Christoph Zimmer

Influenza Prediction Challenge – Yale Team

Influenza forecasting meeting, August 2018

Overview

Data

- ILI Nearby (Delphi, CMU)

Computational model

- humidity based S I R S (Yang, Karspeck, Shaman PlosCompBio 2014)
- humidity data averaged over regions

Objective Function

- Linear noise approximation
- State updating mechanism

Optimization

- Filtering
- Re-sampling based on kernel density estimates

Prediction

Sampling from posterior + run simulation model (Gillespie in COPASI)

Deriving an objective function

system's state (e.g. S I R)

observation (e.g. weekly cases)

$$\begin{tikzcd}
v_0 & \dots \arrow[r, "p"] & v_{i-1} \arrow[r, "p"] \arrow[d, "P"'] & v_i \arrow[r, "p"] \arrow[d, "P"'] & \dots & v_n \\
y_0 & \dots & y_{i-1} & y_i & \dots & y_n
\end{tikzcd}$$

1. Observation probability P known - Gaussian, Poisson, ...
2. No analytical solution for transition probability p in most models

   $\Rightarrow$ Approximate $\nu_i|\hat{\nu}_{i-1} \sim \mathcal{N}(\mu_i, \Sigma_i)$
   with μ_i - ODE solution on $[t_{i-1}, t_i]$
   Σ_i - LNA solution on $[t_{i-1}, t_i]$

   Zimmer 15, IET Systems Bio

3. State estimation

$$\hat{\nu}_i = \arg\max_{\nu_i} P(y_i|\nu_i)p(\nu_i|\hat{\nu}_{i-1})$$

Zimmer 15, Math Biosciences
Zimmer 17, PlosCompBio

Acknowledgements

Yale School of Public Health

- Prof. Ted Cohen, DPH, MD, MPH
- Prof. Reza Yaesoubi, PhD
- Sequoia Leuba, MPH
- Amber Kunkel, PhD

BRIGHAM AND WOMEN'S HOSPITAL

Yale
U54 GM088558
R01 AI112438

MIDAS
Funded by the National Institutes of Health

IWR, Heidelberg

- Prof. Dr. Dr. h. c. Hans Georg Bock
- Dr. Johannes Schlöder

BioQuant, Heidelberg

- Dr. Sven Sahle
- Prof. Dr. Ursula Kummer
- Dr. Ralph Gauges (now Sigmaringen)
- Dr. Frank Bergmann
- Dr. Katrin Hübner

BIOMS

BioQuant
MODEL base of LIFE

HGS MathComp

BOSCH

DFG

Gillespie algorithm

Assuming that the epidemic is at state $v(t)$ at time t :

1. Calculate the sum of rates: $\rho(\nu(t), \theta) = \sum_{r=1}^{R} \rho_r(\nu(t), \theta)$.

Gillespie algorithm

Assuming that the epidemic is at state $v(t)$ at time t :

1. Calculate the sum of rates: $\rho(\nu(t), \theta) = \sum_{r=1}^{R} \rho_r(\nu(t), \theta)$.
2. Sample the time to the next event: $\tau \leftarrow -\frac{1}{\rho(\nu(t),\theta)} \ln u_1$, with $u_1 \sim \mathcal{U}((0, 1])$.

Gillespie algorithm

Assuming that the epidemic is at state $v(t)$ at time t :

1. Calculate the sum of rates: $\rho(\nu(t),\theta) = \sum_{r=1}^{R} \rho_r(\nu(t),\theta)$.
2. Sample the time to the next event: $\tau \leftarrow -\frac{1}{\rho(\nu(t),\theta)} \ln u_1$, with $u_1 \sim \mathcal{U}((0,1])$.
3. Determine the event that just realized: Select the event $\tilde{r}$ such that

$$\sum_{r=1}^{\tilde{r}-1} \frac{\rho_r(\nu(t),\theta)}{\rho(\nu(t),\theta)} < u_2 \leq \sum_{r=1}^{\tilde{r}} \frac{\rho_r(\nu(t),\theta)}{\rho(\nu(t),\theta)}$$

with $u_2 \sim \mathcal{U}((0,1])$.

Gillespie algorithm

Assuming that the epidemic is at state $v(t)$ at time t :

1. Calculate the sum of rates: $\rho(\nu(t), \theta) = \sum_{r=1}^{R} \rho_r(\nu(t), \theta)$.
2. Sample the time to the next event: $\tau \leftarrow -\frac{1}{\rho(\nu(t),\theta)} \ln u_1$, with $u_1 \sim \mathcal{U}((0, 1])$.
3. Determine the event that just realized: Select the event $\tilde{r}$ such that

$$\sum_{r=1}^{\tilde{r}-1} \frac{\rho_r(\nu(t), \theta)}{\rho(\nu(t), \theta)} < u_2 \leq \sum_{r=1}^{\tilde{r}} \frac{\rho_r(\nu(t), \theta)}{\rho(\nu(t), \theta)}$$

   with $u_2 \sim \mathcal{U}((0, 1])$.
4. Update epidemic state given the realized event $\tilde{r}$.

Gillespie algorithm

Assuming that the epidemic is at state $v(t)$ at time t :

1. Calculate the sum of rates: $\rho(\nu(t), \theta) = \sum_{r=1}^{R} \rho_r(\nu(t), \theta)$.
2. Sample the time to the next event: $\tau \leftarrow -\frac{1}{\rho(\nu(t),\theta)} \ln u_1$, with $u_1 \sim \mathcal{U}((0, 1])$.
3. Determine the event that just realized: Select the event $\tilde{r}$ such that

$$\sum_{r=1}^{\tilde{r}-1} \frac{\rho_r(\nu(t), \theta)}{\rho(\nu(t), \theta)} < u_2 \leq \sum_{r=1}^{\tilde{r}} \frac{\rho_r(\nu(t), \theta)}{\rho(\nu(t), \theta)}$$

   with $u_2 \sim \mathcal{U}((0, 1])$.
4. Update epidemic state given the realized event $\tilde{r}$.
5. Until a desired condition is satisfied, increment time $t \leftarrow t + \tau$ and move to Step 1.

go back