

Emotion Contagion in Agent-based Simulations of Crowds: A Systematic Review

JAAMAS Track

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ABSTRACT

Emotions are known to spread among people, a process called emotion contagion. Both positive and negative emotions are believed to be contagious, but the mass spread of negative emotions has attracted the most attention due to its danger to society. The use of agent-based techniques to simulate emotion contagion in crowds has grown over the last decade and a range of contagion mechanisms and applications have been considered. With this review we aim to give a comprehensive overview of agent-based methods to implement emotion contagion in crowd simulations. We took a systematic approach and collected studies from Web of Science, Scopus, IEEE and ACM that propose agent-based models that include a process of emotion contagion in crowds. We classify the models in three categories based on the mechanism of emotion contagion and analyse the contagion mechanism, application and findings of the studies. Additionally, a broad overview is given of other agent characteristics that are commonly considered in the models. We conclude that there are fundamental theoretical differences among the mechanisms of emotion contagion that reflect a difference in view on the contagion process and its application, although findings from comparative studies are inconclusive. Further, while large theoretical progress has been made in recent years, empirical evaluation of the proposed models is lagging behind due to the complexity of reliably measuring emotions and context in large groups. We make several suggestions on a way forward regarding validation to eventually justify the application of models of emotion contagion in society.

KEYWORDS

Emotion contagion; Crowd simulation; Agent-based; Collective emotion; Computational modelling

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1 INTRODUCTION

Emotion contagion, the flow of affect among people, drives the formation of collective emotion and thereby impacts group dynamics. While both positive and negative emotions have been suggested to

be contagious, research involving crowds has largely focussed on the contagion of negative emotions in scenarios like evacuations, riots and failure of public services. In these events, emotion spirals are thought to trigger collective behaviour that is irrational and difficult to manage. The rapid escalation and potentially severe consequences of such events emphasise the challenge governments, civil engineers, event planners and security staff face in managing emotional crowds. Moreover, factors such as the increasing urbanisation [11] and growing access to internet and social media [12, 14] may facilitate the organisation of (spontaneous) large-scale events and the fast spread of sentiments [1, 3, 7, 8]. Hence, in recent years calls have been echoed to improve the understanding of crowd dynamics, and to develop realistic models and tools that may be used in planning and management decisions and in training.

The present review focusses on agent-based methods to simulate the spread of emotions in human crowds. The bottom-up approach of agent-based models is particularly suitable because it acknowledges the heterogenic nature of the crowd, which is known to affect the emotion contagion process [10]. This area of research draws upon the fields of social and neuroscience to study emergent collective behaviour, by considering individual psychological and cognitive aspects of crowd members at the microscopic level. To improve the resemblance to real crowds, individual variation is frequently included in the emotional state, personality, mood, knowledge, goals and social relationships of agents.

While the number of agent-based models that consider emotion contagion has grown rapidly in recent years, a clear synthesis is lacking on the wide range of contagion mechanisms, simulated scenarios and individual traits that have been considered. Therefore, a systematic literature review dedicated to agent-based models of emotion contagion is important to establish a common baseline and aid further research. We have formulated the following research questions with the aim of producing a structured overview and providing directions for future study: 1) How can the identified agent-based contagion mechanisms be structured into categories? 2) What are the consequences of the fundamental differences among the identified categories of contagion mechanisms for their applications, performance and limitations? 3) What are the current gaps in research involving agent-based emotion contagion?

2 METHODS

A systematic approach was taken to promote the reliability and transparency of the process. We followed the guidelines of Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) for the collection and selection of literature as set out

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in the PRISMA 2020 checklist [13]. We performed a review of the relevant literature in accordance with these guidelines but did not perform a meta-analysis, because most papers included in the review do not report results in a way that facilitates a comparison. Therefore, instead, our objective is to evaluate the emotion contagion mechanisms in two ways that are more suitable to the collected work. The first is by analysing the theoretical consequences and limitations of the different mechanisms to their performance and applications. The second is by reviewing the evidence from studies that directly compare mechanisms of emotion contagion, while keeping the other aspects of the simulated system equal.

We formulated two search queries: 1) “emotion* contagion” AND crowd AND (simulation OR model), and 2) “collective emotion*” AND crowd AND (simulation OR model). The star in emotion* can stand for any set of letters following the word. The final literature search was performed on August 31st 2021 in four databases (Scopus, WoS, IEEE and ACM). In total 170 unique studies were collected, of which 136 studies were excluded based on 7 criteria, leaving 34 studies for analysis.

3 STRUCTURING EMOTION CONTAGION MECHANISMS

To produce a structured overview, we propose three categories of emotion contagion models, called group statistic, epidemiological, dyadic relations (Fig. 1). The two features that delineate categories are 1) whether contagion occurs continuously or categorically and 2) whether the interactions are considered on a dyadic or group level. The group statistic category contains models where the emotion of an agent is affected continuously based on a local group statistic, such as the average emotion (e.g. [2]). The epidemiological-based mechanisms model contagion as a categorical change in state of the receiver, shifting from a susceptible to an infected state (e.g. [6]). The dyadic relations category contains models that consider continuous contagion at a dyadic level, where individual properties of the sender and receiver, such as their personalities and physical distance, determine the flow of emotion between them (e.g. [4]).

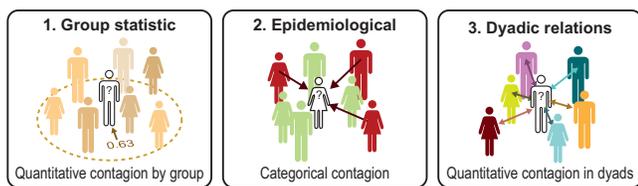


Figure 1: Classification of agent-based mechanisms of emotion contagion.

4 PATTERNS IN PERFORMANCE, APPLICATION AND LIMITATIONS

Data was collected for each selected study on the application, the findings and the method of validation. In summary, we found that most models focussed on emergency scenario’s with either panic or anger as the dominant emotion. Contagion mechanisms of the ‘group statistic’-type are relatively simple, as these do not consider interactions among individuals, but between a (local) group and an

individual. While this has computational benefits, it cannot capture inter-personal factors that are believed to influence emotion contagion. The ‘epidemiological’ and ‘dyadic relations’ categories differ fundamentally in their view of the emotion contagion process. The categorical nature of epidemiological models makes them especially suitable to simulate scenarios where there is a clear difference in emotional states, that can flip like the change from calm to panic. In contrast, models of the ‘dyadic relations’-type assume all levels of emotion are expressed to varying degrees and contagion occurs constantly, including when the level of emotion is very low. If correct, this makes them theoretically more suitable than epidemiological mechanisms to simulate more subtle forms of emotion contagion, like a slow change in atmosphere at a bar. A drawback is the extra computation that is required to calculate contagion among all agents instead of a subset. We conclude that based on only a handful of comparative studies no clear conclusions can be drawn about the performance of the broad categories of contagion mechanisms, despite fundamental differences in the approach.

5 CURRENT KNOWLEDGE GAPS

Despite large theoretical advances over the last decade, we conclude there is a significant knowledge gap with regard to the validity of these models, supported by a lack of shared methodology and data sets. Indeed, validating models that involve emotional groups poses major challenges that stem from both practical and ethical limitations to measuring psychological characteristics of people, especially in uncontrolled conditions [9]. Technically it is difficult to accurately track the emotional state of many people, without invasive procedures or technology that may impact natural behaviour. While still in an early phase, machine learning techniques to recognise emotional expressions may provide a way forward in the future [5]. Further, obtaining psychological data in the wild is restricted by rights to privacy and consent, as this includes highly personal information. Even though collecting data experimentally seems a promising route, because of the possibility to ask for consent, exposing participants to the extreme situations that are the focus of many studies, would pose an unacceptable risk to their safety. And, if the participants are aware that they are recorded and that there is no real personal danger, their behavioural and emotional response may be different from natural situations. Still, after a decade of large theoretical development, advances in empirical evidence are needed to determine to what degree the models can predict the behaviour of emotional crowds under different circumstances to come to practical applications.

First, we recommend that future research aims to establish a clear and shared methodology for validating models of emotion contagion in groups, for which might be drawn upon the experience in social sciences. Second, we recommend that future work focuses on the collection of high-quality data of emotional development in small groups in an experimental setting, to determine the validity of models of emotion contagion at a more fundamental level. This would allow to control for factors like other emotional stimuli, social relations and personality, via careful experiment design and the use of questionnaires. This way a start can be made to determine minimal models that are adequate to simulate specific types of crowds and ultimately justify their application in society.

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