Discrete event simulation using SimJulia

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Libraries

```
using ResumableFunctions
using SimJulia
using Distributions
using DataFrames
using Random
using StatsPlots
using BenchmarkTools
```

Utility functions

```
function increment!(a::Array{Int64})
    push!(a,a[length(a)]+1)
end

function decrement!(a::Array{Int64})
    push!(a,a[length(a)]-1)
end

function carryover!(a::Array{Int64})
    push!(a,a[length(a)])
end;
```

Transitions

```
mutable struct SIRPerson
    id::Int64 # numeric ID
    status::Symbol # :S,I,R
end;
```

```
mutable struct SIRModel
    sim::Simulation
    β::Float64
    c::Float64
    γ::Float64
    ta::Array{Float64}
    Sa::Array{Int64}
    Ia::Array{Int64}
    Ra::Array{Int64}
    allIndividuals::Array{SIRPerson}
end
```

These functions update the state of the 'world' when either an infection or recovery occurs.

```
function infection_update!(sim::Simulation,m::SIRModel)
    push!(m.ta,now(sim))
    decrement!(m.Sa)
    increment!(m.Ia)
    carryover!(m.Ra)
end;
```

```
function recovery_update!(sim::Simulation,m::SIRModel)
    push!(m.ta,now(sim))
    carryover!(m.Sa)
    decrement!(m.Ia)
    increment!(m.Ra)
end;
```

The following is the main simulation function. It's not efficient, as it involves activating a process for all susceptibles; a more efficient algorithm would involve just considering infected individuals, and activating each susceptible individual when infection occurs. This however requires more bookkeeping and detracts from the ability to easily compare between implementations.

```
@resumable function live(sim::Simulation, individual::SIRPerson, m::SIRModel)
  while individual.status==:S
      # Wait until next contact
      @yield timeout(sim,rand(Distributions.Exponential(1/m.c)))
      # Choose random alter
      alter=individual
      while alter==individual
          N=length(m.allIndividuals)
          index=rand(Distributions.DiscreteUniform(1,N))
          alter=m.allIndividuals[index]
      end
      # If alter is infected
      if alter.status==:I
          infect = rand(Distributions.Uniform(0,1))
          if infect < m.β
              individual.status=:I
              infection_update!(sim,m)
          end
      end
  end
  if individual.status==:I
      # Wait until recovery
      @yield timeout(sim,rand(Distributions.Exponential(1/m.γ)))
      individual.status=:R
      recovery_update!(sim,m)
  end
end;

function MakeSIRModel(u0,p)
    (S,I,R) = u0
    N = S+I+R
    (β,c,γ) = p
    sim = Simulation()
    allIndividuals=Array{SIRPerson,1}(undef,N)
    for i in 1:S
        p=SIRPerson(i,:S)
        allIndividuals[i]=p
    end
    for i in (S+1):(S+I)
        p=SIRPerson(i,:I)
        allIndividuals[i]=p
    end
    for i  in (S+I+1):N
        p=SIRPerson(i,:R)
        allIndividuals[i]=p
    end
    ta=Array{Float64,1}(undef,0)
    push!(ta,0.0)
    Sa=Array{Int64,1}(undef,0)
    push!(Sa,S)
    Ia=Array{Int64,1}(undef,0)
    push!(Ia,I)
    Ra=Array{Int64,1}(undef,0)
    push!(Ra,R)
    SIRModel(sim,β,c,γ,ta,Sa,Ia,Ra,allIndividuals)
end;

function activate(m::SIRModel)
     [@process live(m.sim,individual,m) for individual in m.allIndividuals]
end;

function sir_run(m::SIRModel,tf::Float64)
    SimJulia.run(m.sim,tf)
end;

function out(m::SIRModel)
    result = DataFrame()
    result[!,:t] = m.ta
    result[!,:S] = m.Sa
    result[!,:I] = m.Ia
    result[!,:R] = m.Ra
    result
end;
```

Time domain

```
tmax = 40.0;
```

Initial conditions

```
u0 = [990,10,0];
```

Parameter values

```
p = [0.05,10.0,0.25];
```

Random number seed

```
Random.seed!(1234);
```

Running the model

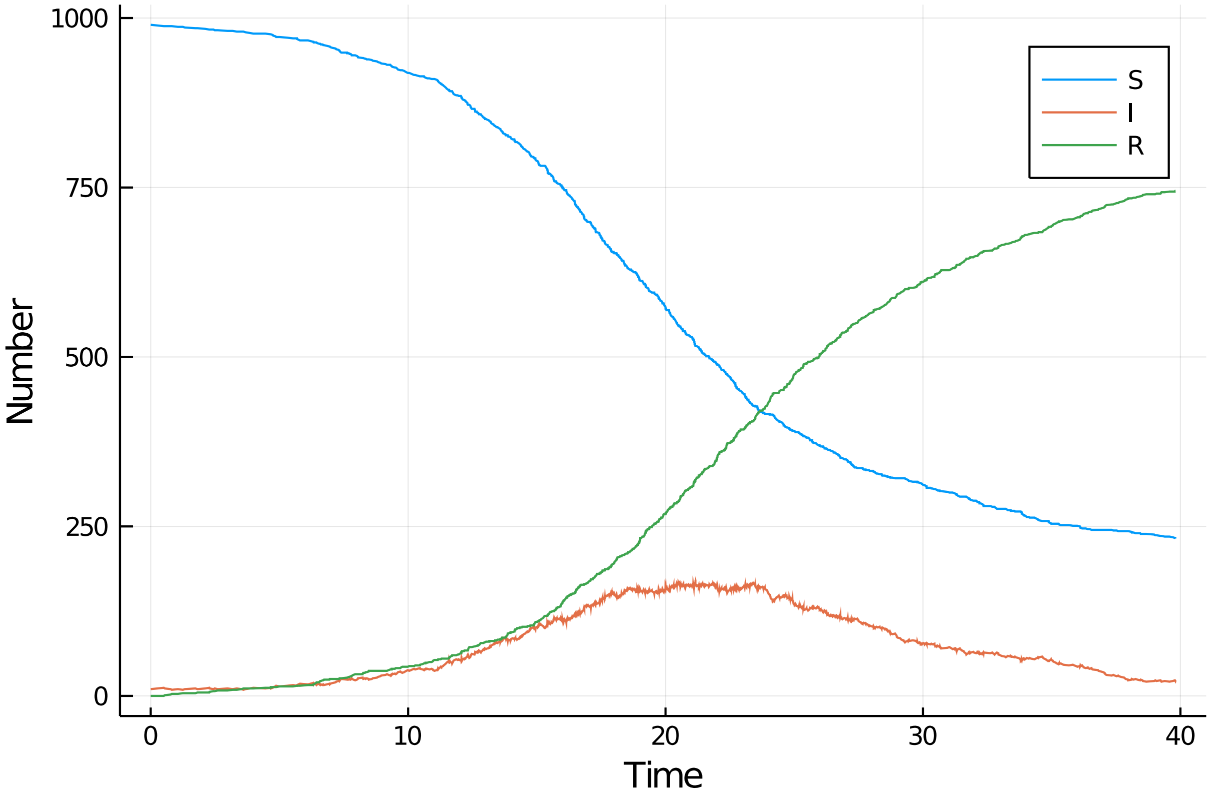
```
des_model = MakeSIRModel(u0,p)
activate(des_model)
sir_run(des_model,tmax)
```

Postprocessing

```
data_des=out(des_model);
```

Plotting

```
@df data_des plot(:t,
    [:S :I :R],
    labels = ["S" "I" "R"],
    xlab="Time",
    ylab="Number")
```



Benchmarking

```
@benchmark begin
    des_model = MakeSIRModel(u0,p)
    activate(des_model)
    sir_run(des_model,tmax)
end
```

```
BenchmarkTools.Trial:
  memory estimate:  71.19 MiB
  allocs estimate:  2142769
  --------------
  minimum time:     1.082 s (1.64% GC)
  median time:      1.134 s (1.29% GC)
  mean time:        1.190 s (1.04% GC)
  maximum time:     1.398 s (1.05% GC)
  --------------
  samples:          5
  evals/sample:     1
```

Appendix

Computer Information

```
Julia Version 1.4.0
Commit b8e9a9ecc6 (2020-03-21 16:36 UTC)
Platform Info:
  OS: Windows (x86_64-w64-mingw32)
  CPU: Intel(R) Core(TM) i7-8550U CPU @ 1.80GHz
  WORD_SIZE: 64
  LIBM: libopenlibm
  LLVM: libLLVM-8.0.1 (ORCJIT, skylake)
Environment:
  JULIA_NUM_THREADS = 4
```

Package Information

```
Status `~\.julia\environments\v1.4\Project.toml`
[80f14c24-f653-4e6a-9b94-39d6b0f70001] AbstractMCMC 1.0.1
[46ada45e-f475-11e8-01d0-f70cc89e6671] Agents 3.1.0
[b19378d9-d87a-599a-927f-45f220a2c452] ArrayFire 1.0.6
[c52e3926-4ff0-5f6e-af25-54175e0327b1] Atom 0.12.10
[6e4b80f9-dd63-53aa-95a3-0cdb28fa8baf] BenchmarkTools 0.5.0
[a134a8b2-14d6-55f6-9291-3336d3ab0209] BlackBoxOptim 0.5.0
[336ed68f-0bac-5ca0-87d4-7b16caf5d00b] CSV 0.6.2
[be33ccc6-a3ff-5ff2-a52e-74243cff1e17] CUDAnative 3.1.0
[3a865a2d-5b23-5a0f-bc46-62713ec82fae] CuArrays 2.2.0
[717857b8-e6f2-59f4-9121-6e50c889abd2] DSP 0.6.6
[2445eb08-9709-466a-b3fc-47e12bd697a2] DataDrivenDiffEq 0.3.1
[a93c6f00-e57d-5684-b7b6-d8193f3e46c0] DataFrames 0.21.0
[1313f7d8-7da2-5740-9ea0-a2ca25f37964] DataFramesMeta 0.5.1
[ebbdde9d-f333-5424-9be2-dbf1e9acfb5e] DiffEqBayes 2.1.1
[eb300fae-53e8-50a0-950c-e21f52c2b7e0] DiffEqBiological 4.3.0
[459566f4-90b8-5000-8ac3-15dfb0a30def] DiffEqCallbacks 2.13.1
[aae7a2af-3d4f-5e19-a356-7da93b79d9d0] DiffEqFlux 1.10.2
[c894b116-72e5-5b58-be3c-e6d8d4ac2b12] DiffEqJump 6.7.5
[1130ab10-4a5a-5621-a13d-e4788d82bd4c] DiffEqParamEstim 1.14.1
[41bf760c-e81c-5289-8e54-58b1f1f8abe2] DiffEqSensitivity 6.14.1
[6d1b261a-3be8-11e9-3f2f-0b112a9a8436] DiffEqTutorials 0.1.0
[0c46a032-eb83-5123-abaf-570d42b7fbaa] DifferentialEquations 6.14.0
[31c24e10-a181-5473-b8eb-7969acd0382f] Distributions 0.23.2
[634d3b9d-ee7a-5ddf-bec9-22491ea816e1] DrWatson 1.11.0
[587475ba-b771-5e3f-ad9e-33799f191a9c] Flux 0.10.4
```

```
[0c68f7d7-f131-5f86-a1c3-88cf8149b2d7] GPUArrays 3.3.0
[28b8d3ca-fb5f-59d9-8090-bfdbd6d07a71] GR 0.49.1
[523d8e89-b243-5607-941c-87d699ea6713] Gillespie 0.1.0
[7073ff75-c697-5162-941a-fcdaad2a7d2a] IJulia 1.21.2
[e5e0dc1b-0480-54bc-9374-aad01c23163d] Juno 0.8.1
[23fbe1c1-3f47-55db-b15f-69d7ec21a316] Latexify 0.13.2
[961ee093-0014-501f-94e3-6117800e7a78] ModelingToolkit 3.4.0
[d41bc354-129a-5804-8e4c-c37616107c6c] NLSolversBase 7.6.1
[76087f3c-5699-56af-9a33-bf431cd00edd] NLopt 0.6.0
[d9ec5142-1e00-5aa0-9d6a-321866360f50] NamedTupleTools 0.13.2
[73a701b4-84e1-5df0-88ff-1968ee2ee8dc] NamedTuples 5.0.0
[429524aa-4258-5aef-a3af-852621145aeb] Optim 0.20.1
[1dea7af3-3e70-54e6-95c3-0bf5283fa5ed] OrdinaryDiffEq 5.38.1
[91a5bcdd-55d7-5caf-9e0b-520d859cae80] Plots 1.2.6
[e6cf234a-135c-5ec9-84dd-332b85af5143] RandomNumbers 1.4.0
[c5292f4c-5179-55e1-98c5-05642aab7184] ResumableFunctions 0.5.1
[428bdadb-6287-5aa5-874b-9969638295fd] SimJulia 0.8.0
[05bca326-078c-5bf0-a5bf-ce7c7982d7fd] SimpleDiffEq 1.1.0
[8ce77f84-9b61-11e8-39ff-d17a774bf41c] Soss 0.12.0
[2913bbd2-ae8a-5f71-8c99-4fb6c76f3a91] StatsBase 0.32.2
[4c63d2b9-4356-54db-8cca-17b64c39e42c] StatsFuns 0.9.4
[f3b207a7-027a-5e70-b257-86293d7955fd] StatsPlots 0.14.6
[789caeaf-c7a9-5a7d-9973-96adeb23e2a0] StochasticDiffEq 6.22.0
[a759f4b9-e2f1-59dc-863e-4aeb61b1ea8f] TimerOutputs 0.5.5
[fce5fe82-541a-59a6-adf8-730c64b5f9a0] Turing 0.7.1
[44d3d7a6-8a23-5bf8-98c5-b353f8df5ec9] Weave 0.9.2
[37e2e46d-f89d-539d-b4ee-838fcccc9c8e] LinearAlgebra
[cf7118a7-6976-5b1a-9a39-7adc72f591a4] UUIDs
```