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Guest Editorial

Special Issue on Computational Intelligence and Affective Computing

Affective Computing (AC) was first introduced by Professor Picard (MIT Media Lab) in 1995 as "*computing that relates to, arises from, or deliberately influences emotions*." It has been gaining popularity rapidly in the last decade, largely because of its great potential in the next generation of human-computer interfaces. Figure 1 shows the number of publications containing the phrase "affective computing," over the last 17 years returned by Google Scholar. In 2012 there were close to 2000 publications on it.

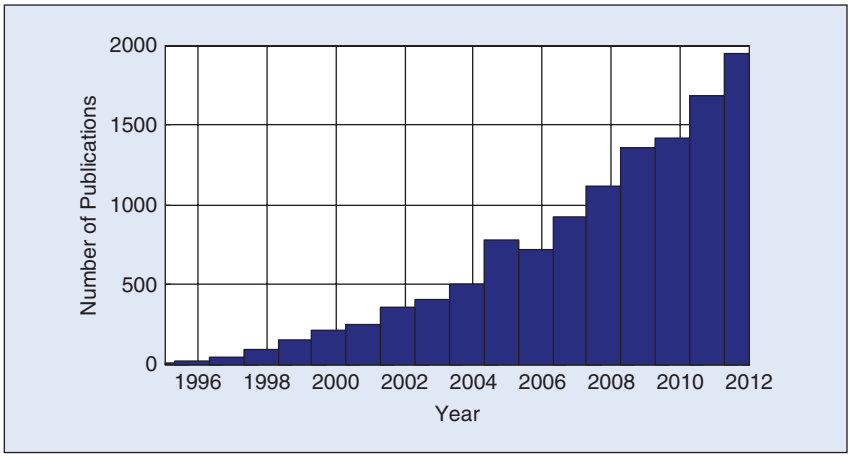

FIGURE 1 Number of Google Scholar publications on affective computing since 1995.

Many countries have been also very supportive of AC research, particularly in relation to priority areas such as supporting children's social and cognitive development and the backdrop of a rapidly aging demographic, where human-tangible computing such as affective robot companions is expected to provide essential benefits. In April 2012 the United States National Science Foundation awarded $10M to a 5-year project "Socially Assistive Robotics" under the Expeditions in Computing program[1], which[2] "*will develop the fundamental computational techniques that will enable the design, implementation, and evaluation of robots that encourage social, emotional, and cognitive growth in children, including those with social or cognitive deficits*." The European Union has funded many relevant projects under the 6th and 7th Framework Programmes. The HUMAINE[3] (HUman-MAchine Interaction Network on Emotions) Network of Excellence was established in 2004 and now has 33 partners from 14 countries. The RoboCom (Robot Companions for Citizens) project[4] is one of the six candidates for the two €1 billion 10-year Future and Emerging Technologies Flagships[5]. These robots will be able to display soft behavior based on new levels of perceptual, cognitive and emotive capabilities.

There are also two journals and an international conference dedicated to AC. The HUMAINE association established the bi-annual *International Conference on Affective Computing and Intelligent Interaction* (Beijing, China, 2005; Lisbon, Portugal, 2007; Amsterdam, The Netherlands, 2009; Memphis, USA, 2011; Geneva, Switzerland, 2013) in 2005, and the *IEEE/ACM Transactions on Affective Computing* in 2010. IGI Global established the *International Journal of Synthetic Emotions* in 2010.

Notably, the IEEE Computational Intelligence Society (CIS) is very active on AC research. It is a sponsor of the IEEE Transactions on Affective Computing, the Workshop on Affective Computational Intelligence in the 2011 IEEE Symposium Series on Computational Intelligence (SSCI 2011), and the Symposium on Computational Intelligence for Creativity and Affective Computing in SSCI 2013. The CIS Emergent Technologies Technical Committee has established an Affective Computing Task Force[6], which is currently chaired by the two Guest

[1]http://nsf.gov/news/news_summ.jsp?cntn_id=123707
[2]http://www.robotshelpingkids.org/index.php

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[3]http://emotion-research.net/
[4]http://www.robotcompanions.eu/
[5]http://cordis.europa.eu/fp7/ict/programme/fet/flagship/6pilots_en.html

[6]https://sites.google.com/site/drwu09/actf

Computational intelligence methods, including fuzzy sets and systems, neural networks, and evolutionary algorithms, provide ideal capabilities to develop intuitive and robust emotion recognition algorithms. Emotions, which are intrinsic to human beings, may also inspire new CI algorithms.

Editors of this special issue. The Task Force organized a special session on "Affective Computing and Computational Intelligence" at the 2012 World Congress on Computational Intelligence (WCCI 2012) with a view to make it a bi-annual event held at WCCI.

The combination of AC and computational intelligence is very natural. AC raises many new challenges for signal processing, affect recognition & modeling, and information aggregation. Physiological signals which are frequently used as a basis for affect recognition are very noisy and highly subject-dependent. Computational intelligence methods, including fuzzy sets and systems, neural networks, and evolutionary algorithms, provide ideal capabilities to develop intuitive and robust emotion recognition algorithms. Further, emotions, which are intrinsic to human beings, may also inspire new CI algorithms, just like the human brain inspired neural networks and the survival of the fittest in nature inspired evolutionary computation.

AC research itself has rapidly expanded and today frequently goes beyond the initial core research challenge of mapping body signals (facial expressions, voice, gesture, physiological signals, etc.) to affective states. As an area which relies on contributions from a series of academic disciplines, including Psychology, Biology, and Computer Science, much of the research in AC is firmly grounded in a multi-disciplinary approach. The four articles in this special issue of *IEEE Computational Intelligence Magazine* represent some latest progress on the combination of AC and computational intelligence. They were selected from 20 submissions through peer-review and provide a highly interesting view of the current research and potential avenues of computational intelligence in AC. The breadth of the research captured by these articles provides an indication of the importance of affect in modern human-centric computation and indicates the potential for further development of Computational Intelligence in this space.

The first article, "Learning Deep Physiological Models of Affect," describes the first study that applies deep learning to AC using psychophysiological signals (skin conductance and blood volume pulse). Deep learning is a very active research area in machine learning, especially for object recognition in images. In this article the authors use a deep artificial neural network for automatic feature extraction and feature selection. They adopt preference-based (or ranking-based) annotations for emotion rather than traditional rating-based annotation, as the former provides more reliable self-report data. Experiments show that deep learning can extract meaningful multimodal data attributes beyond manual ad-hoc feature design. For some affective states, deep learning without feature selection achieved similar or even better performance than models built on ad-hoc extracted features boosted by automatic feature selection. More importantly, the method is generic and applicable to any affective modeling task.

In the second article, the authors present two models that employ interval type-2 fuzzy sets to model the meaning of words describing emotion. The first model represents three factors for each word: dominance, valence, and activation. After describing the model the authors deploy it in conjunction with similarity measures for the task of translating from one emotion vocabulary to another. As an initial outcome, the authors show that while the model works well with smaller vocabularies, performance (rated by comparison with human translators) decreases when larger vocabularies are used. The authors then introduce a second model which aims to overcome this limitation by taking a different approach to modeling words where interval type-2 fuzzy sets are used to represent the truth values of answers to questions about emotion. A crowd-sourced evaluation of the latter approach is conducted and the results presented.

The third article, "Modeling Curiosity-Related Emotions for Virtual Peer Learners," proposes a virtual peer learner with curiosity-related emotions. It represents one of the latest advances on personalized learning, which was selected by the United States National Academy of Engineering as one of its 14 Grand Challenges[7]. The idea is that "*instruction can be individualized based on learning styles, speeds, and interests to make learning more reliable. … Personal learning approaches range from modules that students can master at their own pace to computer programs designed to match the way it presents content with a learner's personality.*" Experiments show that the curiosity-related emotions can guide the curious peer learner to behave naturally in a virtual learning environment, and the curious virtual peer learner can demonstrate a higher tendency for learning in breadth and depth.

In the fourth article, "Goal-Based Denial and Wishful Thinking," the authors propose a novel approach to model an agent's beliefs that aims to incorporate denial and wishful thinking. While not traditionally related to AC, their work on belief revision highlights an important aspect of emotion in belief-structure with direct consequences for the design of artificial agents. They describe how traditional rational belief systems for autonomous artificial agents can be extended to capture a more human-like approach to belief creation, preservation and revision. Significantly, the authors show how their approach enables the autonomous ranking and re-ranking of beliefs

[7] http://www.engineeringchallenges.org/cms/8996/9127.aspx

subject to new evidence and changes in an agent's goals which in turn allow an agent to autonomously revise its beliefs without relying on their external prioritization. As part of scenarios, the authors instantiate their belief model and demonstrate the behavior of the agent in particular in terms of the "denial and wishful thinking" belief revision driven by the context experienced by the agent.

In summary, the four selected papers for this special issue highlight a subset of the challenging and novel applications of computational intelligence to AC. We would like to express our sincere thanks to all the authors and gratitude to reviewers for extending their cooperation in preparing and revising the papers. Special thanks go to Professor Kay Chen Tan, Editor-in-Chief of *IEEE Computational Intelligence Magazine*, for his suggestions and advice throughout the entire process of this special issue. We hope that this issue will inspire others to work on the exciting new frontier of computational intelligence and AC.

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