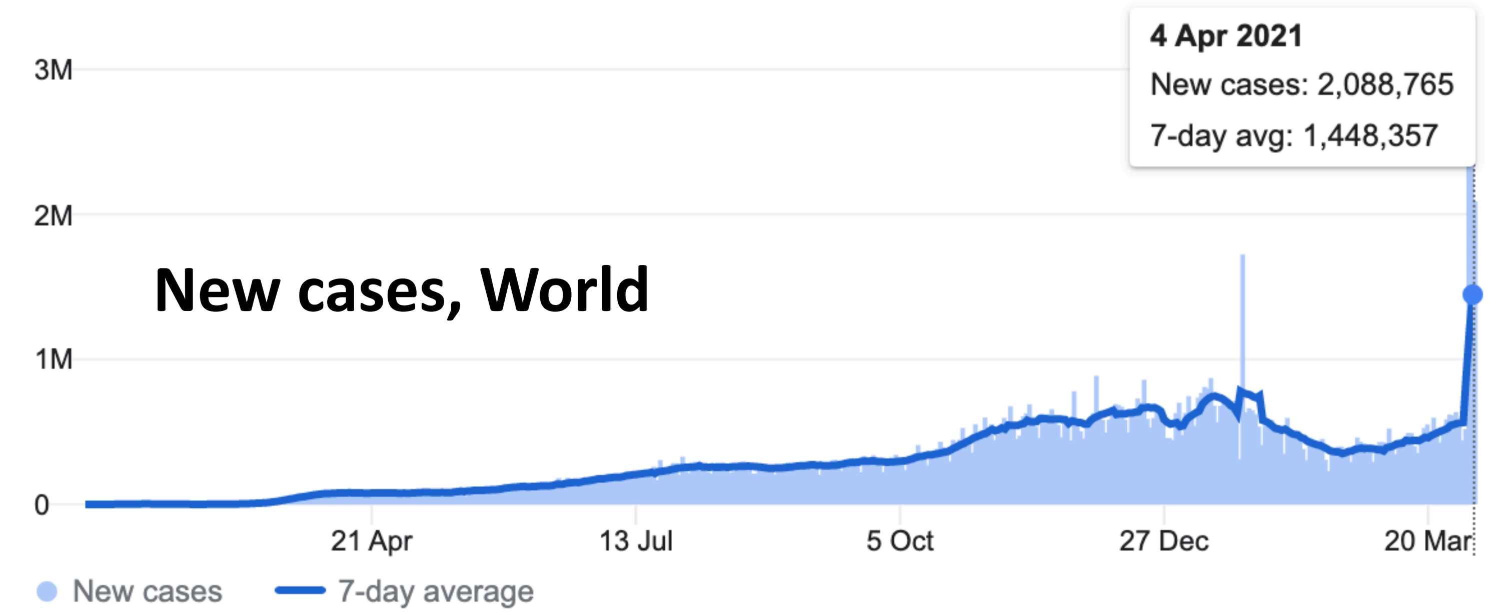
Epidemic Model Guided Machine Learning for COVID-19 Forecasts

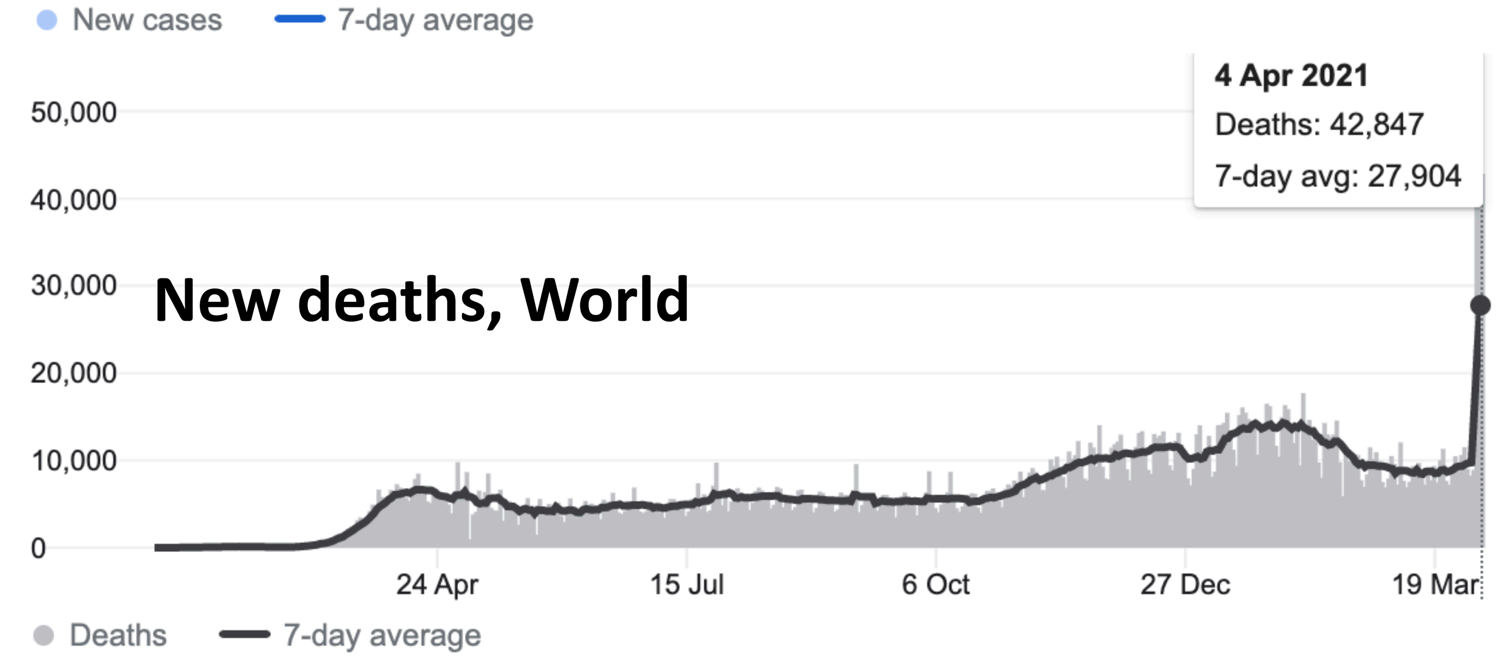
Difan Zou, Lingxiao Wang, Pan Xu, Jinghui Chen, Weitong Zhang, Quanquan Gu

Computer Science Department, University of California, Los Angeles

UCLA ICLR

Severity of the Pandemic

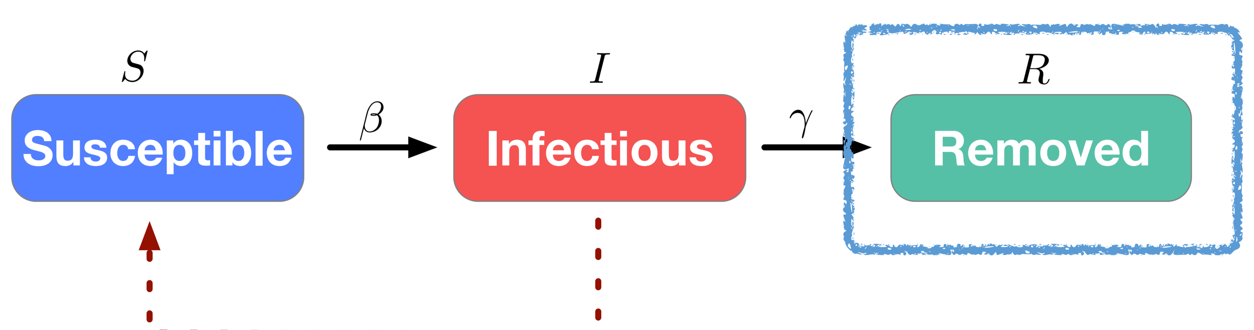




How to model the spread of the virus and make accurate forecasts for deaths and cases?

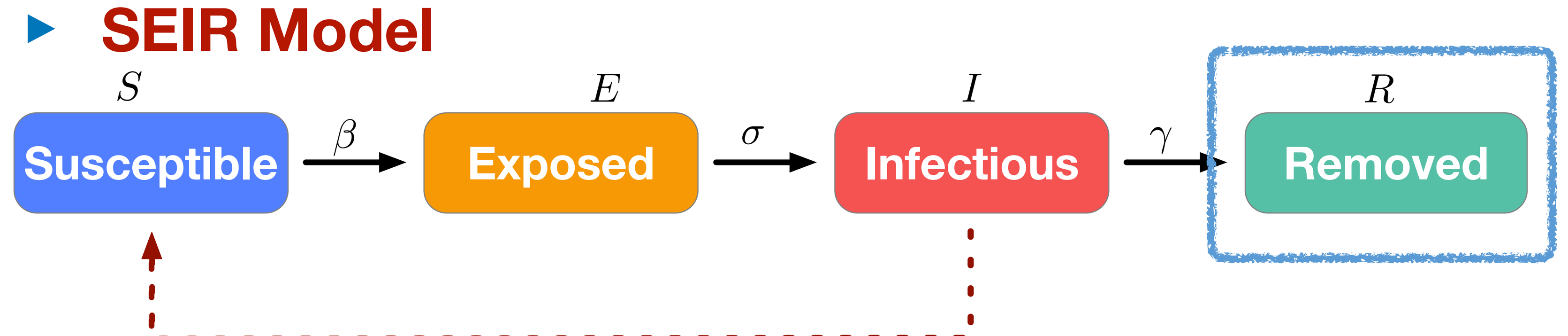
Conventional Epidemic Models

SIR Model



Including fatality and recovered cases

SEIR Model

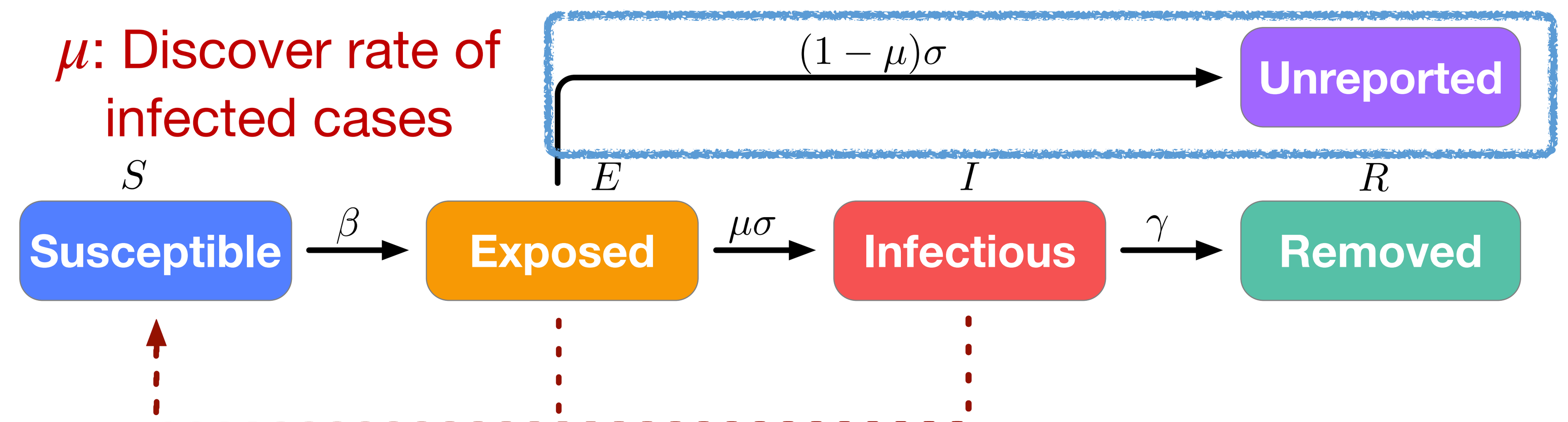


β: Contact/Infectious rate σ: Incubation rate γ: Recover rate

Many exposed cases may not be tested and further reported to the public.

Our Model (SuEIR)

μ: Discover rate of infected cases



ODE Description

Basic reproduction number

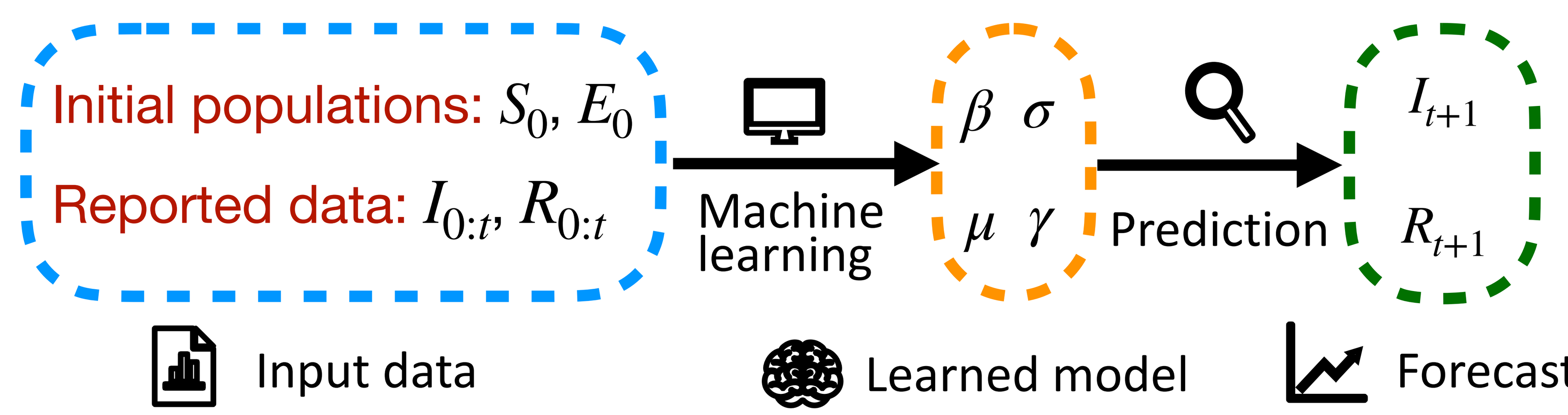
$$\frac{dS_t}{dt} = -\frac{\beta(I_t + E_t)S_t}{N}, \quad \frac{dE_t}{dt} = \frac{\beta(I_t + E_t)S_t}{N} - \sigma E_t,$$

$$\frac{dI_t}{dt} = \mu\sigma E_t - \gamma I_t, \quad \frac{dR_t}{dt} = \gamma I_t.$$

$$\boxed{R_0 = \frac{\beta}{\sigma} + \frac{\beta\mu}{\gamma}}$$

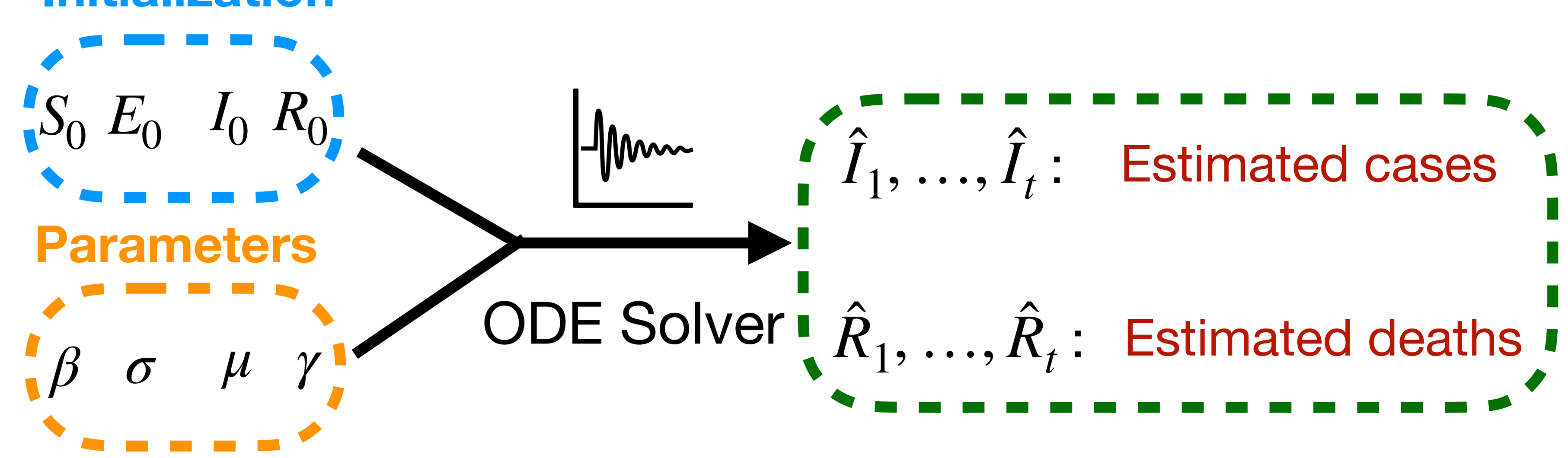
Machine Learning Framework

Machine Learning Pipeline



Learning Model Parameters

Initialization



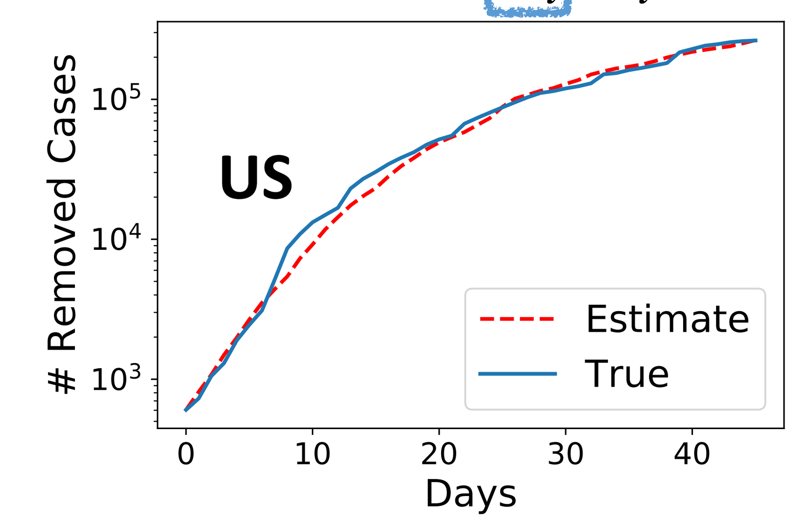
Loss Function

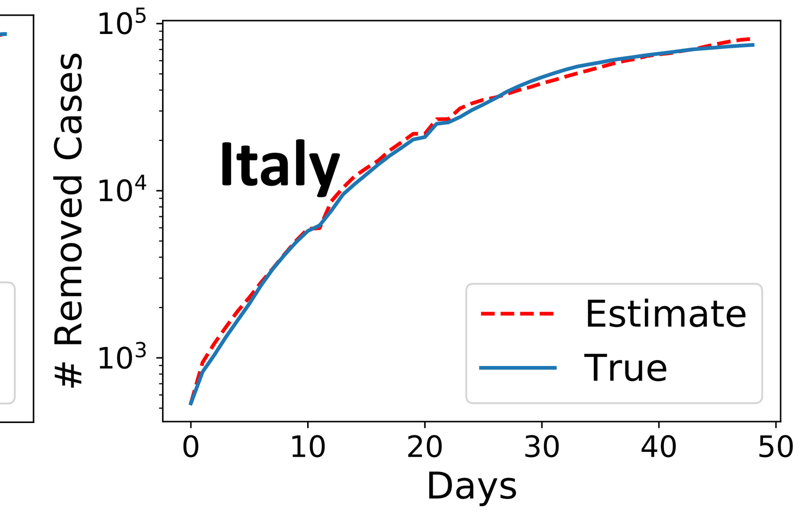
$$L(\beta, \sigma, \mu, \gamma; I_{1:T}, R_{1:T}) = \frac{1}{T}\sum_{t=1}^{T}\left[\left(\log(\hat{I}_t/I_t)\right)^2 + \left(\log(\hat{R}_t/R_t)\right)^2\right]$$

Implementation Details

Decomposition of Removed Cases

Fatality cases $\boxed{F_t}/R_t = a\exp(-bt) + c$





Validation

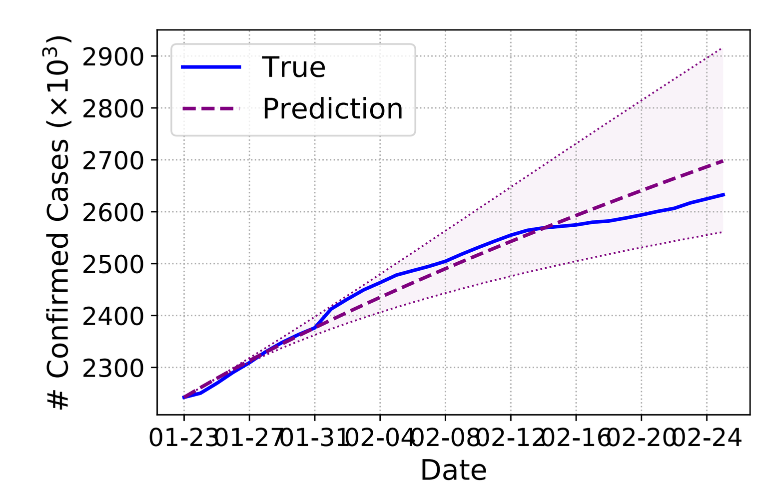
We try different initial guesses S_0, E_0 and select the model with smallest validation risk.

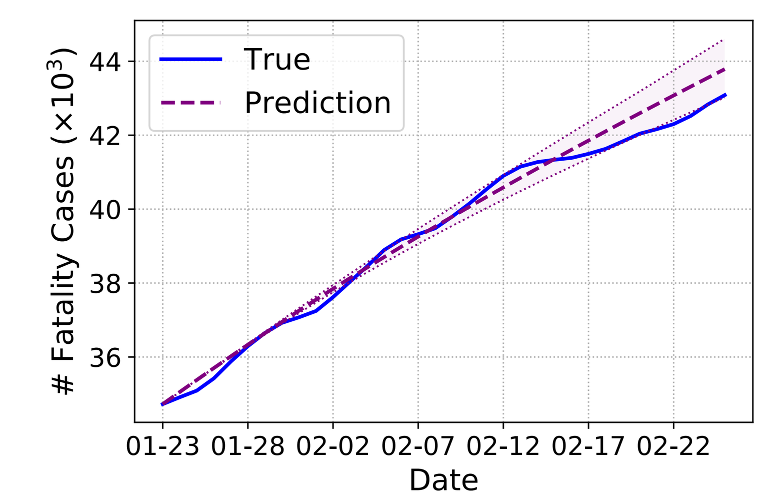
Modeling the Resurgence

- We split the training period into multiple stages and train multiple SuEIR models separately.
- Susceptible populations are assumed to increase after the resurgence date.

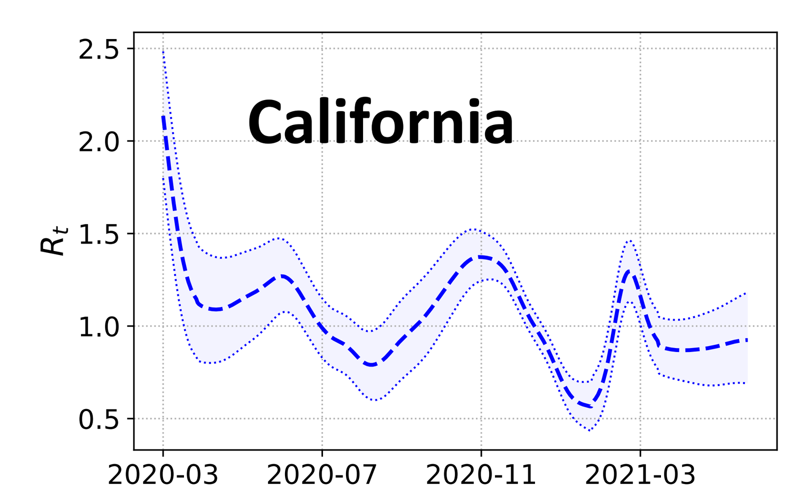
Forecasts and Reproduction Numbers

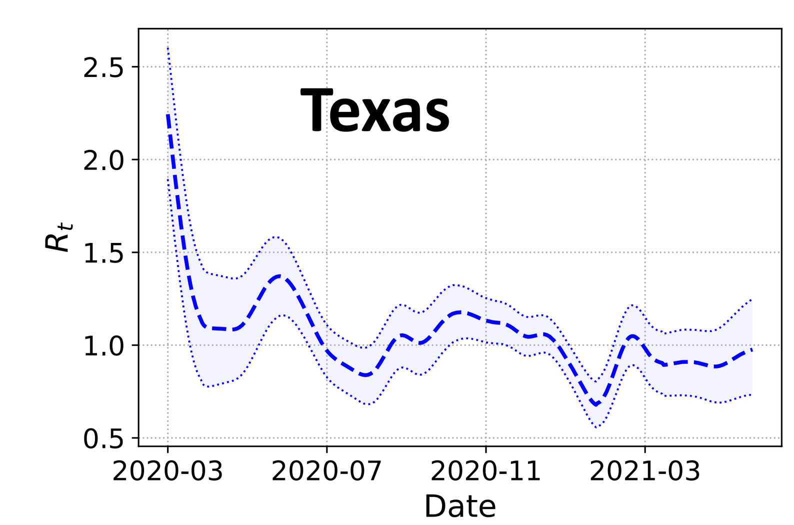
Forecasts (Texas)



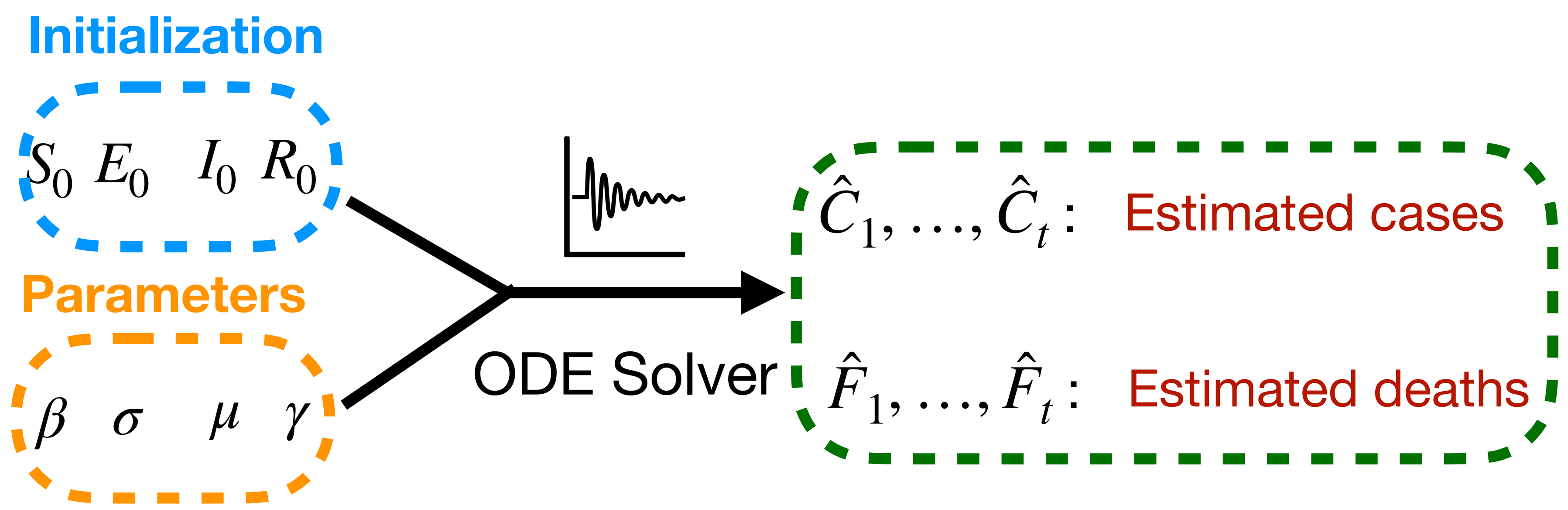


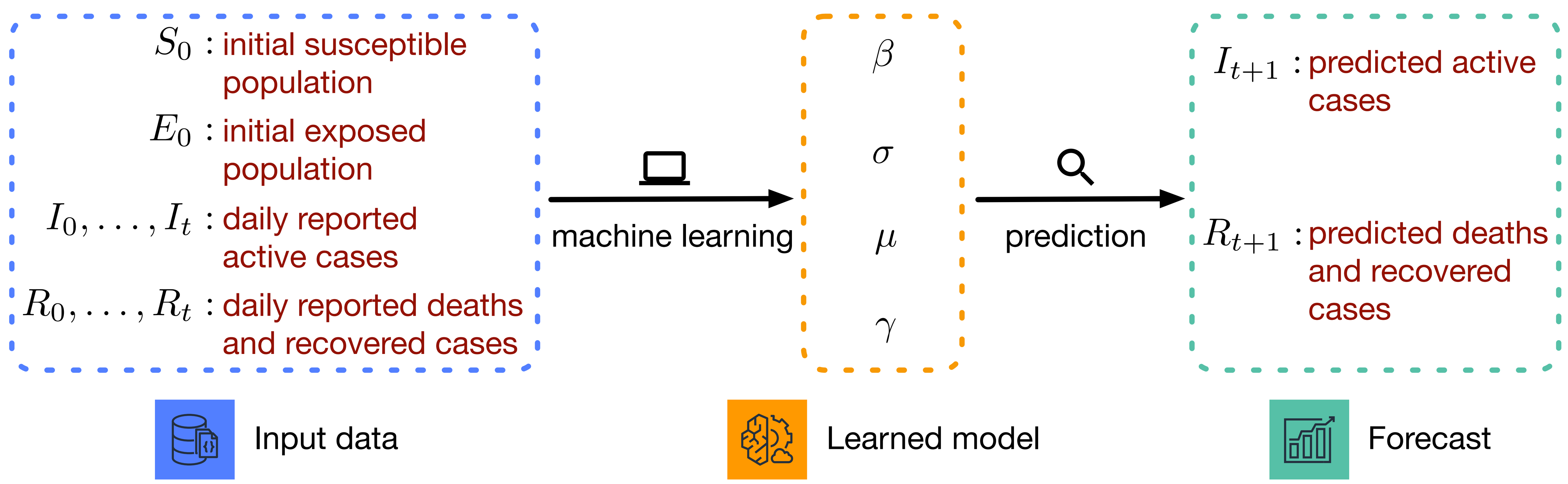
Reproduction Numbers

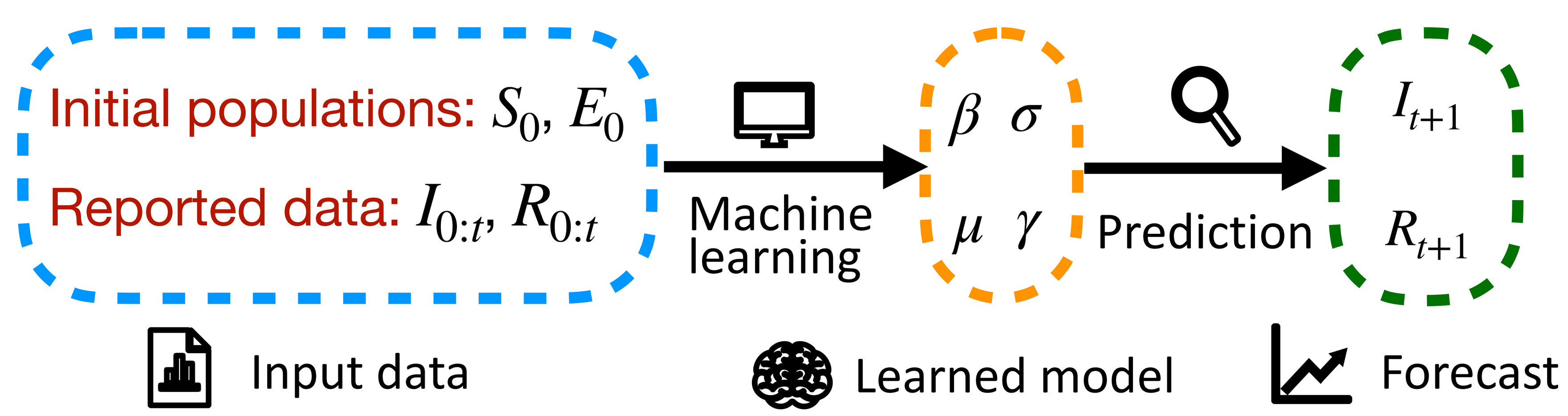




ICLR 2021 Workshop: Machine Learning for Preventing and Combating Pandemics







$$L(\boldsymbol{\theta}; I_{1:T}, R_{1:T}) = \frac{1}{T} \sum_{t=1}^{T} \left[\left(\log(\hat{I}_t / I_t) \right)^2 + \left(\log(\hat{R}_t / R_t) \right)^2 \right]$$