Improving tuberculosis treatment by integrating optimization and learning

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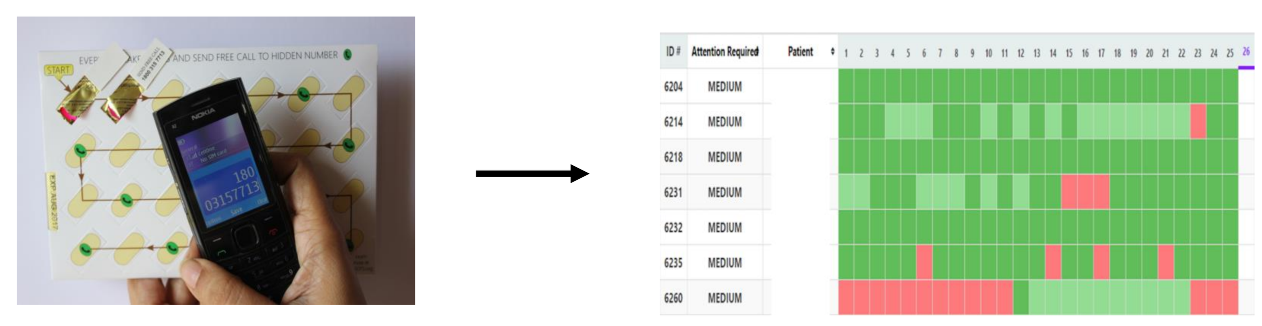
Tuberculosis treatment

- **2.8 million cases** in India alone
- Treatment: **6 months** of daily antibiotics
- Low adherence leads to **reinfection** and **drug resistance**

Adherence tracking with 99DOTS

- Patients call each day after taking medication
- Health worker observes adherence for their patients

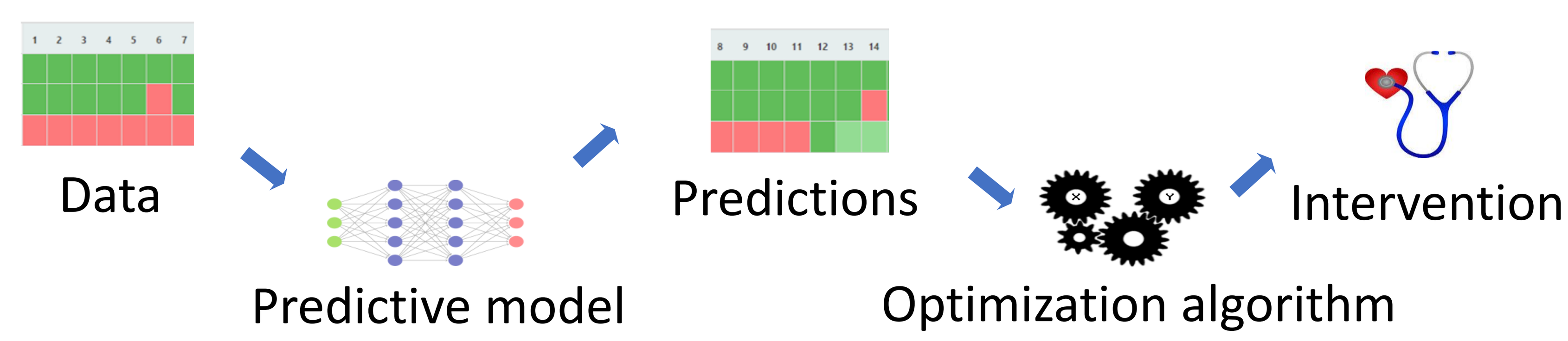


How can ML help?

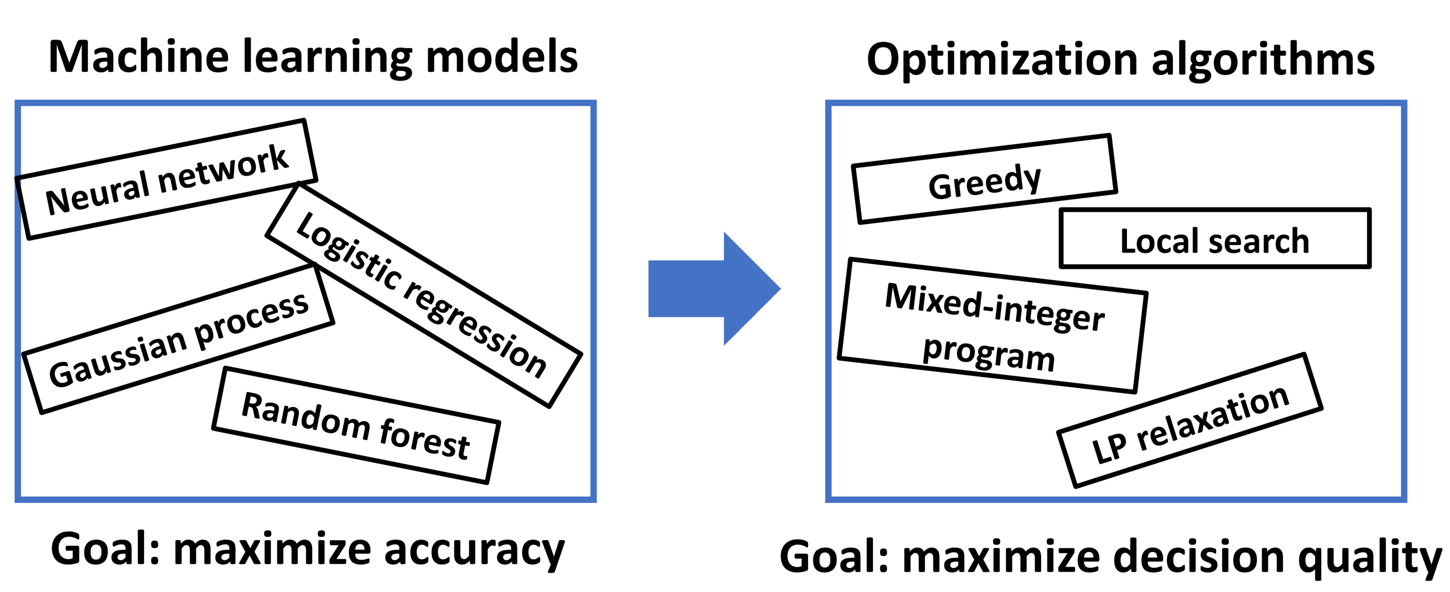
- Health workers have **limited resources** (100+ patients/worker)
- Status quo: follow-up with patients is **reactive**
  - Visit patients who have stopped adhering
- Goal with ML: **proactive** interventions
  - Visit patients predicted to not adhere

Combining ML and optimization

- Aim: solve a resource allocation problem for health workers
- Objective is predicted from past data



Typical two-stage approach



Challenge

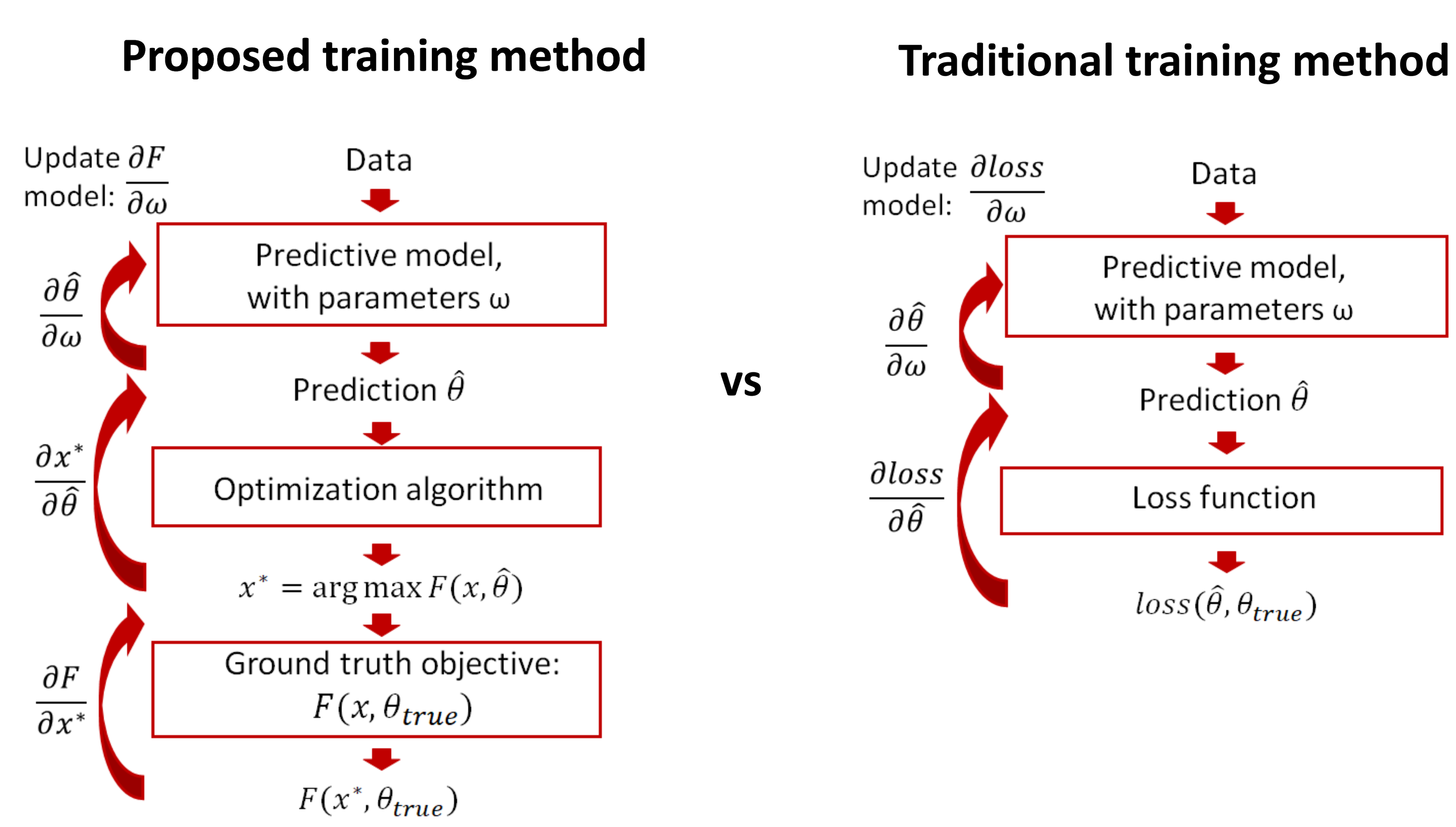
- Maximizing accuracy ≠ maximizing decision quality
- "All models are wrong, some are useful"
- Two-stage training doesn't align with end goal

How can machine learning training incorporate the objective of a combinatorial optimization problem?

End-to-end training

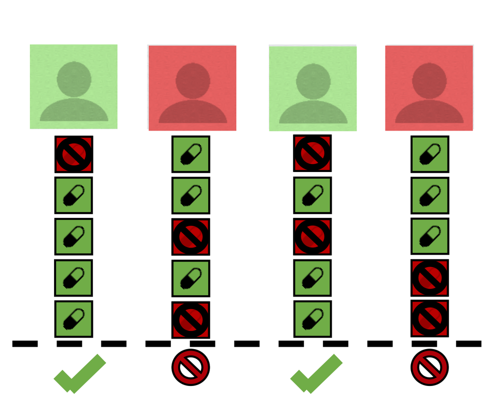
- Approach: differentiate optimal solution with respect to θ, train model via gradient descent
- Challenge: the optimization problem is discrete!
- Solution: relax to continuous problem, differentiate that, and then round

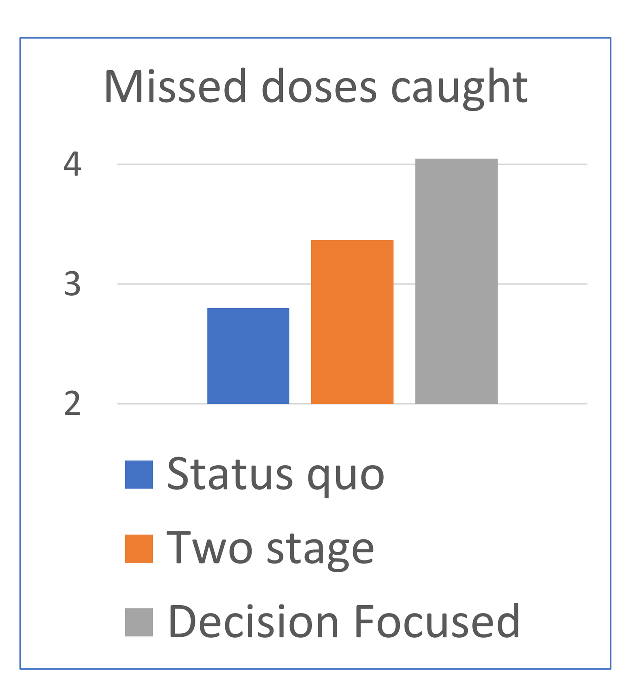
Discrete		Continuous
$\max_{x \in X} f(x, \theta)$	➡	$\max_{x \in conv(X)} F(x, \theta)$
x = binary decision		x = fractional decision F = continuous objective

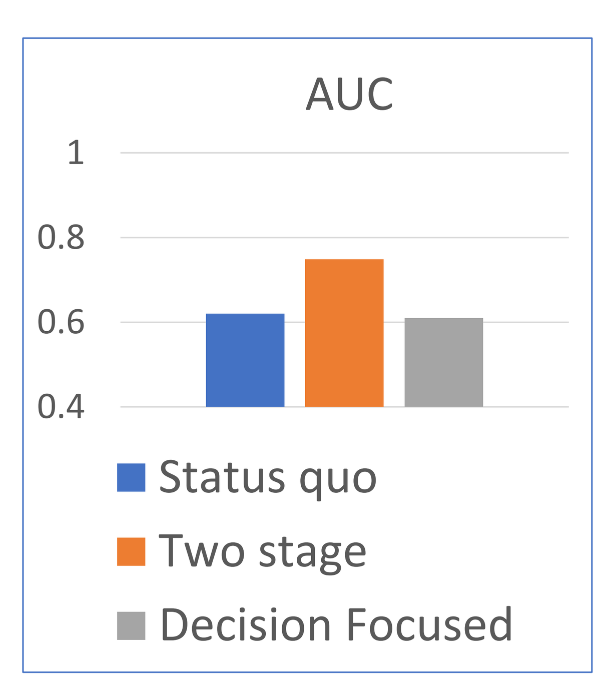


Results: 99DOTS data from Mumbai

- Data from 17,000 patients in Mumbai
- Predict 1-week adherence with LSTM
- Compare status quo, standard two stage training, and decision-focused training







Less "accurate", but +15% successful interventions!

Wilder et al. Melding the Data-Decisions Pipeline: Decision-Focused Learning for Combinatorial Optimization. AAAI 2019

Killian et al. Learning to Prescribe Interventions for Tuberculosis Patients using Digital Adherence Data. KDD 2019