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Time-delay effects on dynamics of a two-actor conflict model

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ABSTRACT

We present a study of time-delay effects on a two-actor conflict model based on nonlinear differential equations. The state of each actor depends on its own state in isolation, its previous state, its inertia to change, the positive or negative feedback and a time delay in the state of the other actor. We use both theoretical and numerical approaches to characterize the evolution of the system for several values of time delays. We find that, under particular conditions, a time delay leads to the appearance of oscillations in the states of the actors. Besides, phase portraits for the trajectories are presented to illustrate the evolution of the system for different time delays. Finally, we discuss our results in the context of social conflict models.

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1. Introduction

The study of conflicts has been the object of researchers from social sciences and, recently, has attracted the attention of investigators from other areas of science. A conflict can be described as the opposition of individuals or groups related to different competing interest, opinions or identities. An important question about the evolution of conflict is to identify the main mechanisms by which conflict — between individuals, groups or nations — evolves toward similar or opposite states after transitory periods. In recent years, several models of conflict have been proposed, which are based on qualitatively defined reaction functions between actor linear models [1]. In Ref. [2], Liebovitch et al. proposed a nonlinear differential equation model of the conflict between two actors. This model is based on Gottman et al.'s [3] proposal and Deutsch's [4] suggestions with particular attention to capture the cooperative or competitive behavior of actors through a limited number of parameters. Besides, their local stability analysis together with numerical simulations revealed important characteristics similar to those observed in real situations. On the other hand, differential equation models with time delays have been proposed to analyze systems ranging from regulatory genetic processes to control theory [5–12]. It is recognized that time delays play an important role in changing the stability of a fixed point. For example, in biological systems time delays are known to be important because they are involved in many regulation processes [13,14]. Within the context of control theory, time delays have been used to explore the possibility of inducing chaotic behavior for a time-continuing system with exponentially stable equilibrium points [15]. Besides, delayed-feedbacks controlling the spreading of epidemics in small-world evolving networks have been reported to play an important role [16], and also, for the study of dynamical behavior of delayed neural networks [17].

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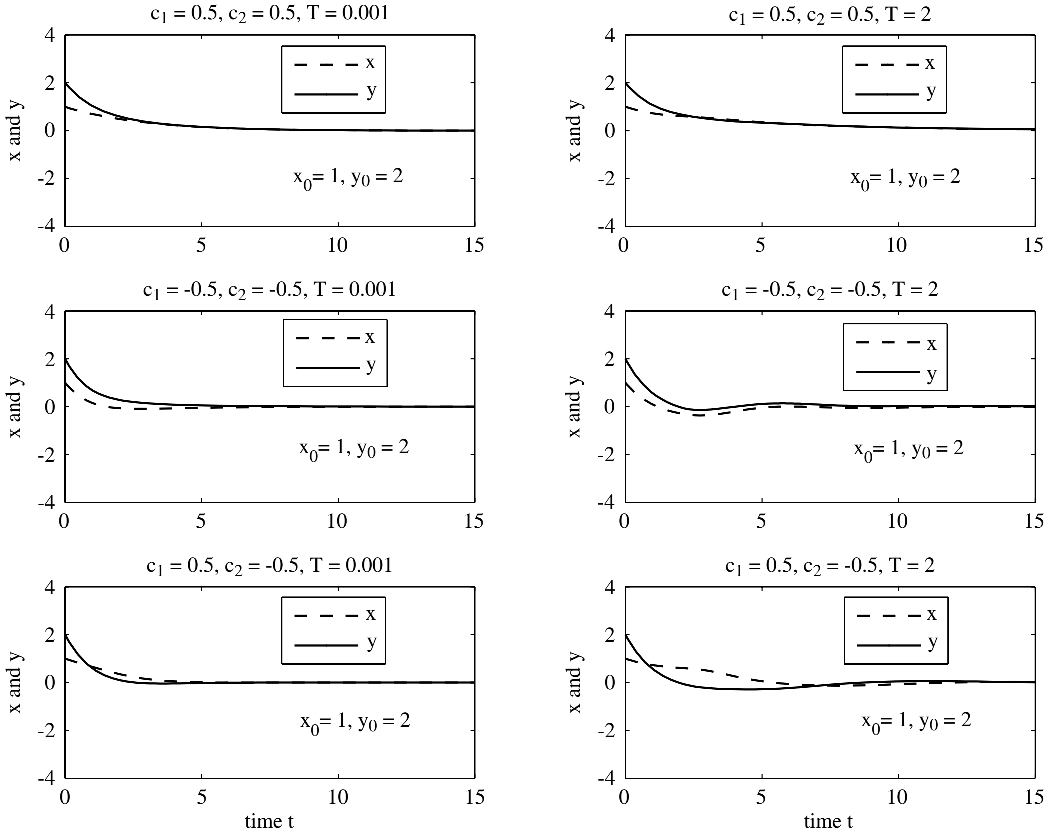

Fig. 1. Results of numerical integration of the states *x* and *y* for two different time delays.

Here, we focused on the effect of time delays on dynamics of a two-actor conflict model [2]. In particular, we evaluate the effect of time delays on the stability of fixed points by means of both theoretical and numerical approaches. We observe that under specific situations sustainable oscillations appear when a time delay is considered. This paper is organized as follows. In Section 2, a brief description of the two-actor conflict model with time delays is presented. The results of the effects of time delays on the stability of the system are described in Section 3. Finally, in Section 4 discussions and some concluding remarks are given.

2. Two-actor conflict model with time delays

We consider the two dimensional model described in Ref. [2] given by:

$$\frac{dx}{dt} = f(x, y) = m_1 x + c_1 \tanh(y_T) \quad (1)$$

$$\frac{dy}{dt} = g(x, y) = m_2 y + c_2 \tanh(x_T) \quad (2)$$

where x and y represent the state of each actor at time t, m_1 and m_2 are constants related to decaying rates, c_1 and c_2 represent the strength of the feedback between the groups and T is a time delay. Given the values of constants m_1, m_2 (representing the inertia moments), and c_1, c_2 (the strength of the feedback), we are interested in evaluating the effects of time delays on three different cases: (i) positive feedback (cooperation) between actors; (ii) negative feedback (competition) between actors; and (iii) mixed feedback (cooperation-competition). For $T = 0$, the dynamics is characterized by the stability properties of the fixed points leading to two main cases: weak feedback ($|c| < |m|$) and strong feedback ($|c| > |m|$). For positive or negative weak feedback, there is only one stable fixed point located at the origin, and both groups tend to the neutral state as the time evolves. As the strength of the feedback increases (positive or negative) two new fixed points appear and the origin becomes an unstable saddle. For the special mixed case, positive–negative feedback, there is only one fixed point at the origin whose eigenvalue is a complex number with negative real part, indicating that both groups tend to the neutral state presenting oscillations with decaying amplitude.

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