Vaxx Project: Source Code for Experiment 3 (using Beta distribution based on CA county-level flu claims data)

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This code is intended for private research and not for public use. As such, the code is specifically designed for the narrow set of research questions and not for mass consumption. The author will provide no support, no help debugging, and no evaluation of model output.

Directory

```
NotebookDirectory[]
```

```
C:\MyResearchTemp\Vaccination\Codex\
```

```
SetDirectory[NotebookDirectory[]];
```

Functions

Initialize the Population Grid

```
population[X_,Y_]:=

(

Z=X*Y;

toIndex[n_,m_]:=n-1+(m-1)*X; (* function for transforming (n, m) into a single index number *)

toCoord[x_]:={Mod[x,X]+1,Quotient[x,X]+1}; (* function for transforming an index number into (n, m) coordinates *)

);
```

Create and Populate the Hubs

```
hubmember[xH_, yH_] :=
  {
   Do[
    hub[a, b] = Flatten[Table[toIndex[i, j], {j, (b - 1) * yH + 1, b * yH}, {i, (a - 1) * xH + 1, a * xH}]],
    {a, 1, Floor[X, xH]},
    {b, 1, Floor[Y, yH]}];
   Do[
    Do[
     agentHub[k] = {i, j},
     {k, hub[i, j]}],
    {i, 1, Floor[X / xH]},
    {j, 1, Floor[Y / yH]}];
  };
```

```
contact[netSize_, pC_] :=
  (
   (* construct hub source *)
   Do[cntP[i] = DeleteCases[hub[agentHub[i][[1]], agentHub[i][[2]]], i], {i, 0, X * Y - 1}];
   (* exclude oneself from one's own hub *)
   (* construct actual network *)
   Do[cntA[i] = {}, {i, 0, X * Y - 1}];
   avail = Table[i, {i, 0, X * Y - 1}];
   totLen = 0; avgLen = 0;
   invZ = Table[i, {i, 0, X * Y - 1}];
   While[avgLen < netSize,
    trial1 = RandomChoice[avail];
    indp = RandomReal[];
    trial2 = Which[0 ≤ indp ≤ pC, RandomChoice[cntP[trial1]], pC < indp ≤ 1,
      RandomChoice[Complement[invZ, hub[agentHub[trial1][[1]], agentHub[trial1][[2]]]]]];
If[FreeQ[cntA[trial1], trial2],
cntA[trial1] = Join[cntA[trial1], {trial2}];
cntA[trial2] = Join[cntA[trial2], {trial1}];
totLen = totLen + 2;
avgLen = totLen / (X * Y);
     ];
    ];
   );
```

Parameters

```
X = 100; Y = 100; (* z (= X*Y): population *)
xH = 10; yH = 10; (* H = xH*yH: hubs *)
netSize = 20; (* c̄: average size of the contact networks *)
nseed = 10; (* number of seed agents who are initially infected *)
pC = 0.95; (* p^C: local specificity of contact networks *)
S = 100; (* s̃: number of seasons *)
nB = 1; (*κ: multiple for beta distribution parameters*)
```

Population and the Hub Membership

```
population[X, Y];

hubmember[xH, yH];
```

Epidemics

```
dx = 0; (* data file index *)
```

Vaccination rates for CA counties

```
V = {46.63, 20.86, 49.86, 40.34, 40.50, 40.99, 48.12, 38.14, 49.45, 46.50, 35.93, 40.52, 33.53, 43.51, 37.75,
     36.97, 28.54, 30.47, 41.86, 39.79, 51.93, 31.02, 27.97, 42.72, 16.86, 31.82, 45.13, 45.52, 49.46, 49.71,
     52.95, 21.60, 40.94, 47.16, 50.17, 32.36, 43.49, 44.32, 45.23, 49.79, 52.17, 49.25, 53.08, 51.29,
     43.04, 20.11, 30.96, 37.76, 48.11, 44.36, 51.33, 42.22, 30.24, 43.65, 46.75, 48.11, 52.58, 41.66} / 100;
```

Beta distribution shape parameters based on CA data

$$\alpha = \left(\left(\left(\text{Mean}[V]\right)^2 * \left(1 - \text{Mean}[V]\right)\right) / \text{Variance}[V]\right) - \text{Mean}[V];$$
$$\beta = \left(\left(\text{Mean}[V] * \left(1 - \text{Mean}[V]\right)^2\right) / \text{Variance}[V]\right) - \left(1 - \text{Mean}[V]\right);$$

Infection characteristics

```
beta = 0.02; (* β: infection probability *)
tauE = 2; (* length of the latent period *)
tauI = 7; (* length of the infectious period *)
```

Contagion dynamics

state[s, t, i]: infection state of agent i in period t of season s

        = 0 if vaccinated and immune   (V, R);

        = 1 if unvaccinated and susceptible   (NV, S);

        = 2 if unvaccinated and exposed   (NV, E);

        = 3 if unvaccinated and infectious   (NV, I);

        = 4 if unvaccinated and recovered   (NV, R);

```
stInt = {}; stFin = {}; contactN = {};

Do[
   SeedRandom[s];
   (*contact network*)
   contact[netSize, pC];
   comNet = Table[Map[UndirectedEdge[i, #] &, cntA[i]], {i, 0, X * Y - 1}];
   dirNet = Table[Map[i → # &, cntA[i]], {i, 0, X * Y - 1}];
   pl[s] = MeanGraphDistance[Flatten[dirNet]] // N;
   (*vaccination rates*)
   rV = RandomVariate[BetaDistribution[nB * α, nB * β], 100];
   (*accination rates for the hubs *)
   Do[nV[k] = rV[[10 * (agentHub[k][[2]] - 1) + agentHub[k][[1]]]], {k, 0, X * Y - 1}];
   (*individual's vaccination rate*)
   (*epidemic*)
   SeedRandom[s];
   t = 1;
   Do[y[k] = RandomChoice[{nV[k], 1 - nV[k]} → {0, 1}], {k, 0, X * Y - 1}];
   (*individual's vaccination status*)
```

```
init = Flatten[Table[{y[k]}, {k, 0, X * Y - 1}]];
seed = RandomSample[Position[init, 1], nseed];
state[s, t] = ReplacePart[init, seed → 2];
tinf = ReplacePart[Table[0, {i, 1, X * Y}], seed → 1];
stemp = state[s, t];
numV[s, t] = Count[stemp, 0]; (* number of vaccinated agents in t *)
numS[s, t] = Count[stemp, 1]; (* number of susceptible agents in t *)
numE[s, t] = Count[stemp, 2]; (* number of exposed agents in t *)
numI[s, t] = Count[stemp, 3]; (* number of infectious agents in t *)
numR[s, t] = Count[stemp, 4]; (* number of recovered agents in t *)
t = t + 1;
While[numE[s, t - 1] > 0 || numI[s, t - 1] > 0,
 q[s, t] = Table[1 - (1 - beta) ^ Count[state[s, t - 1][[cntA[i] + 1]], 3], {i, 0, X * Y - 1}];
 randQ = Table[RandomReal[], {i, 1, X * Y}];
 infected = Intersection[Position[state[s, t - 1], 1], Position[randQ - q[s, t], n_ /; n ≤ 0]];
 stemp = ReplacePart[stemp, infected → 2];
 tinf = ReplacePart[tinf, infected → t];
 infectious =
  Intersection[Position[state[s, t - 1], 2], Position[tinf, n_ /; n > 0], Position[t - tinf, n_ /; n ≥ tauE]];
 stemp = ReplacePart[stemp, infectious → 3];
 recovered = Intersection[Position[state[s, t - 1], 3],
   Position[tinf, n_ /; n > 0], Position[t - tinf, n_ /; n ≥ tauE + tauI]];
 stemp = ReplacePart[stemp, recovered → 4];
 numV[s, t] = Count[stemp, 0];
 numS[s, t] = Count[stemp, 1];
 numE[s, t] = Count[stemp, 2];
 numI[s, t] = Count[stemp, 3];
 numR[s, t] = Count[stemp, 4];
 state[s, t] = stemp;
 t++];
final[s] = t - 1;
(* save state and network data *)
stInt = Append[stInt, state[s, 1]]; (* initial state of the population in t=1 *)
```

```
    stFin = Append[stFin, state[s, final[s]]]; (* final state of the population at the end of epidemic *)
    contactN = Append[contactN, Table[cntA[i], {i, 0, X * Y - 1}]]; (* contact networks for population *)
    , {s, 1, S}];
```

Export the simulation output

```
vx = Table[Table[numV[k, i], {i, 1, final[k]}], {k, 1, S}];
sx = Table[Table[numS[k, i], {i, 1, final[k]}], {k, 1, S}];
ex = Table[Table[numE[k, i], {i, 1, final[k]}], {k, 1, S}];
ix = Table[Table[numI[k, i], {i, 1, final[k]}], {k, 1, S}];
rx = Table[Table[numR[k, i], {i, 1, final[k]}], {k, 1, S}];

Export["dataCAB" <> ToString[dx] <> "/final.dat", Table[final[i], {i, 1, S}], "WDX"];
Export["dataCAB" <> ToString[dx] <> "/pl.dat", Table[pl[i], {i, 1, S}], "WDX"];
Export["dataCAB" <> ToString[dx] <> "/vx.dat", vx, "WDX"];
Export["dataCAB" <> ToString[dx] <> "/sx.dat", sx, "WDX"];
Export["dataCAB" <> ToString[dx] <> "/ex.dat", ex, "WDX"];
Export["dataCAB" <> ToString[dx] <> "/ix.dat", ix, "WDX"];
Export["dataCAB" <> ToString[dx] <> "/rx.dat", rx, "WDX"];
Export["dataCAB" <> ToString[dx] <> "/stInt.dat", stInt, "WDX"];
Export["dataCAB" <> ToString[dx] <> "/stFin.dat", stFin, "WDX"];
Export["dataCAB" <> ToString[dx] <> "/contactN.dat", contactN, "WDX"];
```