CURRICULUM VITAE

ROHIT JIVANLAL PARIKH

Education: Ph.D. (Mathematics, Harvard 1962)
A.B. (Magna with highest honors in Physics, Harvard 1957)
Putnam prize winner: 1955, 1956, 1957. William Lowell Putnam Fellow: 1957. Phi Beta Kappa, Harvard 1957.

Research interests in chronological order: Formal languages, Recursive function theory, Proof theory, Non-standard analysis, Logic of programs, Logic of knowledge, Philosophy of Language, Belief revision, Social software and Game theory (I apologize for the fact that there are so many). However, the theme which concerns most of the recent papers is Social Software, an analysis of social procedures, from elections to cake cutting, using ideas from Computer Science, Game Theory and Logic.

Current position: CUNY Distinguished Professor affiliated with Department of Computer Science, Brooklyn College and Ph.D. Programs in Computer Science, Philosophy and Mathematics, CUNY Graduate Center. Also visitor at Courant Institute, NYU, 1998-2001.

Previous Positions:

Visiting Professor of Computer Science, Courant Institute, Spring 1981. Visiting Scientist, MIT Lab for Computer Science, 1979-1982 and 1977-1978. Professor of Mathematics, Boston University, 1972-1982. Gast (research associate) ETH-Zurich, Spring 1979. Visiting Professor, Computer science group, Tata Institute of Fundamental Research, Jan-April 1979. Research Associate, Dept of EECS, Berkeley, Fall 1978. Visiting Scholar, Stanford University, Fall 1978. Visiting Professor, Philosophy Department, Stanford University, Spring and Summer 1974. Associate Profesor of Mathematics, Boston University, 1967-1972. Visiting Associate Professor, Math dept, SUNY-Buffalo, 1971-1972. Research Associate, School of Mathematics, Tata Institute of Fundamental Research, Bombay, Jan-June 1971. Lecturer in Mathematics, Bristol University, 1965-67. Reader in Mathematics, Panjab University, 1964-65. CSIR Fellow, Bombay University, Jan-March 1964. Instructor in Mathematics, Stanford University, 1961-63. Research Associate, Bell Labs, Summer 1961. Research Assistant to Noam Chomsky, MIT, 1960-61. Teaching Fellow in Mathematics, Harvard, 1959-61. Student Engineer, Minneapolis Honeywell, Summer 1958 and 1959. Research Assistant to Garrett Birkhoff, Harvard, Summer 1956 and 1957.

Member of AMS, ACM, ASL, IEEE. Referee for various journals, reviewer for the Math Reviews. Chaired session on Logic and Computation at the tenth world computer congress, Dublin 86.

Administrative and Organisational Experience: Director of the Boston Logic Colloquium 1972-78. Program chair for four conferences, *Logic of Programs, Brooklyn, '85, Logic in Computer Science, Monterey, CA, Theoretical Aspects of Reasoning about Knowledge, Monterey, CA, Association for Symbolic Logic, Baltimore, Md (1998).* Managing Editor for *International Journal for Foundations of Computer Science 93-95* Editor for *Journal of Philosophical Logic* 1999-2003. Program committee for STOC-86, TARK-86 (theoretical aspects of reasoning about knowledge) LICS-86. Organising committee for LICS, and advisory committee for the FST-TCS conference (in India) 1981-86. Member, Brooklyn college tenure committee for science, 1983-84. Chair, Brooklyn college tenure committee for science, 1984-85. Brooklyn college promotion committee for science, 1997-98. Member, appointments committee, CIS department, Brooklyn college, 1985-1988. Member, Doctoral faculty policy committee, CUNY graduate center, 1984-1987. Executive committee, department of computer science, CUNY Graduate center, 1993-current. Committee on faculty membership, department of computer science, CUNY graduate center, 1985-1997. Chair, library committee, department of CIS, Brooklyn college, 1985-current.

Doctoral theses supervised: (at Boston University) David Ellerman (Math), Tom Sibley (Math), John Buoncristiani (Math) and Shlomit Pinter (CS). (at CUNY) Paul Krasucki (CS), Alessandra Carbone (Math), Gilbert Ndjatou (CS), Konstantinos Georgatos (Math) and Angela Weiss (Math). Also Amy Greenwald (CS-NYU), Samir Chopra (CUNY, Philosophy). Eric Pacuit (CS-CUNY, 2005), Salame Samer (CS - CUNY 2006) and Chris Steinsvold (Philosophy-CUNY) 2007.

Some other doctoral theses influenced by my work: Rani Siromoney (Madras University), Rick Statman (Stanford), Fran Berman (Washington), Bob Streett (MIT), Bill Farmer (Wisconsin), Joe Halpern (Harvard), David Peleg (Weizmann), Jan Plaza (CUNY) Laxmi Parida (NYU) , Marc Pauly (Amsterdam) (I have only mentioned those people with whom I have had some personal contact.)

Invited Talks: Given at Harvard, Oxford, Stanford, Berkeley, MIT, Washington, CMU, Cornell, Penn State, SUNY-Stony Brook, SUNY-Buffalo, SUNY-Albany, Rutgers, IBM-YT, IBM-SJ, New York Academy of Science, The New School, Indian Institutes of Technology (IIT) at Kanpur, Madras, Delhi and Bombay, Tata Institute of Fundamental Research (Bombay), Indian Institute of Science (Bangalore), Universities of Leiden, Amsterdam and Utrecht, ETH-Zurich, Kansas, Rutgers, Hebrew University, Weizmann Institute, Madras Christian College, MATSCI-Madras, Vanderbilt University, City College, Baruch College, Saint Joseph's University, Indiana University, Florida Atlantic University, Fordham University, University of South Carolina, University of California at Santa Cruz, Purdue, Tulane, University of Delaware and Mathematical Sciences Research Institute, Berkeley. Also Indian Math Society, American Math Society, Indian Computer Society and various conferences. SIAM lecturer for 1980-81. Other talks at U. Acireale (Sicily), U. Pisa, U. Milan, U. Torino, CNRS (Paris), UCLA, Boston University, U. of Rome, William Paterson College, Stevens Institute of Technology, Carnegie Mellon University, Uppsala university, Indiana university, Logic at Botik, University of Amsterdam, Logica 99. WOLLIC 2002, Social Software, First Indian Conference in Logic, 2005, Second Indian Conference in Logic, 2007, Association for Symbolic Logic, ESSLLI-2001,2006,2007, NASSLLI 2002,2003. (list is partial).

Grants: Funded by NSF grants since 1979. Other grants from IBM as well as CUNY Faculty Research Assistance Program awards.

Publications

(#1 is a research report, #2, #3, #11, #12 and #13 are abstracts. The results in these were never submitted for publication. Paper #4 and most papers from #22 on are in Computer Science)

1. (With Garrett Birkhoff) *The Tabulation of Michell's Function*, Research report, Harvard 1958.

This is a paper on using numerical analysis to solve a case of the heat equation.

2. "Many one degrees of Certain Sets of Recursive Well Orderings", *Notices of the AMS* 8 (1961) 495.

Partial solution of an open problem of Kreisel, Shoenfield and Wang regarding many one degrees of certain sets of recursive sets of well orderings.

3. (With J.N. Crossley) "On Isomorphisms of Recursive Well Orderings", *Journal of Symbolic Logic* (abstract) 28 (1963) 308.

4. "On Context Free Languages", *Jour. ACM 13* (1966) 570-81. Originally published in 1961 as a research report at RLE, MIT.

This paper was published at the invitation of Knuth. It proves two basic results about context free languages. One is that commutative maps of context free languages are semi linear sets. The notion of semi linearity is introduced in this paper. The other is the first theorem establishing the existence of inherently ambiguous context free languages. Both theorems appear in textbooks: the first in Lewis and Papadimitriou and the second in Hopcroft and Ullman as well as in Harrison's book.

5. "Some Generalisations of the Notion of Well Ordering", *Zeit. Math. Logik u. Grund. Math.* 12 (1966) 333-340.

Shows that there are linear orders which are pseudo well ordered in that they have no recursive descending sequences, but exponentiating them yields orders that have primitive recursive descending sequences.

6. "Some Theorems in Logic", *Math. Student 34* (1966) 125-29.

Expository talk given to the Indian Math Society. Explains first order model theory and Skolem's paradox.

7. “Nonuniqueness in Transfinite Progressions”, *Jour. Ind. Math. Soc.* 31 (1967) 23-32.

Solves an open problem of Kreisel’s. It is shown that transfinite progressions which have hyperarithmetic definitions, always break down, in that different notations for the same ordinal yield different objects.

8. “A Nonstandard Theory of Topological Groups”, in *Applications of Model Theory Ed. W.A.J. Luxemburg, Holt, Rheinhart and Winston* (1969) 279-284.

The title is self explanatory. The existence of Haar measure is proved and some other basic results are established.

9. “A Conservation Result”, same source as above, 107-108.

Shows that the Robinson enlargement of a first order theory is always a conservative extension of the standard version.

10. “Existence and Feasibility in Arithmetic”, *Jour. Symbolic Logic* 36 (1971) 494-508.

Several results on Peano arithmetic are proved. It is shown that postulating that large numbers are not finite leads to an inconsistent extension of arithmetic which is, however, coservative for proofs of low complexity. This paper also shows that there are formulae whose proofs are long, but the proof that they are provable are short. Finally it is also shown that provable recursive functions of bounded arithmetic are polynomially bounded and in linear space. This is the first paper that I know of which makes a connection between complexity and formal theories.

11. “D-Structures and their Semantics”, *Notices of the AMS* 19 (1972) A329.

12. (With J. Mayberry) “D-structures and *-structures”, *Notices of the AMS* 19 (1972) A454.

13. (With D.H.J.de Jongh and N. Goodman) “On Regular *-structures with Classical Theories”, *J. Symb. Logic* 37 (1972) 777.

These three abstracts explore a nonstandard semantics for first order languages. Special cases include the standard semantics, intuitionistic semantics, and the *-semantics of Ehrenfeucht in which axioms of infinity cannot be expressed.

14. “On the Length of Proofs”, *Trans. AMS* 177 (1973) 29-36.

Shows that k-provability is decidable for Peano arithmetic if plus and times are taken to be ternary predicates. Consequences include the Kreisel conjecture, and a strong version of Godel’s speed-up theorem. The doctoral theses of Statman (Stanford) and Farmer (Wisconsin) are both influenced by this paper.

15. “A Note on Rigid Substructures”, *Proc. AMS* 33 (1972) 520-522.

Solves an open problem of Kreisel’s.

16. (With M. Parnes) “Conditional Probability can be Defined for Arbitrary Pairs of Sets of Reals”, *Advances in Math* 9 (1972) 520- 522.

It is shown using nonstandard techniques that there is a finitely additive, translation invariant conditional probability measure defined on all pairs of sets of reals.

17. "A Note on Paths through $\mathcal{O}$", *Proc. AMS* 39 (1973) 178-180.

It is shown that Π^1_1-paths through Church-Kleene $\mathcal{O}$ have very little information in that a hyperarithmetic set which is truth table reducible to one is already recursive in the halting problem.

18. (With M. Parnes) "Conditional Probabilities and Uniform Sets", *Proc. Victoria Symp. Nonstandard Analysis* Ed. Hurd and Loeb, Lecture Notes in Math #369, 180-84.

Detailed version of no. 16 above.

19. (Editor) *Logic Colloquium* Lecture Notes in Math #453 (1975)

20. "An $\aleph_0$-categorical Theory whose Language is Countably Infinite", *Proc. AMS*

The title is clear. This solves an open problem due to Baldwin and Tait to find an -categorical theory whose language is inherently infinite.

21. (With D.H.J. de Jongh) "Well Partial Orderings and Hierarchies", *Proc. Kon. Ned. Akad. Sci* Series A 80 (1977) 195- 207.

Establishes an interesting and important connection between hierarchies defined by closure operations and well partial orderings studied by Higman and Kruskal.

22. "The Completeness of Propositional Dynamic Logic", *7th MFCS* (1978) LNCS #64 403-415. (LNCS=Lecture Notes in Computer Science)

Solves an open problem of Fischer and Ladner to provide a complete set of axioms and rules for the propositional dynamic logic.

23. "A Decidability Result for a Second Order Process Logic", *19th IEEE-FOCS* (1978) 177-183.

This is a fundamental paper on process logic describing a powerful system SOAPL which includes PDL (propositional dynamic logic) and temporal logic, but is decidable.

24. "Propositional Dynamic Logics of Programs: Systems, Models and Complexity", *7th ACM-POPL* (1980) 186-192.

Model theory of PDL.

25. (With A. Meyer) "Definability in Dynamic Logic", *12th ACM- STOC* (1980) 1-7, also *JCSS* 23 (1981) 279-298.

Shows that first order dynamic logic and infinitary logic are closely connected. It is also shown that array assignments and random assignments add strength to Dynamic Logic.

26. "Propositional Logics of Programs: A Survey" in *Logics of Programs* Ed E. Engeler, LNCS #125 (1980) 102-144.

The title is clear. One of the sections was written by Dexter Kozen.

27. "Effectiveness", *the Philosophical Forum* XII (1980) 68-81.

A discussion of Church's thesis.

28. (With D. Kozen) "An Elementary Completeness Proof for PDL" *Theor. Comp. Sci* 14 (1981) 113-118.

A streamlined version of #22 above.

29. (With D. Harel, D. Kozen) "Process Logic: Expressiveness, Decidability, Completeness", *JCSS* 25 (1982) 144-170.

A study of decidability and completeness of process logic.

30. (With A. Ehrenfeucht and G. Rozenberg) "Pumping Lemmas and Regular Sets", *SIAM J. Computing* 10 (1981) 536-41.

It is shown that the usual pumping lemma does not imply regularity, and in fact, there are uncountably many languages satisfying the pumping lemma, but that an extension, the block pumping lemma, is equivalent to regularity.

31 (With A. Chandra, J. Halpern, A. Meyer) "Equations between Regular Terms and an Application to Process Logic", *13th STOC* (1981) 384-390, also in *SIAM J. Computing* 14 (1985) 935-942.

It is shown that it is undecidable whether regular equations have solutions, and hence "nonlocal" process logic is also undecidable.

32. "The Problem of Vague Predicates", in *Logic, Language and Method* Ed. Cohen and Wartofsky, Reidel (1982) 241-261.

A philosophical investigation of the question whether so called fuzzy predicates are actually predicates. The paper uses as background certain work of Dummett, Kit Fine, Crispin Wright, and Volpin. This paper is better known among philosophers than among computer scientists.

33. "Models for Programs", *Proc. 1st Bangalore Conference on Foundations of Software Theory and Theoretical Computer Science (FST-TCS)* TIFR (1981) 109-121.

Investigates a certain topology associated with programs and which explains why Hoare logic is incomplete.

34. (With A. Mahoney) "A Theory of Probabilistic Programs", in *Logic of Programs* Ed. Clarke and Kozen, LNCS #164 (1983) 396-402.

35. (with D. Kozen) "A Decision Procedure for the Propositional μ-calculus", in *Logic of Programs* (Ed Clarke and Kozen) Springer Lecture Notes in Comp. Sci. (LNCS) #164 (1983) 313-325.

The title is quite clear. The decision procedure is nonelementary, but an elementary decision procedure was later found by Streett.

36. "Propositional Logics of Programs: New Directions", *FCT-83* LNCS #158, 347-359.

37. "Propositional Game Logic", *24th IEEE-FOCS* (1983) 195-200.

The two papers above investigate game logic which stands in the same relation to PDL that alternating Turing machines do to nondeterministic ones. Completeness and decidability are proved. The doctoral thesis of David Peleg at Weizmann Institute, to appear in JACM, is essentially an outgrowth of these papers.

38. "Some Applications of Topology to Program Semantics", *Math. Sys. Theory* 16 (1983) 111-131.

Extends the work of #33 above.

39. "The Logic of Games and its Applications" *Annals of Discrete Math.*, 24 (1985) 111-140.

This is a journal version of #36 and #37 above.

40. "Logics of Knowledge, Games and Dynamic Logic", *Foundations of Software Theory and Theoretical Computer Science* Springer LNCS #181, (1984) 202-222.

Shows how to interpret a nonmonotonic rule of McCarthy and obtains completeness and decidability results.

41. "Introductory Note to Gödel's paper on the Length of Proofs", in *the Collected Works of K. Gödel* Ed. by Feferman et al., Oxford 1986, pp. 394-399.

42. "Modal Logic", in *the Encyclopedia of Artificial Intelligence*, John Wiley 1987.

43. (With R. Ramanujam) "Distributed Processing and the Logic of Knowledge", in #44 below, pp. 256-268.

Defines a notion of knowledge for distributed processes which obeys the S5 laws and shows how to connect it with questions like safety and liveness.

44. *Logics of Programs* (Editor), Proceedings of a Conference at Brooklyn College, June 1985, Springer Lecture Notes in Computer Science #193.

45. "Levels of Knowledge in Distributed Computing", in *Proc IEEE Symposium on Logic in Computer Science,* June 1986, 314-321.

Makes some connections between knowledge, well partial orders and formal language theory to show *exactly* which states of knowledge are attainable among n processes. One of the theorems is joint with my student Paul Krasucki.

46. "Some Recent Contributions of Logic to Computer Science", in *Proc. World Computer Congress*, Dublin, Sep. 1986, 391-392.

Position paper as chairman of a symposium in Dublin.

47. “Communication, Consensus and Knowledge”, (with P. Krasucki), *J. Economic Theory* **52** (1990) pp. 178-189.

A connection between knowledge as studied in mathematical economics and in distributed computing.

48. “Knowledge and the Problem of Logical Omniscience” *ISMIS- 87* (International Symp. on Methodology for IntelligentSystems), North Holland (1987) pp. 432-439.

Proposes a way of solving the problem that in most current logics of knowledge, knowledge is closed under logical inference, so that, for example, a person who knows the axioms of Peano arithmetic must also know all the theorems. This feature is not only unrealistic, it makes it impossible to understand how there can be ignorance of mathematical facts and why public key cyptography should be possible.

49. “Some Recent Applications of Knowledge” in *FST and TCS 7*, Proceedings of a Conference in Pune, India, December 1987, LNCS #287, pp. 528-539.

A survey of some recent results in the logic of knowledge as applied in computer science.

50. “Decidability and Undecidabilty in Distributed Transition Systems” IBM Research report. In *A Perspective in Theoretical Computer Science*, Ed. R. Narasimhan, World Scientific Ltd. 1989 pp. 199-209.

We prove two results about a propositional logic for concurrency. One that the non-deterministic version of this logic is decidable in NEXPTIME. The other is that the deterministic version is highly undecidable, in fact Π^1_1-complete.

51. “Dumb-founded Sets”, *Bull. EATCS*, no. 43, Feb 1991, pp. 183-184.

A skit, based on the proliferation of set theories.

52. “Finite and Infinite Dialogues”, in the *Proceedings of a Workshop on Logic from Computer Science*, Ed. Moschovakis, MSRI publications, Springer 1991 pp. 481-498.

There are various puzzles current in the literature, the muddy children puzzle for instance, which nicely bring out the structure of common knowledge and the role it plays in communication. We consider variants and extensions of this puzzle including some where a conversation may go on through the transfinite ordinals before terminating and others where one may speak even when one is not sure but can be penalized for an incorrecti answer.

53. (with P. Krasucki), “Levels of knowledge in distributed computing”, *Sadhana - Proc. Ind. Acad. Sci.* **17** (1992) pp. 167-191.

We show a correspondence between levels of knowledge, with common knowledge being the highest level, and certain regular languages.

54. “Recent Trends In Reasoning about Knowledge”, in *Theoretical Aspects of Reasoning about Knowledge*, Morgan Kaufmann, Los Altos, California, 1990 pp. 3-10.

A brief survey of some of the recent activity in reasoning about knowledge.

55. *Theoretical Aspects of Reasoning about Knowledge*, (editor) Morgan Kaufmann, Los Altos, California, 1990.

56. "Probabilistic Knowledge and Probabilistic Common Knowledge" (with Paul Krasucki and Gilbert Ndjatou), *ISMIS 90*, North Holland 1990, pp. 1-8.

We show how to answer questions like "How much does A know about B's knowledge of C?", in a manner which naturally generalises Shannon's definition. In particular we show how there can be probabilistic common knowledge in a group even when there is no common knowledge in the usual sense.

57. "Topological Resaoning and the Logic of Knowledge". (with Larry Moss,). in *TARK 4*, Ed. Yoram Moses, Morgan-Kaufmann publishers, March 1992, pp. 95-105.

It was noticed long ago by Gödel and Tarski that topological spaces can be used to analyse modal notions. We carry the ball in the opposite direction and show that many topological notions have a strong modal-theoretical and knowledge-theoretic character and that a modal intuition underlies some of our reasoning about topology.

58. "Dynamic Logic and the Logic of Conditionals". Under preparation.

We give two translations of the Logic of Conditionals into Propositional Dynamic Logic (Deterministic Propositional Dynamic Logic) which immediately give decision procedures for two important cases.

59. "The Effect of AI on Other Fields of Research", *Proc. Phoenix Conference on Computers and Communication*, March 1991.

Position paper in a panel discussion.

60. "Monotonic and Non-monotonic Logics of Knowledge", in *Fundamenta Informatica* special issue, *Logics for Artificial Intelligence* vol XV (1991) pp. 255-274.

Journal version of no. 40, above

61. "A Test for Fuzzy Logic", *SIGACT NEWS,* **22**, 3, Summer 1991, pp. 49-50.

Examines the question of whether Fuzzy logic can provide an adequate semantics for our linguistic practices.

62. "A Logical Study of Distributed Transition Systems", with Lodaya, Ramanujam and Thiagarajan. *Information and Computation* **119** May 1995, 91-119.

63. "Notes of Rohit Parikh's lectures on Reasoning about Knowledge", by Anna Maria Zanaboni. (the Lectures were given in Acireale at an International School for Computer Scientists) published in Italy, summer 1993. (Cassa di Risparmio di Padova e Rovigo)

64. "Vagueness and Utility: the Semantics of Common Nouns" in *Linguistics and Philosophy* **17** 1994, 521-35.

We point out that to date there do not exist satisfactory logics or semantics for vague predicates. We show that these predicates are person dependent, i.e. the way they are applied varies from person to person and also from occasion to occasion. Hence a theory is needed of why they are useful in communicatio and do not lead to misunderstandings. We show how there are settings where despite some differences in application by the various individuals involved, communication is useful. These are the settings in which we do in fact use these predicates, avoiding them in other areas where such sturdiness does not obtain.

65. "Logical omniscience", in *Logic and Computational Complexity* Ed. Leivant, Springer Lecture Notes in Computer Science no. 960, (1995) 22-29.

Current logics of knowledge have the property that under their definition of what it means for i to know some formula A, i knows all valid formulas and also the consequences of anything that i knows. This is implausible and to find more plausible definitions of knowledge is the problem of logical omniscience. We make some algorithim based suggestions.

66. "Language as Social Software"(abstract), International Congress on Logic, Methodology and Philosophy of Science (1995), page 417. Full paper in *Future Pasts: the Analytic Tradition in Twentieth Century Philosophy*, Ed. J. Floyd and S. Shieh, Oxford U. Press, 2001, 339-350.

One can view language as playing the role of a system of signals to facilitate social behaviour. It turns out that this view is very flexible and can explain various philosophical puzzles like Searle's Chinese room puzzle or Quine's indetermincy of translation thesis.

67. "Knowledge based computation (Extended abstract)" in *Proceedings of AMAST-95* Montreal, July 1995, Edited by Alagar and Nivat, LNCS no. 936, 127-42.

A short survey of work in this area done to date.

68. "Some reminiscences of Kreisel", in *Kreiseliana* edited by P. Odifreddi, 1999.

69. "Topological Reasoning and The Logic of Knowledge" (with Dabrowski and Moss) *Annals of Pure and Applied Logic* **78** (1996) 73-110

While it is true that one's knowledge depends on one's evidence, traditional definitions of knowledge leave out the fact that one can *gather* or improve one's knowledge. E.g. a measurement of some quantity can be made more accurate by using better instruments. This observation allows us to develop a logic with two modalities, one for knowledge and the other for effort. Some topological notions like closed or perfect can be defined in this logic. We prove axiomatizations and provide completeness results.

70. "How far can we formalize language games?" in *The Foundational Debate* edited by DePauli-Scimanovich, Köhler and Stadler, Kluwer Academic (1995) pp. 89-100.

Wittgenstein's views in the Philosophy of Mathematics are examined and shown to be very modern in spirit. We raise the question how far one can provide formal versions of language games as a way of making certain problems more explicit.

71. "Computation", *MacMillan Encyclopedia of Philosophy* - supplement (1996), pp. 86-87.

A brief survey of logical developments coming out of Computer Science.

72. “Church’s theorem and the decision Problem”, *the Routledge Encyclopedia of Philosophy*, 1998.

A discussion of the Church-Turing theorem that first order logic is undecidable and its connection to the Church-Turing thesis.

73. “Vague predicates and language games”, *Theoria* Spain, vol XI, no. 27, Sep 1996, pp. 97-107.

Further research along the lines of #64, above.

74. ”Beliefs, Belief Revision, and Splitting Languages” in *Proc. Logic, Language and Computation*, Ed. Moss, Ginzburg and de Rijke, CSLI 1999, pp. 266-278 (earlier version appeared in 1996 in the prliminary proceedings).

The celebrated AGM axioms for belief revision allow the trivial revision under which all old information is lost. We show how we can incorporate a formal notion of relevance which allows one’s information to be split uniquely into a number of disjoint subject areas. Revising information only in those areas where new information is received blocks the trivial revision.

75. “Length and structure of proofs”, in *Synthese* **114** 1998, special issue edited by J. Hintikka.

A survey of work in the theory of proofs, beginning with our own work in the late sixties and early seventies and giving an account of subsequent results to date.

76. “Frege’s puzzle and belief revision”, typescript, November 1997. Presented at the World Congress of Philosophy, Boston 1998.

Ever since Frege there have been, largely unsuccessful, attempts to work out a notion of sense or meaning which will allow us to explain the cognitive contribution made by a sentence and aslo explain how its truth value is determined. Various puzzles, Frege’s Hesperus-Phosphorus puzzle, Kripke’s Pierre puzzle, Burge’s arthritis puzzle, etc show up the difficulty of the problem. We show how an approach based on the notion of belief revision can address these various issues.

77. (with J. Dauben) “Mathematics in India in the 20th century” to appear in the Italian Encyclopedia of Mathematics, 1998.

78. “Propositions, propositional attitudes and belief revision” in K. Segerberg, M. Zakharyaschev, M. de Rijke, H. Wansing, editors, *Advances in Modal Logic, Volume 2*, CSLI Publications, 2001.

This is a somewhat revised version of #76 above

79. “The Santa Fe bar problem revisited” (with Amy Greenwald and Bud Mishra), presented at the Stony Brook workshop on Game theory, summer 1998.

The Santa Fe bar problem is a problem about a bar in Santa Fe New Mexico. The capacity of the bar is less than the number of people who want to go there but even people who do want to go, would not like to if it is crowded. This creates a game theoretic problem where it is impossible for the prospective customers to have a uniform strategy which can succeed. We investigate what kind of learning is possible.

80. (with Laxmi Parida and Vaughan Pratt) "Sock Sorting", appeared in a volume dedicated to Johan van Benthem, University of Amsterdam, August 99, reprinted in *Logic J. of IGPL*, vol 9 (2001).

If a person puts n pairs of socks in the washing machine and then the drier, when the wash is completed, what he has is 2^*n individual socks. Socks which are near enough in color will seem to match, but this matching relation is not transitive. This results in the situation that naive matching can leave socks un-matched. The problem looks on the face of it as if it can be NP-complete, but we show that there is a polynomial algorithm.

81. (with Samir Chopra) "An Inconsistency Tolerant Model for Belief Representation and Belief Revision" appeared in *Proc. IJCAI 99. Annals of Math and AI*, 2001.

We define the notion of a B-structure which consists of a number of theories with overlapping languages glued together, and which allow us to localize an agent's beliefs as well as represent a situation where an agent's beliefs are globally incosistent but locally consistent. This model provides for both query answering and belief revision. Axioms analogous to those of AGM are satisfied.

82. (with Samir Chopra and Konstantinos Georgatos) "Non-Monotonic Inference on Sequenced Belief Bases", *Proceedings of the Delphi Conference in Logic*, July 1999. Final version in *JANCL* vol 11, 1-2 (2001)

Similar theme to 81, above.

83. (with Horacio Arlo Costa) "Two place probabilities, beliefs and belief revision: on the foundations of iterative belief kinematics", in *Proc. 12th Amsterdam Colloquium*, December '99, edited by Paul Dekker, pp. 1-6.

We offer a probabilistic model of *rational consequence relations* by appealing to the extension of the classical Ramsey-Adams test proposed by Vann McGee. Previous and influential models of non-monotonic consequence relations have been produced in terms of the dynamics of *expectations*. 'Expectation' is a term of art in these models, which should not be confused with the notion of expected utility. The expectations of an agent allude to some form of beliefs weaker than absolute certainty. Our model offers a modified and extended version of an account of qualitative belief in terms of conditional probability, first presented by vanFraassen in 1995. We use this model in order to relate probabilistic and qualitative models of non-monotonic relations in terms of expectations. In doing so we propose a probabilistic model of the notion of expectation.

We provide characterization results both for logically finite languages and for logically infinite, but countable, languages. The latter case shows the relevance of imposing or not imposing the axiom of countable additivity on our probability functions. We show that a rational logic defined over a logically infinite language can only be characterized in terms of finitely additive conditional probability.

84. (with Samir Chopra and Renata Wasserman) "Approximate belief revision", presented at *WOLLIC-2000*, Brazil. To appear in the *Logic Journal of the IGPL*.

The standard AGM theory for belief revision provides an elegant and powerful framework for reasoning about how a rational agent should change its beliefs when confronted with new information. However, the agents considered are extremely idealized. Some recent models attempt to tackle the problem of plausible belief revision by adding structure to the belief bases and using nonstandard inference operations. One of the key ideas is that not all of an agent's beliefs are relevant for an operation of belief change.

In this paper we incorporate the insights pertaining to local change and relevance sensitivity with the use of *approximate inference relations*. These approximate inference relations offer us partial solutions at any stage of the revision process. The quality of the approximations improves as we allow for more and more resources to be used. We are provided with upper and lower bounds to what would be obtained with the use of classical inference.

85. "Social Software", *Synthese*, **132**, Sep 2002, 187-211.

We suggest that the issue of constructing and verifying social procedures, which we suggestively call *social software*, be pursued as systematically as computer software is pursued by computer scientists. Certain complications do arise with social software which do not arise with computer software, but the similarities are nonetheless strong, and tools already exist which would enable us to start work on this important project. We give a variety of suggestive examples and indicate some theoretical work which already exists.

86. "Some thoughts on election procedures", in *Aurora*, Jan 2001. (Doctoral program in Philosophy, CUNY Graduate center).

Just a very informal survey of some existing work along with some observations on what it means to have an election procedure which fairly implements the wishes of the public.

87. "Completeness of certain bimodal logics for subset spaces" (with Angela Weiss), *Studia Logica*, **71** (June 2002), 1-30.

This extends the work with Dabrowski and Moss on the connections between topology and knowledge.

88. "*D*-Structures and their semantics", appeared in a volume dedicated to Johan van Benthem, University of Amsterdam, August 99.

This is a completely novel approach to the semantics of first order languages which includes as special cases, classical semantics, intuitionistic (Heyting) semantics and Ehrenfeuchts' *-semantics.

89. "Towards a theory of social software", in *Proceedings of DEON'02, (Deontic Logic in CS)* Imperial College, London, pages 265-277

90. Rohit Parikh, States of Knowledge, Plenary address, *WOLLIC 2002*, Rio de Janeiro.

91. (with Jouko Vaananen), Finite information logic, *Annals of Pure and Applied Logic*, **134** (2005) 83-93.

We introduce a generalization of *Independence Friendly (IF)* logic in which Eloise is restricted to a finite amount of information about Abelard's moves. This Logic is shown to be equivalent to a sublogic $\exists\forall$ of first order logic, has the finite model property, and decidable, and closer to real world concerns. Moreover, it gives an exponential compression relative to $\exists\forall$ logic.

92. (With R. Ramanujam), A Knowledge based Semantics of Messages, *J. Logic, Language and Information* **12** 2003, 453-467

We investigate the semantics of messages, and argue that the meaning of a message is naturally and usefully given in terms of how it affects the *knowledge* of the agents involved in the communication. We note that this semantics depends on the protocol used by the agents, and thus not only the message itself, but also the protocol appears as a parameter in the meaning. Understanding this dependence allows us to give formal explanations of a wide variety of notions including language dependence, implicature, and the amount of information in a message.

93. (With Marc Pauly), Game Logic - An Overview, in *Studia Logica*, 2003.

Game Logic is a modal logic which extends Propositional Dynamic Logic by generalising its semantics and adding a new operator to the language. The logic can be used to reason about determined 2-player games. We present an overview of meta-theoretic results regarding this logic, also covering the algebraic version of the logic known as Game Algebra. Game Logic was invented by Parikh in the early 80's (see #39).

94. Levels of Knowledge, Games, and Group Action, *Research in Economics* **57** 2003, 267-281.

We study levels of knowledge intermediate between individual knowledge and common knowledge and show how these are relevant to some practical situations, and also how they work formally in some toy examples. What agents know and what they know (or believe) other agents know affects their choices. We show that the outcome of a game is deeply affected by such knowledge facts.

95. (with Eric Pacuit) A logic for communication graphs, presented at ASL annual meeting in May 2004, and at DALT 2004. To appear in the *proceedings of DALT 2004*.

We consider a communication graph where agents can receive information from other agents only along the edges of the graph. This gives rise to an interesting extension of *TOpologic*, investigated earlier by Moss and Parikh.

96. (with Eric Pacuit and Eva Cogan) The logic of knowledge based obligation, presented

at Society of Exact Philosophy meeting in Maryland, and at *DALT 2004.* Final version in *Synthese*, **149** (2006) 311-341.

An agent's obligations depend not only on a situation but also on what the agent knows. For instance a doctor is responsible to treat a patient only if the doctor is *informed* that the patient is sick. We develop a semantics to represent such issues.

97. (with Samir Chopra and Eric Pacuit) Knowledge theoretic properties of strategic voting, presented at *JELIA 2004*.

Sometimes a voter who knows how other voters are voting can change his vote so as to get a more favourable outcome than he would get if he voted for his favourite. E.g. in year 2000, some Nader voters voted for Gore for this reason. But other agents may also strategize in this way. This may or may not lead to an equilibrium. We investigate various scenarios.

98. (with Horacio Arlo Costa) "Conditional probability and defeasible inference", *Journal of Philosophical Logic*, **34** (2005) 97-119.

We offer a probabilistic model of *rational consequence relations* (as in Lehmann and Magidor) by appealing to the classical Ramsey-Admas text proposed by Vann McGee. An earlier version appeared in #83.

99. "WHAT do we know and what do WE know?", the proceedings of *Theoretical Aspects of Rationality and Knowledge*, June 2005, University of Singapore.

100. (with Eric Pacuit) "Safe votes, sincere votes, and strategizing", presented at *Uncertainty in Economics*, Singapore 2005.

101. (with Eric Pacuit and Samer Salame) "Some results on Adjusted Winner", presented at the *International Game Theory Conference at Stony Brook* (July 2005)

102. (with Eric Pacuit) Social Interaction, Knowledge, and Social Software, in *Interactive Computation: The New Paradigm*, ed. Dina Goldin, Sott Smolka, Peter Wegner, Springer 2007, 441-461.

103. (With Melvyn Nathanson) Density of Natural Numbers and the Levy Group, *the Journal of Number Theory*, **124** (2007) 151-158.

Given a set X of natural numbers, let x_k be the number of elements of X which are $\leq k$. If the limit $d = x_k/k$ exists, then it is called the *density* $d(X)$ of X. Suppose f is a permutation (1-1, onto function) of N. Abusing language a bit, denote by $f(X)$ the set $\{f(n)|n \in X\}$. If f has the property that whenever X has a density, then so does $f(X)$, then for all such X, $d(X) = d(f(X))$.

104. (Wth Larry Moss and Chris Steinsvold) Topology and Epestimic Logic, in *Logic of Space*, edited by Johan van Benthem et al, 2007.

105. "Some Puzzle About Probability and Probabilistic Conditionals", in *Logical Foundations of Computer Science*, edited by Artemov and Nerode, Springer, June 2007, pp. 449-456. Revised version "Probabilistic Conditionals are almost Monotonic", with

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Let W be a finite space. Let A, B denote predicates over W, i.e., subsets of W. Say that the probabilistic conditional $A > B$ is true if the conditional probability $p(B|A)$ is high, say over .95. It is well known that monotonicity does not hold and $p(B|A \wedge X)$ may be low even though $p(B|A)$ is high. We show that nonetheless, if W is large and finite, and $p(B|A) > .95$ then for almost all $X \subseteq W$, $p(B|A \wedge X) > .94$. In other words, probabilistic conditionals are almost monotonic.

106. Sentences, Propositions and Logical Omniscience, to appear in *The Review of Symbolic Logic.*

In this paper we attack the problem of logical omniscience for the single agent case by defining belief states in terms of an agent's choices (rather than the other way around). This allows us to assign belief states not only in terms of what an agent says, but also in terms of what an agent does. This approach allows us to deal with issues of lack of logical omniscience, as well as of agents holding inconsistent beliefs.

107. Is there a logic of society?, to appear in *Logic at the Crossroads*, edited by Benthem, Gupta and Parikh - 2008.

A survey of recent developments in logic.

108. Logical Omniscience in the Many Agent Case, manuscript, July 2007.

It is commonly assumed that when two agents are in a common situation, then they have common knowledge of facts about it. E.g. if they see a sunset then they have common knowledge of this fact. But such assumptions take it for granted that we all have a perfect theory of mind, which is not typically the case. This is why games are not always played in terms of Nash equilibria. We deal with this problem by reducing group states of belief to certain kinds of betting games, and show also that tradiional states of knowledge correspond to Nash equilibria of such games. However, other states of knowledge which do not correspond to such equilibria can also exist in practice, due to our limited reasoning abilities.

109. On Public Language and Private Language

110. On the Interaction between Computer Science and Economics, edited by Eric Pacuit, January 21, 2004.