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Designing an Agent-based Simulation of Collective Emotions

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Abstract

The creation and demise of e-communities is strongly influenced by emergent emotional phenomena that warrant study above the level of individuals: collective emotions. For an agent-based simulation of these phenomena, our requirements are constrained both by the data available as well as by the scenarios of use for the simulation. In this paper, we consider both the relation to mathematical models developed in parallel as well as the use of the simulation as decision support for interactive conversational systems. We show how both of these 'docking' attempts inform and contribute to the simulation design.

1 Introduction

Emotional factors play an important role in the interaction of individuals and, while transformed, this is still true for computer-mediated communication in e-communities. The recently started 4-year EU project Cyberemotions[1] has taken on the task of exploring the concept of *collective emotions*, an emotional phenomenon that emerges in e-communities, i.e. among the users of social websites, chats, discussion fora, mailing lists, and similar online media that connect groups of people. Section 2 presents a short characterisation of the concept as well as related notions from theories of emotion that are relevant for the different levels of simulation mentioned later.

An interdisciplinary approach is needed to capture this phenomenon scientifically and a successful account of the dynamics and influence factors of collective emotions has strong implications for detection and intervention possibilities. For this reason, the project connects approaches from psychology, social network analysis, and sociophysics modelling with agent-based simulation and application prototyping using interactive agents. The latter are motivated by a long-term vision to allow online analysis and interactive probing of participants in discussions about the current state and, in the distant future, to potentially enable interventions that prolong positive states and shorten negative ones. This paper takes the stance of agent-based simulation as one building block of this project and presents the design implications of the interdisciplinary endeavour to 'dock' simulation to both mathematical equation-based modelling and real-time application in interactive agents.

Synergies exist between agent-based and equation-based modelling [Norling *et al.*, 2009; Parunak, 2009]. Further, interactive agents can use not only the results of offline simulation as a basis for strategies, but also those of reduced online simulations as input to decision processes. Sections 3 and 4 provide details about resulting requirements. Specifics of agent-based simulation models can also inform the design of the control architecture of conversational systems; another synergy that, however, is not topic of this paper. Finally, section 5 explains design choices prompted by identified requirements, followed by conclusions in section 6. The design provides for different accounts of individual and collective emotions. Varying degrees of affective and cognitive capabilities are planned to fulfill the requirements selectively, building on previous work in affective agent control architectures [Rank *et al.*, 2005; Rank, 2009].

2 Collective Emotions

Consider the reaction of thousands of netizens when a celebrity they admired suddenly dies, or the reaction of developers and users of a piece of open source software when a seemingly minor change in functionality triggers a fork[2] (a split of the development team). Both of these rather different examples can be seen as specimen of *collective emotions*. Psychology, social psychology, and philosophy offer definitions of collective emotions and the related concept of group-based emotions which is, depending on the theory, distinct from the former. This distinction is, e.g., related in [Bar-Tal *et al.*, 2007]; collective emotions are then defined generally as shared by a large number of individuals in a society [Stephan and Stephan, 2000] while group-based emotions are felt by individuals as a result of their membership in a group [Smith, 1993].

[1] http://www.cyberemotions.eu/ (all URLs last accessed 2009-11-29)

[2] See http://developer.pidgin.im/ticket/4986 for an example of a discussion that preceded a fork.

Philosophical accounts of collective emotions focus on the (philosophical) intentionality of emotion, i.e., its *mode*, *content*, and *subject*, to distinguish individual emotion from forms of collective emotions [Schmid, 2008]. The mode defines the kind of emotion and can be shared, e.g. via emotional contagion [Hatfield *et al.*, 1993], or social emotion regulation. This type of collective emotion would be characterised by a group of people sharing the same kind of emotion. The content consists of the *target* at which the feeling is directed, as well as the *concern* making it relevant for the subject. Both target and concern can be shared between individuals, an example would be a group of individuals reacting to the same event. For the subject both the individual that has the emotion, as well as the phenomenal subject, the implicit self as which the emotion is felt, are relevant. The latter allows for the idea of a *plural subject*, some group that is commited to doing something as a body.

For the present project, the main interest lies in conditions for elicitation of collective emotions and particularly their effects on e-communities, their role in forming, strengthening, splitting, or dissolving them. The crucial, and open, theoretical question is the relation of collective emotions to individual emotions in dynamic social networks. The increasing academic interest in the role of (individual) affect for computing resulted in the establishment of the EU-funded Network of Excellence "Human-Machine Interaction Network on Emotion"[3], aiming to contribute to "the development of systems that can register, model and/or influence human emotional and emotion-related states and processes". Since 2004, the network and the subsequently established association have been providing a valuable basis for the study of emotion in human-machine interaction. Its theoretical results [Taylor *et al.*, 2005; Fontaine *et al.*, 2007] as well as our own work as part of the network [Rank *et al.*, 2005; Rank and Petta, 2006; Rank and Petta, 2007] provide a suitable source for the description of emotions at different levels of granularity.

The spectrum starts from the characterisation of emotions as areas in a multi-dimensional space such as pleasure, arousal, and dominance [Mehrabian, 1995] and a rough correlation of the dimensions to physiological parameters like skin conductance rate and specific muscle activation, see e.g. [Kappas and Pecchinenda, 1999]. At the other end, one can find complex process models of the elicitation and behavioural consequences of emotions that relate the notion of concern, i.e. "a motive or need, a major goal or value, a more or less enduring disposition to prefer particular states of the world" [Frijda, 2007] p.7, through evaluation criteria to processes of appraisal and regulation [Frijda, 1986; Ellsworth and Scherer, 2003].

A succcessful use of modelling and simulation for the purpose of decision support and understanding [Ören, 2009; Epstein, 2008] depends on the availability of reference data. For the realm of individual emotions this consists of self-report as well as behavioural and physiological measurements [Mauss and Robinson, 2009], including laboratory measurement of physiological correlates of emotional responses during interaction in experimental settings [Kappas and Pecchinenda, 1999]. This type of data relates mostly to dimensional accounts of emotional states. Data about online communication consists mainly of anonymised message exchanges collected from online channels such as MySpace, news fora, blogs, or Internet Relay Chat (IRC). Compared to human face-to-face interaction these communication channels are severely impoverished. Only rarely messages are annotated with affective valences, e.g. mood icons for posts in discussion fora, leaving automatic classification as the most practical option [Dodds and Danforth, 2009]. Part of the project are efforts to incrementally improve automatic methods for annotating text messages in online communication with valences using different classification methods [Prabowo and Thelwall, 2009] as well as to adapt the methods to further kinds of online channels acknowledging the different communication styles used. As a bare minimum, the annotation of individual messages with separate values of positivity and negativity is assumed.

An important requirement for agent-based simulation of collective emotions is therefore to balance the connection to available data with the levels of cognitive capabilities indicated by different accounts of individual emotions. For simulations that incorporate more complex notions of individual emotion processes, their value for the purpose of understanding lies also in the operationalisation of theories, even before there are corresponding methods of more direct evaluation based on data.

3 Equation-based Modelling

A starting point for the study of the influence of collective emotions is opinion dynamics [Holyst *et al.*, 2001; Hegselmann and Krause, 2002; Lorenz, 2008]. In continuous opinion dynamics models, agents hold a fixed set of opinions modelled as continuous values. Overall these models are characterised by the assumption of mostly homogenous agents, potentially distinguishing between different bounds of confidence, the analysis of results focuses on consensus, polarisation, or fragmentation in the simulated population, typically illustrated with bifurcation diagrams. This modelling approach lends itself to mathematical formulation and analysis in terms of master and rate equations [Lerman and Galstyan, 2001]. These models are examples of sociophysics, i.e. the application of methods that are successful in physics to large scale social phenomena: social processes are characterised in analogy to physical quantities and the analysis aims to identify general laws such as the applicability of fluctuation scaling [Eisler *et al.*, 2008] or power-law behaviour in empirical data [Clauset *et al.*, 2009]. While equation-based models offer the prospect of strong clarity of understanding, an agent-based simulation is complementary and allows for model-to-model analysis [Hales *et al.*, 2003] by *dock-*

[3]HUMAINE http://emotion-research.net/

ing the different simulation models [Axtell *et al.*, 1996; Parunak, 2009]. Prerequisites are studying the same phenomenon, ensured by the relation to data collected during the project, and comparable parameters and outcomes of the simulations. For general mathematical models of collective emotions, a dimensional account of emotion is, at least initially, suitable, quantifying emotional states of individuals and aggregate entities as points in a three-dimensional space of valence, arousal, and dominance.

4 Use in Interactive Systems

As part of the Cyberemotions project, the development of conversational systems that interact with users of network communication channels is undertaken. These systems communicate with Internet users to probe for affective states and related background knowledge. We call these kinds of systems *Affect Listeners*, sharing the following characteristics: They communicate with users, rely on integrated affective sentiment analysis for detecting textual expressions of the users' affective states, and use the acquired information to aid generation and selection of responses. Affect Listeners monitor events and processes that draw attention of Internet users, by analysing content of websites (e.g., semi-automatic news aggregators or folksonomy-driven sites[4]).

Affect Listeners interact with users via a range of communication channels and interfaces, both predominantly synchronous ones (e.g., Internet Relay Chat, Jabber/XMPP, online chat sites) and asynchronous ones such as online fora. The aim is to adapt to the users' affective states, and to suitably respond to utterances both on the content- and the affect-related level. The planned evaluation scenarios include also application in laboratory settings for measuring physiological correlates of emotional responses during interaction in experiments.

The system-user communication is text-based, real-time and oriented at detection and acquisition of users' affective states. The initial realisation is an open-domain system, i.e., communication is not limited to a specific domain, topic, or ICT-mediated community. The functionality of the conversational systems consists of direct conversation with user, listening to multi-party conversations, and, in later iterations, targeted interventions. Of course, conversational systems like these, are strongly limited in the sense that they cannot match the conversational abilities of humans. However, this is neither the goal of the Affect Listener systems nor required for them to fulfill their purpose. While the interaction is, as mentioned above, unrestricted, the domain is constrained in so far as the system concerns itself only with the emotional states of individual participants as well as the dynamics of collective emotions and employs suitable strategies to keep the conversation going.

The role of agent-based simulation in this kind of interactive system is decision support. This entails several requirements that concern both the results of simulation runs as well as runtime characteristics and the adaptability of the simulation based on data collected during previous interactions. Relevant questions that a conversational system would benefit from getting answers to are:

- Which individual in a group is most likely to provide an accurate response to probing about the group's emotional state, and which one will be most reliable?
- What influence can individuals have on the evolution of the collective emotions in an e-community, and which of the specific participants is likely to have the biggest influence?
- Can potential escalations, both in the negative and in the positive direction, be detected early on?
- What influence will a specific intervention of the conversational system have at the current moment, and which style of intervention is most effective?

While offline simulation, as well as the results of equation-based models, can be very helpful for the control architecture of these conversational systems, the potential for interactive use, i.e., running a simulation on demand to query about the above questions, is most promising. This not only adds the requirement of timely, or ideally anytime, responses but also the need to parameterise the simulation to adapt it to the current state of an e-community, ideally using the recorded history.

5 Agent-Based Approach

As a starting point for the implementation of an agent-based simulation of collective emotions in e-communities, we designed a simulation that exhibits the same statistical properties as one of the first datasets collected in the project. The website of the BBC offers topical message boards, i.e. discussion fora, to its visitors. These fora often host heated debates, and a subset of these were selected for initial data collection as part of the Cyberemotions project. Many newly posted discussion topics never get any answer from another user and only some of them will grow to considerable length. The dataset consists of a set of messages, each linked to a specific discussion thread, and originating from a specific user. The messages in a thread are ordered temporally and they have a certain length. Figures 1 and 2 show histograms of the number of messages posted in a thread and the number of users that participate in a thread.

Initially, we ignore any affective annotation of the data or reply-relations that show a more detailled communication structure. Starting with a model of non-affective comunication provides a basis for the selective introduction of emotional model elements to enrich the simulation incrementally and allows for the comparison to previous iterations. Since the affective annotation in datasets encodes affective content as attributes of the messages rather than as affective states of the agents, we chose a simple attribute of messages,

[4] An example is http://www.reddit.com/

their length, as next target for simulations. Figure 3 shows a histogram of the average lengths of all messages sent by a user. Further iterations will replace this element of the model with affective annotations as they become available. While the structure of different communication channels that are of interest in the project is different, especially concerning synchronicity and other temporal characteristics as well as typical message length (cf. Internet Relay Chat and instant messaging versus discussion fora), the structure of this dataset is suitable for a prototype since the basic elements are there: agents, messages, as well as groupings of these, e.g. threads.

5.1 Implementation Tools

As initial implementation platform, we selected the framework MASON [Luke *et al.*, 2005] in combination with the social networks package JUNG. The baseline simulation of message exchanges relies on probability settings for the agent population, divided into a number of groups. The probabilities influence the likelihood of an individual agent to start a new discussion, to read recently posted messages, and to respond to read messages. Further iterations adjust the latter two probabilities based on message lengths while the length of messages generated is randomly selected from a predefined range. Such parameterisation is not suitable for a theoretical account of statistical features found, however, it provides a starting point for further development and for comparison with equation-based models.

5.2 Simulated Collective Emotions

A simulation of collective emotions should account for different possible types of collective emotions, as described in section 2. *Sharing subjecthood* can be accounted for most directly: by tracking different groups of agents, distinguished e.g. simply by participating in a discussion thread, these groups can be modelled as plural subjects. For *sharing the mode* of an emotion, or its content, i.e. *target* and *concern*, the design of the baseline model needs to be adapted. The mode requires first of all a representation of emotion in the system. As explained above, dimensional characterisations of emotion, while less than ideal for in-depth modelling of processes related to emotions, provide a baseline in this respect. For sharing the mode, one of the following is needed:

- The emotional content of a set of posts is aggregated by, e.g., requiring them to be close to each other in the dimensional space used and/or to be related through the structure of the communication system or by an external object.
- The emotional state of agents is modelled based on initial settings and a model of emotion dynamics. Similarly to messages, the emotional states of a set of agents can then be aggregated.

Shared content can be analysed separately for shared targets of emotions and for sharing concerns. However, the emotional annotation needs to include the targets of emotion:

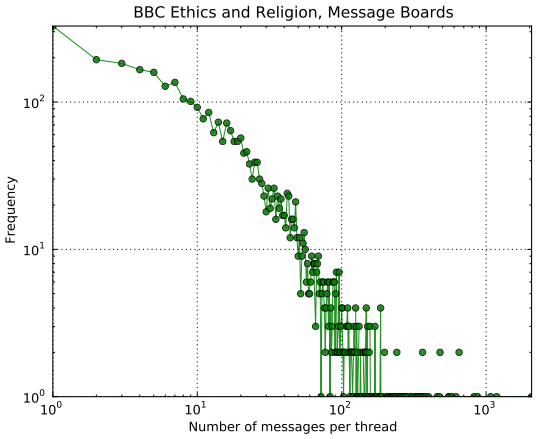

Figure 1: The distribution of the number of messages in a discussion thread.

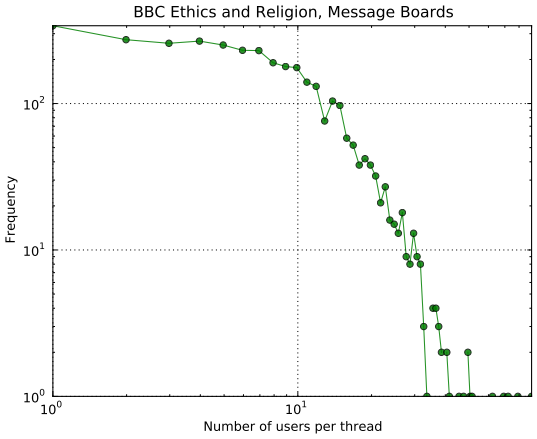

Figure 2: The distribution of the number of participants in a discussion thread.

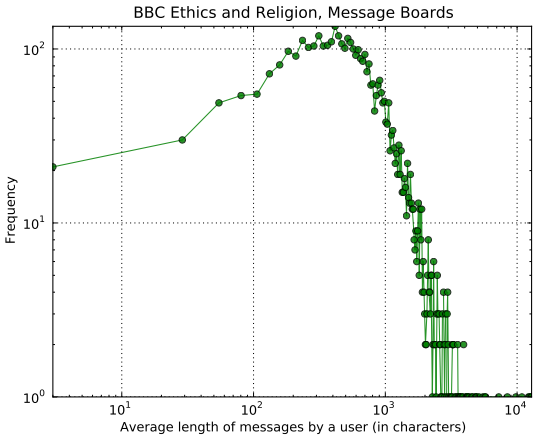

Figure 3: The distribution of the average length of messages by a user.

- As a first step, only messages and communicating agents are potential targets.
- A full model needs to allow for external objects as targets and referents of messages.

For shared concerns, the explicit modelling of concerns of participating agents is necessary. The next subsection will provide more details on the planned design. An aggregate of a set of agents can be used to model such a shared concern. Apart from these design choices regarding the complexity of the cognitive capabilities of agents, representations of exchanged messages can range from annotations with values for positivity and negativity to the introduction of referent objects and tagged values that code for *action tendencies* reflected in messages.

5.3 Degrees of Affective Capabilities

One of the goals of this project is to iteratively enhance this stochasting baseline simulation using elements of the operationalisation of appraisal processes as described in theories of emotion. The minimum requirements for the modelling of appraisal processes in an affective agent architecture are representations of an agent's concerns or desires, including standards about praise- or blameworthy behaviour, as well as preferences for certain types of objects or situations. Further, a method for evaluating changes in an agent's environment based on these is needed. For the purpose of e-communities, the changes to be evaluated encompass the posted messages and their content as far as it is modelled, but also the perceived entrance or exit of participants in a discussion. We expect that the introduction of specific *surface concerns* and a suitable approximation of an agent's evaluation processes could account for observed behaviour in e-communities. This level of affective capabilities is not directly relatable to existing datasets, but results could be an indication for beneficial extensions of future data collection efforts and are of theoretical interest by themselves. A simple example is the effect of daytime on the behaviour of participants in an online channel. Modelling not only the location of participants, i.e. timezone, but also concerns regarding engagement with the communication channel depending on daytime would account for these effects.

5.4 Comparability of Results

To ensure comparability of results betweeen different levels of simulation and different modelling methods, the available data serves as reference frame. The tracking of groups of agents and membership in groups forms the basis for accounts of both plural subjects and sharing the mode of emotions, as well as for the evaluation of simulation results concerning creation, partitioning and dissolving of (sub-)communities. The status of these aggregate entities, as well as standard network measures provide a common denominator for the comparison of simulation results. Increased complexity of more refined groupings necessarily limits the size of the simulation, but it also offers an increasing potential for iterative development and introduction of further emotional model features. Exploiting simulation results in conversational systems benefits from the possibility of parameterisation of simulations based on data collected by these systems. The current state of individual agents, of groups of agents, or of parts of the communication channel as detected by a conversational system should influence simulation runs to reflect the probabilities of future developments of the actual environment the system is facing.

6 Conclusions

We presented the design choices for an agent-based simulation of collective emotions in e-communities. The relation to mathematical models developed in parallel influences the choice of a baseline simulation as well as the requirements for the simulation outcomes. The use of the simulation as decision support for interactive conversational systems adds different requirements including real-time and online use. Both of these connections contribute to the design of the simulation and will be references during its evolution.

Future work, apart from implementing those elements of the design presented here, will focus on modelling the potential role of individuals in the genesis of collective emotions; as mentioned, this is an important aspect for the use in interactive agents. Similarly, the effect of intervention types on the evolution of e-communities will be studied in close collaboration with the development of conversational systems.

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