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Introduction to the Special Issue

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This special issue honors the research and mentorship contributions of Dr. Aravind Joshi, the 2003 David E. Rumelhart Prize recipient. This prize was instituted in 2001, funded by the Robert J. Glushko and Pamela Samuelson Foundation. The prize is awarded annually to an individual or collaborative team making a significant contemporary contribution to the formal analysis of human cognition. Mathematical modeling of human cognitive processes, formal analysis of language and other products of human cognitive activity, and computational analyses of human cognition using symbolic or non-symbolic frameworks all fall within the scope of the award. In 2003, the prize selection committee consisted of Alan Collins, Robert Glushko, Mark Liberman, Anthony Marley, and James McClelland (chair). Perhaps best known for his contributions to connectionist, or neural network, models, Dr. Rumelhart also exploited symbolic models of human cognition, formal linguistic methods, and the formal tools of mathematics. Reflecting this diversity, the first two winners of the David E. Rumelhart Prize represented connectionist modeling (Geoffrey Hinton) and mathematical psychology (Richard Shiffrin). It is fitting that the third prize winner represents a third aspect of Dr. Rumlehart's research—formal linguistic methods. The current special issue is organized around the general theme of computational linguistics, and the influence of Dr. Joshi's specific contributions to computational linguistics is evident in each of the articles.

1. Research biography of Aravind Joshi

Dr. Joshi is the Henry K. Salvatore Professor of Computer and Cognitive Science at the University of Pennsylvania. He has previously received considerable recognition for his accomplishments. He was a Guggenheim fellow in 1971–1972, served as president of the Association for Computational Linguistics in 1975, and was made a fellow of the Institute of Electrical and Electronics Engineers (IEEE) in 1976. He received the 1987 Best Paper Award at the National Conference on Artificial Intelligence (AAAI), and was elected a Founding Fellow of AAAI in 1990. In 1997, he was the recipient of the highest honor in the field of artificial intelligence, the Research Excellence Award of the International Joint Conference of Artificial Intelligence (IJCAI), a distinction held by only eight other outstanding computer scientists.

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In 1999, he was appointed to the National Academy of Engineering, the only researcher in Natural Language Processing to have ever received this distinction. In 2002, he was the first recipient of the Lifetime Achievement Award given by the Association for Computational Linguistics.

In his work on semantics and discourse, Aravind Joshi began by asking a different question than had been asked before: *What are reasonable constraints on the inferences that an agent could be expected to draw in understanding a text*? The first class of inferences that he explored with his students, that seemed particularly amenable to constrained computation, was the class of presuppositions and entailments—inferences keyed to lexical items in particular syntactic structures. The problems lay in the fact that such structures are embeddable and that the conclusions that can be drawn from them are not simply conjoinable. Dr. Joshi and his student, Ralph Weischedel, were able to develop a systematic and constrained method of automatically computing such inferences that was then extended by subsequent work with his student, Stanley Rosenschein.

Perhaps the best known of Dr. Joshi's contributions to the formal science of language is the Tree Adjoining Grammar. His work on TAG has played an important role both in natural language processing and in theoretical linguistics. Two key ideas underlying TAG are, first, that the statement of local syntactic and semantic dependencies can be factored apart from recursion and, second, that a modest increase in power beyond context-free grammar is sufficient to characterize natural language syntax. The TAG adjoining operation, as defined by Dr. Joshi, achieves both of these results in an elegant way, providing a powerful tool for linguistic description that at the same time yields grammars guaranteed to be computationally tractable. A large body of mathematics, computational, empirical linguistic, and psycholinguisitc work by Dr. Joshi and numerous others has been developing the consequences of Dr. Joshi's original insight for more than a quarter of a century.

Dr. Joshi's work in mathematical linguistics over the years has had an extraordinary impact on linguistic theory, beyond the impact of TAGs themselves. To give just two examples here: (a) Dr. Joshi's generalization of an earlier result of Stanley Peters' to show that arbitrary booleans of context sensitive filters on context free grammars still result in context free languages led directly to the development of Gerald Gazdar's GPSG framework (actually first developed, we believe, while Dr. Gazdar was visiting Penn); (b) the generalization of TAGs to an entire class of languages (the so-called "Mildly Context Sensitive Languages") provided a formally precise way to understand the relationships among a number of distinct linguistic theories from Combinatory Categorial Grammar to Head Grammar and HPSG to Government-Binding Theory and Minimalism.

Another key contribution of Dr. Joshi's to the science of language (along with Scott Weinstein and Barbara Grosz) is Centering Theory, a computationally tractable model of attention during discourse. Centering Theory has attracted a wide following among linguists and computer scientists working on formal models of discourse. Centering Theory is grounded in the conviction that only constrained inference can be a valid model of human language behavior. Although many individuals may be mentioned in a sentence as part of a discourse, there is one individual that is singled out. Having such a salient individual, which they called the center of the sentence, facilitates efficient inferencing, by allowing sentences to be temporarily represented as monadic predicates and inferencing to be done in a simpler, monadic predicate

logic. The theory is attractive in part because it provides a framework for capturing not only the relationship of a current utterance to previous utterances but also expectations regarding utterances yet to come. Centering Theory has been found relevant for modeling a number of properties related to discourse coherence, including anaphora resolution, the distribution of various types of pronouns, and aspects of prosody.

Dr. Joshi's writing has been both prolific and of exceptionally high quality. In the introduction of Gazdar et al.'s bibliography "Natural Language Processing in the 1980s," they note that "The most prolific author represented, by quite a large margin, is Aravind Joshi." Several of his most important works are listed below. In all, Dr. Joshi is the editor of two books and 113 articles on computational linguistics. He has written on formal language theory, parsing and generation, tree automata, the logics of partial information, natural language interfaces to information systems, the grammar of long-distance dependencies, extraposition, nested and crossed dependencies, coordination, and code-switching.

He continues to be remarkably creative and prolific. Recently, Dr. Joshi has turned his attention to the application of ideas from mathematical linguistics to the analysis of DNA and the human genome. This follows an observation some years ago (by others) that while CFGs provide a formal basis for the mathematical analysis of the DNA that generates hairpin structures, the pseudo-knot structures of molecules like tRNA are generated by a non-context free DNA structure that can be nicely modeled by TAG.

2. Dr. Joshi's service and teaching contributions

Aside from his scientific work, Dr. Joshi has played a key organizational role in fostering the development of the new discipline of cognitive science. Over the past two decades and more, the University of Pennsylvania has developed a thriving program in cognitive science, largely due to the outstanding vision and tireless leadership that Dr. Joshi contributed to the effort. He led the effort to win an NSF Science and Technology Center for cognitive science and was founding co-director (with Lila Gleitman) of the Institute for Cognitive Science at Penn, a post which he held with great success until last year. His approach to these efforts has always been to foster the broadest possible participation by researchers in different domains and with different orientations and always to emphasize the importance of educating young researchers and of supporting them morally and materially.

Dr. Joshi has also promoted the cause of cognitive science by being an exceptional teacher and advisor. He has been the mentor to a surprisingly large number of individuals who have developed noteworthy and fertile research programs. He has supervised 36 Ph.D. theses, ranging from information and coding theory to pure linguistics. The success of his students is documented by the inclusion of several of his students among the authors of the contributed articles.

Selected Research Publications by Aravind Joshi

Bangalore, S., & Joshi, A. (1999). Supertagging: an approach to almost parsing. *Computational Linguistics*, *25*, 237–265.

Grosz, B., Joshi, A. K., & Weinstein, S. (1995). Centering: A framework for modeling local coherence of discourse. *Computational Linguistics*, *2*(21), 203–225.

Joshi, A. K. (1985). Tree adjoining grammars: How much context-sensitivity is necessary for assigning structural descriptions? In D. Dowty, L. Karttunen & A. Zwicky (Eds.), *Natural language parsing*. Cambridge University Press.

Joshi, A. K. (1990). Processing crossed and nested dependencies: An automaton perspective on the psycholinguistic results. *Language and Cognitive Processes*, *5*, 1–27.

Joshi, A. K., & Rosenschein, S. J. (1975). A formalism for relating lexical and pragmatic information: Its relevance to recognition and generation. In *Proceedings of an interdisciplinary workshop on theoretical issues in natural language processing*. Cambridge, MA, USA.

Joshi, A., & Schabes, Y. (1997). Tree adjoining grammars. In A. Salomaa, G. Rosenberg (Eds.), *Handbook of formal language and automata*. Heidelberg: Springer.

Joshi, A. K., & Weischedel, R. (1977). Computation of a unique subclass of inferences: Presupposition and entailment. *American Journal of Computational Linguistics*, 3.

Joshi, A., Becker, T., & Rambow, O. (1994). Complexity of Scrambling: A new twist to the competence/performance distinction. In A. Abeille, & O. Rambow (Eds.), *Tree-adjoining grammars: formalisms, linguistic analysis and processing*. Stanford University: CSLI Publications.

Joshi, A. K., Levy, L., & Takahashi, M. (1975). Tree Adjunct Grammars. *Journal of Computer and System Sciences*, *10*, 136–163.

Joshi, A. K., Vijay-Shanker, K., & Weir, D. (1991). The Convergence of Mildly Context-Sensitive Grammar Formalisms. In P. Sells, S. Shieber & T. Wasow (Eds.), *Foundational Issues in Natural Language Processing*. MIT Press.

Webber, B., Stone, M., Joshi, A., & Knott, A. (1999). Anaphora and discourse structure. *Computational Linguistics*, *29*(4), 545–587.