- Decision makers, general public

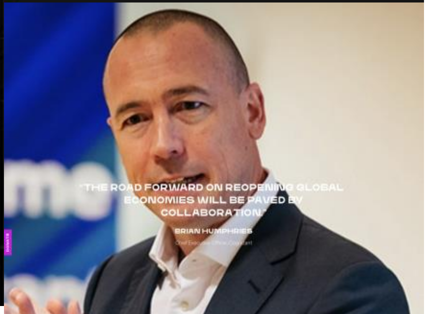
XPRIZE amplified it tremendously
- Many people around the world could participate, publizice
- 1.2B views of the results

Follow-up: Pandemic Resilience (GPAI)
- Focusing on utilizing multiple models

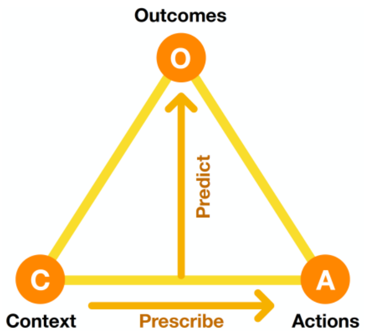
Follow-up: PIPP (NSF)
- Focusing on science communication

Follow-up: Project Resilience (UN/ITU)
- Build an AI for Good ecosystem





Conclusions

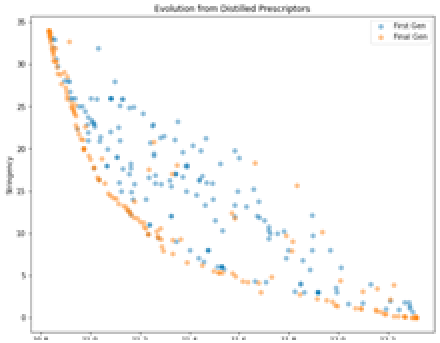


Data-driven approach can be accurate, general, and adaptable

- Can make worthwhile discoveries

Making models useful for decision makers

- Alternatives (Pareto front)
- Interactive exploration (scratchpad)
- Uncertainty estimates (confidence bounds)
- Explainability (rule-sets)
- Combining human expertise and machine exploration (RHEA)



Future expansion

- Better predictive and prescriptive models
- Better communication with decision-makers and the public
- Expanding the scope to other fields