SIR implementation in a mobility network

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REAL TIME EPIDEMIC DATATHON

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Contents

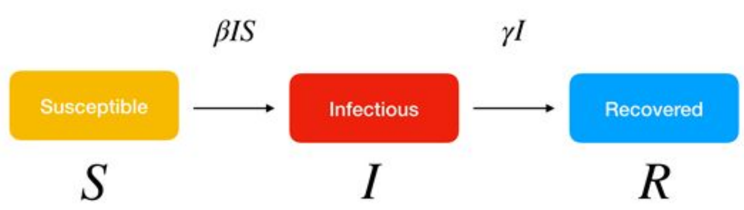
SIR Model

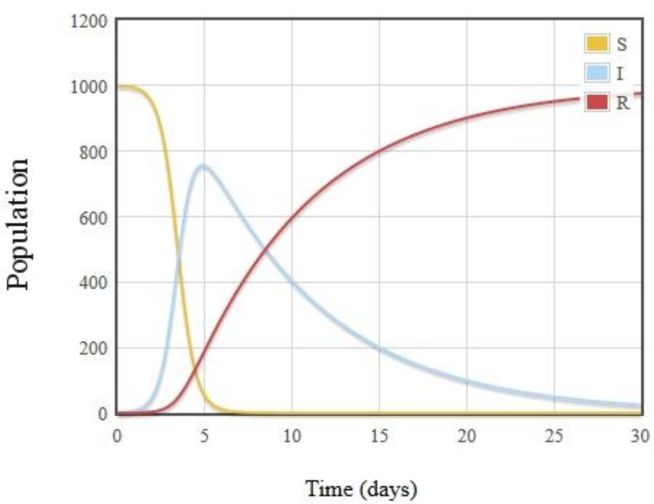
Three compartments

- Susceptible, infectious, recovered
- Interaction parameters β, γ

Every US State is own compartment model

- No mobility between states included (yet)
- Parameters initially unknown, but bounds are given; fitting is optimisation problem
- Dynamics change with every wave: adaptive parameters



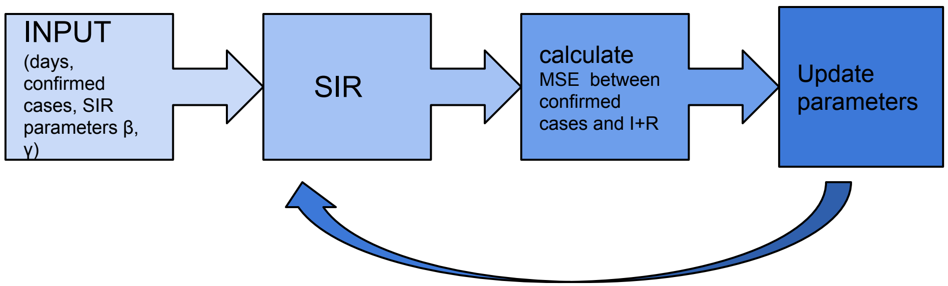


Implementation:

Code based on

https://github.com/cidacslab/Mathematical-and-Statistical-Modeling-of-COVID19-in-Brazil/blob/master/main/modelos.py

Pipeline



Preparing the data:

- Group by state total number of confirmed cases.
- Create an array per state of number of confirmed cases.
- Create a dictionary with key=state name and value=Population size.
- Initialize SIR object for each state, with their respective population size.

Optimization

Powell method vs. L-BFGS-B method

Needed to check:

- Sensitivity of initial parameters
- Local minima

We observed that:

- Minima obtained with Powell method were more consistent.
- Values obtained with L-BFGS-B tended to go to the boundaries.
- Comparing both methods, Powell gave generally lower errors.

Second approach: Nonhomogeneous β

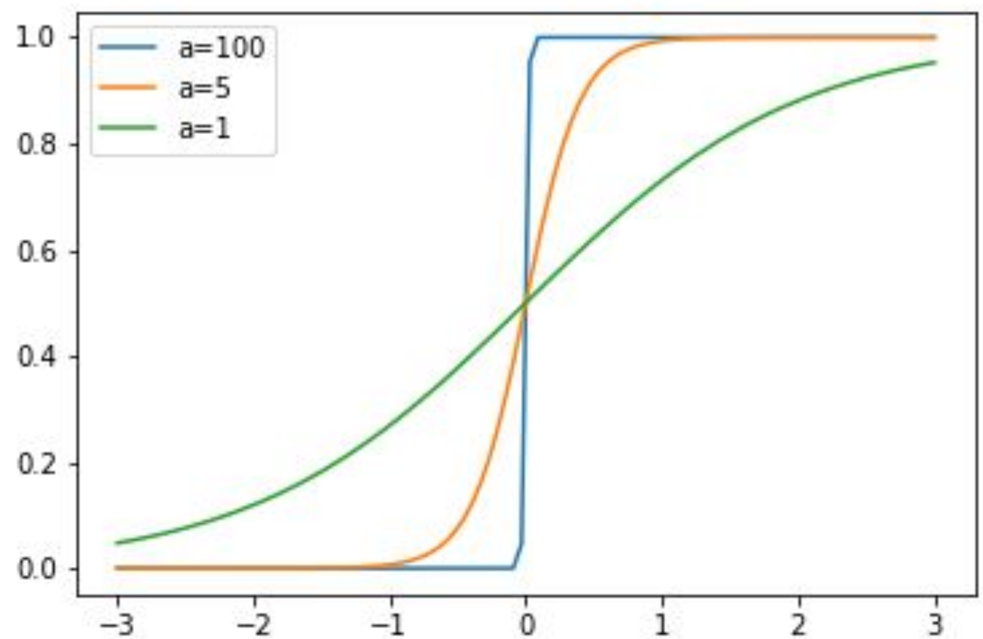
Assuming a constant β might not be the best way to model the dynamics.

We used a “discrete time varying” beta instead, of the form

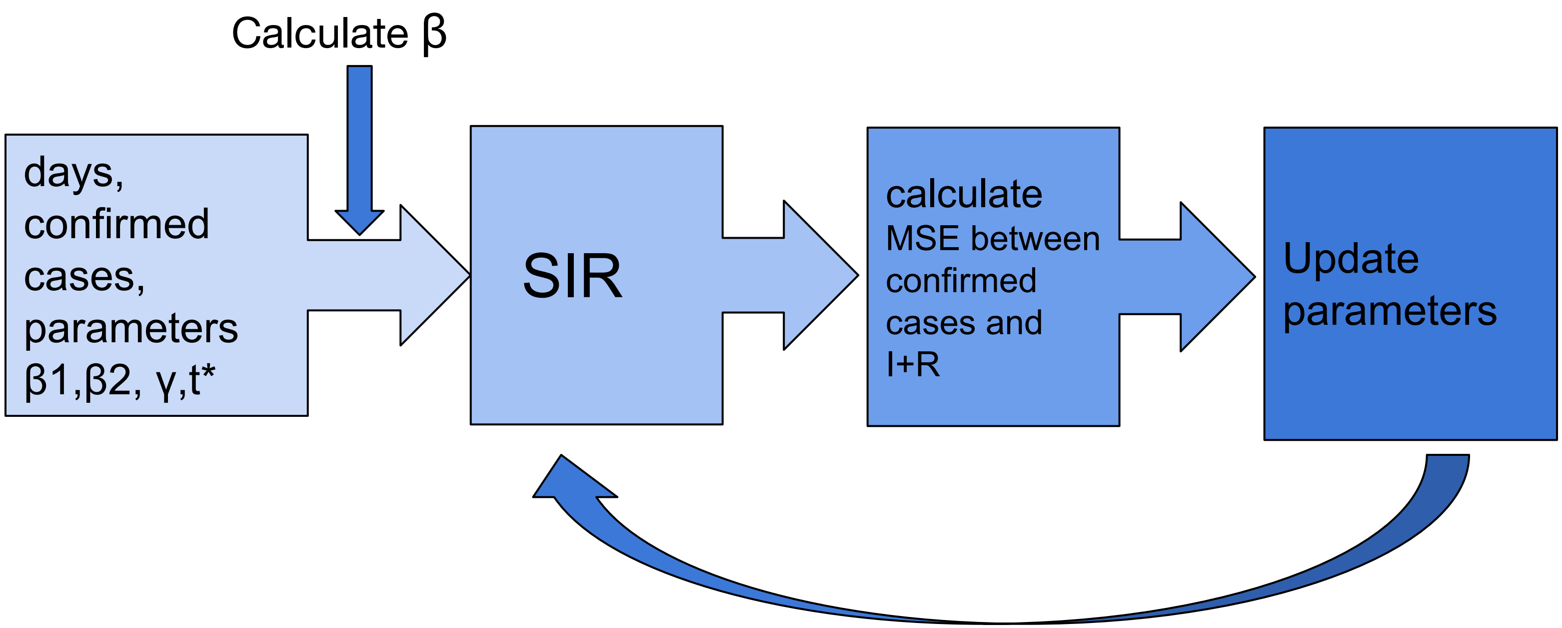
$$\beta(t) = \beta_1 f(t^* - t) + \beta_2 f(t - t^*)$$

where

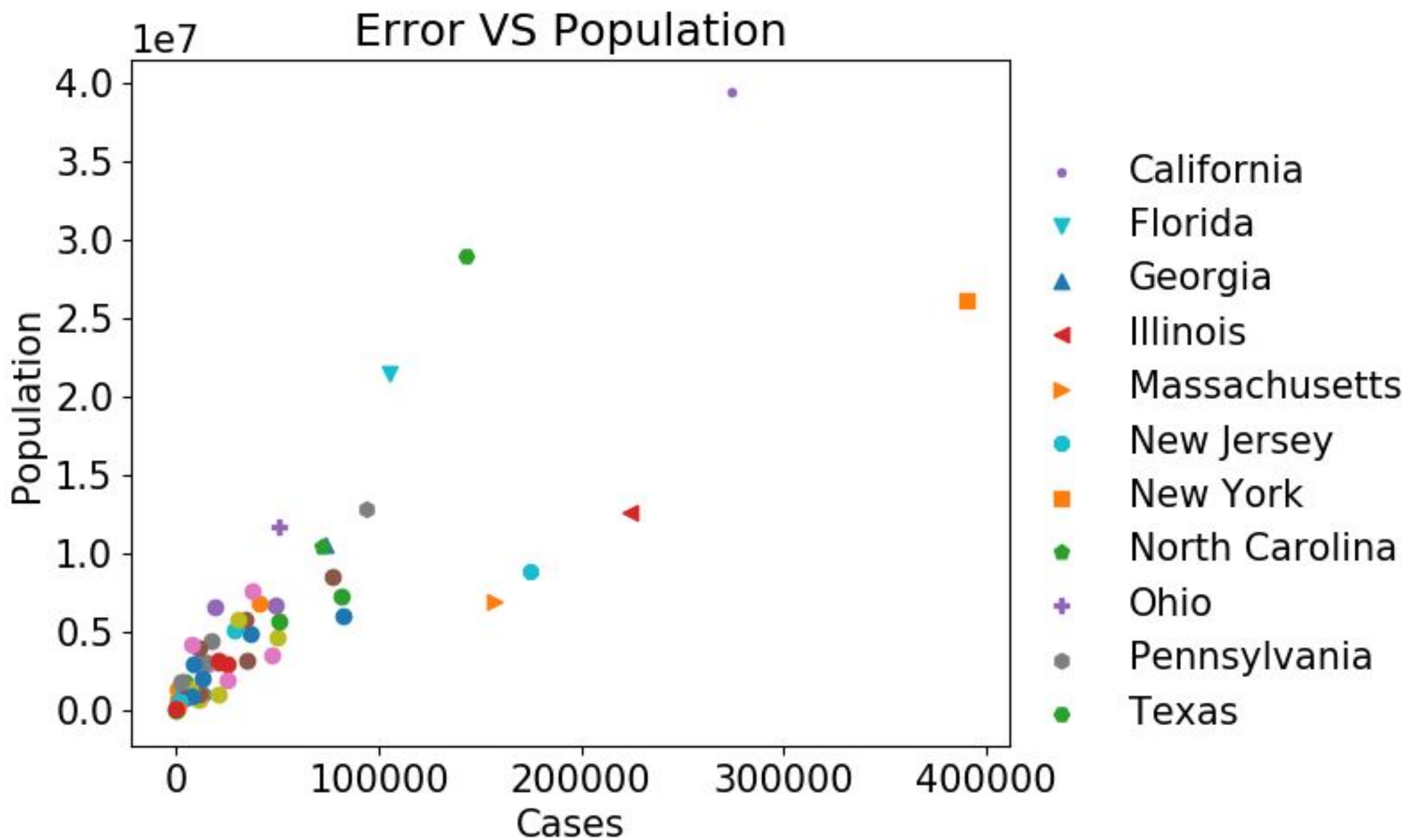
$$f(t) = \frac{1}{1+e^{-at}}$$



Fitting pipeline



Cases distribution



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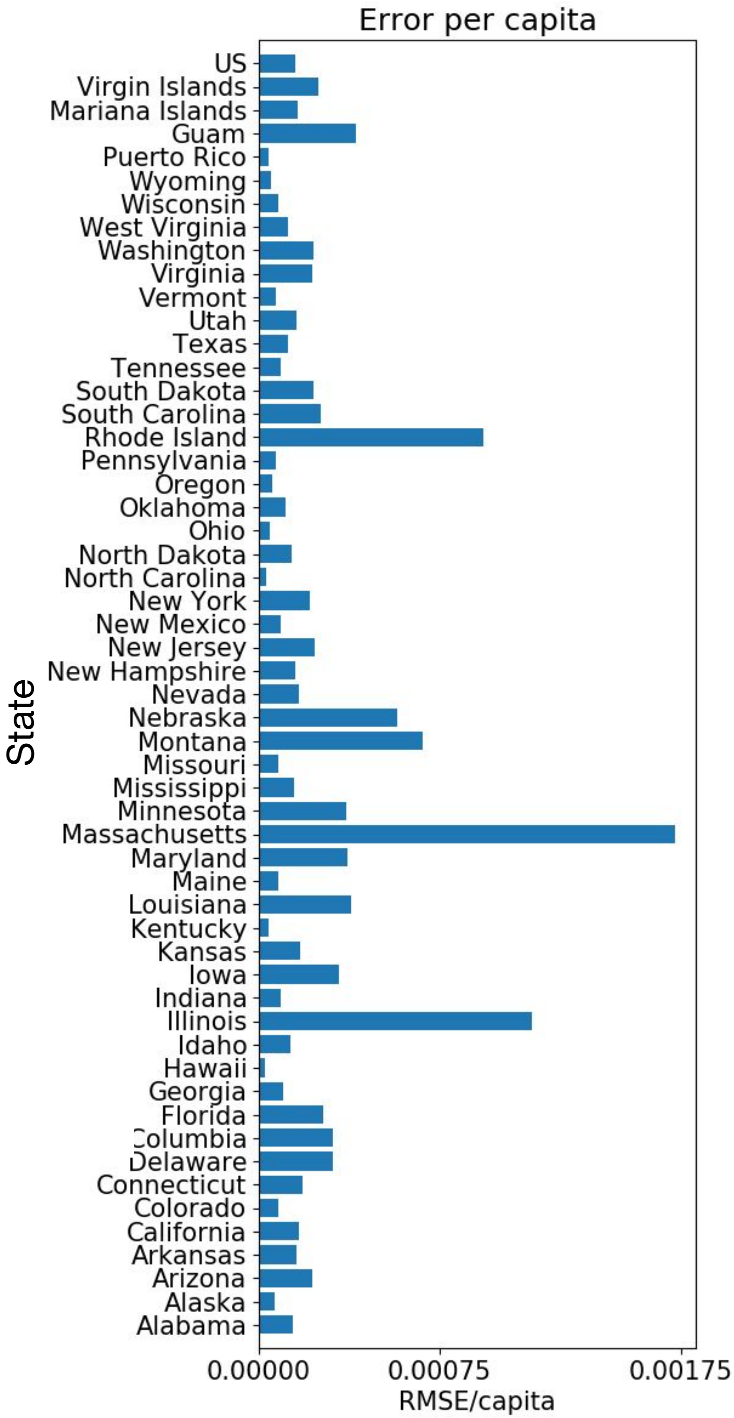
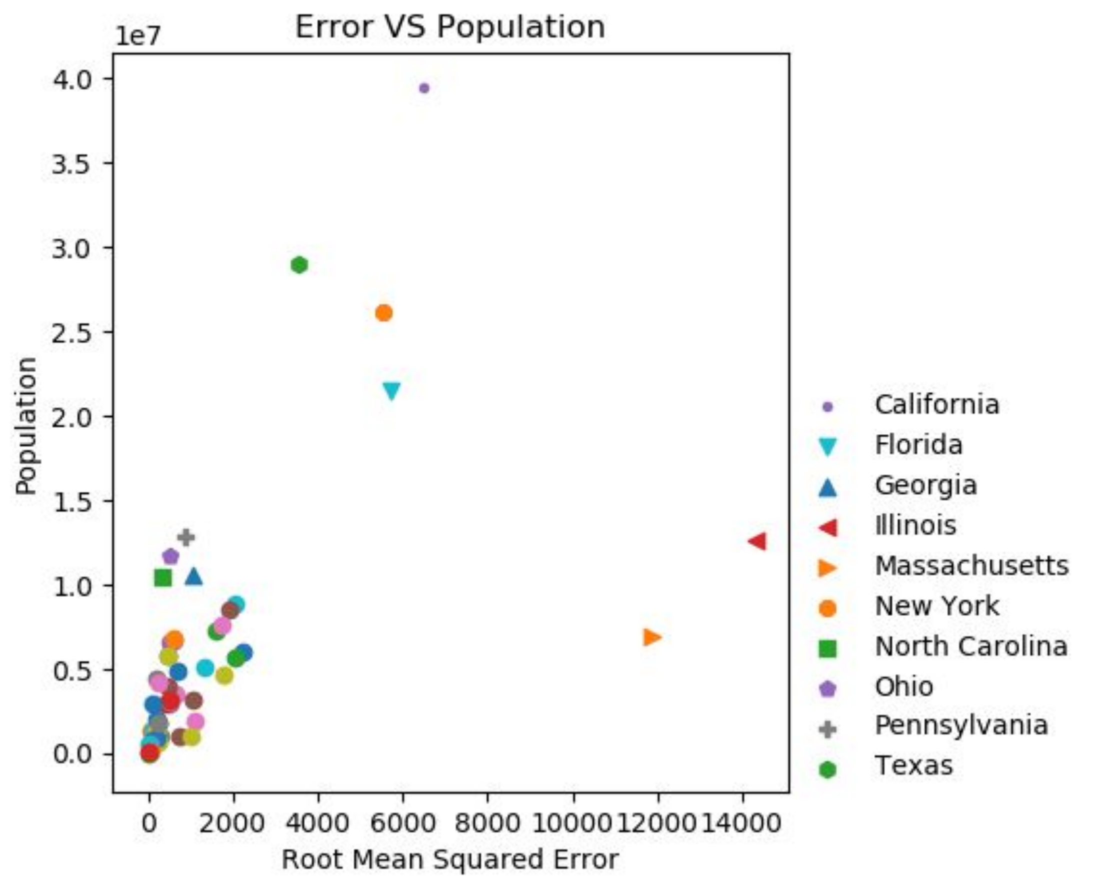
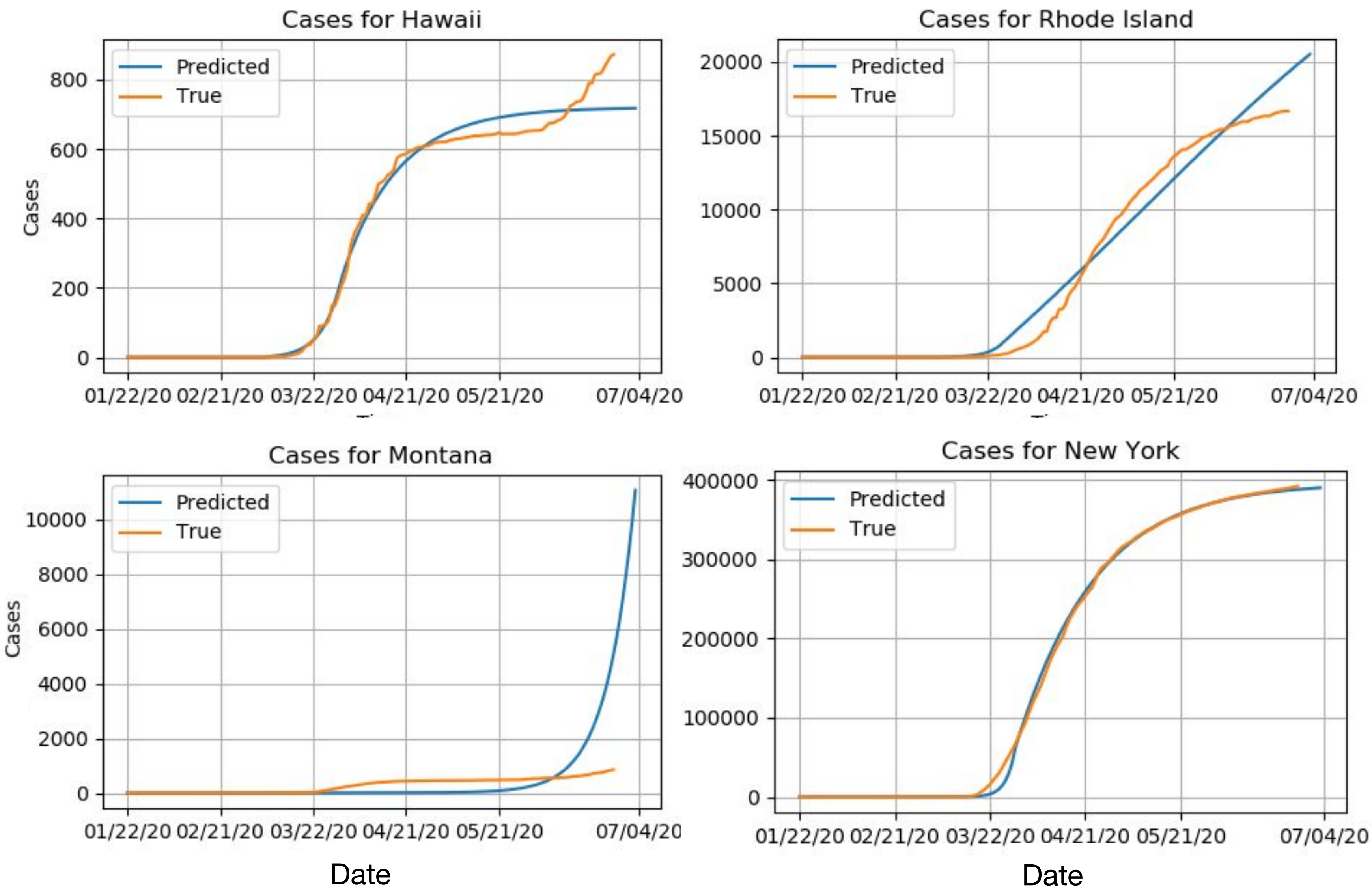
Results by state

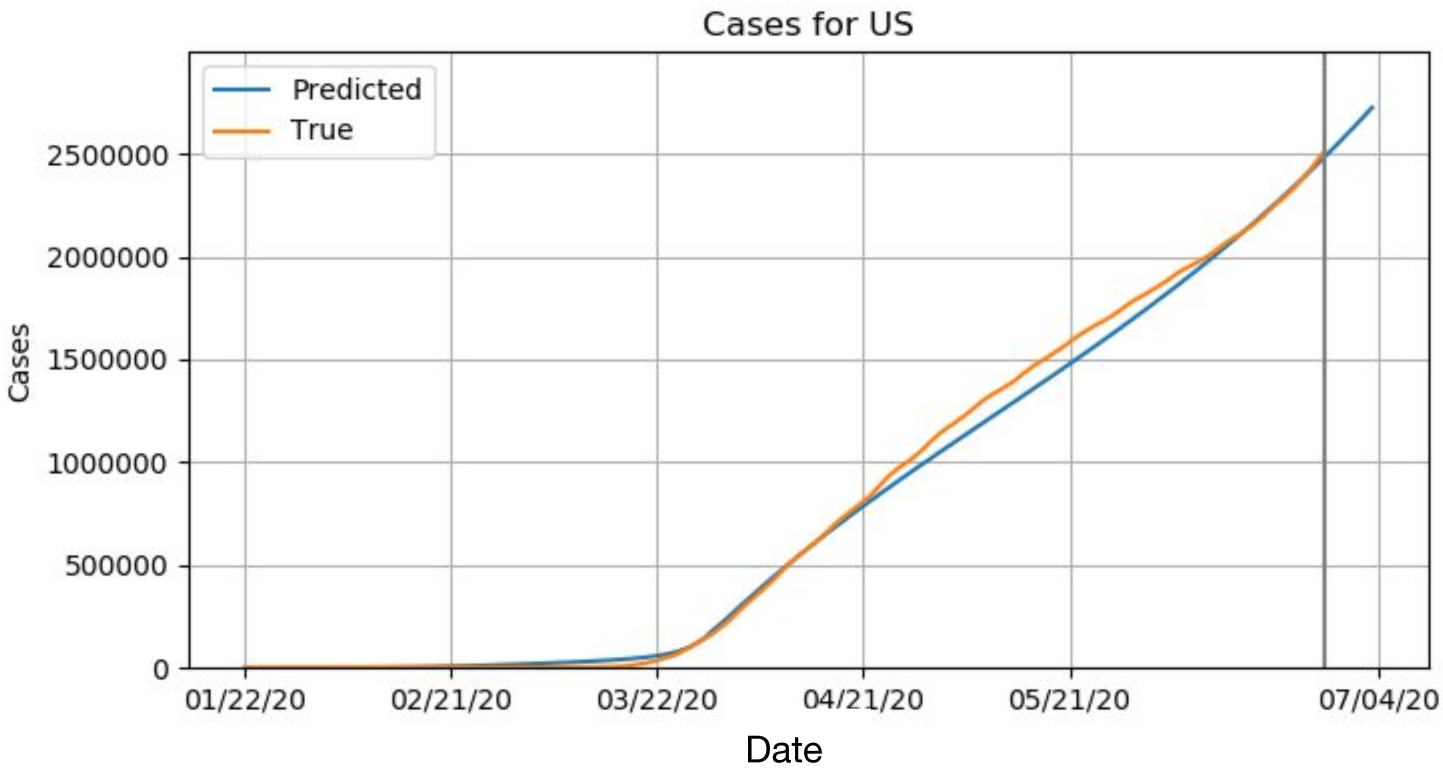




Results by state



National results



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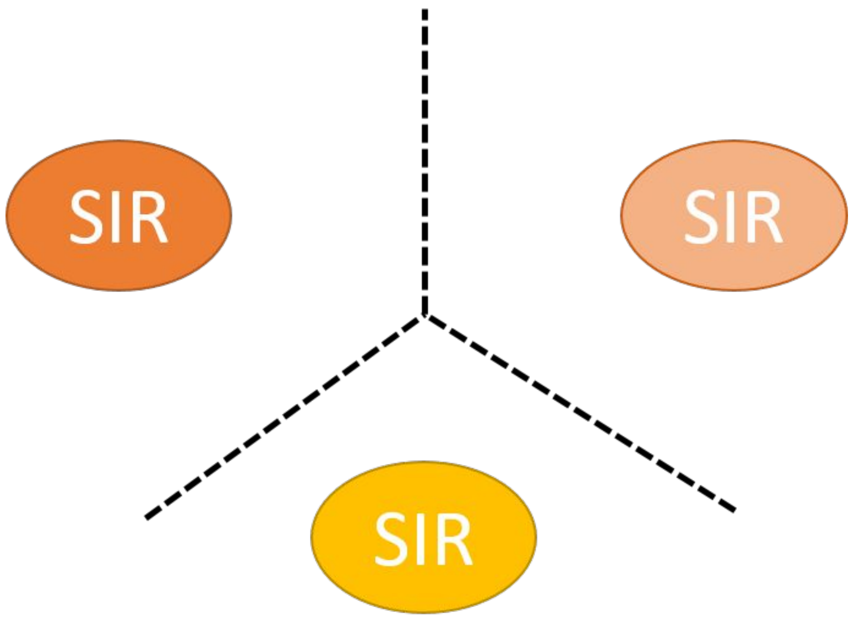
Further work: Mobility dependencies

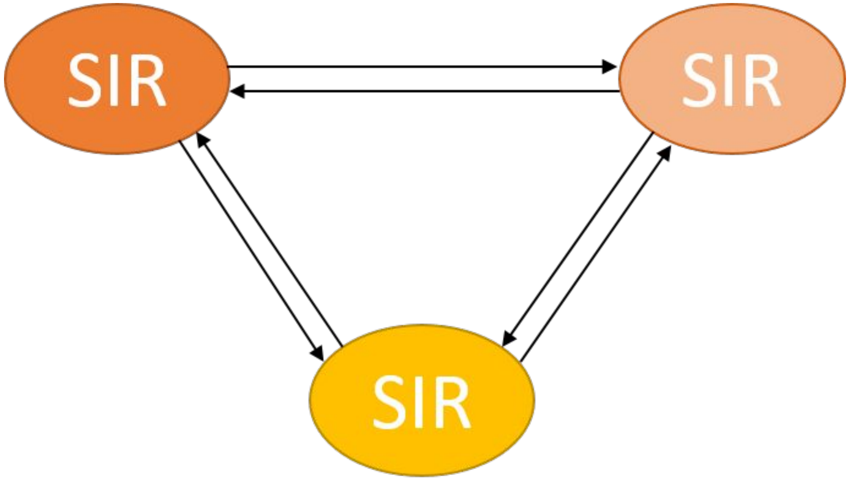


How to include mobility data ?

$$\beta_{m_i} = \frac{1}{\alpha} \sum_{j \neq i} m_{ji} \frac{I_j}{Pop_j}$$

where m_{ji} is the number of passenger from j to i.

Further work: Mobility dependencies



We then need to combine the betas:

$$\beta_i = \theta \beta_{0_i} + (1 - \theta)\, \beta_{m_i}$$

2 general parameters to optimize:

$\boldsymbol{\alpha}$ **and** $\boldsymbol{\theta}$

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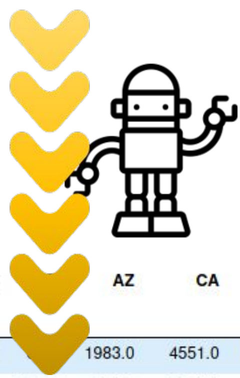
Further work: Getting mobility data



DEST_STATE_ABR	AK	AL	[illegible]	AZ	CA	CO	CT	FL	GA	HI	...
Abb											
AK	23662.0	106.0	[illegible]	1983.0	4551.0	1090.0	20.0	1517.0	458.0	3124.0	...
AL	122.0	42.0	284.0	1400.0	4865.0	2550.0	340.0	8107.0	925.0	337.0	...
AR	75.0	274.0	0.0	1057.0	4043.0	1393.0	145.0	5185.0	2152.0	255.0	...
AZ	2026.0	1374.0	1030.0	436.0	78713.0	26445.0	1585.0	20189.0	7583.0	5395.0	...
CA	4852.0	4848.0	4102.0	77403.0	406497.0	73748.0	4782.0	88940.0	36153.0	66707.0	...
CO	1161.0	2676.0	1463.0	26581.0	74921.0	2373.0	1618.0	49143.0	14010.0	5778.0	...
CT	19.0	352.0	168.0	1606.0	4735.0	1549.0	0.0	28343.0	2936.0	243.0	...
FL	1627.0	8283.0	5157.0	20160.0	90002.0	47857.0	28126.0	35519.0	63993.0	3396.0	...
GA	499.0	969.0	2125.0	7616.0	36208.0	13997.0	3053.0	64664.0	1737.0	1793.0	...
HI	3280.0	360.0	268.0	5350.0	67129.0	5693.0	254.0	3474.0	1766.0	106325.0	...

- We have coded a bot that gather the needed data and combine it to mobility matrix.
- A script linking the matrix rows to the corresponding state in the code has been done.
- The global optimization has not been implemented.

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Conclusion

- A model of independent SIRs has been implemented with automatic data cleaning.
- A dual beta model has been done to take time dependency into account.
- An alternative model to take mobility data into account has been proposed including data acquisition.

What we have learned:

- An understanding of pandemic modeling including its difficulties.
- Good practice for further projects on modeling and prediction.