Challenges in Computational Modeling of Affective Processes

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Abstract—In this special section we report on the workshop Standards in Emotion Modeling held in August 2011, Leiden, The Netherlands. An important goal of this workshop was to identify challenges related to the development and evaluation of computational models of affective processes. These challenges were approached from a psychological and a computational modeling perspective. In this introduction we present a summary of the results of this week-long workshop. In addition to that, we are proud to present an invited contribution that proposes solutions to several of these challenges.

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1 INTRODUCTION

AFFECTIVE computing [6], [15], [16] has grown to be a vibrant cross-disciplinary field of research, as evidenced by this journal. A key area of research within affective computing is concerned with *computational modeling of affective processes* (for a review see also [12]). This area addresses fundamental questions, including:

- Where do emotions come from? This question is typically addressed by computational modeling of emotion elicitation.
- What are emotions "used" for? This question is typically addressed by computational modeling of effects of emotion on cognition and behavior.
- How do affective phenomena relate to each other? This question is addressed by computational modeling of the relation between emotion, mood, personality, attitude, etc.

These questions can be approached from an applied and a theoretical perspective [4]. The applied perspective focuses on using the computational model in some concrete form, for example as a model that drives the generation of emotions in an intelligent virtual character. The theoretical perspective focuses on a better understanding of affective processes per se through the use of computational modeling, for example, a model that implements and tests hypotheses about when, where and how fear and sadness arise. The applied and theoretical perspectives are by no means mutually exclusive [4], quite the contrary, as the application of such models also involves testing them, potentially shedding light on the underlying affective processes. However, emphasizing one of these two perspectives does focus the research involved in developing the model, and up to this date most computational models of affective processes have a primarily applied goal.

To give some insight into the process of developing computational models of affective processes, consider the following simplified example for the development of a model for emotion elicitation (generation). First, a psychological theory of emotion elicitation is selected, such as OCC [14] or Scherer's stimulus checks [18]. Then the theory is formalized using a formal language or an agent/cognitive architecture, for example using KARO [19] SOAR [10], or ACT-R [1]. This formalization allows subsequent implementation in the form of a computer program (code), for example cognitive appraisals are encoded within Soar [7]. This program represents a "running" version of the theory of emotion upon which the model was based. The runnable code can be applied in systems that need simulated emotions and can also be used to better understand emotion elicitation.

From an applied perspective this often means that the computational model is embedded in an agent and the agent can be embedded in a task context, enabling the model to produce for humans meaningful output. For example, an intelligent virtual character can express emotions while it negotiates with a human [9].

From a theoretical perspective this means that the computational model should help to better understand the mechanisms that play a role in the generation and influences of affect [20]. As a computational model is in a real sense a runnable version of a cognitive-affective theory, it can generate predictions derived from that theory and can thus be used to investigate the mechanisms emotion psychology aims to understand [17].

However, there are three main challenges related to the development and evaluation of computational models of affective processes:

- *First*, there is the challenge of evaluating whether a model works as intended. Often this is done based on face value (i.e., if the behavior of the virtual agent looks as expected, the underlying computational model is assumed to be a good one), while occasionally this validation is scenario based [13]. Sometimes, formal evaluation techniques are used to

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analyze the structure of the model while it is still in the formal specification stage [5], [19]. Finally, model-driven empirical evaluations can be used to compare predictions coming from the model's performance on a task with human subject behavior on the same task [3], [11]. However, there are no commonly agreed upon protocols for evaluation, nor do benchmark scenarios for testing appropriate emotional behavior exist.

- *Second*, computational models of affective processes are rarely critically analyzed with respect to the models of others (for exceptions see [2], [8]). This is partly due to the first challenge, but also simply because, more often than not the scope of the models differs in terms of the aspects of emotional phenomena modeled; they are applied to different domains as well as important assumptions and computational choices made are left undocumented, making it difficult to build upon each other's work. An underlying problem is that it is currently unclear what assumptions and computational mechanisms should be reported on in the first place that might impact a model's workings and output (see also [21]).

- *Third*, the impact of computational models of affective processes on emotion psychology remains small. Predictive results (e.g., the behavior a computational model produces in a particular simulated situation) are rarely translated back into knowledge that is useful for emotion psychologists. This is exemplified by the relative lack of citations by emotion psychologists to affective computing researchers. An important reason, related to the second challenge, is that the choices made in order to develop the computational model are often ad hoc, implicit, and insufficiently documented. Another reason is that the results are often not discussed in light of emotion psychology in terms relevant to emotion psychology. Many studies lack a discussion of simulation results related to existing emotion theories and experimental findings. As a result, the psychological significance of the outcome of the model is difficult to interpret.

2 WORKSHOP ON STANDARDS IN EMOTION MODELING

These challenges are major hurdles to take for the further development and impact of computational modeling of affective processes. In this special section we summarize the results of the workshop Standards in Emotion Modeling (SEM2011), and present an article that addresses several of the main workshop challenges. The workshop's aim was to better understand the process of computational modeling of affective processes. In particular, how can computational models be evaluated, comparable to other models, and grounded in psychology in a transparent way so that it is also clear what the boundaries of the model are? This is needed for two main reasons.

First, the diversity in computational models of emotion will continue to grow, and diversity is good if we understand what "diversity" in fact means. In other words, we need to know in detail how the different models relate to each other [12]. This will help us to better decide what kind of emotion model is needed for what context, how to develop it and how to evaluate it.

Second, if computational models of emotion are viewed as mechanisms-oriented instantiations of psychological theories of emotion, then these should be able to tell us something about emotion in the human species and other animals and generate testable hypotheses, but only if we know exactly how the model is built and how it is grounded.

The workshop aimed to advance the discussion of these two aspects. The workshop was visited by 25 participants from seven countries, and had a good mix of senior and junior researchers and psychologically-oriented and computation-oriented individuals. The workshop consisted in part of plenary sessions of invited speakers and submitted paper presentations, and in part of lively discussion about psychological grounding, model validation, standardization of modeling process, and "super models" (models that include different affective phenomena, such as the interplay between mood and emotion).

A major outcome of the workshop is the realization among all participants that computational models of affective processes are experimental tools to gain insight into emotion, and that many of the details needed for developing these models simply are not available in emotion psychology. Hence, instead of asking for these details from psychologists, the models should bring insight and provide directions for follow-up questions. Further, the workshop identified major challenges that need to be addressed to better understand the process of computational modeling. These include:

- What are the benefits and pitfalls of taking either a domain specific or a domain-independent approach towards modeling affect and affective influence (e.g., modeling emotion in teaching situations versus modeling appraisal and applying the model to teaching situations)?

- What are the issues in using game-like scenarios as complex stimuli to evaluate models and elicit emotions (e.g., what should a benchmark scenario look like, how do we control for unwanted effects when using scenarios and games on subjects)?

- What are the ways in which we can compare alternative models? For example, appraisal theories of emotion and the computational models that realize appraisal typically encompass multiple processes including assessing an event, mapping that assessment to an emotion, and specifying emotions' interaction with behavior and other mental states. Can we use a common decomposition of this appraisal process to decompose the process of evaluating models, to compare alternative models component-by-component, to facilitate the understanding of appraisal theories, or to provide a common implementation framework for theories (e.g., can we agree upon this decomposition, what are the different types of goals, and how do these relate to utility, desire, desirability, (social) values, and appraisal)?

- Can we identify a protocol for the development of a computational model of affective processes (e.g., always reporting why the model was developed and what the designer's goals are, why a particular appraisal theoretical basis was chosen, what the computational assumptions and ramifications are, how the model is evaluated, what its scope is)?
- What are best practices toward computational modeling of affective processes?
- What is the relation and interplay between naive (folk) and scientific models of emotion?

Finally, with respect to what emotion is from an individual (intrapersonal) perspective we agreed that the following best represents both the psychologists' views as well as the computational modelers' interpretations. Emotion refers to the descriptive label for particular patterns of joint activity of multimodal constituents (e.g., a particular pattern of valence, expression, action, arousal, and appraisal is labeled as happy). The experience of emotion refers to the (conscious) detection (global availability) of such patterns. The function of emotion is to provide a complex feedback signal for a(n) (synthetic) organism to adapt its behavior; each emotion has a different kind of signaling function; some are about anticipated outcomes (fear, hope) while others are about past outcomes (sadness, joy).

In addition to this we are proud to present the article by Rainer Reisenzein, Eva Hudlicka, Mehdi Dastani, Jonathan Gratch, Koen Hindriks, Emiliano Lorini, and John-Jules Ch. Meyer presented in this special section. It proposes three ways to "standardize" the process of developing computational models of affective processes. Their aim is not to standardize per se, but to improve knowledge exchange within the field of affective computing as well as between affective computing and emotion psychology. They argue that to do so, clarity is needed with respect to how and why a computational model is built. Concretely, they propose to systematize and classify the assumptions of precomputational emotion theories, to formalize emotion theories in implementation-independent formal languages, and, finally, to model emotions using general cognitive and agent architectures. This article nicely addresses the main concern underlying the SEM2011 workshop: how to make computational models of affective processes that are easier to compare and of which the results are interpretable by emotion psychologists.

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