Set -8: Modelling epidemics and endemic breakouts of infectious diseases

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CS302, Modeling and Simulation

In this report we model epidemics and endemic breakouts of infectious diseases through differential equations, providing insights into their dynamics and impact on populations.

I. EPIDEMICS

A. Introduction

Epidemics are a top concern for governments and public health organisations around the world because they can have serious effects on social, economic, and public health.

B. Model

We divide the population size of $N(constant)$ into three classes: the infected class $x(t)$, the susceptible class $y(t)$, and the recovered class $z(t)$.

$$x(t) + y(t) + z(t) = N \tag{1}$$

The coupled dynamics of these variables is given by,

$$\dot{x} = Axy - Bx \tag{2}$$

$$\dot{y} = -Axy \tag{3}$$

$$\dot{z} = Bx \tag{4}$$

Here A is the infection rate and B is the removal rate, $A = 2.18 \text{ x } 10^{-3}$ and $B = 0.44 \text{ day}^{-1}$.

Also, $N = 763$, $x_0 = 1$, $y_0 = 762$ and $z_0 = 0$.

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C. Results

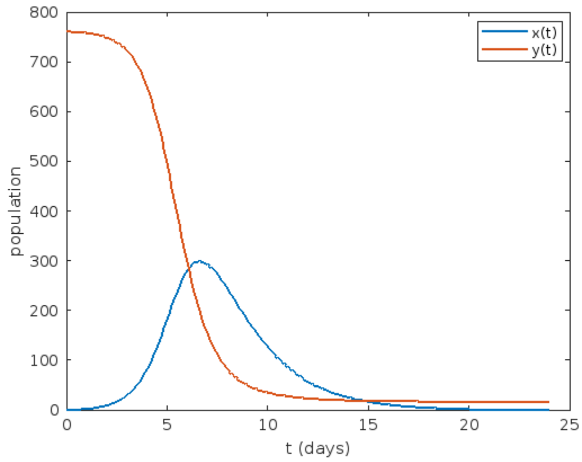

fig. 1. Plot of x(t) and y(t)

At time t = 6.4635 days,
maximum value of x = 295.5749 days

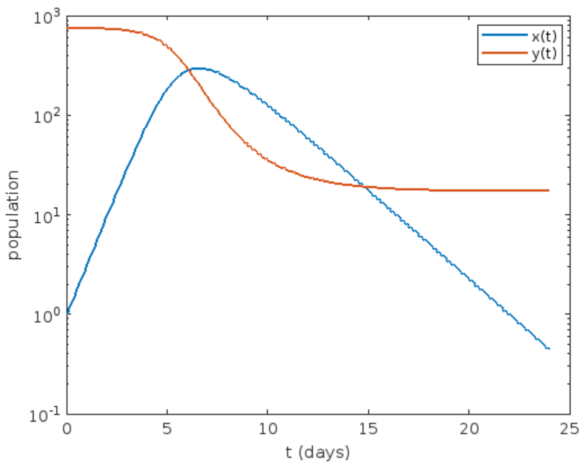

fig. 2. Plot of x(t) and y(t) (logarithmic scale)

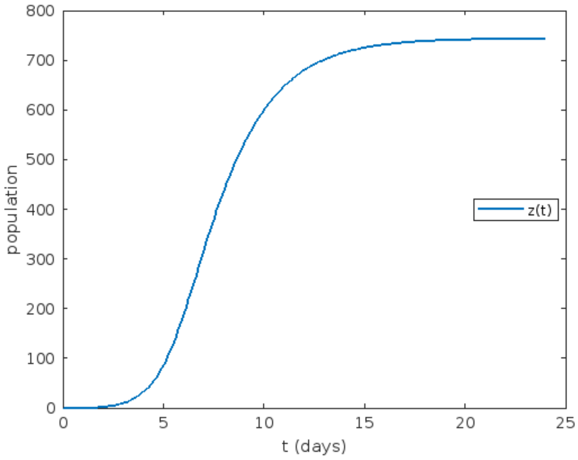

fig. 3. Plot of z(t)

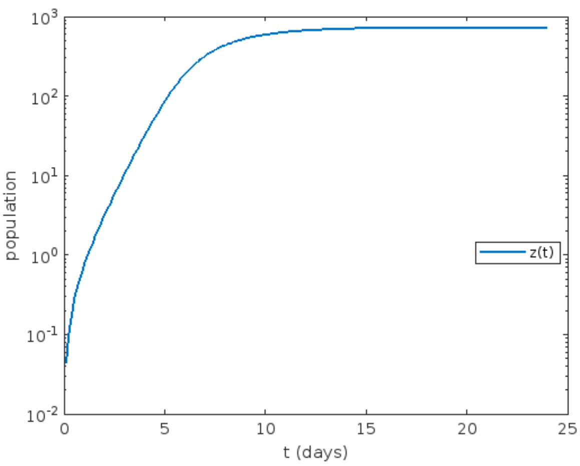

fig. 4. Plot of z(t) (logarithmic scale)

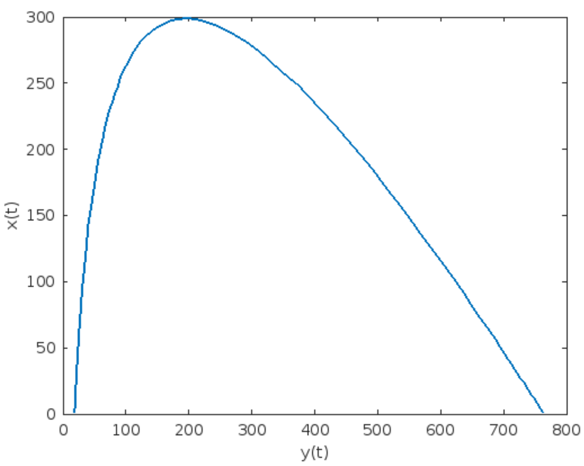

fig. 5. Plot of x(t) vs y(t)

Values	
Threshold value, ρ	201.8349
Reproduction number, R	3.7754

II. ENDEMIC DISEASES

A. Introduction

Endemic diseases persist in a population and break out from time to time.

B. Model

In this case the population size changes i.e. $N(t)$, but changes according to the difference between the birth rate b and the death rate a. Then the relevant coupled system of equations is given by

$$\dot{x} = Axy - Bx - ax \tag{5}$$

$$\dot{y} = bN - Axy - ay \tag{6}$$

$$\dot{z} = Bx - az \tag{7}$$

$$\dot{N} = (b - a)N \tag{8}$$

Here $a = b = 0.02 year^{-1}$, hence N is fixed. Taking $A = 10^{-6}$ and $B = 0.333$ year^{-1},N $= 10^6$, $x_0 = 10^5$ and $y_0 = 9$ x 10^5.

C. Results

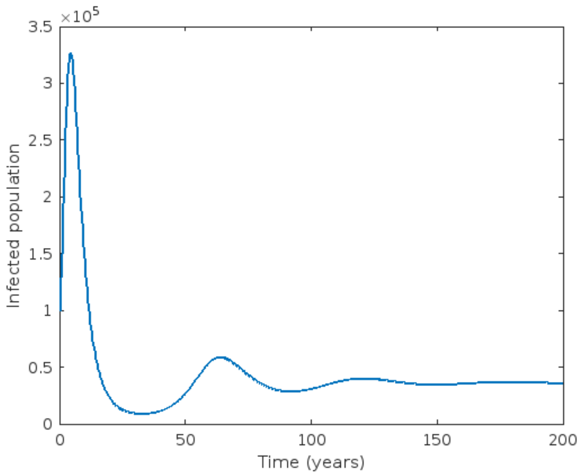

fig. 1. Infected population over time

Peak values	
Time (years)	x
4.2417	3.2668e5
63.8415	0.5906e5
120.6981	0.4049e5
177.6627	0.3740e5

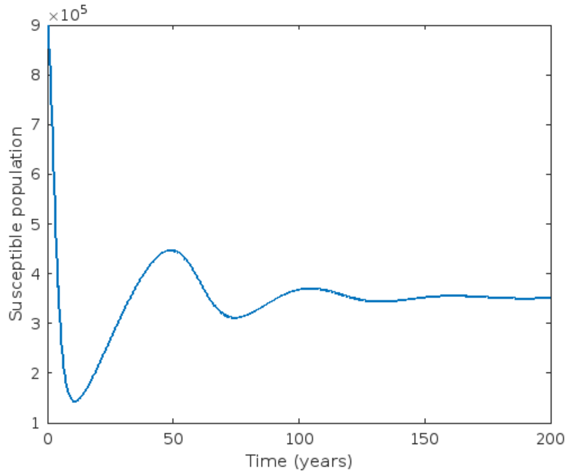

fig. 2. Susceptible population over time

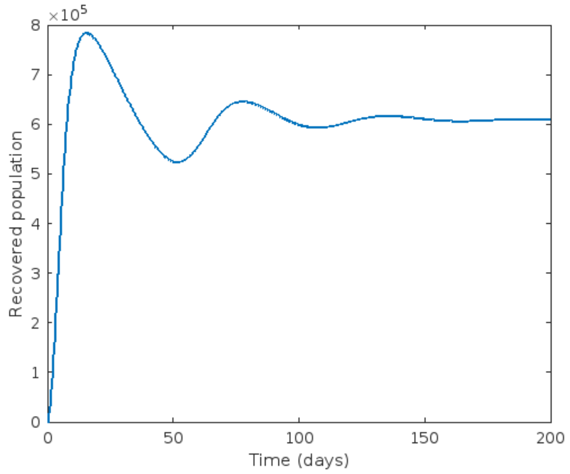

fig. 3. Recovered population over time

[1] Nair, R., Nagarjuna, G. and Ray, A.K., 2009. Finite-size effects in the dependency networks of free and open-source software. arXiv preprint arXiv:0901.4904.

[2] Mullick, A. and Ray, A.K., 2016, October. Nonlinear dynamics of bimodality in vehicular traffic. In Journal of Physics: Conference Series (Vol. 755, No. 1, p. 012009). IOP Publishing.

[3] Ray, A.K. (2010). Modeling Saturation in Industrial Growth. In: Basu, B., Chakravarty, S.R., Chakrabarti, B.K., Gangopadhyay, K. (eds) Econophysics and Economics of Games, Social Choices and Quantitative Techniques. New Economic Windows. Springer, Milano. https://doi.org/10.1007/978-88-470-1501-2$_1$4