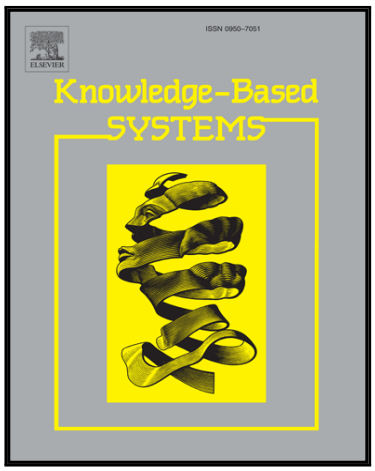

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Computational Models and Optimal Control Strategies for Emotion Contagion in the Human Population in Emergencies☆

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Abstract

Emotions play an important role in the decision-making of individuals. Emotional contagion has an influence on individual and group-level behaviors. Particularly, the contagion of negative emotions like panic emotions may result in devastating consequences in the human population in emergencies. This work develops novel computational models of emotion contagion and solves the optimal control problem of emotion contagion in the human population in emergencies. Firstly, by introducing a concept of latent state and considering complicated interactions among individuals, we develop a novel conceptual model of emotion contagion, and further establish a computational model for describing the dynamics of emotion contagion, called the susceptible-latent-infectious-recovered-susceptible (SLIRS) model. Secondly, by considering vaccination, quarantine and treatment as control measures, we expand the SLIRS model into a controlled SLIRS model, and formulate the control problem of emotion contagion as an optimal control problem, so that the total costs of inhibiting emotion contagion are minimized. Finally, we theoretically discuss the existence and uniqueness of the solution of the controlled SLIRS model, and further derive an optimal control solution of the controlled SLIRS model. The simulation results on the synthesis dataset and the real trace dataset show that the optimal control strategies have significant impact on emotion contagion. Especially, the optimal control strategy with a mixture of vaccination, quarantine and treatment can significantly decrease the scale of the outbreak of negative emotions, and incur the lowest total costs of inhibiting emotion contagion. This enables the optimal decision-making for inhibiting emotion contagion under the consideration of limited resources in the human population in emergencies. Hence, this work will make contributions to crisis management and crowd evacuation in emergencies.

Keywords: emotion contagion, computational model, interaction, differential equation, state transition, optimal control, simulation

1. Introduction

In recent years, sudden disasters such as earthquakes, floods, hurricanes, volcanoes, terrorist attacks and fire disasters have attracted more and more public attention due to their tremendous damage and negative social influence [1, 2]. The large-scale crowd evacuation is an important way for emergency responses of sudden disasters [3, 4, 5]. Many cases have shown that when panic emotions about accidents emerges in some individuals in the human population, their neighboring individuals tend to be infected through emotion contagion, resulting in devastating consequences in the human population in emergencies [6, 7, 8, 9]. Currently, there are many definitions of emotion of individuals. A widely accepted definition of emotion is that emotion is a state of mind of individuals, which is intense short-lived and focuses on a specific target or cause [10]. Emotions of individuals are assumed to be triggered by a certain (internal or external) stimulus, and last usually up to seconds or minutes after the occurrence of the stimulus that triggered them [11]. Functionally, individual emotions about events play a very important role in individual response decision making, and further affect individual behaviors. In general, emotions of individuals may be positive or negative. Especially, positive emotions, like calmness and optimist, may cause an ordered and efficient evacuation, whereas negative emotions, such as panic, anxiety and fear, may lead to confusion and congestion in the large-scale crowd evacuation in emergencies. Although there has been significant research on emotions from a computational perspective, one area scarcely explored is emotional contagion [1, 2, 3, 4, 5, 6, 12]. The so called *emotion contagion* is that a certain emotion in some individuals propagates to other individuals through interactions among individuals, such as face-to-face communications [6]. Emotion contagion is important in group situations where a certain emotional state of an individual influences the behavior of other individuals. Specifically, negative emotions of individuals outbreak through emotion contagion, and further influence collective behaviors, lead-

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