Chitta Baral
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Research Interests

• **Natural Language Understanding (NLU) and Question Answering.** Instruction Tuning; Bias and fairness in NLP; Robustness and Selective answering in NLP; Semantic parsing; NLI; Combining QA and Information Retrieval, NLU based question answering; Knowledge hunting from natural language text; Information Extraction; NLP Applications to Cybersecurity, Scientific discovery in Biology, and Robotics Combining NLU with deep reasoning; Answering Why, How, and What-If questions; and Solving combinatorial puzzles described in natural language.

• **Bio and Health informatics.** AI and Database applications to Bioinformatics; Representation and reasoning about signal pathways, protein-protein interactions and gene networks; Learning causal connection between genes from micro-array data; Knowledge extraction from Biological texts; and Clinical NLP.

• **Knowledge representation, reasoning and declarative problem solving.** Declarative problem solving and optimizations (with applications to planning, job-shop scheduling, tournament scheduling, supply chain planning, combinatorial auctions, product configuration, diagnosis, explanation generation and constraint satisfaction problems); Knowledge Representation and Non-monotonic Reasoning (with applications to common-sense reasoning, reasoning with defaults, reasoning with incomplete information, reasoning with priorities and preferences, and inheritance hierarchies); Logic Programming; Temporal Reasoning, Combining knowledge bases; Reasoning with Uncertainty; Causality and AI in general.

• **Actions, Goals and Autonomous agents.** Mobile robots; Robot control – formal characterization and automatic generation; Cognitive robotics; Representation and reasoning about actions (concurrent actions, complex actions, actions with causal effects, actions with non-deterministic effects, narratives, sensing actions, and actions with probabilistic effects), Multi agent actions, and Goal languages.

• **Image Understanding**
Knowledge representation and Reasoning in Computer Vision and Image Understanding; Visual common-sense for scene understanding; Visual Question Understanding; Semantic representation of images/videos; Visual Question Answering; Caption Generation; and Constructing Scene Description Graphs of images.

• **Human-Robot paradigm**
Human Robot Collaboration; Human Robot Communication; Human Robot Interaction; Robot Interaction Languages; Imitation Learning; and Learning From Demonstration.

Education

Doctor of Philosophy, Computer Science August 1991.
University of Maryland, College Park, Maryland.
Dissertation: *Issues in Knowledge Representation : Semantics and Knowledge Combination.*
Advisor: Prof. Jack Minker.

Master of Science, Computer Science May 1990.
University of Maryland, College Park, Maryland.

Bachelor of Technology with Honors, Computer Science and Engineering May 1987.
Indian Institute of Technology, Kharagpur, India.

Professional Experience

Professor: (August 2002 - present) Faculty of Computer Science and Engineering, School of Computing, and Augmented Intelligence, Arizona State University.

Chair: (August 2014 - July 2022) Graduate Programs in Computer Science, Arizona State University.

Chair: (March 2008 - May 2009) Department of Computer Science and Engineering, Arizona State University.

Associate Professor: (August 1999 - August 2002) Department of Computer Science and Engineering, Arizona State University.

Visiting Scientist: (June 99 - August 99) Department of Computer and Information Science, Linkoping University, Sweden.

Associate Professor: (August 1996 - August 1999) Department of Computer Science, University of Texas at El Paso.

Visiting Scientist: (June 98 - August 98) i2 Technologies, Dallas. Worked on planning and scheduling methods for supply chain planners.

Visiting Professor: (Dec 1996 - Jan 97) Department of Computer Science, University of New South Wales, Sydney, Australia.

Assistant Professor: (August 1991 - August 1996) Department of Computer Science, University of Texas at El Paso.

Graduate Research Fellow: (August 1990 - June 1991) University of Maryland, College Park. Research towards my dissertation.

Graduate Research Assistant: (May 1988 - June 1991) Department of Computer Science, University of Maryland, College Park. Dissertation work on semantics of knowledge representation languages and theory of combining knowledge bases. Also investigated the use of semantic

constraints to constrain the search space in a parallel logic programming environment.

Teaching Assistant: (August 87 - May 88) Department of Computer Science, University of Maryland, College Park. Assisted courses in Computer Architecture, Compiler Design and Data structures.

Publications

Books

[1] C. Baral. Knowledge representation, reasoning and declarative problem solving. Cambridge University Press, 2003, ISBN 0521818028.

[2] Paulo Shakarian, Chitta Baral, Gerardo I. Simari, Bowen Xi, Lahari Pokala. Neuro Symbolic Reasoning and Learning. Springer, 2023

[3] Man Luo, Tejas Gokhale, Neeraj Varshney, Yezhou Yang, Chitta Baral. Advances in Multimodal Information Retrieval and Generation. Springer. 2024. (in press)

Journal Articles

[1] Aarohi Srivastava, Abhinav Rastogi, Abhishek Rao, ... Chitta Baral ... (hundreds of coauthors). Beyond the Imitation Game: Quantifying and extrapolating the capabilities of language models. (BIG BENCH) Transactions on Machine Learning Research, 2023.

[2] Chitta Baral, Gregory Gelfond, Enrico Pontelli, Tran Cao Son: An action language for multi-agent domains. Artificial Intelligence 302: 103601 (2022)

[3] Pratyay Banerjee, Kuntal Kumar Pal, Murthy V. Devarakonda, Chitta Baral: Biomedical Named Entity Recognition via Knowledge Guidance and Question Answering. ACM Transactions on Computational Health 2(4): 33:1-33:24 (2021)

[4] Arindam Mitra, Chitta Baral: Incremental and Iterative Learning of Answer Set Programs from Mutually Distinct Examples. TPLP 18(3-4): 623-637 (2018)

[5] Chitta Baral, Shih-Fu Chang, Brian Curless, Partha Dasgupta, Julia Hirschberg, Anita Jones. Ask not what your postdoc can do for you. Communications of. ACM 61(1): 42-44 (2018).

[6] Somak Aditya, Yezhou Yang, Chitta Baral, Yiannis Aloimonos and Cornelia Fermuller. Image Understanding using Vision and Reasoning through Scene Description Graph. Computer Vision and Image Understanding Journal. 173: 33-45 (2018). `https://doi.org/10.1016/j.cviu.2017.12.004.`

[7] Saadat Anwar, Chitta Baral, and Katsumi Inoue. Encoding Petri Nets in Answer Set Programming for Simulation Based Reasoning. Theory and Practice of Logic Programming 13 (4-5), Online Supplement, 2013.

[8] L. Tari, Nguyen Vo, Shanshan Liang, Jagruti Patel, Chitta Baral and James Cai. Identifying novel drug indications through automated reasoning Authors and Affiliations. In PLoS ONE, 2012.

[9] Chitta Baral, Juraj Dzifcak, Marcos Alvarez Gonzalez and Aaron Gottesman. Typed answer set programming lambda calculus theories and correctness of inverse lambda algorithms with respect to them. Theory and Practice of Logic Programming. 12(4-5): 775-791, 2012.

[10] J. Hakenberg, Dmitry Voronov, Vo H Nguyen, Shanshan Liang, Saadat Anwar, Robert Leaman, Luis N Tari and Chitta Baral. A SNPshot of PubMed to find associations between genetic variants, drugs, and diseases. Journal of Biomedical Informatics. 45(5): 842-850, 2012.

[11] L. Tari, P. Tu, J. Hakenberg, Y. Chen, T. Son, G. Gonzalez and C. Baral. Parse Tree Database for information Extraction. IEEE Transactions on Knowledge and Data Engineering. Vol 24, Number 1, January 2012, pages 86-99.

[12] J. Hakenberg, Ills Slot, Domonkos Tikk, Nguyen Ha Vo, Luis Tari, Quang Long Nguyen, Chitta Baral and Ulf Leser. Molecular Event Extraction from Link Grammar Parse Trees in the BioNLP'09 Shared Task. Computational Intelligence 27(4): 665-680 (2011).

[13] Chitta Baral, Gregory Gelfond, Enrico Pontelli and Tran Cao Son. Logic programming for finding models in the logics of knowledge and its applications: A case study. Theory and Practice of Logic Programming 10(4-6): 675-690 (2010).

[14] Luis Tari, Saadat Anwar, Shanshan Liang, James Cai and Chitta Baral. Discovering drug-drug interactions: a text-mining and reasoning approach based on properties of drug metabolism. Bioinformatics 26(18): (2010).

[15] J. Hakenberg, Robert Leaman, Nguyen Vo, Siddhartha Jonnalagadda, Ryan Sullivan, Christopher Miller, Luis Tari, Chitta Baral and Graciela Gonzalez. Efficient Extraction of Protein-Protein Interactions from Full-Text Articles. IEEE/ACM Trans. Comput. Biology Bioinform. 7(3): 481-494 (2010).

[16] Nam Tran and Chitta Baral. Hypothesizing about signaling networks. Journal of Applied Logic 7(3): 253 - 274 (2009).

[17] Luis Tari, Chitta Baral and Seungchan Kim. Fuzzy c-means clustering with prior biological knowledge. Journal of Biomedical Informatics 42(1): 74-81 (2009).

[18] Chitta Baral, Michael Gelfond and J. Nelson Rushton. Probabilistic reasoning with answer sets. Theory and Practice of Logic Programing 9(1): 57-144 (2009).

[19] Richard B. Scherl, Tran Cao Son and Chitta Baral: State-Based Regression with Sensing and Knowledge. Int. J. Software and Informatics 3(1): 3-30 (2009).

[20] Chitta Baral, Thomas Eiter, Marcus Bjareland and Mutsumi Nakamura. Maintenance goals of agents in a dynamic environment: Formulation and policy construction. Artificial Intelligence 172(12-13): 1429-1469 (2008).

[21] N. Tran and C. Baral. Reasoning about non-immediate triggers in biochemical networks. Annals of Mathematics and Artificial Intelligence. Volume 2-4, 267-293 (2007).

[22] Phan Huy Tu, Tran Cao Son and Chitta Baral. Reasoning and Planning with Sensing Actions, Incomplete Information, and Static Causal Laws using Answer Set Programming Theory and Practice of Logic Programming. 7(4): 377-450 (2007).

[23] Tuan Le, Chitta Baral and Son Tran. A State-Based Regression Formulation for Domains with Sensing Actions and Incomplete Information. In Logical Methods in Computer Science (Electronic journal) Volume 2, Issue 4, 2006.

[24] Xin Zhang, Seungchan Kim, Tie Wang and Chitta Baral. Joint learning of logic relationships for studying protein function using phylogenetic profiles and the Rosetta Stone method. IEEE Transactions on Signal Processing. Volume 54, Issue 6, Part 2, pages 2427-2435, 2006.

[25] Tran Cao Son, Chitta Baral, Sheila McIlraith and Nam Tran. Planning with domain-dependent knowledge of different kinds – an answer set programming approach. ACM Transactions on Computational Logic. Volume 7, Number 4 (October 2006), pages 1-70.

[26] Nam Tran, Chitta Baral, Vinay Nagaraj and Lokesh Joshi. Knowledge-Based Framework for Hypothesis Formation in Biochemical Networks: application to the p53 network. Bioinformatics, 21: ii213-ii219. (Supplement for the papers of ECCB'2005)

[27] C. Baral and Y. Zhang. Knowledge updates: Semantics and complexity issues. Artificial Intelligence. 164(1-2): 209-243 (2005).

[28] Graciela Gonzalez, Chitta Baral and Michael Gelfond. Alan: An Action Language for Modelling Multimedia Presentations Using Non- Markovian Domains. Studia Logica. 79(1): 115-134 (2005).

[29] Chitta Baral and Nam Tran. Representation and reasoning about evolution of the world in the context of reasoning about actions. Studia Logica. 79(1): 33-46 (2005).

[30] C. Baral, K. Chancellor, Nam Tran, M. Berens, A. Joy and Nhan Tran. A knowledge based approach for representing and reasoning about signal networks. Bioinformatics. vol 20, supplement 1, pages i15-i22, Supplement for the long papers of ISMB/ECCB'04, 2004.

[31] R. Trejo, J. Galloway, C. Sachar, V. Kreinovich, C. Baral and L. Tuan. From planning to searching for the shortest plan: an optimal translation. International journal of uncertainty, fuzziness and knowledge-based systems. 9 (6): 827-837, 2001.

[32] G. Trajcevski, C. Baral and J. Lobo: Formalizing and Reasoning About the Requirements Specifications of Workflow Systems. IJCIS 10(4): 483-507 (2001).

[33] T. Son and C. Baral. Formalizing sensing actions – a transition function based approach. In *Artificial Intelligence*, 125, 1-2, 19-93, 2001.

[34] C. Baral, V. Kreinovich and R. Trejo. Computational complexity of planning and approximate planning in presence of incompleteness. In *Artificial Intelligence*, 122, 241-267, 2000.

[35] C. Baral. Abductive reasoning through filtering. In *Artificial Intelligence*, 120 (1), 1-28, 2000.

[36] C. Baral, A. Gabaldon and A. Provetti. Value minimization in Circumscription. In *Artificial Intelligence*, 102/2, 163-186, July 1998.

[37] C. Baral, A. Gabaldon and A. Provetti. Formalizing narratives using nested circumscription. In *Artificial Intelligence*, 104/1-2, 107-164, Sept 1998.

[38] C. Baral and T. Son. Relating theories of actions and reactive control. In *Electronic Transactions on Artificial Intelligence*, vol 2, issue 3-4, 211-271, July - December 1998.

[39] C. Baral, M. Gelfond and O. Kosheleva. Expanding queries to incomplete databases by interpolating general logic programs. In *Journal of Logic Programming*, vol 35, 1998, 195-230.

[40] C. Baral, G. Gonzalez and T. Son. Conceptual modeling and querying in multi-media databases. In *Multimedia Tools and Applications*, 7, 37-66 (1998).

[41] C. Baral and Michael Gelfond. Reasoning about effects of concurrent actions. In *Journal of Logic Programming*, Vol 31(1-3), May 97, 85-117.

[42] C. Baral. Embedding Revision Programs in Logic Programming Situation Calculus. In *Journal of Logic Programming*, vol 30(1), Jan 97, 83-97.

[43] C. Baral, M. Gelfond and A. Provetti. Representing Actions: Laws, Observations and Hypothesis. In *Journal of Logic Programming*, Vol 31(1-3), May 97, 201-243.

[44] C. Baral. Relating Logic programming theories of actions and partial order planning. In *Annals of Math and AI*, Vol. 21 (1997) Nos. 2-4.

[45] C. Baral. Varying Selection Function to Relate Conditional Logics and Preferential Models. In *Fundamenta Informaticae*, vol 21, No. 4 (1994), 307-320.

[46] C. Baral and M. Gelfond. Logic Programming and Knowledge Representation. In *Journal of Logic Programming*, 19,20:73-148, 1994.

[47] C. Baral, S. Kraus, J. Minker and V. S. Subrahmanian. Combining Default Logic Databases. In *International Journal of Intelligent and Co-operative Information Systems*, vol. 3, No. 3, 319-348, 1994.

[48] C. Baral and V. S. Subrahmanian. Duality between Alternative Semantics of Logic Programs and Nonmonotonic Formalisms. In *Journal of Automated Reasoning*, 10:399-420, 1993.

[49] C. Ramamoorthy, D. Cooke and C. Baral. Maintaining the Truth of Specifications in Evolutionary Software. In *International Journal of Tools for Artificial Intelligence*, vol 2, No 1 (1993) 15-31.

[50] C. Baral and V. S. Subrahmanian. Stable and Extension Class Theory for Logic Programs and Default Logics. In *Journal of Automated Reasoning*, 8: 345-366, 1992.

[51] C. Baral, J. Lobo and J. Minker. Generalized Disjunctive Well-founded Semantics for logic programs. In *Annals of Math and Artificial Intelligence*, 5 (1992) 89-132.

[52] C. Baral, S. Kraus, J. Minker and V. S. Subrahmanian. Combining Knowledge Bases Consisting of First Order Theories. In *Computational Intelligence*, 8, 1, (1992), 45-71.

[53] C. Baral, J. Minker and S. Kraus. Combining Multiple Knowledge Bases. In *IEEE Transactions on Knowledge and Data Engineering*, June 1991, volume 3, number 2, pages 208-221.

Edited Books/Proceedings/Special Issues

[1] Chitta Baral, James P. Delgrande, Frank Wolter: Principles of Knowledge Representation and Reasoning. Proceedings of the Fifteenth International Conference, KR 2016, Cape Town, South Africa, April 25-29, 2016. AAAI Press 2016, ISBN 978-1-57735-755-1.

[2] Chitta Baral, Giuseppe De Giacomo and Thomas Eiter. Principles of Knowledge Representation and Reasoning: Proceedings of the Fourteenth International Conference, KR 2014, Vienna, Austria, July 20-24, 2014. AAAI Press 2014, ISBN 978-1-57735-657-8.

[3] Chitta Baral and Peter Schueller. Proceedings of the 1st Workshop on Natural Language Processing and Automated Reasoning co-located with 12th International Conference on Logic Programming and Nonmonotonic Reasoning (LPNMR 2013), A Corunna, Spain, September 15th, 2013. CEUR Workshop Proceedings 1044, CEUR-WS.org. 2013.

[4] Adrien Coulet, Nigam H. Shah, Lawrence Hunter, Chitta Baral and Russ B. Altman. Proceedings of the PSB 2010 workshop on Extraction of Genotype-Phenotype-Drug Relationships from Text: From Entity Recognition to Bioinformatics Application. 2010.

[5] Chitta Baral, Gerd Brewka and John Schlifp. Logic Programming and Nonmonotonic Reasoning, 9th International Conference, LPNMR 2007, Tempe, AZ, May 14-17, 2007, Proceedings, Springer 2007.

[6] Chitta Baral Proceedings of AAAI 2006 Spring Symposium on Formalizing and Compiling Background Knowledge and its Applications to Knowledge Representation and Question Answering. AAAI, 2006.

[7] Chitta Baral, Gianluigi Greco, Nicola Leone and Giorgio Terracina. Logic Programming and Nonmonotonic Reasoning, 8th International Conference, LPNMR 2005, Diamante, Italy, September 5-8, 2005, Proceedings Springer 2005.

[8] C. Baral, A. Provetti and T. Son. Introduction to the special issue on Programming with Answer Sets. TPLP 3(4-5): 387-391 (2003).

[9] C. Baral and S. McIlraith. Proceedings of the Third International Cognitive Robotics Workshop. July 28, 2002.

[10] C. Baral and M. Truszczynski. Proceedings of 8th International Workshop on Nonmonotonic reasoning. April 9-11, 2000.

[11] C. Baral and H. Mohanty. CIT'99: Trends in Information Technology, (Proceedings of the International Conference on Information Technology), 1999. Tata-McGrawHill Publishers. ISBN 0-07-463747-9.

[12] C. Baral and R. Goldman. Proceedings of the AAAI 97 Workshop on Robots, Softbots and Immobots: Theories of action, planning and control.

[13] C. Baral, V. Kreinovich and V. Lifschitz. Special issue on Logic programming, nonmonotonic reasoning and reasoning about actions. Annals of Math and AI. Volume 21 (2-4), 1997.

[14] C. Baral. Theories of action, planning and robot control: Bridging the gap. Papers from the 1996 Workshop. AAAI, August 1996. ISBN 1577350219.

[15] C. Baral, M. Gelfond, J. Lobo and A. Rajasekar. Proceedings of the Workshop on Logic Programming with Incomplete Information. October 1993.

Conference and Workshop Papers (refereed)

[1] Nisarg Patel, Mohith Kulkarni, Mihir Parmar, Aashna Budhiraja, Mutsumi Nakamura, Neeraj Varshney, Chitta Baral. Multi-LogiEval: Towards Evaluating Multi-Step Logical Reasoning Ability of Large Language Models. EMNLP 2024.

[2] Nemika Tyagi, Mihir Parmar, Mohith Kulkarni, Aswin RRV, Nisarg Patel, Mutsumi Nakamura, Arindam Mitra, Chitta Baral. Step-by-Step Reasoning to Solve Grid Puzzles: Where do LLMs Falter? EMNLP 2024.

[3] Mihir Parmar, Nisarg Patel, Neeraj Varshney, Mutsumi Nakamura, Man Luo, Santosh Mashetty, Arindam Mitra, Chitta Baral. Towards Systematic Evaluation of Logical Reasoning Ability of Large Language Models. ACL 2024.

[4] Himanshu Gupta, Kevin Scaria, Ujjwala Anantheswaran, Shreyas Verma, Mihir Parmar, Saurabh Arjun Sawant, Chitta Baral, Swaroop Mishra. TarGEN: Targeted Data Generation with Large Language Models. COLM 2024.

[5] Aswin RRV, Nemika Tyagi, Md Nayem Uddin, Neeraj Varshney, Chitta Baral. Chaos with Keywords: Exposing Large Language Models Sycophancy to Misleading Keywords and Evaluating Defense Strategies. ACL 2024 (Findings).

[6] Neeraj Varshney, Pavel Dolin, Agastya Seth, Chitta Baral. The Art of Defending: A Systematic Evaluation and Analysis of LLM Defense Strategies on Safety and Over-Defensiveness. ACL 2024 (Findings).

[7] Kevin Scaria, Himanshu Gupta, Siddharth Goyal, Saurabh Arjun Sawant, Swaroop Mishra, Chitta Baral. InstructABSA: Instruction Learning for Aspect Based Sentiment Analysis. NAACL 2024.

[8] Neeraj Varshney, Agneet Chatterjee, Mihir Parmar, Chitta Baral. Investigating Acceleration of LLaMA Inference by Enabling Intermediate Layer Decoding via Instruction Tuning with 'LITE'. Findings of NAACL 2024.

[9] Kuntal Kumar Pal, Ati Priya Bajaj, Pratyay Banerjee, Audrey Dutcher, Mutsumi Nakamura, Zion Leonahenahe Basque, Himanshu Gupta, Saurabh Arjun Sawant, Ujjwala Anantheswaran, Yan Shoshitaishvili, Adam Doupe, Chitta Baral, Ruoyu Wang. Len or index or count, anything but v1: Predicting Variable Names in Decompilation Output with Transfer Learning. IEEE Symposium on Security and Privacy 2024.

[10] Divyanshu Raj, Omkar Patil, Weiwei Gu, Chitta Baral, Nakul Gopalan. Learning Temporally Composable Task Segmentations with Language. IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS), 2024.

[11] Maitreya Patel, Naga Sai Abhiram kusumba, Sheng Cheng, Changhoon Kim, Tejas Gokhale, Chitta Baral, Yezhou Yang. TripletCLIP: Improving Compositional Reasoning of CLIP via Vision-Language Negatives. Accepted to NeuRIPs 2024.

[12] Agneet Chatterjee, Gabriela Ben Melech Stan, Estelle Guez Aflalo, Sayak Paul, Dhruba Ghosh, Tejas Gokhale, Ludwig Schmidt, Hanna Hajishirzi, Vasudev Lal, Chitta Baral, Yezhou Yang. Getting it Right: Improving Spatial Consistency in Text-to-Image Models. ECCV 2024.

[13] Agneet Chatterjee, Yiran Luo, Tejas Gokhale, Yezhou Yang, Chitta Baral. REVISION: Rendering Tools Enable Spatial Fidelity in Vision-Language Models. ECCV 2024.

[14] Michael Saxon, Yiran Lawrence Luo, Sharon Levy, Chitta Baral, Yezhou Yang, William Yang Wang. Lost in Translation? Translation Errors and Challenges for Fair Assessment of Text-to-Image Models on Multilingual Concepts. NAACL 2024.

[15] Maitreya Patel, Tejas Gokhale, Chitta Baral, Yezhou Yang. ConceptBed: Evaluating Concept Learning Abilities of Text-to-Image Diffusion Models. AAAI 2024.

[16] Maitreya Patel, Changhoon Kim, Sheng Cheng, Chitta Baral, Yezhou Yang. ECLIPSE: A Resource-Efficient Text-to-Image Prior for Image Generations. CVPR 2024

[17] Agneet Chatterjee, Tejas Gokhale, Chitta Baral, Yezhou Yang. On the Robustness of Language Guidance for Low-Level Vision Tasks: Findings from Depth Estimation. CVPR 2024

[18] Mutsumi Nakamura, Santosh Mashetty, Mihir Parmar, Neeraj Varshney, and Chitta Baral. LogicAttack: Adversarial Attacks for Evaluating Logical Consistency of Natural Language Inference. Findings of EMNLP 2023.

[19] Garima Agrawal, Kuntal Pal, Yuli Deng, Huan Liu, and Chitta Baral. AISecKG: Knowledge Graph Dataset for Cybersecurity Education. AAAI-MAKE 2023: Challenges Requiring the Combination of Machine Learning 2023 (2023).

[20] Neeraj Varshney, Chitta Baral. Post-Abstention: Towards Reliably Re-Attempting the Abstained Instances in QA. ACL (1) 2023: 967-982

[21] Man Luo, Shashank Jain, Anchit Gupta, Arash Einolghozati, Barlas Oguz, Debojeet Chatterjee, Xilun Chen, Chitta Baral, Peyman Heidari. A Study on the Efficiency and Generalization of Light Hybrid Retrievers. ACL (2) 2023: 1617-1626

[22] Neeraj Varshney, Himanshu Gupta, Eric Robertson, Bing Liu, Chitta Baral. A Unified Evaluation Framework for Novelty Detection and Accommodation in NLP with an Instantiation in Authorship Attribution. ACL (Findings) 2023: 1794-1818

[23] Man Luo, Zhiyuan Fang, Tejas Gokhale, Yezhou Yang, Chitta Baral. End-to-end Knowledge Retrieval with Multi-modal Queries. ACL (1) 2023: 8573-8589

[24] Tung Thai, Mudit Verma, Utkarsh Soni, Sriram Gopalakrishnan, Ming Shen, Mayank Garg, Ayush Kalani, Nakul Vaidya, Neeraj Varshney, Chitta Baral, Subbarao Kambhampati, Jivko Sinapov, Matthias Scheutz. Methods and Mechanisms for Interactive Novelty Handling in Adversarial Environments. AAMAS 2023: 2385-2387

[25] Himanshu Gupta, Neeraj Varshney, Swaroop Mishra, Kuntal Kumar Pal, Saurabh Arjun Sawant, Kevin Scaria, Siddharth Goyal, Chitta Baral: "John is 50 years old, can his son be 65?" Evaluating NLP Models' Understanding of Feasibility. EACL 2023: 407-417

[26] Ravsehaj Singh Puri, Swaroop Mishra, Mihir Parmar, Chitta Baral. How Many Data Samples is an Additional Instruction Worth? EACL (Findings) 2023: 1012-1027

[27] Mihir Parmar, Swaroop Mishra, Mor Geva, Chitta Baral. Don't Blame the Annotator: Bias Already Starts in the Annotation Instructions. EACL 2023: 1771-1781 (**Outstanding paper award**)

[28] Anjana Arunkumar, Swaroop Mishra, Bhavdeep Singh Sachdeva, Chitta Baral, Chris Bryan: Real-Time Visual Feedback to Guide Benchmark Creation: A Human-and-Metric-in-the-Loop Workflow. EACL 2023: 2891-2919

[29] Tejas Gokhale, Rushil Anirudh, Jayaraman J. Thiagarajan, Bhavya Kailkhura, Chitta Baral, Yezhou Yang: Improving Diversity with Adversarially Learned Transformations for Domain Generalization. WACV 2023: 434-443

[30] Y. Wang, S. Mishra, P. Alipoormolabashi, Y. Kordi, A. Mirzaei, A. Naik, A. Ashok, A. S. Dhanasekaran, A. Arunkumar, D. Stap, E. Pathak, G. Karamanolakis, H. Lai, I. Purohit, Ishan; Mondal, J. Anderson, K. Kuznia, K. Doshi, K. K. Pal, M. Patel, M. Moradshahi, M. Parmar, M. Purohit, N. Varshney, P. R. Kaza, P. Verma, R. S. Puri, R. Karia, S. Doshi, S. K. Sampat, S. Mishra, S. Reddy, S. Patro, T. Dixit, X. Shen, C. Baral, Y. Choi, N. A. Smith, H. Hajishirzi, and D. Khashabi. Super-NaturalInstructions: Generalization via Declarative Instructions on 1600+ Tasks. EMNLP 2022.

[31] Man Luo, Arindam Mitra, Tejas Gokhale, Chitta Baral: Improving Biomedical Information Retrieval with Neural Retrievers. AAAI 2022: 11038-11046

[32] Yiran Luo, Pratyay Banerjee, Tejas Gokhale, Yezhou Yang, Chitta Baral. To Find Waldo You Need Contextual Cues: Debiasing Who's Waldo. ACL (2) 2022: 355-361

[33] Swaroop Mishra, Daniel Khashabi, Chitta Baral, Yejin Choi, Hannaneh Hajishirzi. Reframing Instructional Prompts to GPTk's Language. ACL (Findings) 2022: 589-612

[34] Tejas Gokhale, Abhishek Chaudhary, Pratyay Banerjee, Chitta Baral, Yezhou Yang. Semantically Distributed Robust Optimization for Vision-and-Language Inference. ACL (Findings) 2022: 1493-1513

[35] Neeraj Varshney, Swaroop Mishra, Chitta Baral. Investigating Selective Prediction Approaches Across Several Tasks in IID, OOD, and Adversarial Settings. ACL (Findings) 2022: 1995-2002

[36] Neeraj Varshney, Pratyay Banerjee, Tejas Gokhale, Chitta Baral. Unsupervised Natural Language Inference Using PHL Triplet Generation. ACL (Findings) 2022: 2003-2016

[37] Tejas Gokhale, Swaroop Mishra, Man Luo, Bhavdeep Singh Sachdeva, Chitta Baral. Generalized but not Robust? Comparing the Effects of Data Modification Methods on Out-of-Domain Generalization and Adversarial Robustness. ACL (Findings) 2022: 2705-2718

[38] Neeraj Varshney, Swaroop Mishra, Chitta Baral. ILDAE: Instance-Level Difficulty Analysis of Evaluation Data. ACL (1) 2022: 3412-3425

[39] Swaroop Mishra, Daniel Khashabi, Chitta Baral, Hannaneh Hajishirzi. Cross-Task Generalization via Natural Language Crowdsourcing Instructions. ACL (1) 2022: 3470-3487

[40] Swaroop Mishra, Arindam Mitra, Neeraj Varshney, Bhavdeep Singh Sachdeva, Peter Clark, Chitta Baral, Ashwin Kalyan. NumGLUE: A Suite of Fundamental yet Challenging Mathematical Reasoning Tasks. ACL (1) 2022: 3505-3523

[41] Man Luo, Sharad Saxena, Swaroop Mishra, Mihir Parmar, Chitta Baral. BioTABQA: Instruction Learning for Biomedical Table Question Answering. CLEF (Working Notes) 2022: 291-304

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[187] C. Baral, G. Gonzalez and T. Son. Design and Implementation of Display Specification for Multi-media Answers. In proceedings of 1998 International Conference on Data Engineering (ICDE 98), 558-565.

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[194] C. Baral and J. Lobo. Formal Characterization of Active Databases. In proceedings of the International Workshop on Logic in Databases, 1996 (LID'96), pages 175-195, LNCS 1154.

[195] C. Baral, A. Gabaldon and A. Provetti. Value minimization in Circumscription. In KR 96, pages 474-481.

[196] C. Baral and T. Son. Relating reasoning about actions and reactive control. In proceedings of the workshop on *Reasoning about actions, planning and robot control: bridging the gap*, held Aug 2-3 during AAAI 96, Portland, OR, USA.

[197] C. Baral, L. Floriano, A. Gabaldon, D. Morales, T. Son and R. Watson. A reactive mobile robot based on a formal theory of action. In proceedings of AAAI 96 as a robot competition abstract, page 1350. *Our entry was placed third in the competition.*

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[199] G. Mendez, J. Lobo, J. Llopis and C. Baral. Temporal logic and reasoning about actions. Presented in Common-sense 96.

[200] C. Baral, A. Gabaldon and A. Provetti. Formalizing Narratives using Nested Abnormality Theories. Presented in Common-sense 96.

[201] C. Baral. A systematic approach to reason about actions, planning and Robot Control. Proceedings of 33rd Annual Allerton Conference on Communication, Control and Computing, October 4-6, 1995. (Invited non-refereed paper)

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[203] C. Baral. Reasoning about actions: Non-deterministic effects, Constraints, and Qualification. In proceedings of IJCAI 1995, 2017-2023, August 1995.

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[215] C. Baral and V. S. Subrahmanian. Stable and Extension Class Theory for Logic Programs and Default Logics. Presented in the *Third International Workshop on Non-monotonic Reasoning*, South Lake Tahoe, California, May 31, 1990.

[216] C. Baral, J. Lobo and J. Minker. Generalized disjunctive well-founded semantics for logic programs: Declarative semantics. In M. Zemankova, Z. W. Ras and M. L. Emrich, editors, *Proc. of Fifth International Symposium on Methodologies for Intelligent Systems*, pages 465–473, Knoxville, TN, 1990. North-Holland.

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[219] C. Baral, S. Kraus and J. Minker. Communicating between Multiple Knowledge Based Systems. Presented in the *International Working Conference on Cooperating Knowledge Based Systems*, University of Keele, England, October 1990.

[220] A. Roy, V. Haldar and C. Baral. Identification of Geometric Features from Hierarchical Coding of Images. Presented in the *Second International Conference on Advances in Pattern Recognition and Digital Techniques*, Calcutta, India, Jan 6-9, 1986.

Book Chapters (refereed)

[1] Tran Cao Son, Enrico Pontelli, Chitta Baral. A Non-monotonic Goal Specification Language for Planning with Preferences. Advances in Knowledge Representation, Logic Programming, and Abstract Argumentation 2015: 202-217.

[2] Tran Cao Son, Enrico Pontelli and Chitta Baral. A Non-monotonic Goal Specification Language for Planning with Preferences. Advances in Knowledge Representation, Logic Programming, and Abstract Argumentation, pages 202-217, 2015.

[3] Chitta Baral, Marcos Alvarez Gonzalez and Aaron Gottesman. The Inverse Lambda Calculus Algorithm for Typed First Order Logic Lambda Calculus and Its Application to Translating English to FOL. Correct Reasoning, pages 40-56, 2012.

[4] Enrico Pontelli, Tran Cao Son, Chitta Baral and Gregory Gelfond. Answer Set Programming and Planning with Knowledge and World Altering Actions in Multiple Agent Domains. Correct Reasoning, pages 509-526, 2012.

[5] Chitta Baral and Gregory Gelfond. On Representing Actions in Multi-agent Domains. Logic Programming, Knowledge Representation, and Nonmonotonic Reasoning. Springer. 2011: 213-232.

[6] Enrico Pontelli, Tran Cao Son, Omar Elkhatib and Chitta Baral. A Framework for Composition and Inter-operation of Rules in the Semantic Web. In Managing Web Service Quality: Measuring Outcomes and Effectiveness, edited By: Khaled Khan, 2008.

[7] M. Balduccini, C. Baral and Y. Lierler. Knowledge representation and Question Answering. In Handbook of Knowledge Representation, editors Vladimir Lifschitz, Frank van Harmelen and Bruce Porter, 2008.

[8] C. Baral and M. Gelfond. Logic Programming and Reasoning about Actions. In *Handbook of Temporal Reasoning in AI*, editors M. Fisher, D. Gabbay and L. Vila, Elsevier Publications, 2005. pages 389-428.

[9] C. Baral and M. Gelfond. Reasoning agents in dynamic domains. In *Logic based AI*, editor J. Minker, Kluwer Academic Publishers, pgs 257-279, 2000.

[10] C. Baral, Michael Gelfond and Richard Watson. Reasoning about actual and hypothetical occurrences of concurrent and non-deterministic actions. In *Dynamic Worlds: From the frame problem to knowledge management*, pages 73-107, Edited by, Remo Pareschi and Bertram Fronhofer, Kluwer Academic Publishers, 1999.

Reports, Special Write-ups

[1] Chitta Baral, Thomas Bolander, Hans van Ditmarsch, Sheila A. McIlraith. Epistemic Planning (Dagstuhl Seminar 17231). Dagstuhl Reports 7(6): 1-47 (2017)

[2] Graciela Gonzalez, Chitta Baral, Jeff Kiefer, Suengchan Kim, Jieping Ye. Session Introduction. Pacific Symposium on Biocomputing 2015: 80-83

Courses Taught

• Taught undergraduate courses on Automata and Languages (Fall 91 and Fall 92), Computer Architecture (Fall 92, Fall 93, Fall 94, Fall 95, Fall 96), Operating Systems (Spring 92, Spring 93, Spring 94, Spring 95), Database Systems (Fall 97, Fall 98, Spring 01), Design and analysis of Algorithms (Spring 00), Building and Programming Mobile Robots (Spring 96, Spring 97, Spring 98, Spring 99, Fall 00), Computing Ethics (Spring 09), Computer Organization & Assembly Language Programming (Spring 12), Introduction to Computer Science & Engineering (Fall 09), Introduction to theoretical Computer Science (Spring 02, Fall 02, Spring 04, Spring 08, Spring 13, Spring 14, Spring 15, Fall 17, Fall 19), and Artificial Intelligence (Fall 91, Fall 10, Fall 11, Fall 12, Fall 13, Fall 14, Spring 16, Spring 17).

• Taught graduate courses on Database Theory (Spring 92, Spring 93, Spring 94, Spring 95, Spring 96, Spring 97, Spring 98), Object Oriented and Distributed Databases (Fall 93, Fall 94), Cognitive Robotics (Fall 95), Knowledge Representation (Summer 92), Autonomous Agents (Fall 97, Fall 01, Fall 04, Fall 07, Spring 11), Web authoring and multi-media databases (Fall 96), Multimedia Systems (Fall 98), Artificial Intelligence (Fall 99, Spring 01, Fall 03, Spring 05, Spring 07), Computational Molecular Biology (Spring 03), Application of AI to molecular biology (Fall 03, Spring 06), Computational Pharmacogenomics (Fall 06), Text analysis with applications to biomedicine and archaeology (Fall 08 - with Joerg Hakenberg), Multi-agent Systems (Spring 09), Natural Language Understanding and Question Answering (Spring 12, Spring 13, Spring 14), Biological Networks (Fall 09 - with Joerg Hakenberg), Distributed and Logical Semantics of NL (Spring 16), Vison and Language (Spring 2021), Topics in Natural Language Processing (Fall 08, Fall 10, Fall 15, Fall 16, Spring 18, Fall 18, Spring 19, Spring 20, Fall 20, Fall 21, Fall 22, Fall 23, Fall 24).

Honors

• Outstanding paper award in EACL 2023, for the paper "Don't Blame the Annotator: Bias Already Starts in the Annotation Instructions" with Mihir Parmar, Swaroop Mishra and Mor Geva.

• Invited Plenary Panelist on "The Place of Linguistics and Symbolic Structures" at NAACL 2022. `https://2022.naacl.org/program/keynotes-panels/`. Moderator: Dan Roth, U Penn. Panelists: Emily M. Bender, University of Washington; Dilek Hakkani-Tür, Amazon Alexa AI; Chitta Baral, Arizona State University; Christopher D. Manning, Stanford University.

• PLUS Alliance fellow. 2016-2022

• Invited Tutorial on Knowledge Representation and Reasoning issues in Natural Language Question Answering at ICLP 2019. September 2019.

• Invited Speaker. Gave talk on Question Answering that requires reasoning, common-sense and deeper understanding of the world at AAAI 2019 Workshop on Reasoning for Complex QA. Jan 28, 2019.

• Invited Speaker. Gave talk on Combining reasoning with machine learning methods for understanding text and images at the TRIPODS conference at Biosphere 2. May 24, 2018

• Invited Speaker LPNMR 2011.

• Invited Speaker KR 2010.

• Invited Speaker AAAI'05.

• Our entry in Biocreative II.5 in 2009 was the best in the normalization task and was also the best in the protein-protein interaction extraction task. There were 15 participants and greater than 100 submissions. (Based on the above we were invited to write about our entry in the IEEE Transactions on Computational Biology.)

• Our entry in Biocreative II in 2007 was number 4 in the protein-protein interaction extraction task. There were 20 participants.

• ASU Computer Science and Engineering Department "Researcher of the Year Award" for 2006.

• Awarded one of the best paper award at the Fifth IFCIS International conference on Cooperative Information Systems (CoopIS'2000) for the paper 'Formalizing (and Reasoning About) the Specifications of Workflows' with Jorge Lobo and Goce Trajcevski.

• Best paper award at the ATAL 99 (Agent theories, architectures and languages) for the paper 'Extending Congolog with partial order' with Tran Son.

• Team advisor of the robot team entry from UTEP that won the first place in the 'Home vacuuming' part of the AAAI 97 robot contest.

• Team advisor of the robot team entry from UTEP that won the third place in 'Office Navigation' part of the AAAI 96 robot contest.

• Invited Speaker at the 33rd Annual Allerton Conference on Communication, Control and Computing, October 4-6, 1995.

• Received the NSF RIA (1992) and CAREER (1995) awards.

• Received a Graduate Research Fellowship (1990) award from the graduate school of University of Maryland, College Park, MD 20742.

• Awarded the J. N. Tata scholarship (1987) for higher studies.

• Awarded the R. D. Sethna scholarship (1987) for higher studies.

• Received the "Best B. Tech thesis" award in Computer Science and Engineering in 1987 at the Indian Institute of Technology, Kharagpur, India, for the thesis titled : "Natural Language Interface for a Relational Database" (co-author A. Patel).

• Won the joint first prize in undergraduate IEEE student paper writing contest (1985) for the papers

  • C. Baral and A. G. Ray. An Efficient Recursive Algorithm for Constructing Quadtrees.

  • C. Baral. Alternative efficient structures for linear quadtrees and Octtrees.

Grants and Contracts

• PI, Research in Knowledge Representation and Common Sense Reasoning.
NSF RIA (Research Initiation Award) grant IRI-9211662 of $89,956 for the period 7/92 to 12/95.

• PI, A Systematic Approach to Reasoning about Actions and Change.
NSF CAREER award (IRI-9501577) of $135,000 for the period 9/95 to 9/99.

• Co-PI (till Aug 98), PI (Aug 98 - May 99), The University of Texas at El Paso Network Resources and Training Site.
NASA, $2,499,822 for 9/1/1995 - 8/31/2000.

• PI, Implementation of spatial data management at Ft. Bliss – support for student S. Sahu.
US Army Constr Engg Research, Ltd $4,273 for 6/01/96-8/31/96.

• PI, An undergraduate laboratory for building and programming intelligent mobile robots.
NSF ILI award of $40,000 for the period of 7/1/97 - 6/30/99.

As required by the NSF ILI program UTEP matches the award by another $40,000.

• Co-PI, AI technologies for space applications.
United Space Alliance, Houston, $57,660 for the period 6/1/97 to 8/31/98.

• PI, A Systematic approach to reasoning about actions – Transfer to ASU. NSF. $62,027 for the period of 8/31/99 - 8/31/00.

• PI, Reasoning and planning with sensing actions and their applications. NSF. $331,714 for the period of 4/1/2000 - 3/31/2005.

• PI, Agent development and control verification using dual characterizations. NASA. $175,000 for the period of 3/1/2001 – 3/31/2004.

• PI, Answering complex questions and performing deep reasoning in advance question answering systems, AQUAINT program, ARDA, $808,019 for the period of 5/3/04-10/31/06. (includes external sub-contract of $469,007; hence ASU portion is $339,012.)

• PI, Knowledge representation, reasoning, and problem solving in a cellular domain, NSF, $399,000 for the period of 8/1/04-7/31/07.

• PI, Integrating knowledge based reasoning, common sense reasoning and natural language semantics in a QA system, DTO. About $400,000 for the period of 10/1/06-9/30/07. (includes external sub-contract of half that amount.)

• Co-PI, Compiling AnsProlog to first-order theories an approach to integrate AnsProlog knowledge bases with first-order knowledge bases, DTO. About $100,000 for the period of 10/1/06-9/30/07. (Shared with PI Joohyung Lee.)

• PI, Generalized Text Extraction form Life Science and Biomedicine Abstracts: empowering the CBioC Mass Collaborative Curation and Reasoning Systems. Science Foundation of Arizona, $126,136 for the period of 03/01/07 - 08/28/08. (Co-PIs: Graciela Gonzalez, Yi Chen and Lokesh Joshi)

• PI, Developing a state of the art biological interaction extraction system. Science Foundation Arizona, $99,000 for the period of 06/01/08 - 05/31/09.

• PI (ASU part), Human-Robot Interaction in Littoral and Urban Military Domains: Human-Unmanned Systems Interactions. MURI award from ONR of $1 million for the period 7/1/2007-6/30/2012. (PI of the overall grant of $2.5 million is Matthias Sheutz of Indiana University and the ASU part is shared with Subbarao Kambhampati, Pat Langley and Mike McBeath. Pat Langley was the lead in assembling the team and wrote big parts of the proposal. Other team members include Stanley Peters from Stanford.)

• PI, Integrating Machine Learning and Knowledge Representation for Discovery of Social Goals of groups. IARPA. $1,000,000 for 08/24/09-10/23/11.

• PI, EAGER: Enabling collaboration in the creation of scientific databases from the published

literature. NSF. $179,927 for the period of 09/01/09 - 08/31/12.

• Participant: Computational Analysis of Gene Expression Pattern Images (R01) NHGRI (NIH). (PI : Sudhir Kumar). My budget was for half month. 2011-2014.

• PI, Natural Language Interaction With Systems and Agents: Acquiring Knowledge, Understanding Text, Reasoning and Responding. ONR, $324,763. 01/01/2013-12/31/2015.

• PI, A Foundational Model for Postdoctoral Programs in Computer Science & Engineering at Large Universities, Sub Award for PostDoc Best Practices, CRA, $892,350. 04/01/2014-03/31/2017.

• Co-PI, DataNet Federation Consortium SubAward to ASU, Sub-award from UNC (originally from NSF), $108,000. 09/01/2013-08/31/2016.

• Co-PI, Big Data Server for Social Media Analytics: Social-Radio and Programmable Antenna Implementation, $99,373. ONR. 8/15/2015 - 8/14/2016

• PI, Cognitive Processing of Combined Visual and Textual Inputs for Hard and Explainable QA. (coPI- Yezhou Yang) NSF $499,999 8/01/2018 - 7/31/2021

• Co-PI Cognitive Human Enhancements For Cyber Reasoning Systems (CHECRS). PI - Fish Wang. DARPA CHESS (Computers and Humans Exploring Software Security) program. $11.7 million. 11/29/2018 - 5/29/2022.

• PI (ASU part), ACT-NOW: Autonomous Cognitive Technologies for Novelty in Open Worlds. Co-PI Subbarao Kambhampati. DARPA (through Tufts University, PI-Matthias Scheutz) SAIL-ON (Science of AI and Learning) program. $2,349,749. 11/15/2019 - 6/30/2023.

• PI, Doc-In-A-Box. ONR. $150,000. 5/1/2020-4/30/2021

• PI, NSF IJCAI 2019 Doctoral consortium. $20,000 8/1/2019-7/31/2020.

• co-PI, DOD Human-Assisted Cyber Reasoning Systems and Oppositional Human Factors. $3,300,000. 1/1/2022-3/31/2024 (PI - Yan Shoshitaishvili)

• Co-PI, NSF RI: An Active Approach for Data Engineering to Improve Vision Language Tasks, $499,903, 04/01/2022 - 03/31/2025.

• ASU PI, Automating Data Extraction from Electronic Health Records and Reasoning to Assist Treatment Decision-Making for Prostate Cancer. 2023 Mayo Clinic and Arizona State University Alliance for Health Care Collaborative Research Seed Grant Program. (With Irbaz Bin Riaz, Mayo). $100,000, 07/01/2023-06/30/2024.

• Co-PI, Leveraging Machine Learning for Binary Software Understanding, DOD Security of Science. (PI - Adam Doupe) $748,949, 8/31/2023-8/30/2026.

Student mentoring and advising

Doctoral Students[1]

Tran Son graduated in Spring 2000. Professor at the New Mexico state University.
(Best doctoral dissertation of the University of Texas at El Paso award, 2000.)

Graciela Gonzalez graduated in Fall 2000. Associate Professor at the University of Pennsylvania.

Raul Trejo graduated in Spring, 2001. (Was also co-advised by Vladik Kreinovich of UT El Paso.) Worked at ITESM, Mexico City.
(Best doctoral dissertation of the University of Texas at El Paso award, 2001.)

Le-Chi Tuan graduated in December 2004. Research Scientist at GCAS, Inc.

Nam Tran defended his Ph.D dissertation (at ASU) in October 2006. Works at GE Research.

Xin Zhang defended her Ph.D dissertation (at ASU) in 2008. Works at Google.

Luis Tari defended her Ph.D dissertation (at ASU) in 2010. Works at GE Research.

Jicheng Zhao defended her Ph.D dissertation (at ASU) in 2011. Works at Baidu in China.

James R. Leaman defended his Ph.D dissertation (at ASU) in 2012. (Co-advised by Graciela Gonzalez). Works at NIH.

Saadat Anwar defended his Ph.D dissertation (at ASU) in 2013. Works at ASU.

Vo Nguyen defended his Ph.D dissertation (at ASU) in 2015. Works at Google.

Gregory Gelfond defended his Ph.D dissertation (at ASU) in 2018. Works at University of Nebraska, Omaha.

Somak Aditya defended his Ph.D dissertation (at ASU) in 2018. Works at Adobe Research, India.

Arpit Sharma defended his PhD dissertation (at ASU) in 2019. Dissertation Title: "Towards Understanding Natural Language: Semantic Parsing, Commonsense Knowledge Acquisition, Reasoning Framework and Applications". Works at Walmarts Lab, USA.

Arindam Mitra defended his PhD dissertation (at ASU) in 2019. Dissertation Title: "Knowledge Representation, Reasoning and Learning for Non- Extractive Reading Comprehension". Works at Microsoft Inc.

[1]The first three students are the 2nd, 3rd and 4th student to obtain a Ph.D from the computer science department at the University of Texas at El Paso. The first four students that graduated from this program are in academia as faculty. I had a major role to play in establishing this program at UT El Paso.

Pratyay Banerjee. Ph.D, March 2022; GPC voted to award one of the Outstanding Graduating Doctoral Student in Computer Science Award in Spring 2022). Works at Amazon.

Kazuaki Kashihara. Ph.D, November 2022. Works at Design Pickle.

Swaroop Mishra. Ph.D, February 2023. CEN-CS PhD Outstanding Student Award for Spring 2023; and one of the 2022-23 Dean's Dissertation Award recipient. Works at Google-DeepMind.

Man Luo. Ph.D, April 2023. Works at Mayo.

Tejas Gokhale. Co-advised by Yezhou Yang. Ph.D, April 2023. Works as Assistant Professor at the University of Maryland, Baltimore County.

Kuntal Pal. Ph.D, June 2023. Works at JP Morgan.

Current Ph.D Students: *Ming Shen*, *Mihir Parmar*, *Pavel Dolin* (Dean's fellow), *Agneet Chaterjee* (co-advised by Yezhou Yang), *Neeraj Varshney*, *Yiran Luo* (co-advised by Yezhou Yang), *Maitreya Patel* (co-advised by Yezhou Yang), *Santosh Mashetty*, *Md Nayem Uddin* (co-advised by Eduardo Blanco), *Seyyedamirhossein Saeidi* (co-advised by Irbaz Bin Riaz, Mayo), and *Shailaja Sampat*.

Masters Students

Advised or mentored thesis/project of the following students (A. Gabaldon[2] , Y. Gelfond, S. Hota, D. Bhattacharya, R. Vijayrangam, G. Gonzalez, P. Madden, D. Morales, A. Nandigam, B. Ayuluri, B. Rachamreddy, S. Sahu, M. Hampton, D. Schirmer, and A. Hardesty at UTEP; and S. Culver, Luis Tari, Piyun Chang, Deepthi Chidambaram[3], Hiro Takahashi, Dmitry Voronkov, Matthew Greene, Marcos Alvarez Gonzalez, Barry Lumpkin, Kanchan Kumbhare, Tejas Budukh, Meghna Pollimera, Matthew Hunsaker, Arpit Sharma[4], Subham Agarwal and Trideep Rath at ASU. Recent Masters students and thesis title are as follows.

Prashant Garg: Improving Intent Classification by Automatic Data Augmentation Using Word Sense Disambiguation, November 2018.

Vaishnavi Batni. Reasoning over Text: A Case Study with Adaptations, Behaviors and Variations in Organisms. 2019.

Ishan Shrivastava. Understanding the Importance of Entities and Roles in Natural Language Inference : A Model and Datasets. 2019.

Ashok Prakash. Can Knowledge Rich Sentences Help Language Models To Solve Common Sense Reasoning Problems? 2019.

[2]He finished his Ph.D from the University of Toronto.

[3]co-advised by Hasan Davulcu

[4]For his MS thesis titled "Solving Winograd Schema Challenge : Using Semantic Parsing, Automatic Knowledge Acquisition and Logical Reasoning" he was awarded the best Masters Student in Computer Science award for 2014-2015.

Aurgho Bhattacharjee. Modeling Actions and State Changes for a Machine Reading Comprehension Dataset. 2019.

Shubham Gondane. Analysis of Tweets for Social Media Health Applications. 2019.

Sanjay Narayana. Interpretable Question Answering using Deep Embedded Knowledge Reasoning to Solve Qualitative Word Problems. 2020.

Sam Rawal. Multi-Perspective Semantic Information Retrieval in the Biomedical Domain. 2020.

Kuldeep Rathor. Referring Expression Comprehension for CLEVR-Ref+ Dataset. 2020

Mihir Parmar, Automation of Title and Abstract Screening for Clinical Systematic Reviews, 2021

Yankai Zeng, Weakly-Supervised Visual-Retriever-Reader Pipeline for Knowledge-Based VQA, 2021

Sharad Saxena, Medical Question Answering using Instructional Prompts, 2021

Bhavdeep Sachdeva, We Need to Talk About Robustness to Adversarial Attacks While Removing Spurious Dataset Biases, 2021

Ujjawala Anantheswaran, Event Detection as Multi-Task Generation, 2022

Kirby Kuznia, Using Language Models to Generate Text-to-SQL Training Data - An Approach to Improve Performance of a Text-to-SQL Parser, 2023.

Undergraduate and High School Students

Undergraduate students that worked with me and our group: Guray Alsac, Sajid Anwar, Amy Baldwin, Garth Bjerk, Alfredo Gabaldon, Anthony Gitter, Graciela Gonzalez, Matthew Greene, Jared Guiou, Jenny Hastings, Jacob Jorgensen, Patrick Kahl, Sidharth Kulkarni, Barry Lumpkin, Ismael Mercado, Kirk Morales, Shawn Nikkila, Joseph North, Sam Rawal, Sid Rawal, Saswati Sahoo, Craig Teegarden, Ryan Wendt, Amanda Ziegler, Major Brown, Kartik Aggarwal, Shankar Kailas, Mandy Zhu, and Ariana Bui.
Alfredo Gabaldon and Patrick Kahl started working with me when they were undergraduates and went on to do their M.S and Ph.D.

Guray Alsac worked with me as an undergraduate researcher and was supported by an NSF REU supplement. He joined Ph.D at University of Massachusetts, Amherst.

Anthony Gitter worked in our group as an undergraduate, received an NSF graduate fellowship based on his work in our group and finished his Ph.D at CMU.

Barry Lumpkin was awarded an honorable mention in the CRA outstanding research awards for 2010.

Amy Baldwin received the Google Anita Borg Memorial Scholarship in 2014.

Jacob Jorgensen. Did Honors thesis, Spring 2015.

Jared Guiou. Did Honors thesis, Fall 2016.

Sidharth Kulkarni started working as High School student; Was supported by FURI.

Sam Rawal. Was supported by FURI. Did Honors thesis. 2018.

Sid Rawal. Was supported by FURI. Did Honors thesis. 2020.

High School students that worked with me and our group: Misha Koshelev (went to Harvard for undergraduate and then finished MD-PhD from Baylor.), Sidharth Kulkarni, and Soham Samal.

External Students

• Opponent of Joakim Gustafsson, Linkoping University, Sweden.

• Examiner for Mikhail Prokopenko, Macquarie University NSW 2109, Australia.

• External Ph.D committee member of Esra Erdem, University of Texas at Austin.

• External Ph.D committee member of Yuting Zhao, Hong Kong University of Science and Technology.

• External Ph.D committee member of Rajdeep Niyogi, Indian Institute of Technology, Kharagpur, India.

• External Ph.D committee member of Marcello Balduccini, Texas Tech University.

• Zeynep Gozen Saribatur. Vienna University of Technology.

Professional Activities

• President of KR Inc, 2016-2018. (`http://kr.org`) [5]

• Associate Editor, Artificial Intelligence, January 2015 - December 2022.

• Associate Editor, JAIR (Journal of AI Research) : March 2007 - February 2010

• Area Editor (Knowledge representation, non-monotonic reasoning and answer sets), ACM Transactions on Computational Logic. 2005-present

[5] Principles of Knowledge Representation and Reasoning, Incorporated (KR, Inc.) is a not for profit Scientific Foundation incorporated in the state of Massachusetts of the United States of America, concerned with fostering research and communication on knowledge representation and reasoning.

• Editorial Advisor of the journal "Theory and Practice of Logic Programming". 4/15/2005-2019

• Co-Organizer of ODRUM (Open-Domain Retrieval Under Multi-Modal Settings) workshop at CVPR 2023.

• Co-Organizer of ODRUM (Open-Domain Retrieval Under Multi-Modal Settings) workshop at CVPR 2022.

• Co-Program Chair of the Applications Track of KR 2020.

• Co-Chair: Doctoral Consortium of IJCAI 2019.

• General Chair, Knowledge Representation & Reasoning (KR), 2016.

• Co-Program Chair, Knowledge Representation & Reasoning (KR), 2014.

• Area Chair: AAAI 2022, , IJCAI 2021, KR 2021, AAAI 2018, IJCAI 2017.

• Senior Program Committee: ACL 2023, IJCAI 2022, ECAI 2020, AAAI 2017, IJCAI 2016, AAAI 2016, IJCAI 2015, AAAI 2015.

• Program Committee of recent major conferences: ICLP 2015, LPNMR 2015, EMNLP 2016, LPNMR 2017, EMNLP 2017, ICLP 2019, LPNMR 2019, ACL 2019, ACL 2020, NAACL 2020, ICLP 2020, CIKM 2020, LSP 2021, SLSP 2022, KR 2022, LPNMR 2022, KR 2023, ICLP 2023.

• Program Committee of recent specialized conferences and workshops: Various including Common Sense 2015, NLPAR 2015, ONTOLOP 2015, SUM 2015, SBP 2015, SUM 2016, DLAI 2016, KET Special Track 2016, KnowPros 2016, KnowPros 2017, Declare 2017, INAP 2017, Common Sense 2017, ACS 2017, ASPOCP 2019, Datalog 2.0 2019, DPSW 2020, CogVis 2019, SLSP 2020.

• Program committee member of AAAI 2007, AAAI 2006, AAAI 2005.

• Steering committee member of International Workshops on Nonmonotonic Reasoning. 2005.

• Co-Program Chair, LPNMR'05.

• General Chair, CIT'04.

• Senior program committee of AAAI 2008, AAAI 2004.

• Program committee member of IJCAI 2003.

• Co-Editor, Special issue of *Theory and practice of Logic Programming* on answer set programming to appear in 2003.

• Co-Program Chair of CogRob'2002.

• Senior program committee of AAAI 2002.

• Organizing Committee, AAAI Spring symposium on Answer set programming, 2001.

• Co-Program Chair of NM'2000 (8th International Workshop on Non-monotonic reasoning).

• Program Chair of CIT 99 (Second International Conference on Information Technology).

• Organizing Committee, CogRob'2000 (2nd International Cognitive Robotics Workshop).

• Program Committee of AAAI 97, AAAI 98, AAAI 99, AAAI 2000, IJCAI'2003; AAAI 98 Fall Symposium on Cognitive robotics; CIT98; LPNMR 99; CLIMA-00 (Workshop on Computational Logic in Multi-agent systems); KR 2008; PADL 2008.

• Overseas Secretary, Orissa Information Technology Society: 1998-2001.

• Co-Editor, Special issue of *Annals of Math and AI*, Vol. 21 (1997) Nos. 2-4.

• Co-Chair, AAAI 97 Workshop on "ROBOTS, SOFTBOTS, IMMOBOTS: Theories of Action, Planning and Control".

• Chair, AAAI 96 Workshop on "Reasoning about actions, planning algorithms and control architectures : Bridging the gap."

• Member of program committee and main organizer of Workshop on *Logic Programming with Incomplete Information*, held together with 1993 International Symposium on Logic Programming, Vancouver, BC, Canada.

• Member, Program Committee of the *ICLP'95 Workshop on Abduction in Deductive Databases and Knowledge-based Systems* Kanagawa, Japan.

• Panelist, 1995 Spring Symposium on Extending theories of actions.

• Refereed articles for AI Journal, Journal of AI Research, Journal of Automated Reasoning, Journal of Logic Programming, Journal of Logic and Computation, Annals of Math and AI, Journal of Experimental and Theoretical AI, Journal of Intelligent Information Systems, ACM transactions on Database Systems, IEEE Transactions on Knowledge and Data Engineering, and various conferences on Databases, Artificial Intelligence, Logic Programming and Knowledge Representation.

• Refereed articles for conferences such as: ICLP90, VLDB90, NACLP90, DOOD91, AAAI93, IJCAI93, ICLP93, LPNMR93, ILPS94, ISMIS94, ICLP95 and LPNMR95.

Invited Lectures

• "Semantics of Nonmonotonic Formalisms", Department of Computer Science, New Mexico State University, Las Cruces, USA (Dec 1991).

• "A language for reasoning about actions and change", Department of Law and Philosophy, University of Bologna, Italy (Jan 1994).

• "Abductive Logic Programming", Department of Computer Science, University of Modena, Italy (Jan 1994).

• "Logical Basis of Disjunctive Databases", Department of Computer Science, University of Milan, Italy (Jan 1994).

• "Knowledge Representation in Artificial Intelligence", Xaviers School of Business Management, Bhubaneswar, India (Jan 1994).

• "Rule Based Updates in Simple Knowledge Bases", Department of Computer Science, University of Nebraska, Lincoln, USA (April 1994).

• "Reasoning about Situations", Department of Computer Science, University of Texas at Austin, USA (August 1994).

• "Reasoning about Actions and Change", Department of Electrical Engineering and Computer Science, University of Illinois at Chicago, USA (October 20, 1994).

• "A systematic approach to reason about actions, planning and Robot Control". Invited Speaker at the 33rd Annual Allerton Conference on Communication, Control and Computing, October 4-6, 1995.

• "Reasoning about actions and its relation to robot control and database updates", Department of Computer Science, University of Corona, La Cornua, Spain (June 1996).

• "Reasoning about actions and its relation to robot control and database updates", Department of Computer Science, Griffith University, Brisbane, Australia (Jan 17, 1997).

• "From action theories to agents – a formal approach to agents", Seminar at IRST, Trento, Italy, Aug 18, 1997.

• "From action theories to agents – a formal approach to agents", Invited Lecture at the Symposium on logical approaches to agent modeling and design, held as part of the ESSLLI'97 (Ninth European Summer School in Logic, Language and Information), Aix-en-Provence, France, August 20, 1997.

• "From action theories to agents – a formal approach to agents", TRAIL seminar at Imperial College, London, Aug 26, 1997.

• "From action theories to agents", University of Toronto, Feb 6, 1998.

• "Representing actions: Laws, Observations and Hypothesis", York University, Toronto, Feb 7, 1998.

• "From action theories to agents", Linkoping University, Sweden, Sept 18, 1998.

• "Knowledge representation, reasoning and declarative problem solving", International Conference on Information Technology, Bhubaneswar, Dec 22nd, 2000.

• Invited to speak at the Joint German/Austrian Conference on Artificial Intelligence (KI-2001), Vienna, Sept 2001. (Could not go because of the September 11 incident.)

• Knowledge representation, reasoning and declarative problem solving with answer sets. Dagstuhl seminar. Germany Sept'02.

• Several talks at the Vienna U of Technology Vienna May'03.

• From high-level goals to policies: a polynomial time algorithm for k-maintainable goals. NASA JPL. Jan'04.

• From high-level goals to policies: a polynomial time algorithm for k-maintainable goals. University of Texas at Austin. Feb'04.

• From high-level goals to policies: a polynomial time algorithm for k-maintainable goals. Fundación Universidad de las Américas, Puebla, Mexico. Nov 2004.

• From Knowledge to Intelligence - Building Blocks and Applications. AAAI conference invited talk. Pittsburgh, PA July 2005.

• CBioC and Biosignet: BioAI research in my group. New Mexico State University, Las Cruces. March 2006.

• Using the Probabilistic Logic Programming Language P-log for Causal and Counterfactual Reasoning. Texas Tech University, Lubbock. March06.

• CBIoC: a tool for mass collaborative curation. NLM, NIH, Bethesda, MD. May 2006. (self-invited talk.)

• Towards Overcoming the Knowledge Acquisition Bottleneck in Answer Set Prolog Applications: Embracing Natural Language Inputs. ICLP 2007 conference invited talk. Porto, Portugal, September 11th 2007.

• Combining probabilistic and logical reasoning. Invited talk at Univ of Nova de Lisboa, Lisbon, Portugal, September 13th 2007.

• A knowledge based approach for representing, reasoning and hypothesizing about biochemical networks. Invited talk at the 2007 International Workshop on Abduction and Induction in Artificial Intelligence, Aix-en-Provence, France, September 15th 2007.

• Action, Change and Evolution: reasoning and acting in a dynamic world. Invited talk at the University of Maryland, College Park on November 12th 2007.

• Reasoning about Actions and Change: From Single Agent Actions to Multi-Agent Actions.

Invited talk at KR 2010.

• Lessons from Efforts to Automatically Translate English to Knowledge Representation Languages. Invited talk at LPNMR 2011: 12

• Manual and automatic knowledge representation in Answer Set Programming. Invited talk at CPSAT, Kobe, Japan. May 2012.

• Lessons from Efforts to Automatically Translate English to Knowledge Representation Languages. Invited talk at NII (National Institute of Informatics), Tokyo, Japan. May 2012.

• Invited Panelist at the NIH workshop on Natural language processing: State of the Art, Future Directions and Applications for Enhancing Clinical Decision Making. April 23-24, 2012.

• Invited Participant, NSF Workshop on Research Challenges and Opportunities in Knowledge Representation. February 2013.

• Explanation Producing Combination of NLP and Logical Reasoning through Translation of Text to KR Formalisms. Invited Presentation at NII Shonan Meeting Seminar 057. Japan. November 2014.

• Chitta Baral, Giuseppe De Giacomo: Knowledge Representation and Reasoning: What's Hot. AAAI 2015.

• Combining reasoning with machine learning methods for AI tasks and applications. Allen AI Institute, Seattle. Invited Talk. November 22nd, 2016.

• AI beyond Deep Learning. Microsoft. Seattle. November 21st, 2016.

• Invited talk on Combining reasoning with machine learning methods for AI tasks and applications at ISI California. November 2018.

• Combining reasoning with machine learning methods for understanding text and images. NIH. Feb 12, 2018.

• Invited Talk on "Question Answering that requires reasoning, common-sense and deeper understanding of the world" at AAAI 2019 Workshop on Reasoning for Complex QA. Jan 28, 2019.

Tutorials and Short Courses

• "From Actions Theories to Updates, Transactions, Triggers and Agents", A joint tutorial at DOOD 97 (Montreux, Switzerland) with J. Lobo, Dec 10, 1997.

• "From action theories to agents – planning control strategies for reactive agents", A joint tutorial at AAAI 98 (Madison, Wisconsin) with F. Kabanza. (65 registered participants)

• "A logical approach to building agents, active databases and workflows: representing and reasoning about actions", A two week course to be given at ESSLLI 99 (11th summer school in logic, language and information) with Jorge Lobo and Richard Scherl. (35 registered participants)

• A short course at the Vienna U of Technology, Vienna May'03. 184.186 - 2.0 VU Theorie der Wissensrepräsentation (Theory of Knowledge Representation)

• Two weeks course in Vienna. Summer 2010.

• Invited Tutorial on "Knowledge Representation and Reasoning issues in Natural Language Question Answering" at ICLP 2019. September 2019.

• Tutorial on "The AI Universe of Actions': Agency, Causality, Commonsense and Deception" at IJCAI 2019. August 2019.

• Tutorial at AAAI 2023 on "Advances in Neuro Symbolic Reasoning" with Paulo Shakarian, Gerardo I. Simari, and Alvaro Velasquez.

University Service and Outreach Activities – Highlights

• Chair, CS Graduate Program (Fall 2014 - Summer 2022).

• Member Dean's Faculty Advisory Council (DFAC) (2017-18)

• Co-Ordinator, CIDSE Academic Review Program 2016

• Member of Dean's advisory committee on research 2010-11.

• Recruiting Committee Chair, Dept. of CSE, Arizona State University, Fall 2004 - Spring 2005; Fall 2006-Spring 2008; 2011-12 (for the search on Personalized Learning and Language Processing); 2012-13 (for the search on Human Centered Robotics); 2015-16 (for the search on AI Knowledge Capture/Representation); 2016-17 (for the search on AI and Reasoning); and 2017-18 (for the searches on Deep Learning; and Natural Language Processing).

• Executive Committee, Dept. of CSE, Arizona State University, Fall 2004, Fall 2006-Spring 2007.

• Personnel Committee, Dept. of CSE, Arizona State University, 2000- 2001; 2002- Spring 2005 (Chair during Fall 2003); Fall 2009-Spring 2011; Fall 2012-Spring 2014 (Chair during Fall 2013).

• CEAS Senate representative, member of graduate admission committee, member of TA and financial aid committee, 2001-2004.

• Faculty mentor for one summer intern at Intel as part of the Embedded Systems Initiative.

• Chair of the graduate admissions committee, and member of graduate program committee, Dept. of CSE, Arizona State University, August 1999 – May 2001.

• Graduate Advisor and in charge of the graduate program in Computer Science at UTEP from Fall 94 till Spring 99.

• Instrumental in developing a Ph.D program for Computer science students at UTEP.

• Developed – through students – the first Web pages for the university and the local area (the city of El Paso and Juarez), in 1993 and wrote op-ed articles in the El Paso Times newspaper to increase local awareness about the WWW.

• Held several robot building workshops and robot demonstrations for El Paso area school teachers and students.

• Have been featured (together with my students) many times in the El Paso newspapers, TV stations, and the university alumni magazine.

Community Service Activities and Awards – Highlights

• A detailed documentation of this is at `https://www.public.asu.edu/~cbaral/india.pdf`

• Distinguished Odia Award (2014) by the Odisha Society of the Americas.
`http://www.odishasociety.org/winners-of-osa-awards-2014/`

• Living Legend Award (2012) by OdishaDiary.
`https://web.archive.org/web/20130311180137/www.orissadiary.com/CurrentNews.asp?id=37757`

• Instrumental in the establishment of the National Institute of Science Education and Research (NISER), Bhubaneswar, India. Some articles and pointers that mention my role on this are as follows.

- `http://www.telegraphindia.com/1051109/asp/jamshedpur/story_5454814.asp`
- `http://bit.ly/niser-history`
- `http://iiser.blogspot.com/`
- `http://nis.orissalinks.com/`
- `http://www.odishasociety.org/media/newsletters/january06/utkarsa-january06.pdf`
- `http://bit.ly/Chitta-NIS2`
- `http://www.nis.orissalinks.com/vol1/2005-11-22-pioneer-nis.pdf`

• Contributed to the efforts (at various level) for establishing an IIT (Indian Institute of Technology) in Bhubaneswar.

- `http://bit.ly/Chitta-IExp2`
- `http://bit.ly/Chitta-IExp4`
- `http://bit.ly/Chitta-IIT1`

- http://bit.ly/Chitta-IIT2
- http://bit.ly/Chitta-IIT3
- http://bit.ly/Chitta-IIT6
- http://bit.ly/Chitta-IIT7
- http://bit.ly/Chitta-IIT8
- http://bit.ly/Chitta-IIT9

• Contributed to the dialogue in India about diversifying the locations of centrally funded higher educations in India.

- http://bit.ly/Chitta-IHT
- http://bit.ly/Chitta-IExp3
- http://bit.ly/Chitta-IExp5

• Helped in the establishment of Xavier University Bhubaneswar (XUB), India. This is the first and only Jesuit university in India. An article that mentions my role on this is at http://bit.ly/Chitta-XUB1.

• Mentored the Xavier School of Computer Science and Engineering at XUB and the following programs there.

- B.Tech in Computer Science and Engineering: https://xcomp.edu.in/btechcse.html
- M. Tech in Artificial Intelligence: https://xcomp.edu.in/mtechai.html
- M.S in Data Science and analytics: https://xcomp.edu.in/msdsa.html

• As member of the Higher Education Task Force helped develop vision document for higher education for the state of Odisha, India. Some pointers on this are as follows.

- https://sites.google.com/site/orissavision2020/
- http://govtpress.odisha.gov.in/pdf/2009/1637.pdf

Community Service Writings in Newspapers

[1] C. Baral. March 5, 1995.
Cyberspace: City should tech it out. Guest Column in El Paso Times.

[2] C. Baral. July 01, 2006.
Bias Against Bhubaneswar. Article in the editorial page of Indian Express and New Indian Express. http://bit.ly/Chitta-IExp1

[3] C. Baral. July 11, 2006.
For IIT upgrade, an alternative roadmap Article in the op-ed page of Indian Express and New Indian Express. http://bit.ly/Chitta-IExp2

[4] C. Baral. November 17, 2006.
The gold that keeps Orissa poor. Article in the editorial page of Indian Express and New Indian Express. http://bit.ly/Chitta-IExp3

[5] C. Baral. December 21, 2006.
Higher Education Lower Development. Article in the editorial page of Indian Express and New Indian Express. http://bit.ly/Chitta-IExp4

[6] C. Baral. January 19, 2007.
Central university as development pill. Article in the editorial page of Indian Express. http://bit.ly/Chitta-IExp5

Mention in Media

[1] Mention about our CbioC system. SCIENCE Vol. 312. 23 June 2006.
http://www.sciencemag.org/cgi/reprint/312/5781/1721e.pdf