Analysis of Population Dynamics of Terrorist Cells

An Application of Mathematics

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Abstract

Applied mathematics connects many different fields of sciences. This research focuses on the population dynamics of terrorist organizations, namely Al Qaeda, by creating a mathematical model, while still considering social science fields, such as psychology. By considering psychological interrelations of a terrorist cell and their contact with citizens, we design a model that is a four dimensional system of nonlinear differential equations to better understand the way in which recruitment ensues within such organizations. Using the computer program *Mathematica*, we are able to manipulate multiple parameters simultaneously in order to observe the impact of certain recruitment techniques on the general population. This results in either the absorption of the human race by the terrorist organization, or more positively, a ceiling on the terrorist population. Other scientists, such as psychologists, can use this information to implement new strategies to combat terrorism from a new intellectual perspective.

Main Objectives

- To create a mathematical model that yields results relevant to social scientists
- To better understand the movement of terrorist populations with regard to social interaction
- To provide a basis for further research in social sciences regarding terrorist population dynamics

Assumptions

We assume there exists no other way to join a terrorist organization, apart from the interactions one has with active terrorists or influential martyrs.

We also assume that the population of former terrorists has no positive or negative effect on the potential terrorist population. No such interaction has been observed when studying terrorist organizations.

Mathematical Analysis

The following variables represent the different populations in the model:

P : potential terrorists T : active terrorists
Q : former terrorists M : martyrs

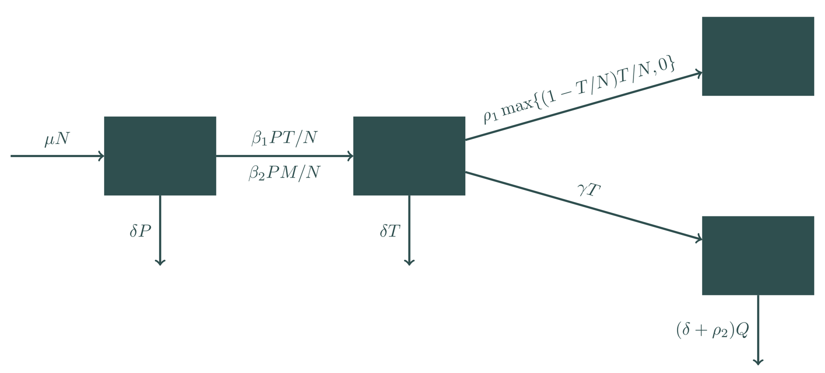

Figure 1: Terrorist Cell Model

The parameters seen in Figure 1 are defined as follows:

N: world population

μ: the percentage of the population considered potential terrorists

β_i: The probability that a potential terrorist will become a terrorist, given, when $i = 1$, that they have contact with an active terrorist, or when $i = 2$, that they are influenced by a martyr

δ: The natural death rate of the population

γ: The rate at which terrorists become inactive (quit)

ρ_1: The rate at which terrorists commit martyrdom

ρ_2: the added death rate for former terrorists

Figure 1 yields the following non-dimensionalized system of nonlinear differential equations:

$$\begin{aligned}
\dot{p} &= \mu - \beta_1\, p\, x - \beta_2\, p\, m - \delta p \\
\dot{x} &= \beta_1\, p\, x + \beta_2\, p\, m - (\delta+\gamma)x - \rho_1 \max\{(1-x)x, 0\} \\
\dot{q} &= \gamma\, x - (\delta+\rho_2)q \\
\dot{m} &= \rho_1 \max\{(1-x)x, 0\}
\end{aligned}$$

The following are estimations for initial conditions and relevant parameters:

$$\begin{array}{lll}
0 \le p_0 \le 0.02 & & 0 \le x_0 \le 0.000005 \\
0 \le q_0 \le 0.00000005 & & 0 \le m_0 \le 0.00001 \\
\mu = 0.02 & \delta = 0.007 & 0 \le \gamma \le 0.5
\end{array}$$

$$0 < \beta_i \le 1, \quad 0 \le \rho_i \le 0.01, \quad \text{where } i = 1, 2$$

The initial conditions and parameters were estimated using numerical data derived from various census reports.

Results

The focus of the results will be those interesting and applicable to the social sciences. We observe changes within the long-term behavior of the solutions when varying recruitment rates β_1 and β_2. Note that one of our assumptions is that there exists no other method through which one may join a terrorist organization than through the interactions with active terrorists or martyrs (represented by β_1 and β_2 in Figure 1).

When manipulating β_1 and β_2 we notice the importance of γ, as it only has a negative effect on the terrorist population. When we set the recruitment rates to be 1 we can observe the influence of γ more thoroughly.

In Figure 2 we plot the movement from the potential terrorists, p, to the active terrorists, x, for the representative case $\gamma = 0.03$. We observe the terrorist population will reach at most $x = 0.6$.

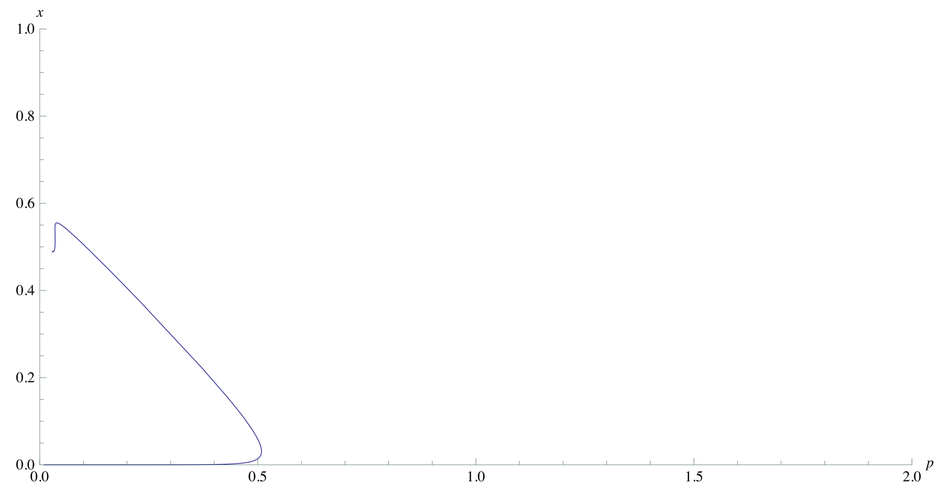

Figure 2: The $p\,x$ phase plane when $\gamma = 0.03$

Conclusions

- We were able to design a mathematical model that furthered our understanding of the dynamics of terrorist organizations in a way that is applicable to social scientists.
- Using *Mathematica*, we were able to observe the impact of β_1 and β_2 on the active terrorist population while varying all other parameters. From this we concluded the importance of γ.
- No matter the rate at which the terrorist population grows, if $\gamma \ge 0.03$ then the terrorist population will always be less than N. If $\gamma < 0.03$, then the active terrorist population will absorb the world population.

Forthcoming Research

Because γ has proven to be important and effective in controlling the long-term behavior of a terrorist organization's population, the social scientist might be motivated to research the inner cells of a terrorist organization to see what would serve as motivation for an active terrorist to quit. This could result in developing more effective governmental policies to control a terrorist organization's population size. Moreover, they might also want to observe or predict what a certain percentage of terrorists quitting may do to the dynamics of the terrorist organization.

It is my hope that a psychologist or sociologist will feel inspired to observe the relationships between those susceptible to terrorist recruitment. There is limited research about terrorist recruitment techniques, and it would be beneficial to the mathematical model to be able to realistically estimate β_1 and β_2.

References

- Castillo-Chávez, C. (2001). *Mathematical models in population biology and epidemiology.* (Vol. TAM 40). New York: Springer-Verlag.
- Victoroff, J. (2009). *Psychology of terrorism.* New York: Psychology Press.
- Census reports obtained from websites are available upon request.

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