A Survey of Models of Emotion Useful in the Context of Computation

Annotated Bibliography

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Last Compiled: September 1, 2003

1 Introduction

This bibliography contains generally three sorts of entries: those that are largely theoretical in nature — based either in philosophy or psychology; those which present theoretical frameworks for the understanding of emotion or consciousness in a computational context; and those which describe frameworks either for implementation or empirical study of emotion in the context of computation. Absent from this bibliography at present are references I may use which Jackson has annotated in his bibliography; papers assigned for the class on emotional speech; and some which I have yet to obtain, particularly a few older references gleaned from [9].

References

[1] Kirstie L. Bellman. Emotions: Meaningful mappings between the individual and its world. In Robert Trappl, Paolo Petta, and Sabine Payr, editors, *Emotion in Humans and Artifacts*. MIT Press, Cambridge, MA, 2002.

> Bellman is a psychologist and Principal Director of the Aerospace Integration Sciences Center at the Aerospace Corporation. She studies domain specific languages and language as it relates to information theory, and studies "reflective architectures" that manage their own resources and reason about appropriate behavior. In the present chapter, she examines why it is important to address emotion in computation, and how this question leads to the examination of self-awareness and consciousness. In particular, she discusses how emotion affects our evaluation of the world and our actions in it; and how we can evaluate emotional capabilities and thus develop a basis for empirical examination of our success in modeling emotion.

[2] Cheshire Calhoun and Robert C. Solomon, editors. *What Is an Emotion: Classic Readings in Philosophical Psychology*. Oxford University Press, New York, 1984.

> Calhoun is Director of Women's Studies and Prof. of Philosophy at Colby College; Solomon is a professor of "Business and Philosophy" at UT Austin. The book is a compendium of primary sources from Aristotle to William James to Sartre to

contemporary thinkers. The lengthy introduction emphasizes the multi-disciplinary nature of the study of emotion, and presents five different models: (1) Sensation Theories; (2) Physiological Theories; (3) Behavioral Theories; (4) Evaluative Theories; (5) Cognitive theories. It also presents an analysis of ten major problems posed by the study of emotion, including what "counts" as an emotion, and the relationship of E with intentionality, rationality, culture, and expression.

[3] Gerald L. Clore and Karen Gasper. Some affective influences on belief. In Nico H. Frijda, Antony S.R. Manstead, and Sacha Bem, editors, *Emotions and Beliefs*. Cambridge University Press, Cambridge, UK, 2000.

Karen Gasper is a psychologist on the faculty of the University of Illinois, Urbana-Champaign, where she studies affect and social cognition. This chapter seems to be representative of Clore's later work, which I mention in [11]. It develops the idea of emotion as information, and describes the process whereby that information is transformed into belief, that is, an understanding of the world, and perhaps a tendency towards action. Of note is the characterization of emotion as believable and immediate information. That is, that the data of emotion often provide instantaneous feedback about our experience in a given context; and that that information is inherently believable. Further, the actual information value of the emotion is dependent upon what the authors call the "attribution principle," the process whereby the emotion is interpreted. In a sense, the chapter is an algorithmic treatment of how emotional information is transformed from feeling to belief and possibly to action; in the interim both being manipulated by and influencing cognitive processes.

[4] Nico H. Frijda. *The emotions*. Sudies in Emotion and Social Interactions. Cambridge University Press, Cambridge, UK, 1986.

Nico H. Frijda is Prof. of Pychology at the University of Amsterdam and a widely-cited authority on the psychology of emotion. This book is considered an important study on emotion, once again, from a cognitive perspective. The approach taken pays more attention than some other cognitive theories

to behavioral issues, and in particular develops a clear definition of the "emotion process" that begins with stimulus, transitions through various phases of what others might call appraisal and finally results in an action tendency. This is examined as a matter of cognitive process, as opposed to a strict behavioral model, which outwardly might fit a similar description. Frijda also examines how this theory of emotion, which he describes as functionalist, "collides" with a variety of other emotional definitions, such as many expressed in [9]. In doing so, incidentally, he enumerates a number of definitions that I had thrown out during my initial reviews as being not operational enough for the current application (and, admittedly, unintuitive to me). In simplistic terms, this book, and its theory, are an in-depth examination of the function of emotion colored by the point of view that emotion is in some way "helpful." This is, of course, terrifically useful in the development of an operational definition for use in computation, since the underlying assumption in that endeavor is of the pragmatic utility of emotion.

[5] Nico H. Frijda, Antony S.R. Manstead, and Sacha Bem. The influence of emotions on beliefs. In Nico H. Frijda, Antony S.R. Manstead, and Sacha Bem, editors, *Emotions and Beliefs*. Cambridge University Press, Cambridge, UK, 2000.

Antony Manstead is a social psychologist on the faculty of Cambridge. Sacha Bem is on the faculty of Leiden University, where he studies cognitive science, the history of psychology, and something I'm willing to claim is the philosophy of science, but honestly my Dutch is pretty weak. This chapter is the introduction to an edited book that addresses the fact that although a great deal of work has been done on how belief influences emotion, not much study has been made of the converse.

[6] Nico H. Frijda and Batja Mesquita. Beliefs through emotions. In Nico H. Frijda, Antony S.R. Manstead, and Sacha Bem, editors, *Emotions and Beliefs*. Cambridge University Press, Cambridge, UK, 2000.

Batja Mesquita is a cultural psychologist on the faculty of Wake Forest University. This chapter is in some ways an ex-

tension of the theory developed in [4] in the sense that emotion in this model is seen much more as an agent (or as a component of agency) than as a reaction or consequence of some stimulus: emotion is useful in *generating* belief (belief in the sense of understanding the world); it is not just produced by our understanding of the world. This is supported by studies done in the 70's of subjects with brain injuries that left them "affectless;" their lack of emotionality was found to severely impair their capacity to make "rational" decisions. (This is work by Damasio, I think; I need to find the reference.)

[7] Carroll E. Izard. *Human Emotions*. Plenum Press, New York, 1977.

Izard is a well-known clinical psychologist at the University of Delaware whose primary area of study is emotion. The present, oft-cited, volume makes a thorough examination of role of emotion in interaction with the environment and with other humans; and of various theories of emotion. Of particular note are the Cognitive-Affective approach, which examines — primarily from a developmental perspective — the role of emotion in making sense of the environment; and "Emotion as the Interaction of Need and the Probability of Goal Achievement" which I like since it supports my idea of emotion as the intersection of intention with context. Chapter 5 examines the principal methods used in the study of psychology of emotion. Chapter 6 discusses the relationship between E and consciousness, particularly how E influences perception and facilitates the experience of consciousness. The balance of the book studies individual emotions in depth.

[8] William James. What is an emotion? *Mind*, 9(34):188–205, 1884.

Useful as a historical foundation for the persistent questions about the nature of emotion. James identifies the contradictions inherent in understanding emotion from either a purely cognitive or purely physiological perspective. In so doing, he elucidates one of the major hurdles to modeling emotion in computation: what is left of emotion if there is no physiological response? His physiological analysis of emotion does not, of course, take into account the knowledge of the last 100

intervening years. That limitation aside, his analysis is a helpful framework for integrating the various components into an understanding of emotion that takes into account mind and the subjective self.

[9] Paul R. Kleinginna and Anne M. Kleinginna. A categorized list of emotion definitions, with suggestions for a consensual definition. *Motivation and Emotion*, 5(4):345–379, 1981.

Paul Kleinginna is a Prof. of Psychology at Georgia Southern University, where Anne Kleinginna is a research librarian. This is the sort of paper that benefits tremendously by having a librarian as co-author. The paper examines 92 different definitions of emotion, breaking them up into primary and secondary categories. The paper's primary value is its use in identifying starting points (and references) for deeper examination of particular kinds of definitions; it also provides a few definitions that are so bad that they are useful in pointing out the pitfalls the topic presents. The "consensual definition" proposed by the paper is, in fact, so consensual that it lacks a point of view, and is thus of dubious value.

[10] Peter J. Lang. What are the data of emotion? In Vernon Hamilton, Gordon H. Bower, and Nico H. Frijda, editors, *Cognitive Perspectives on Emotion and Motivation*, volume 44 of *NATO ASI Series D: Behavioural and Social Sciences*. Kluwer Academic Publishers, Dordecht, The Netherlands, 1988.

Peter Lang is a Prof. of Psychology at the University of Florida, where he studies emotion and cognitive neuroscience. The paper begins by recognizing that the essential problem of studying (and "implementing") emotion is that the basic data of emotion for most people is a state of feeling, and that "the essence of these feeling states is essentially private." The paper posits that the data available are of essentially two types: measurable (such as physiological or behavioural) data; and affective language responses, which are more subjective, but no less rich, varied, and valuable. Lang suggests that the immensity of the naural language vocabulary that describes affect is a reflection of emotion's inherent dimensionality. He

argues for the development of a theory of emotion that takes into account both measurable and subjective data.

[11] Andrew Ortonoy, Gerald L. Clore, and Allan Collins. *The Cognitive Structure of Emotions*. Cambridge University Press, Cambridge, UK, 1988.

Andrew Ortony, a well-known cognitive scientist, is formally Professor of Psychology, Education, and Computer Science at Northwestern University. Together with Clore, he has produced seminal work on relating emotion to cognition, and consequently modeling emotion in AI. Gerald Clore is Prof. of Psychology at the University of Virginia. His current work focuses on the idea that affect per se represents information used in cognitive processing (as opposed to the view that E provides information by way of association). Allan Collins is Prof. of Learning Sciences at Northwestern.
This widely-cited book explores the relationship of emotion to cognition, and as such serves as starting point for a number of models of emotion in AI. The book is based on "the assumption that progress in psychological research on emotion can be attained through an analysis of the cognitions that underlie emotions." They examine the cognitive structure of emotions in general, as well as that of individual emotion. In particular, they examine the cognitive psychology of appraisal, which again I think is a key framework for dealing with emotion in speech, since it is the basis of the sort of heuristic assessment that we want systems to make about user needs and intention; and which we would likewise hope to enable the user to make about the intention expressed by the system. They provide an extensive framework for understanding many of the issues addressed by other authors in this bibliography, such as how emotions are elicited by events, by objects, by context, and by interaction with others. I find their approach to be the most appealing in general of everything I've reviewed. Their ideas could almost be described as a pragmatics of emotion, and it is quite in line with the ideas in [21]. Clore's current work, which I mention above, seems all to be in press at the moment, and I'm working on

tracking some of it down, since it seems to go even farther in this direction.

[12] Paolo Petta. The role of emotions in tractable architectures for situated cognizers. In Robert Trappl, Paolo Petta, and Sabine Payr, editors, *Emotion in Humans and Artifacts*. MIT Press, Cambridge, MA, 2002.

Petta is a computer scientist at the Austrian Research Institute for Artificial Intelligence, and founder of its research group Intelligent Software Agents and New Media. He studies the creation of autonomous intelligent agents and synthetic characters. He argues from a fairly pragmatic perspective that emotions are prerequisite to autonomy and proactivity. He examines the adaptive nature of emotion, particularly from the standpoint of appraisal theories of emotion. This point of view particularly appeals to me since it combines certain pragmatic elements of behavioralism with the subjective perspective I think is necessary in the formation of intention. He follows his theoretical analysis with a lengthy description of the TABASCO (tractable appraisal-based architecture framework for situated cognizers) architecture, which is an architectural framework for building "situated cognizers," software agents that use emotion as a guide for interacting with the environment and for decision making.

[13] Rolf Pfeifer. Artificial intelligence models of emotion. In Vernon Hamilton, Gordon H. Bower, and Nico H. Frijda, editors, *Cognitive Perspectives on Emotion and Motivation*, volume 44 of *D: Behavioural and Social Sciences*. Kluwer Academic Publishers, Dordecht, The Netherlands, 1988.

Pfeifer is Prof. of Computer Science at the University of Zurich and has written widely on artificial intelligence and intelligence in general. The present paper examines a number of models of emotion and artificial intelligence. It starts by articulating a framework for understanding the domains in which emotion is operative, or the roles it takes on: e.g. E as process; the events and conditions that generate emotion; the influence of emotion on the system (and further generation of emotion); E's goal oriented nature; and E as heuristics, that is, how E helps to interpret situations and make predictions.

He examines a number of AI models for emotion, which he separates into two categories: those in which emotion is the primary focus of the system, and those in which emotion augments the functionality of the system. The paper is somewhat historical, but it highlights how the essential issues haven't really changed in the past 15 years.

[14] Rosalind W. Picard. *Affective Computing*. MIT Press, Cambridge, MA, 1997.

Picard is on the faculty in the Media Lab at MIT. This widely cited book examines emotion in computing from two perspectives: an intellectual/philosophical/psychological standpoint; and a more pragmatic, implementational perspective. Of particular note in the first section: an articulation of the general reasoning that it is necessary for machines to be able to deal with emotion in order to exhibit true intelligence; a subtle analysis of the distinction between imitating and duplicating emotions, and how this must be applied in defining and evaluating machine emotion; and—less common in such volumes—a thoughtful discussion of some of the concerns that must be responsibly addressed in the pursuit of "engineering" emotion in machines. The second section examines ways of designing systems that recognize and exhibit emotion, addressing a range of low-level, mid-level, and high-level issues, which she differentiates as signals, patterns, and concepts.

[15] Rosalind W. Picard. What does it mean for a computer to "have" emotions? In Robert Trappl, Paolo Petta, and Sabine Payr, editors, *Emotion in Humans and Artifacts*. MIT Press, Cambridge, MA, 2002.

In this short chapter, Picard makes the novel argument that, once we have empowered machines to do all of the things we need them to do, i.e., by giving them signaling, prioritization, regulatory mechanisms, and a way of interacting with the world that seems intuitive to us, we have already given them emotions, whether or not that's the word we use.

[16] Edmund T. Rolls. A theory of emotion, its functions, and its adaptive value. In Robert Trappl, Paolo Petta, and Sabine Payr, editors, *Emotion in Humans and Artifacts*. MIT Press, Cambridge, MA, 2002.

Rolls is Prof. of Psychology at Oxford, works in Cognitive Neuroscience, studying emotion and memory. This is an examination of the role of emotion in autonomic responses, behavioral responses (especially in relation to reinforcing stimuli), motivation, communication, social bonding, cognitive evaluation of events, and memory. Of particular interest is its examination of the role of emotion in making sense of events, although I find the predominantly behavioral point of view to be limiting.

[17] John R. Searle. *Intentionality.* Cambridge University Press, Cambridge, UK, 1983.

John Searle is Mills Professor of the Philosophy of Mind and Language at UC Berkeley. This book develops a theory of intentionality as it relates to action, perception, causation, meaning, and consciousness. It makes an important distinction between states and events that have intentionality and those that do not. This likewise helps to clarify the role of emotion in various situations by providing a distinction between active and reactive states of mind and the consequent emotions. This perspective (which I am admittedly superimposing on his theory) is somewhat different from any of the theories of emotion I've encountered. It helps to differentiate among emotional states which have goals and those which may be purely reactions to context, and I think this is crucial in developing systems that exhibit emotional intelligence.

[18] Stuart Shanker. *Wittgenstein's Remarks on the Foundations of AI.* Routledge, London, 1998.

Shanker is Prof. of Philosophy at York University, Toronto, and works primarily in philosophy of language and language acquisition. The title of this book is somewhat misleading, in that the work of Wittgenstein that is examined focuses primarily on the mechanist viewpoint, its evolution into information theory and automata theory, and Turing's ideas that grew out of it. That serves as a starting point for a broad examination of the two primary bases for artificial intelligence: the mechanist component described above; and the cognitive revolution that grew out of the work of Piaget and others.

The examination uses the perspectives of the philosophies of language, psychology, and mathematics. I find the book relevant to the study of emotion since it examines the question of what it means for a machine to have persistent (rather than finite state) knowledge, insight, and conceptual understanding, all of which are, I think, prerequisite to emotional intelligence.

[19] Aaron Sloman. How many separately evolved emotional beasties live within us? In Robert Trappl, Paolo Petta, and Sabine Payr, editors, *Emotion in Humans and Artifacts*. MIT Press, Cambridge, MA, 2002.

Sloman is Prof. of Philosophy and Computer Science at U. of Birmingham, UK, where he studies the evolution of mind and the "design" of mind. This section takes an approach that incorporates some of what Minsky calls the society of the mind, and examines how different theories of mind give rise to different theories of emotion. It likewise examines how certain computational architectures might be more suited to modeling emotion as described by a given theoretical framework.

[20] Robert Trappl, Paolo Petta, and Sabine Payr, editors. *Emotions in Humans and Artifacts*. MIT Press, Cambridge, MA, 2002.

See individual sections.

[21] Fred Zimring. Empathic understanding grows the person. *The Person-Centered Journal*, 7(2):101–113, 2000.

Fred Zimring was Prof. of Clinical Psychology at Case Western Reserve. He was a student and friend of Carl Rogers, the father of client centered therapy, and was considered Roger's heir in that tradition. His major area of study was empathy. The present paper develops a framework which attempts to explain the benefit of psychotherapy in terms of empathic understanding. It is generally understood in clinical psychology that all approaches seem to work equally well; it is not understood why that seems to be the case. Zimring argues that the common element among most approaches is the growing belief over time on the part of the client that his/her subjective experience is understood by the the therapist. He

consequently asserts that it is this understanding *per se* that produces the theraputic benefit. This is a compelling examination of the tremendous importance of emotion and the percieved understanding of one's emotional experience in human interaction.