Emotion Contagion among Affective Agents
Issues and Discussion

Mara Pudane[1], Michael A.Radin[2] and Bernard Brooks[2]
[1]*Department of Artificial Intelligence and Systems Engineering, Riga Technical University, Kalku 1, Riga LV–1658, Latvia*
[2]*Rochester Institute of Technology, Rochester, New York 14623, U.S.A.*

Keywords: Agent based Simulation, Affective Agents, Emotion Contagion.

Abstract: Emotional contagion is a mechanism which results in transferring an emotion from one person to another; in fact, it has been proven to be one of the key factors in successful crowd managing and preserving an amiable working atmosphere. However, believable simulation of a group of people with social links amongst them requires not only complex interaction models but also complex internal models as well. This paper describes the progress of an on-going research that explores and simulates various types of emotions while they are being transmitted amongst affective intelligent agents that are connected in simulated social structure. The internal mechanism of agents is based on affective agent architectures while the contagion and its rules are being modelled by using tools from graph theory.

1 INTRODUCTION

Emotions are one of the currently trending topics in various research fields, i.e., psychology, sociology as well as computer science. Previously there has been a long discussion on whether emotions are good, harmful or if they are needed at all; however, lately the consensus amongst the scientists is that emotions are a very crucial part of rational thinking. It is considered that emotions provide humans with necessary adaptation mechanisms as well as allows to make extremely complex decisions with very limited resources.

In the light of these findings, series of research on various internal and external emotion-related mechanisms have emerged. Especially, in 1997, the affective computing was defined (Picard, 1997). It explores how artificial units (such as intelligent agent) and systems can benefit from implementation of affect (broad term for variety of emotion related concepts - emotion, mood, personality etc.) on various complexity levels. Affective computing mostly deals with system's internal structure as well as emotion acquisition and expression thus enabling creation of systems that behave, think or appear to think similarly as a human. However, apart from that, another direction is external mechanisms including emotional interactions among emotional units.

One of such mechanisms is an emotion contagion: the ability to "catch" other people's emotions using the body as emotion elicitor (Hatfield et al., 1993). Emotion contagion is based on bodily feeling theories (see i.e., Damasio, 1994) that proposes emotions that are generated by responding to certain body poses and mimicry.

A proper emotion contagion model would be beneficial not only for practical use but also for research purposes - e.g., it could lead to better understanding of how various higher level affects, such as mood, impact emotional states of group individuals, as well as understanding how the atmosphere of human group develops.

Agent based models are ideal for expressing the knowledge of subject experts in mathematical model and have already been used to model contagion (Bosse et al., 2015), as well as rumour flow on networks (Brooks et al., 2013).

This paper will present preliminary stages, ideas and observations of the research that aims at fully simulating emotional contagion mechanisms. Section 2 presents related work; Section 3 focuses on affective basis of emotion research. Section 4 describes microstructure – i.e., the internal structure of agents, while Section 5 focuses on details of macrostructure – topography of network and transfer rules. Section 6 provides some final notes as well as conclusions.

Pudane M., Radin M. and Brooks B.
Emotion Contagion among Affective Agents - Issues and Discussion.
DOI: 10.5220/0006252603280334
In *Proceedings of the 9th International Conference on Agents and Artificial Intelligence (ICAART 2017)*, pages 328-334
ISBN: 978-989-758-219-6

2 RELATED WORK

A certain amount of attention has been turned to emotion contagion within the past several years as human resource management and research of crowds have become increasingly important. Emotional contagion can be separated into two various mechanisms, namely, primitive emotional contagion which includes mimicking of emotions subconsciously and secondary emotional contagion that involves cognition (Barsade, 2002). The cognition involvement into emotional contagion makes it more complex as it includes social relations and empathy.

The primitive emotion contagion directly refers to group of people that do not have strongly defined structure, i.e., crowd. For this reason, there are some developments that are focused on emotion contagion in crowd for various purposes, i.e., researching how to prevent riots (Bassi, 2006), or to create a learning system - i.e., teaching soldiers how to prevent crowd from becoming unpredictable and uncontrollable by simulation (Aydt et al., 2011).

It has also been proven that an emotional contagion refers to a web environment. Thus this phenomenon has been researched in large scale social networks. Controversial research was conducted by analysing an emotional level in Facebook news feeds (Kramer et al., 2014). Similarly, (AlSagri and Ykhlef, 2016) also focuses on emotion contagion research in online communities; their focus is to reduce contagion of negative emotions.

Despite conducting much research regarding social networks, emotion contagion greatly differs depending on how an emotion is expressed. Thus, the contagion method that works successfully for emotions that are expressed and acquired via written text will substantially differ from the one that works with emotions acquired from facial or vocal expressions. Also, the emotion contagion for the group with practically no structure (i.e., crowd) will differ from a social group where people have links with various weights amongst them. Thus, most of these models cannot be directly applied for modelling a group of people who know each other.

There have also been general models of emotion contagion, i.e., (Bosse et al., 2015). This particular research includes a mathematical model of the spiral effect (i.e., the property of emotion amplifying) in group dynamics. The model of separate group members is also very elaborate and includes not only some personality factors of group members (e.g., expressiveness) but also multi-weighted relationships amongst the people (Bosse et al., 2015). The model also provides mathematical analysis of an emotional contagion. As the authors themselves notice though, the model focuses on only one type of emotion.

Another general framework was developed by (Bispo and Paiva, 2009). It models five emotions: fear, sadness, joy, anger and love. The choice of these emotions comes from theory of Emotional Contagion Scale (Doherty, 1997). The model includes expressiveness and energy of various emotions as well as considering various personalities as a minimum and maximum variable for each emotion.

Although some of the models that allow simulating emotional contagion are elaborate, they still lack internal mechanisms of agents that would enhance the system’s believability.

3 AFFECTIVE BASIS

There are several mechanisms of the system that must be considered and pertinent questions that must be answered from the perspective of psychology and sociology to simulate the emotional contagion.

- Personality of involved people. How to properly represent the personality of people? What personality traits impact the emotional contagion?
- Contagion of various emotions. What emotions to model? How various emotions would interact with rational agent? What should be the internal mechanism of agent to consider secondary emotional contagion?
- Generation of believable network structure. What should be the network structure to be considered believable?
- Emotion contagion patterns. What are mechanisms or patterns that are involved into emotion contagion in a group?

3.1 Personality Impact

The personality of involved people influences the emotional contagion in general as well as emotional intensity level of one individual. Personality in primitive emotion contagion impacts two things, namely, how fast does the emotion spread (i.e., the expressiveness of emotion) and how deep is the impact of an emotional contagion (i.e., susceptibility) (Barsade, 2002). Although some of the related works consider personality as expressiveness and susceptibility variable (e.g., Bosse et al., 2009), these models do not explain what types of personalities have high or low susceptibility, as well as what kind of personality traits impact these factors. The Big Five model is currently the most used and best verified model that allows modelling personality as a combination of five traits: Openness, Conscientiousness, Extroversion, Agreeableness, and Neuroticism (McCrae and Costa, 2003). The usage of such psychologically grounded model would enable better exploration of group of humans, as there are researches that have focused, e.g., on how these traits impact interaction (Pease and Lewis, 2015).

3.2 Types of Emotions

Another vital question to consider is what types of emotions to model. This question has been addressed in affective computing literature as it is one of the basic questions along with how to combine various types of emotion (Hudlicka, 2015). In case of primitive emotional contagion, the process depends on how the emotion is expressed and whether the receiver of emotion has the same bodily feeling. For this reason, it makes sense to model 6 basic emotions identified by (Ekman, 1992): fear, surprise, anger, joy, sadness and disgust. These emotions have been found to be universal amongst the various ages and cultures (Ekman, 1992), thus triggering same emotional responses in various people. Basic emotions also correspond to Damasio's primary emotions (Damasio, 1994).

The secondary emotional contagion, on the other hand, involves not only imitation mechanisms but also social and cognitive evaluation of other's emotion (Barsade, 2002). One option for modelling secondary emotional contagion would be to model same emotions as for primitive contagion, however it does not provide intended diversity of the model.

To simulate such mechanisms, appropriate psychological background is required. The view on emotions separates theories of emotion into three groups: categorical theories (such as Ekman's theory of six basic emotions), dimensional theories and appraisal theories (Lisetti and Hudlicka, 2015).

Appraisal theories reflect agent's cognitive evaluation of the world state in terms of its goals, beliefs, behavioural capabilities and available resources (Lisetti and Hudlicka, 2015). One of the most used models (Lisetti and Hudlicka, 2015) is OCC model (Ortony et al., 1988) which groups emotions into three categories one of them being feelings towards other agent's actions. OCC allows to describe the emotional relations amongst the agents, however, these emotions are related to agent's own emotional state thus is not suitable for direct representation of an emotional contagion. The appraisal theories, however, could be used for an agent to deduce what the other is feeling.

Dimensional theories are theories that explain emotions as a value in multi-dimensional space. One of the most used examples of that is PAD space (Russel and Mehrabian, 1977) that models emotions in Pleasure-Arousal-Dominance space. The research has been conducted based on PAD model the result of which was PAD values for 151 emotions (Russel and Mehrabian, 1977). As there is such formalisation available for this model, theoretically any of these emotions could be modelled, although it would make model unnecessary complex. Russel and Mehrabian offer eight mood types depending on positive or negative values of PAD. These moods are used e.g. in (Gebhard, 2005) to create believable virtual agent. Modelling these moods would make an agent more flexible and would allow to orient itself in a large space of possible PAD value combinations.

3.3 Structure of Network

As mentioned previously, this research focuses on real-life person group. Although such a graph can be obtained by analysing an existing structure (e.g., research lab), we have chosen to generate graphs artificially, elaborated more in section 5. By generating artificial graphs that replicate real graphs we can repeat the Monte Carlo experiments and our results will not be only a function of the few real graphs' topology. There are some things to be considered, regarding relationships amongst the people. The emotional contagion is stronger amongst people that are more connected (Barsade, 2002), the weight can either represent a relationship, or the frequency of the contact during the average day.

The weight of a link would impact, first, whether agent gets emotion at all. Secondly, it would impact intensity of experienced emotion.

3.4 Mechanisms of Emotional Contagion

Although primitive emotional contagion happens in direct interaction amongst two people, there are some more complex mechanisms associated with emotional contagion modelling. One of such mechanisms is so called spiral effect – when mood of entire group becomes worse or better than that of one individual (Barsade, 2002). In (Bosse et al.,

2015) it is modelled as depending on individuals, i.e., each unit in a model has tendency to turn emotions either up or down. These tendencies can be associated with personality in terms of OCEAN model to create more believable models that can also be analysed from point of view of sociology.

We do not consider patterns where an agent is feeling opposite emotions than the other (e.g., gloating if another agent is angry or sad). Although such patterns appear in real-life networks as well as in emotion related literature (e.g. in OCC), it is unclear whether such "negative contagion" can be modelled with the same mechanisms or can be considered as a contagion at all.

4 MICRO LEVEL

Based on issues discussed before, this and next chapter is focused on micro and macro levels of the system (Wooldridge, 2009). The micro level concerns one unit's, in this case, the agent's, architecture and functionality. The macro level focuses on how these agents should interact in terms of interaction protocols and other technical issues that concern architecture of the entire system.

4.1 The Architecture of an Agent

The internal architecture of an affective agent consists of two abstract interrelated parts – emotional computation model and rational processes model (Marsella and Gratch, 2009) as well as defines relations amongst these two parts. Emotional computation model uses one or more emotional theories, some of which are described in Section 3.2. One promising way for modelling affective processes among other options is vertically layered architectures (Wooldridge, 1999). This type of architectures enable organizing rational reasoning components as well as emotion computation components into layers where only some are connected to external environment directly. Such architectures have been successfully applied in multi agent simulations, i.e. in (Tavakoli et al., 2014).

The architecture that we will apply in this research is described in (Pudane et al., 2016). It consists of three interconnected layers: primary emotion layer, secondary (cognitive) emotion layer and tertiary (self-reflection and social) emotion layer (see Figure 1).

The used architecture allows not only rapid stimulus processing on the primary level (i.e., startling from something) but also cognitive and social processing of stimulus on secondary and tertiary levels.

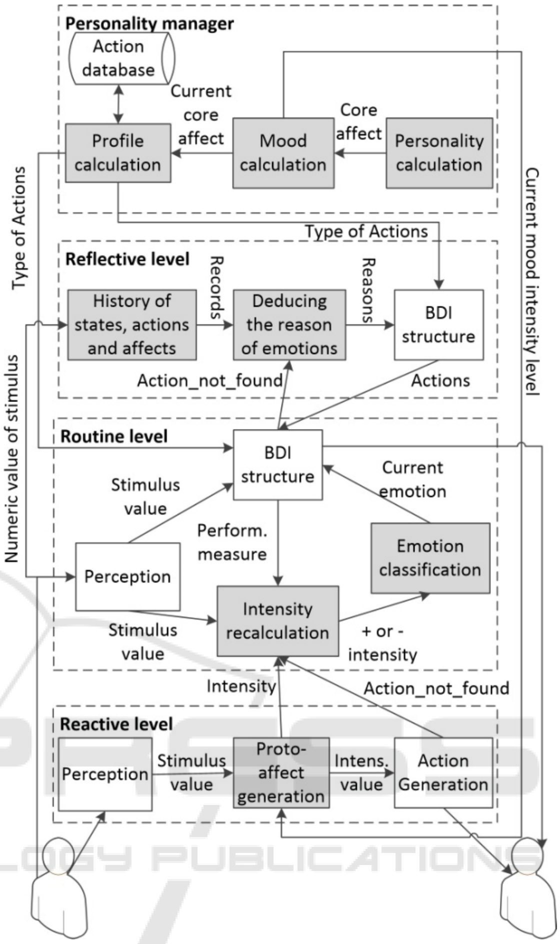

Figure 1: The internal structure of agent.

In an emotional contagion, the primary layer generates primitive emotional contagion responses. The secondary emotional contagion would appear on higher levels, i.e., secondary level that compares the world state to agents Desires and tertiary level that allows to self-reflect and contains social Believes.

4.2. Affective Mechanism of Agent

Agent's affective mechanism of emotional contagion consists of three parts: personality calculation, rapid (primitive) emotional state evaluation and expression as well as performing secondary emotional contagion.

First some processing of agent's personality is needed. Initially it is defined as a set of OCEAN model values. Then those values are transformed into agent's default mood, defined in PAD space –

as done in (Petrovica and Pudane, 2016). This transformation allows associating the OCEAN model with personality functions.

The default mood further impacts parameters of the four functions: the activation function and decay function for emotional state generation (for more information see Petrovica and Pudane, 2016) as well as susceptibility threshold and expression function for emotional contagion. All of the functions are being modelled separately for each of the basic emotions.

Activation function maps objective intensity of irritation to subjective intensity. Sigmoid was chosen as a type of activation function, as it allows more believable activation of emotions by enabling emotion saturation and synergy properties (Picard, 1997). People also do not stay at high emotional state for a very long time: they eventually go back to their default mood thus the second function is exponential Decay function.

Similarly, for each personality there is a level of emotional intensity at which the emotion is started to display (modelled as a threshold Susceptibility function). The Expression function, similarly as Activation function, is a sigmoid and determines how actively the emotion will be expressed.

To implement the second level contagion, higher levels of architecture are used. In the three-layered architecture described before moving to higher levels happens when the action in lower level cannot be found (Pudane et al., 2016). Similarly, in the case of an emotional contagion, if the emotion expression cannot be started because the intensity of an emotion is not above the susceptibility level, the agent still starts processing it. The rational processing is based on both, social and personal, Believes and Goals. Believes also contain relationship weights, depending on which, agent turns the intensity of emotion up (thus emotion may reach the susceptibility threshold and can be shown) or down (thus fastening decay). Social Believe set also include the agent's believes of what are other agent's personalities. For example, if agent knows that another agent is very expressive, he might not feel as upset when another agent expresses sad emotion. Similarly, the Believe about which of the 8 types of moods another agent has, might lead to change in emotional intensity.

The entire mechanism of calculating emotions is shown in Figure 2. After the irritation comes, the objective strength of emotional response is determined (Petrovica and Pudane, 2016). In case of an emotional contagion, the objective strength of emotion is equal to output of first agent's expression function value.

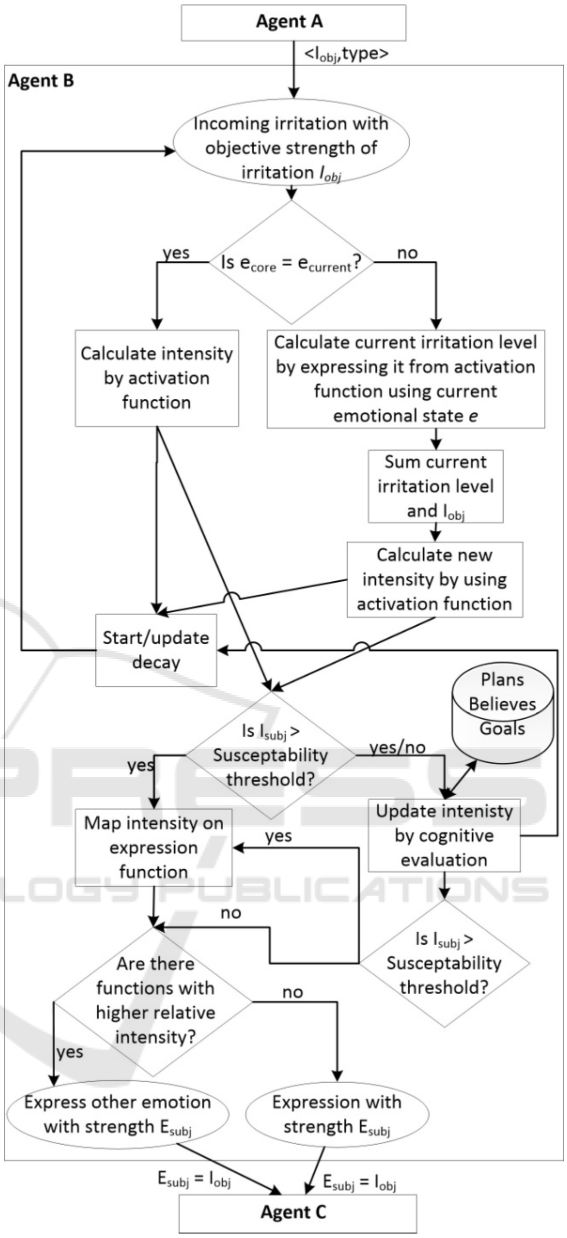

Figure 2: The process of emotional contagion.

The objective value is then applied to current agent's activation and decay functions (which in turn depend on personality) thus calculating the subjective value.

If subjective value is above this threshold, the expression strength is calculated, if not, emotion is still passed to cognitive processing. The output of cognitive processing is new value of emotional intensity which may either fasten decay causing it to drop or reach susceptibility threshold allowing to express emotion. Otherwise the contagion stops.

If two emotions are above the susceptibility threshold, then the relatively highest value is chosen, i.e., if max happiness value of an agent is 5 and max fear value is 3, and current value for both emotions is 2, fear will be expressed instead of happiness.

If there is more than one interaction in a short time period, each type of emotion is processed in its own thread (thus finding the most intensive). If emotions are of the same type, they are processed one by one as shown in Figure 2.

5 MACRO LEVEL

Macro level of a system concerns two issues – how the structure graph is modelled and how the dynamic part of the simulation is executed. The structure of network represents the interaction link amongst the people – i.e., if they know each other and impact each other. The dynamic part of the network runs a simulation based on the structure, representing interactions during specific period of time.

5.1 Structure of Network

The graphs (networks) on which the Monte Carlo experiments will be run will need to be calibrated to real networks. Thus, network metrics such as degree distribution, clustering coefficient and importance measures should match those of real networks. Real networks often display a degree distribution that follows a power law with a few people have many connections and most people having only a few connections.

To randomly generate a network the Barabasi Albert algorithm (Barabasi and Albert, 1999) will be used. This method of randomly creating a network begins with a small graph and adds people (nodes) one at a time until the desired total number of people are connected to the network. Each new node to be added to the network is connected to 2 already connected nodes. The 2 already connected nodes are chosen with a probability proportional to their degree. Hence people who already have many connections have a high probability of acquiring new connections; the rich get richer.

The Barabasi Albert algorithm can be modified in order to better match the particular parameters of target networks. In addition, the people in the network can be considered as identical and the network homogeneous or the network can be comprised of different types of people. It has been shown that the distribution of the different types of people on a network can affect the flow of a contagion-like phenomenon over a network. (Brooks, 2013)

5.2 Simulation in a Network

The agents in this model will alter and transmit their emotional contagions according to axioms grounded in the psychological literature. Monte Carlo experiments will show how these contagions flow across the network.

The simulations will be based on transmitting rules that will depend on agents' personality and weight on edges in network structure.

There are two possible options how weight can impact transmitting rules.

- The weights represent the average value of interaction frequency amongst the people. In this case the weights would increase or decrease the probability that the people would “meet” in simulation.
- The weights represent close relationship amongst the people. In this case the rules will be implemented by using Believe set in agent architecture.

All the rest contagion rules depend on functions described in Section 4.2. If agent does not express emotion, contagion stops.

6 CONCLUSIONS

The paper discusses technical issues as well as affective mechanisms needed for full simulation model of emotional contagion. The model will allow implementing both primitive and secondary (cognitive) emotional contagion mechanisms to simulate real-life group of people.

Such system would enable a lot of features currently simplified in existing models or eliminated at all - such as multiple emotion integration.

The main success of the proposed system is dual focus on both – micro- and macro- levels. It implements rich model for internal agent structure thus enabling agents with full-fledged emotions. Furthermore, the mechanisms described here would enable simulating groups of agents that ensures believable interaction with the user.

This is an on-going research; the future work includes architecture as well as dynamic simulation implementations. Mathematical analysis will be performed as well.

There are some mechanisms that so far are not planned to implement, however it would be of paramount interest to be considered. One such thing would be the simulation of a full working day that would include various interaction events, i.e., meetings. Another issue was already mentioned above – it would be interesting to see how a "negative emotion contagion" works.

ACKNOWLEDGEMENTS

This work is partly funded by Faculty of Computer Science and Information Technology (Riga Technical University) assigned Doctoral grant DOK.DITF/16 and Latvian National Research Program SOPHIS grant No.10-4/VPP-4/11.

REFERENCES

AlSagri, H., Ykhlef, M., 2016. A Framework for Analyzing and Detracting Negative Emotional Contagion in Online Social Networks. In *Proceedings of ICICS 2016.*

Aydt, H., Lees, M., Luo, L., Cai, W., Hean Low, M.Y., Kadirvelen, S.K., 2011. A Computational Model of Emotions for Agent-based Crowds in Serious Games. In *Proceedings of IEEE/WIC/ACM International Conferences on WI-IAT*, vol. 2, pp. 72-80.

Barabasi, A.L., Albert, R., 1999. Emergence of scaling in random networks. In: *Science*, vol. 286, pp. 509–512.

Barsade, S.G., 2002. The Ripple Effect: Emotional Contagion and Its Influence on Group Behavior. In *Administrative Science Quarterly*, 47, pp. 644–675.

Bassi, B., 2006. Computer Simulation of Crowd Dynamics and Destructive Crowd Behavior. Honors Scholar Theses.

Bispo, J., Paiva, A., 2009. A Model for Emotional Contagion Based on the Emotional Contagion Scale. In *Proceedings of ACII 2009*, pp. 1-6.

Bosse, T., Duell, R., Memon, Z.A., Treur, J., and Wal, C.N. van der, 2015. Agent-Based Modelling of Emotion Contagion in Groups. In *Cognitive Computation Journal*. In press.

Brooks, B.P, 2013. Rumour Propagation on Social Networks as a Function of Diversity. In *Advanced Dynamic Modeling of Economic and Social Systems: Studies in Computational Intelligence,* vol. 448/2013, pp. 49-60.

Brooks, B.P., DiFonzo, N., Ross, D., 2013. GBN-Dialogue Model of Outgroup-Negative Rumor Transmission: Group Membership, Belief, and Novelty. In *Nonlinear Dynamics, Psychology and Life Sciences*, vol. 17, no. 2, pp. 269-293.

Damasio, A., 1994. *Descartes' Error, Emotion Reason and the Human Brain*, Avon Books. New York.

Doherty, R.W., 1997. The Emotional Contagion Scale: Measure of Individual Differences. In *Journal of Nonverbal Behavior*, vol. 21, pp. 131-154.

Ekman, P., 1992. Are there basic emotions? In *Psychological Review*, vol. 99, no. 3, pp. 550-553.

Gebhard, P., 2005. ALMA - A Layered Model of Affect. In *Proceedings of AAMAS'05*, pp. 29-36.

Hatfield, E., Cacioppo, J. L. and Rapson, R. L., 1993. Emotional contagion. In *Current Directions in Psychological Sciences*, vol. 2, pp. 96-99.

Hudlicka, E., 2015. Computational Analytical Framework for Affective Modeling: Towards Guidelines for Designing Computational Models of Emotions. In *Handbook of Research on Synthesizing Human Emotion in Intelligent Systems and Robotics.* IGI Global, U.S.A.; pp. 1-62.

Kramer, A., Guilory,J. E., Hancock, J.T., 2014. Experimental evidence of massive-scale emotional contagion through social networks. In *PNAS,* vol. 111 no. 24.

Lisetti, C., Hudlicka, E., 2015. Why and How to Build Emotion-Based Agent Architectures. In *The Oxford Handbook of Affective Computing.* Oxford University Press, UK.

Marsella, S., Gratch, J., 2009. EMA: A computational model of appraisal dynamics. In *Cognitive Systems Research*, vol 10. no. 1, pp. 70-90.

McCrae, R.R., Costa P.T. Jr., 2003. *Personality in Adulthood: A Five-Factor Theory Perspective,* New York: Guilford, 2003.

Ortony, A., Clores, G.L., Collins, A., 1988*. The Cognitive Structure of Emotions,* Cambridge University Press, Cambridge.

Pease, C.R., Lewis, G.J., 2015, Personality links to anger: Evidence for trait interaction and differentiation across expression style. In *Personality and Individual Differences*, Vol. 74, pp. 159–164.

Petrovica, S., Pudane, M., 2016. Emotion Modeling for Simulation of Affective Student-Tutor Interaction: Personality Matching. In *International Journal of Education and Information Technologies*. Vol.10, pp. 159-167.

Picard, W., 1997. *Affective Computing*, MIT Press. Cambridge.

Pudane, M., Lavendelis, E., Radin, M.A., 2016. Human emotional behavior simulation in intelligent agents: processes and architecture. In *Procedia Computer Science*, in press.

Russell, J.A., Mehrabian, A., 1977. Evidence for a three-factor theory of emotions. In *Journal of Research in Personality*, vol. 11, pp. 273-294.

Tavakoli, M., Palhang, M., Kazemifard, M., 2014. Three levels of information processing: improvement using personality. In *Proceedings of ICIS 2014*, pp. 1 – 6.

Wooldridge, M., 1999. Intelligent agents, In *Multiagent Systems: A Modern Approach to Distributed Artificial Intelligence.* MIT Press, Cambridge, pp. 27-78.

Wooldridge, M., 2009. *An Introduction to MultiAgent Systems*. John Wiley & Sons.