

Domain-Specific Language for Epidemiological Modeling

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Objectives

- Provide a DSL for epidemiology modelers
- Deterministic, Stochastic and Multi-agent Simulations
- Generate LaTeX (equations) , C or R (code) from models
- Reuse, validate, share models between experts

Related Works

- **Ronald**: a Domain-Specific Language to study the interactions between Malaria infections and drug treatments (2008)
- Towards **Frabjous**: a 2-level System for Functional Reactive Agent-Based Epidemic Simulation (2012)
- **Simforence**, Epidemiological Modelling made social and on the cloud (Princeton Univ.) (2012)

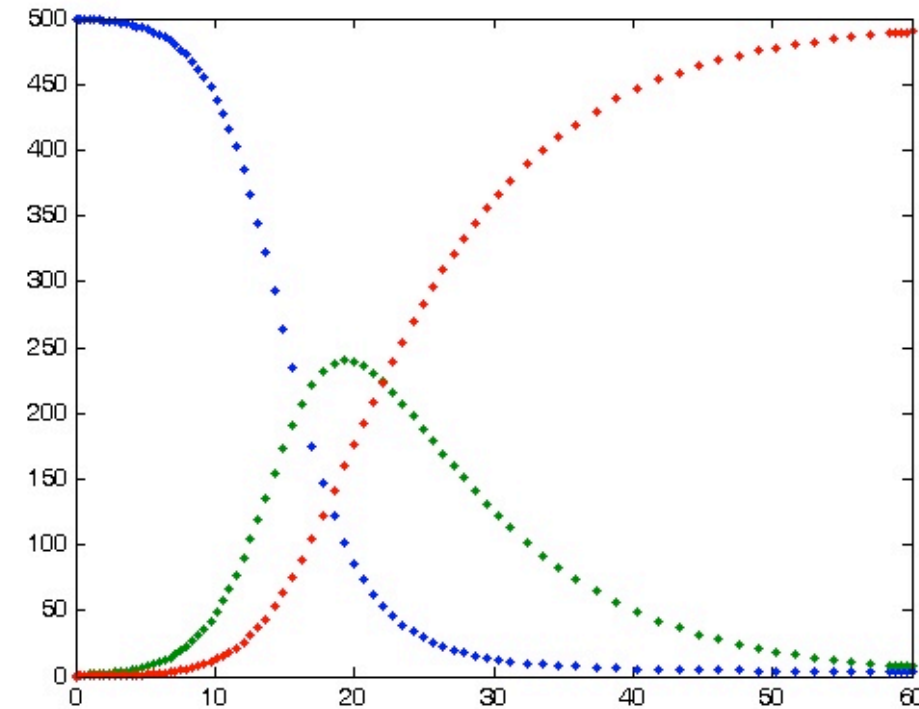
Compartmental Models in Epidemiology



$$\frac{dS}{dt} = -\beta IS$$

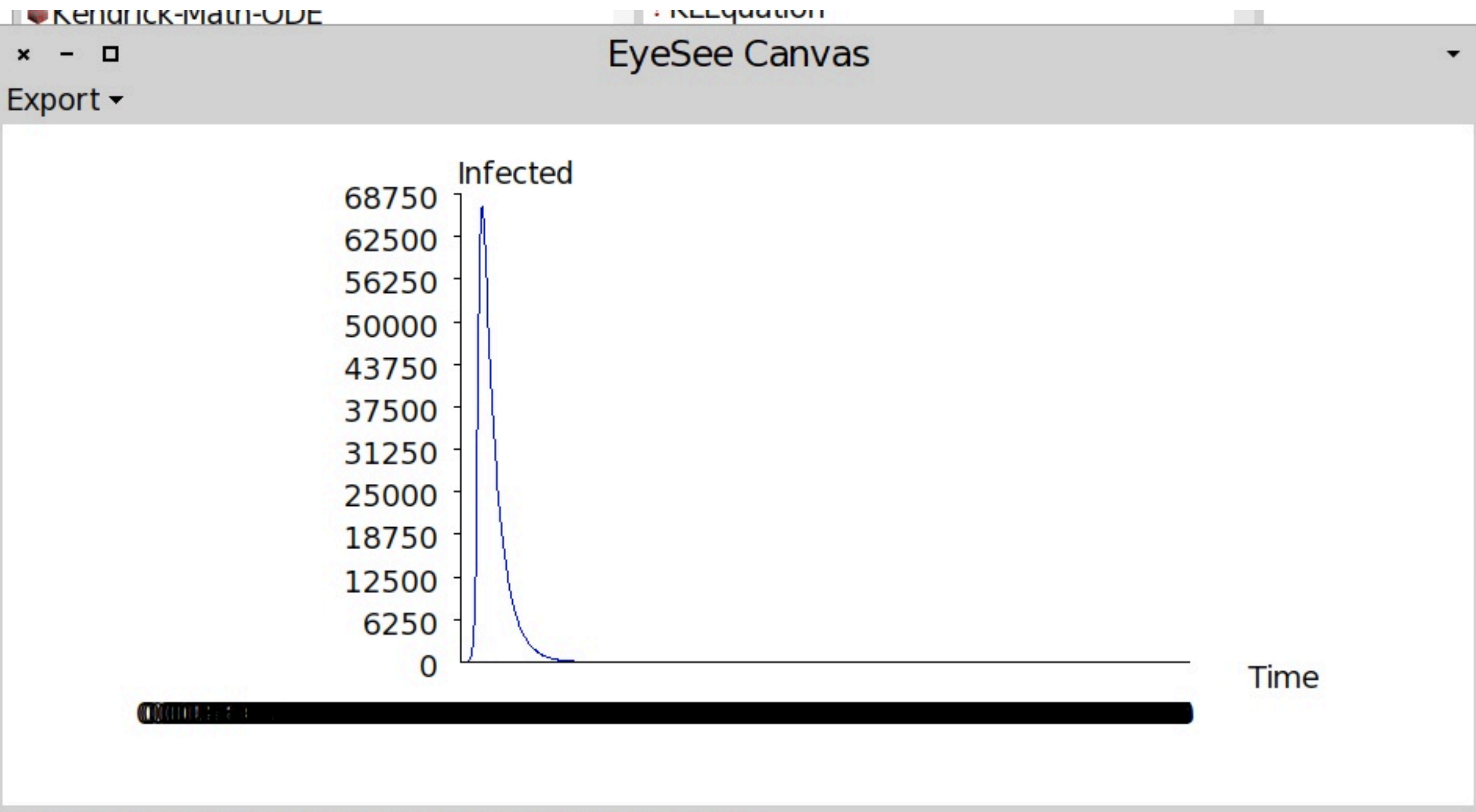
$$\frac{dI}{dt} = \beta IS - \nu I$$

$$\frac{dR}{dt} = \nu I$$



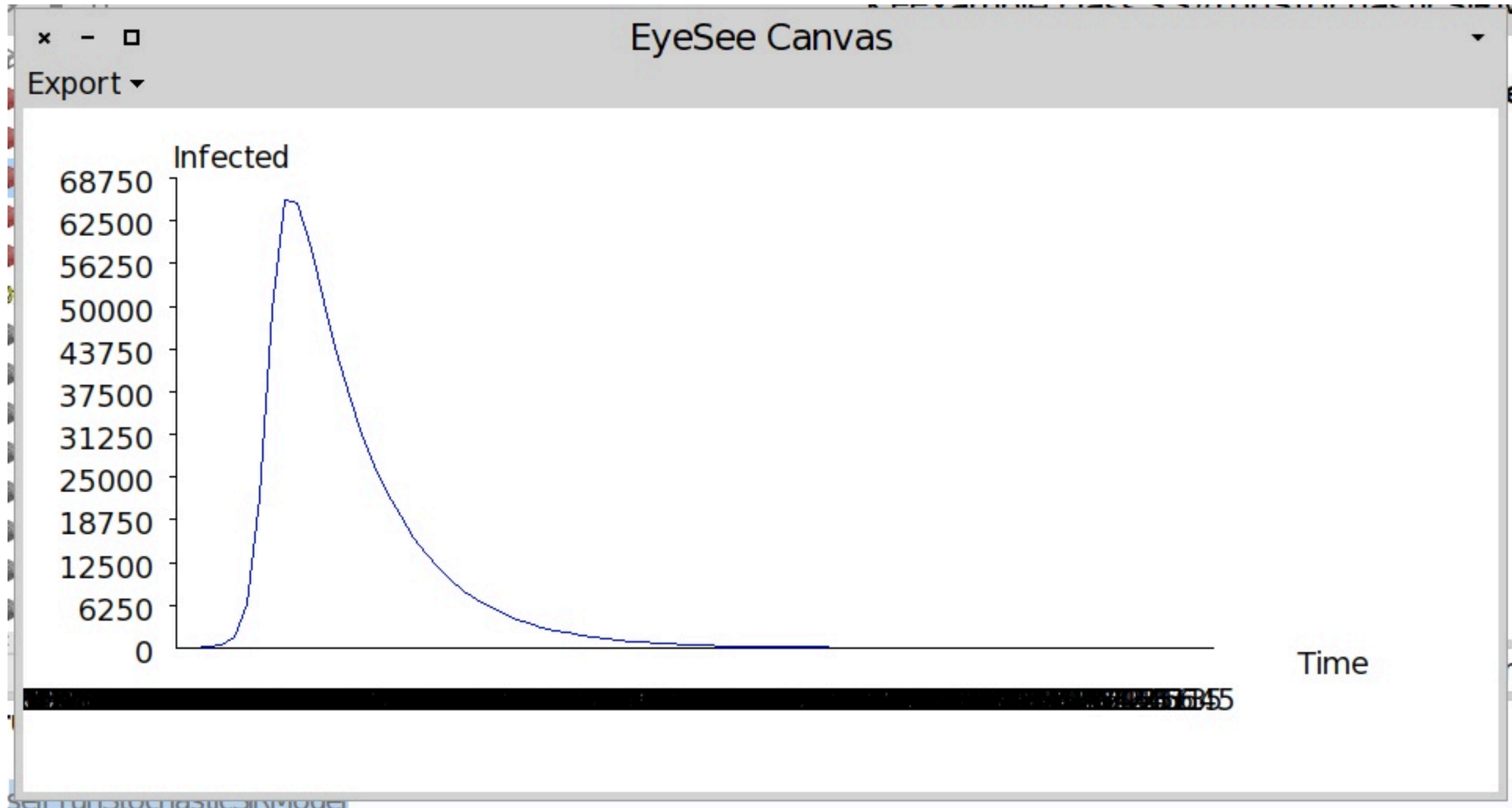
Measles (deterministic)

```
| model |  
model := KEModel new.  
model atCompartment:#S putNumberOfIndividuals: 1e5-1.  
model atCompartment:#I putNumberOfIndividuals: 1.  
model atCompartment:#R putNumberOfIndividuals: 0.  
model atParameter:#beta put: 0.0052.  
model atParameter:#gamma put: 365/7.  
  
model addEquation: (PPODEParser parse:'S:t=-beta*S*I').  
model addEquation: (PPODEParser parse:'I:t=beta*S*I-gamma*I').  
model addEquation: (PPODEParser parse:'R:t=gamma*I').  
  
model runDeterministSimulationFrom: 0.0 to: 1.0 with: 0.001.  
model plot
```



Measles (stochastic)

```
| model |  
model := KEModel new.  
model atCompartment:#S putNumberOfIndividuals: 1e5-1.  
model atCompartment:#I putNumberOfIndividuals: 1.  
model atCompartment:#R putNumberOfIndividuals: 0.  
model atParameter:#beta put: 0.0052.  
model atParameter: #gamma put: 365/7.  
  
model addEquation: (PPODEParser parse:'S:t=-beta*S*I').  
model addEquation: (PPODEParser parse:'I:t=beta*S*I-gamma*I').  
model addEquation: (PPODEParser parse:'R:t=gamma*I').  
  
model runStochasticSimulationFor: (50/365).  
model plot.
```



Multi-host example (deterministic)

```
[model compartment dsdt didt]
```

```
model := KEModel new.
```

```
model atCompartment: #S putNumberOfIndividuals: #(9999 1000 2000).
```

```
model atCompartment: #I putNumberOfIndividuals: #(1 0 0).
```

```
model atParameter: #beta put: {{0 . 0.02 . 0.02} . {0.02 . 0 . 0} . {0.02 . 0 . 0}}.
```

```
model atParameter: #N put: #(10000 1000 2000).
```

```
model atParameter: #mu put: {365/30 . 1/20 . 1/20}.
```

```
model atParameter: #v put: 52.
```

```
model atParameter: #j put: (1 to: 3).
```

```
model atParameter: #i put: (1 to: 3).
```

```
dsdt := 'S[i]:t=mu[i]*N[i]-sum(j, beta[i, j]*I[j])*S[i]-mu[i]*S[i]' parseAsODEEquation.
```

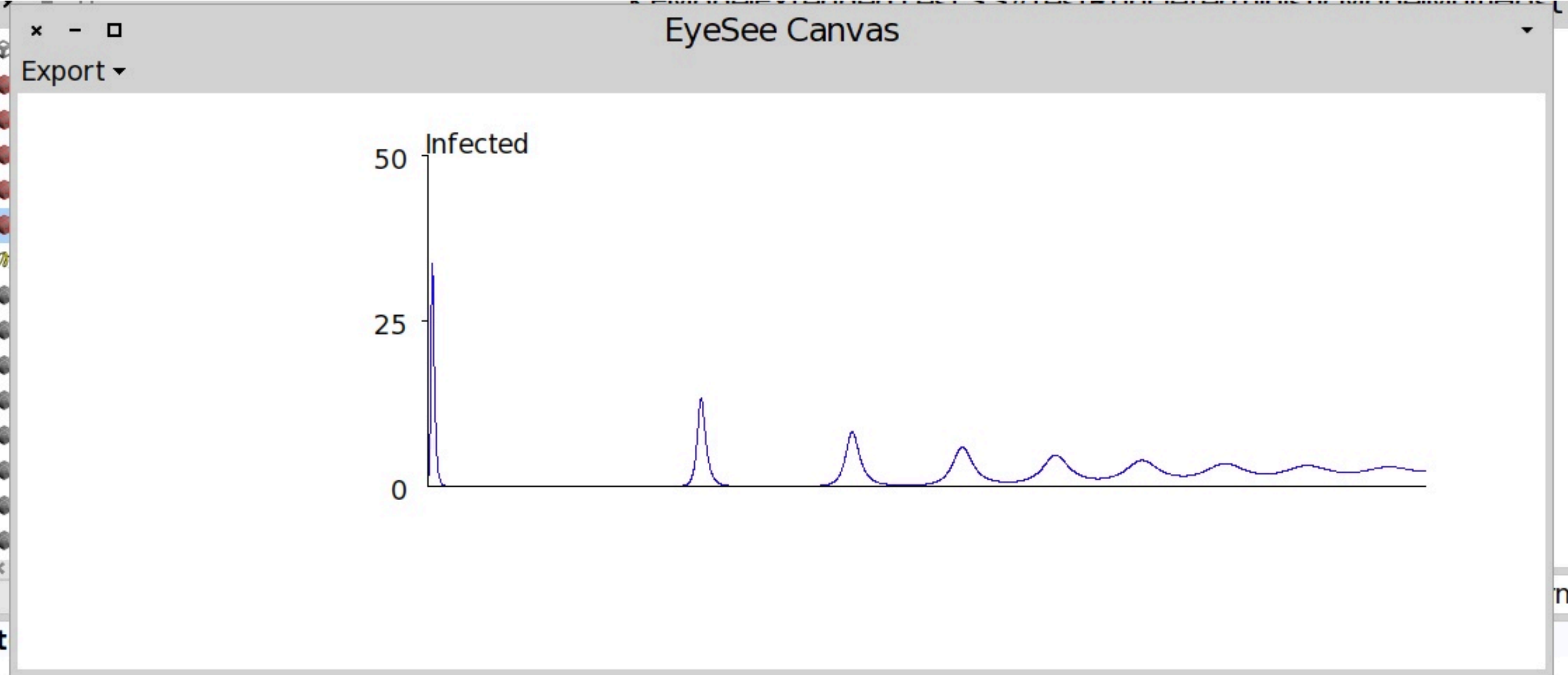
```
didt := 'I[i]:t=sum(j, beta[i, j]*I[j])*S[i]-(mu[i]+v)*I[i]' parseAsODEEquation.
```

```
model addEquation: dsdt.
```

```
model addEquation: didt.
```

```
model runDeterministSimulationFrom: 0 to: 40 with: 0.01 function: #sqrt.
```

```
model plot
```



Model ?

- Compartments (states)
- ODE (ordinary differential equations)
- Parameters

Solving Equations

- Set of non-linear ODEs
- No generic analytic solution
- **Deterministic** => Runge Kutta Solver, ...
- **Stochastic** => Gillespie Algorithm, ...
- **Individual** => Multi-agent system

Challenges

- Coherence/ validation
- Simulation parameters:
 - efficiency: solvers, ...
 - model exploration
- Adapt DSL to different kinds of users (practitioners, decision makers, ...)
- Decouple states & their structures ?