Increasing, Decreasing and Flat Strategies in Information Warfare

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Abstract. The paper studies the mathematical model of information warfare in which each of belligerent parties has the option of choosing between an increasing, decreasing and flat strategies of broadcasting. The broadcasting resource of each of the parties is supposed to be limited. Increasing strategy refers to broadcasting weakly at the start of the campaign and increase the intensity of broadcasting gradually. Similarly, decreasing strategy means broadcasting with high intensity at the start of the campaign and decrease it gradually. Flat strategy refers to constant intensity of broadcasting. Each party faces the question of which strategy is the mast advantageous. We address this problem by making computational experiments with the model of information warfare. Combining three options of the first party with three options of the second party we obtain 9 scenarios. For each of them the numbers of each party's supporters at the end of the warfare is calculated. Which strategy appears to be the best depends on parameters that characterize the intensity of mouth-to-mouth spread of information and deactivation of parties' supporters.

Keywords: Mathematical Modeling, Computational Experiment, Information Warfare, Increasing, Decreasing and Flat Strategies of Broadcasting.

1 Introduction

Information warfare has been an increasingly important topic for mathematicians as well as social science scholars and practitioners. The constantly growing volume of literature includes, among others, papers that introduce, develop and analyze mathematical models.

Mathematical modeling of the dissemination of information in society stems from rumor models that do not take into account broadcasting by mass media but consider only the diffusion of information in interpersonal communications. The earliest models of this kind [1, 2] were proposed back in 1964 and 1973. The model of competing rumors [3] was proposed basing on their approach and can be considered the earliest model of information war. It deals with the spread of two competing rumors, considering that if the spreader of the first rumor meets the spreader of the second rumor, then they switch to spread the second rumor. The idea is that the first rumor is false, and the second contains convincing evidence of its falseness. In this approach, the “winner” of the information war is set by the researcher by defining that the second rumor is stronger than the first. An alternative approach [4] assumes that a supporter of the other party cannot be convinced, thus an individual becomes once and forever a supporter of the party whose information they internalize earlier. The winner of the confrontation is derived from the analysis of the model: in [4] the so-called “victory condition” was analytically obtained, i.e. inequality (containing system parameters), which determines which side of the confrontation has a greater number of supporters when $t \to \infty$. Among modern trends in this area, we also note emphasis on social networks, and agent-based and game theory-based models [5–10]. In models of this kind the network structure plays an important role as well as reputations of agents (network nodes). Related empirical studies (for example, [11–14]) can be used in constructing mathematical models of information warfare.

Approaches to mathematical modeling of information warfare include the model of making a decision by individual as for which party to support. The latest versions of this model [15–17] incorporates the ideas of the agenda-setting [18, 19].

In this paper we address the problem of choosing a strategy in information warfare. Suppose two Parties, say X and Y, are engaged in information warfare. During this extended process each party broadcasts its propaganda via mass media.

It is supposed that each party has a limited resource for broadcasting. A useful image would be that a party has enough resource to broadcast, say, 100 units over a campaign that lasts 25 days. The flat strategy is to release 4 units every day. However, maybe it's more advantageous to broadcast weakly at the start of the campaign and increase the intensity of broadcasting gradually. This would be an increasing strategy. Similarly, decreasing strategies start from powerful broadcasting and decrease the intensity gradually. The other party has the same types of strategies. The question here is which strategy is to choose. We approach it with our mathematical model.

2 Model

Take the model of information warfare [4]

$$\frac{dX}{dt} = \left(\alpha_x(t) + \beta_x X\right)\left(N - X - Y\right) - \gamma X,$$

$$\frac{dY}{dt} = \left(\alpha_y(t) + \beta_y Y\right)\left(N - X - Y\right) - \gamma Y,$$

$$X(0) = X^0,\ Y(0) = Y^0.$$

Here X and Y are numbers of parties' supporters, N is the total numbers of individuals in the population. It comprises supporters of X, supporters of Y and unattached individuals. It is supposed that each party's messages are spread by broadcasting and via interpersonal communication. The intensity of broadcasting of Party X is given by function $\alpha_x(t)$ and the intensity of mouth-to-mouth relaying of their message is characterized by parameter. Similarly, $\alpha_y(t)$ and β_y refer to broadcasting and relaying via interpersonal communication the message of Party Y. The terms $-\gamma X, -\gamma Y$ describe the individuals' shift from supporters to unattached, so that parameter γ characterizes the intensity of this deactivation process. The system is considered at $0 \le t \le T$.

For the sake of simplicity suppose $\alpha_x(t)$, $\alpha_y(t)$ to be linear functions of time:

$$\alpha_x(t) = k_x t + l_x ,$$

$$\alpha_y(t) = k_y t + l_y .$$

In terms of these equations, increasing, decreasing and flat strategies of Party X mean, respectively, $k_x > 0$, $k_x < 0$, $k_x = 0$, and the same for Party Y. Combing various strategies by two parties we get scenarios such as "increasing strategy of Party X vs flat strategy of Party Y" and so on. In comparing various strategies of a party as for which one is more advantageous given the strategy of the other party fixed, it is necessary to control that the total broadcasting resource given by

$$Resource_x = \int_0^T \alpha_x(t)\,dt ,$$

is the same across all strategies of Party X, and ditto for Party Y.

3 Computational Experiment: One of the Parties Has a Greater Broadcasting Resource

Experiment 1. Let the duration of the warfare be *T*=4. Parameters $\beta_x = \beta_y = 1$ and $\gamma = 0.1$. Let the strategies of Party X be

$$\begin{aligned} &Increasing: && \alpha_x(t) = t, \\ &Flat: && \alpha_x(t) = 2, \\ &Decreasing: && \alpha_x(t) = 4 - t, \end{aligned}$$

so that $Resource_x = 8$. Similarly, strategies of Party Y are

$$\begin{aligned} &Increasing: && \alpha_x(t) = 1.2t, \\ &Flat: && \alpha_x(t) = 2.4, \\ &Decreasing: && \alpha_x(t) = 4.8 - 1.2t, \end{aligned}$$

so that $Resource_y = 9.6$. The results are presented in Table 1. The dynamics for two cases is shown in Fig. 1.

It follows from Table 1 that for each party the increasing strategy is dominated by the flat strategy, which in turn is dominated by the decreasing strategy. In other words, under given parameters the decreasing strategy is the most advantageous while the increasing strategy is the worst one.

The explanation of this is that mouth-to-mouth spread of messages is more intensive than the deactivation of partisans, that is $\beta_x = \beta_y >> \gamma$. Given this condition, the idea of effective campaigning is to take the lead at the start, that is to circulate your message powerfully at the start of the campaign and let your supporters relay it further to their interlocutors.

Table 1. Experiment 1: the final numbers of supporters.

	$\alpha_x(t) = t$	$\alpha_x(t) = 2$	$\alpha_x(t) = 4 - t$
$\alpha_y(t) = 1.2t$	X=45.409, Y=54.491	X=98.417, Y=1.481	X=98.698, Y=1.196
$\alpha_y(t) = 2.4$	X=1.154, Y=98.743	X=45.405, Y=54.486	X=62.094, Y=37.804
$\alpha_y(t) = 4.8 - 1.2t$	X=0.958, Y=98.942	X=29.698, Y=70.191	X=45.398, Y=54.478

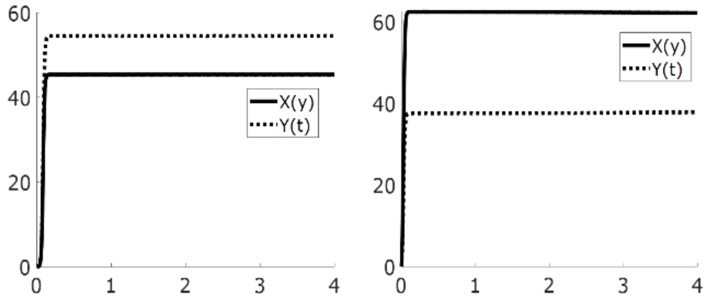

Fig. 1. Dynamics for Experiment 1. Left: $\alpha_x(t) = t$, $\alpha_y(t) = 1.2t$. Right: $\alpha_x(t) = 4 - t$, $\alpha_y(t) = 2.4$.

This being so, one can suppose that in the case of the opposite relation, that is if $\beta_x = \beta_y << \gamma$, then the most advantageous strategy would be the increasing one. This conjecture gives us the idea of the following experiment.

Experiment 2. Put T=10, $\beta_x = \beta_y = 0.1$ and $\gamma = 1$. Let the strategies of Party X be

$$\begin{aligned} &Increasing: \quad \alpha_x(t) = t, \\ &Flat: \quad \alpha_x(t) = 5, \\ &Decreasing: \quad \alpha_x(t) = 10 - t, \end{aligned}$$

so that $Resource_x = 50$. Similarly, strategies of Party Y are

$$\begin{aligned} &Increasing: \quad \alpha_x(t) = 1.2t, \\ &Flat: \quad \alpha_x(t) = 6, \\ &Decreasing: \quad \alpha_x(t) = 12 - 1.2t, \end{aligned}$$

so that $Resource_y = 60$. The results are presented in Table 2. The dynamics for two cases is shown in Fig. 2.

Table 2. Experiment 2: the final numbers of supporters.

	$\alpha_x(t) = t$	$\alpha_x(t) = 5$	$\alpha_x(t) = 10 - t$
$\alpha_y(t) = 1.2t$	X=44.040, Y=52.848	X=33.002, Y=63.356	X=15.368, Y=80.174
$\alpha_y(t) = 6$	X=55.105, Y=41.118	X=43.343, Y=52.011	X=21.949, Y=71.944
$\alpha_y(t) = 12 - 1.2t$	X=74.768, Y=20.347	X=64.959, Y=28.532	X=41.014, Y=49.217

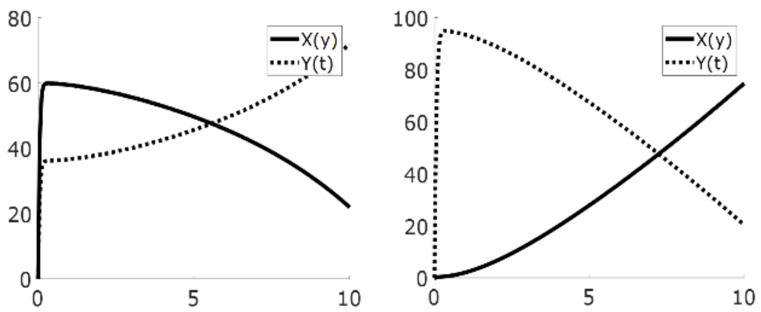

Fig. 2. Experiment 2. Left: $\alpha_x(t) = 10 - t$, $\alpha_y(t) = 6$. Right: $\alpha_x(t) = t$, $\alpha_y(t) = 12 - 1.2t$.

As expected, the best strategy for each party is the increasing one. The intuition behind the conclusion is like this. Imagine a person who receives a party's message to become a supporter of this party but gives up their partisanship before relaying the message to someone else. In this situation there is no sense of wasting much resource to recruit many supporters at the start of the campaign. More rationally would be to keep your broadcasting resource until the final burst. This means an increasing strategy.

An obvious question arises about the intermediate case. We have got that decreasing strategies tend to be the most advantageous when $\beta_x = \beta_y >> \gamma$ whereas increasing strategies tend to be the most advantageous when $\beta_x = \beta_y << \gamma$. Thus the intermediate case is presumably represented by equality $\beta_x = \beta_y = \gamma$. This is the question of the following experiment.

Experiment 3. Put T=15, $\beta_x = \beta_y = \gamma = 1$. Let the strategies of Party X be

$$\begin{aligned} &\textit{Increasing}: && \alpha_x(t) = t, \\ &\textit{Flat}: && \alpha_x(t) = 7.5, \\ &\textit{Decreasing}: && \alpha_x(t) = 15 - t, \end{aligned}$$

so that $Resource_x = 112.5$. Similarly, strategies of Party Y are

$$\begin{aligned} &\textit{Increasing}: && \alpha_x(t) = 1.3t, \\ &\textit{Flat}: && \alpha_x(t) = 9.75, \\ &\textit{Decreasing}: && \alpha_x(t) = 19.5 - 1.3t, \end{aligned}$$

so that $Resource_y = 146.25$. The results are presented in Table 3. The dynamics for two cases is shown in Fig. 3.

Table 3. Experiment 3: the final numbers of supporters.

	$\alpha_x(t) = t$	$\alpha_x(t) = 7.5$	$\alpha_x(t) = 15 - t$
$\alpha_y(t) = 1.3t$	X=43.151, Y=56.097	X=43.217, Y=55.986	X=34.927, Y=64.227
$\alpha_y(t) = 9.75$	X=44.795, Y=54.361	X=43.103, Y=56.034	X=36.230, Y=62.826
$\alpha_y(t) = 19.5 - 1.3t$	X=54.038, Y=45.091	X=50.472, Y=48.575	X=42.996, Y=55.895

The important point here is that there is no dominating strategies in this experiment.

4 Computational Experiment: A Viral Message vs Greater Resource

In this section we consider a situation where Party X circulates a viral message, which is relayed by individuals more intensively than the message of party Y. On the other side, Party Y has a greater broadcasting resource.

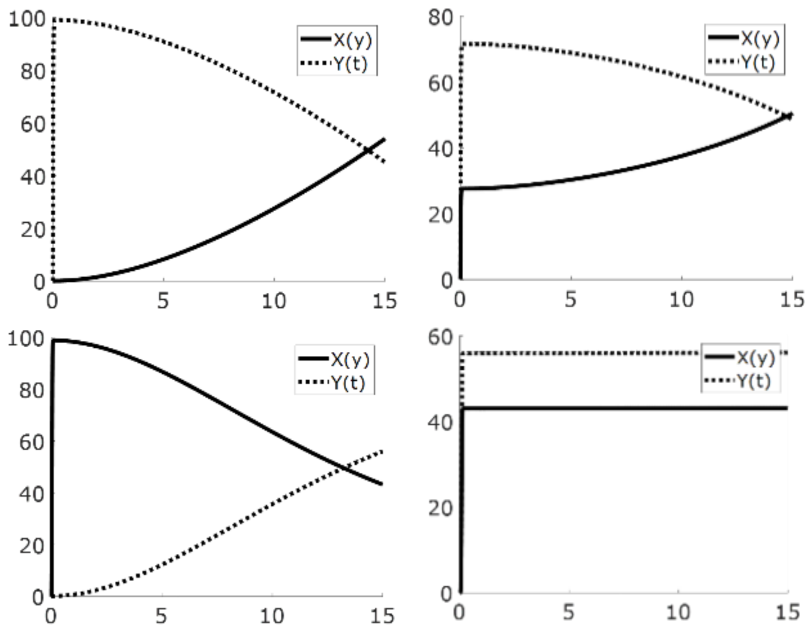

Fig. 3. Experiment 3. Top left: $\alpha_x(t)=t,\ \ \alpha_y(t)=19.5-1.3t$. Top right: $\alpha_x(t)=7.5$, $\alpha_y(t)=19.5-1.3t$. Bottom left: $\alpha_x(t)=7.5,\ \ \alpha_y(t)=1.3t$. Bottom right: $\alpha_x(t)=t$, $\alpha_y(t)=1.3t$.

Experiment 4. Put T=10, $\beta_x=0.24, \beta_y=0.2, \gamma=0.8$. Let the strategies of Party X be

$$
\begin{aligned}
&\mathit{Increasing}: && \alpha_x(t)=t,\\
&\mathit{Flat}: && \alpha_x(t)=5,\\
&\mathit{Decreasing}: && \alpha_x(t)=10-t,
\end{aligned}
$$

so that $\mathit{Resource}_x=50$. Similarly, strategies of Party Y are

$$
\begin{aligned}
&\mathit{Increasing}: && \alpha_x(t)=1.2t,\\
&\mathit{Flat}: && \alpha_x(t)=6,\\
&\mathit{Decreasing}: && \alpha_x(t)=12-1.2t,
\end{aligned}
$$

so that $\mathit{Resource}_y=60$. The results are presented in Table 4. The dynamics for one of the cases is shown in Fig. 4.

Table 4. Experiment: the final numbers of supporters.

	$\alpha_x(t)=t$	$\alpha_x(t)=5$	$\alpha_x(t)=10-t$
$\alpha_y(t)=1.2t$	X=51.670, Y=46.445	X=47.005, Y=50.947	X=37.113, Y=60.515
$\alpha_y(t)=6$	X=54.856, Y=43.063	X=52.590, Y=45.006	X=43.486, Y=53.616
$\alpha_y(t)=12-1.2t$	X=67.599, Y=29.967	X=65.272, Y=31.833	X=57.452, Y=38.977

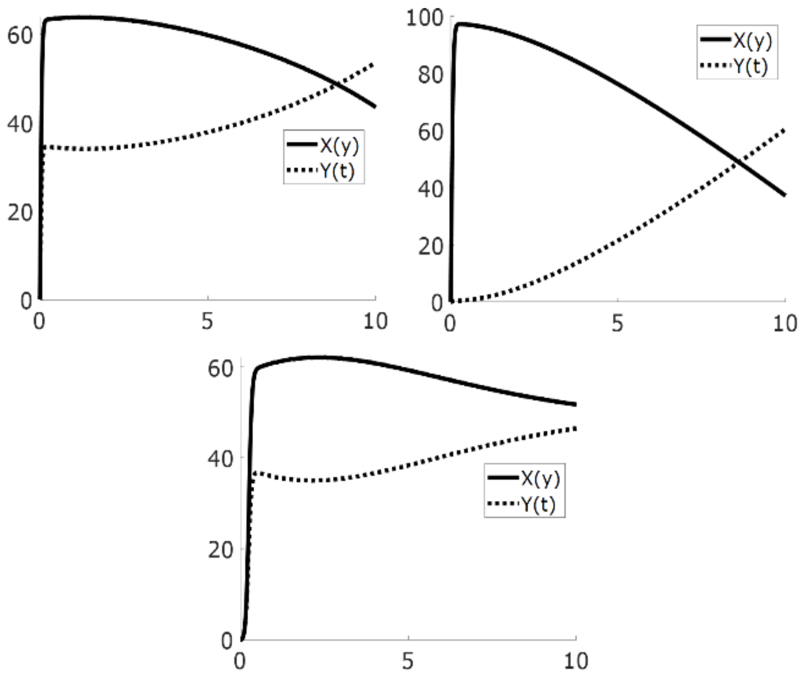

Fig. 4. Experiment 4. Top left: $\alpha_x(t)=10-t,\ \ \alpha_y(t)=6$. Top right: $\alpha_x(t)=10-t$, $\alpha_y(t)=1.2t$. Bottom: $\alpha_x(t)=t,\ \ \alpha_y(t)=1.2t$.

To sum up the computational results, the generic feature is that the choice of strategy depends on relation between the intensity of relaying messages via interpersonal communication and the intensity of deactivation of individuals that is between β and γ . Relatively big values of β and small values of γ are favorable for decreasing strategies and reverse.

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