

## BENJAMIN JACK KUIPERS

University of Michigan  
Computer Science and Engineering  
2260 Hayward Street  
Ann Arbor, Michigan 48109

kuipers@umich.edu  
<http://eecs.umich.edu/~kuipers/>  
(734) 647-6887 work  
(734) 763-1260 fax

### RESEARCH INTERESTS

Benjamin Kuipers is a Professor of Computer Science and Engineering at the University of Michigan. He previously held an endowed Professorship in Computer Sciences at the University of Texas at Austin, where he served as Department Chair. He received his B.A. from Swarthmore College, his Ph.D. from MIT, and he is a Fellow of AAAI, IEEE, and AAAS. His research in artificial intelligence and robotics has focused on the representation, learning, and use of foundational domains of knowledge, including knowledge of space, dynamical change, objects, and actions. His research accomplishments include developing the TOUR model of spatial knowledge in the cognitive map, the QSIM algorithm for qualitative simulation, the Algernon system for knowledge representation, and the Spatial Semantic Hierarchy model of knowledge for robot exploration and mapping. He is currently investigating ethics as a foundational domain of knowledge for robots and other AIs that may act as members of human society.

### EDUCATION

Ph.D. (Mathematics), Massachusetts Institute of Technology, 1977.  
B.A. with High Honors (Mathematics), Swarthmore College, 1970.

### ACADEMIC POSITIONS

2009-present: Professor, Computer Science & Engineering, University of Michigan  
1997-2008: Endowed Professorship in Computer Sciences, UT Austin  
1997-2001: Chairman, Department of Computer Sciences, UT Austin  
1992-97: David Bruton, Jr. Centennial Professor of Computer Sciences, UT Austin  
1985-92: Associate Professor of Computer Sciences, UT Austin  
1984-85: Research Associate, MIT Laboratory for Computer Science  
1978-84: Assistant Professor of Mathematics, Tufts University  
1977-78: Research Associate, MIT Division for Study and Research in Education

### SELECTED PUBLICATIONS

- B. Kuipers. AI and Society: Ethics, Trust, and Cooperation. *Communications of the ACM (CACM)* **66**(8): 39–42, 2023.
- P. Foster, C. Johnson and B. Kuipers. The Reflectance Field Map: Mapping glass and specular surfaces in dynamic environments. *IEEE Int. Conf. Robotics & Automation (ICRA)*, 2023.
- B. Kuipers. Trust and cooperation. *Frontiers in Robotics and AI* **9**: 676767, 2022.  
doi: 10.3389/frobt.2022.676767.
- B. Kuipers. Perspectives on Ethics of AI: Computer Science. In Markus Dubber, Frank Pasquale & Sunit Das (Eds.), *Oxford Handbook of Ethics of AI*, Oxford University Press, 2020. Chapter 22, pages 421–441.

- J. Juett and B. Kuipers. Learning and acting in peripersonal space: Moving, reaching, and grasping. *Frontiers in Neurorobotics* **13**:4, 2019. doi:10.3389/fnbot.2019.00004.
- J. Juett and B. Kuipers. Learning to grasp by extending the peri-personal space graph. *IEEE/RSJ Conf. Intelligent Robots and Systems (IROS)*, 2018.
- B. Kuipers. How can we trust a robot? *Communications of the ACM (CACM)* **61**(3): 86–95, March 2018. doi:10.1145/3173087.
- C. Johnson and B. Kuipers. Socially-aware navigation using topological maps and social norm learning. *AAAI/ACM Conference on Artificial Intelligence, Ethics, and Society (AIES)*, 2018.
- Emanuelle Burton, Judy Goldsmith, Sven Koenig, Benjamin Kuipers, Nicholas Mattei & Toby Walsh. Ethical considerations in artificial intelligence courses. *AI Magazine* **38**(2): 22–34, Summer 2017.
- J. J. Park, S. Lee and B. Kuipers. Discrete-time dynamic modeling and calibration of differential-drive mobile robots with friction. *IEEE Int. Conf. on Robotics and Automation (ICRA)*, 2017.
- T. Williams, M. Scheutz, C. Johnson and B. Kuipers. A tale of two architectures: A dual-citizenship integration of natural language and the cognitive map. *Proc. Conf. Autonomous Agents and Multi-Agent Systems (AAMAS)*, 2017.
- B. Kuipers, E. A. Feigenbaum, P. E. Hart, N. J. Nilsson. Shakey: From conception to history. *AI Magazine* **38**(1): 88–103, Spring 2017.
- B. Kuipers. Why and how should robots behave ethically? In J. Seibt, M. Nørskov & S. S. Andersen (Eds.), *What Social Robots Can and Should Do*, Frontiers in Artificial Intelligence and Applications, vol. 290, IOS Press Ebooks, 2016, pages 15–18, doi:10.3233/978-1-61499-708-5-15.
- J. Juett and B. Kuipers. Learning to reach by building a representation of peri-personal space. *IEEE-RAS Int. Conf. on Humanoid Robots*, Cancun Mexico, 2016.
- B. Kuipers. Beyond Asimov: how to plan for ethical robots. <https://theconversation.com/beyond-asimov-how-to-plan-for-ethical-robots-59725>. Published 6-1-2016.
- B. Kuipers. Remembering Marvin Minsky. *AI Magazine* **37**(3): 96–97, 2016.
- B. Kuipers. Toward morality and ethics for robots. *AAAI Spring Symposium on Ethical and Moral Considerations in Non-Human Agents (EMCAI 2016)*, Stanford, 2016.
- B. Kuipers. Human-like morality and ethics for robots. *AAAI-16 Workshop on AI, Ethics & Society*, AAAI, 2016.
- J. J. Park & B. Kuipers. Feedback motion planning via non-holonomic RRT\* for mobile robots. *IEEE/RSJ Conf. Intelligent Robots and Systems (IROS)*, 2015.
- G. Tsai & B. Kuipers. Handling perceptual clutter for robot vision with partial model-based interpretations. *IEEE/RSJ Conf. Intelligent Robots and Systems (IROS)*, 2014.
- G. Tsai, C. Johnson & B. Kuipers. Semantic visual understanding of the indoor environment: from structures to opportunities for action. *Vision Meets Cognition Workshop*, CVPR, 2014.
- R. Mittelman, M. Sun. B. Kuipers & S. Savarese. A Bayesian generative model for learning semantic hierarchies. *Frontiers in Psychology: Hypothesis and Theory* **5**(417): 1–9, 2014.

- R. Mittelman, B. Kuipers, S. Savarese, H. Lee. Structured recurrent temporal Restricted Boltzmann Machines. *International Conference on Machine Learning (ICML)*, 2014.
- G. Tsai and B. Kuipers. Focusing attention on visual features that matter. *British Machine Vision Conference (BMVC)*, 2013.
- J. Mugan and B. Kuipers. Autonomous representation learning in a developing agent. In G. Baldassare and M. Mirolli (Eds.), *Computational and Robotic Models of the Hierarchical Organization of Behavior*. Springer Verlag, 2013, pages 63–80.
- R. Mittelman, M. Sun, B. Kuipers and S. Savarese. Learning hierarchical linguistic descriptions of visual datasets. *The 2013 Conference of the North American Chapter of the Association for Computational Linguistics: Human Language Technologies (NAACL HLT)*, 2013.
- R. Mittelman, H. Lee, B. Kuipers and S. Savarese. Weakly supervised learning of mid-level features with Beta-Bernoulli process restricted Boltzmann machines. In *IEEE Int. Conf. on Computer Vision and Pattern Recognition (CVPR)*, 2013, pages 476–483.
- P. Foster, Z. Sun, J. J. Park and B. Kuipers. VisAGGE: Visible angle grid for glass environments. In *IEEE Int. Conf. on Robotics and Automation (ICRA)*, 2013, pages 2213–2220.
- J. J. Park and B. Kuipers. Autonomous person pacing and following with Model Predictive Equilibrium Point Control. In *IEEE Int. Conf. on Robotics and Automation (ICRA)*, 2013, pages 1060–1067.
- C. Xu, J. Liu and B. Kuipers. Moving object segmentation using motor signals. In *European Conference on Computer Vision (ECCV)*, 2012.
- C. Johnson and B. Kuipers. Efficient search for correct and useful topological maps. In *IEEE/RSJ Conf. Intelligent Robots and Systems (IROS)*, 2012.
- J. J. Park, C. Johnson, and B. Kuipers. Robot navigation with model predictive equilibrium point control. In *IEEE/RSJ Conf. Intelligent Robots and Systems (IROS)*, 2012.
- G. Tsai and B. Kuipers. Dynamic visual understanding of the local environment for an indoor navigating robot. In *IEEE/RSJ Conf. Intelligent Robots and Systems (IROS)*, 2012.
- B. Kuipers. An existing, ecologically-successful genus of collectively intelligent artificial creatures. *Collective Intelligence*, 2012. (arXiv:1204.4116v1 [cs.SI])
- J. Mugan and B. Kuipers. Autonomous learning of high-level states and actions in continuous environments. *IEEE Transactions on Autonomous Mental Development* **4**(1): 70–86, 2012.
- G. Tsai, C. Xu, J. Liu and B. Kuipers. Real-time indoor scene understanding using Bayesian filtering with motion cues. *Int. Conf. Computer Vision (ICCV)*, 2011.
- J. Stober, R. Miikkulainen and B. Kuipers. Learning geometry from sensorimotor experience. In *Proc. First Joint Conf. on Development and Learning and Epigenetic Robotics*, 2011.
- C. Xu, J. Liu and B. Kuipers. Motion segmentation by learning homography matrices from motor signals. *Canadian Conf. Computer and Robot Vision (CRV-11)*, 2011. **Best Student Paper award**.
- C. Xu and B. Kuipers. Object detection using principal contour fragments. *Canadian Conf. Computer and Robot Vision (CRV-11)*, 2011.

- J. Liu, M. Shah, B. Kuipers and S. Savarese. Cross-view action recognition via view knowledge transfer. *IEEE Int. Conf. on Computer Vision and Pattern Recognition (CVPR)*, 2011.
- J. Liu, B. Kuipers and S. Savarese. Recognizing human actions by attributes. *IEEE Int. Conf. on Computer Vision and Pattern Recognition (CVPR)*, 2011.
- J. J. Park and B. Kuipers. A smooth control law for graceful motion of differential wheeled mobile robots in 2D environment. *IEEE Int. Conf. on Robotics and Automation (ICRA)*, 2011.
- C. Xu and B. Kuipers. Towards the Object Semantic Hierarchy. *IEEE Int. Conf. on Development and Learning (ICDL)*, 2010.
- P. Beeson, J. Modayil and B. Kuipers. Factoring the mapping problem: Mobile robot map-building in the Hybrid Spatial Semantic Hierarchy. *International Journal of Robotics Research* **29**(4): 428–459, 2010. doi:10.1177/0278364909100586.
- J. Mugan and B. Kuipers. Autonomously learning an action hierarchy using a learned qualitative state representation. *International Joint Conference on Artificial Intelligence (IJCAI)*, 2009.
- J. Modayil and B. Kuipers. The initial development of object knowledge by a learning robot. *Robotics and Autonomous Systems* **56**: 879–890, 2008.
- B. Kuipers. Drinking from the firehose of experience. *Artificial Intelligence in Medicine* **44**: 155–170, 2008. doi:10.1016/j.artmed.2008.07.010.
- A. Murarka, M. Sridharan, and B. Kuipers. Detecting obstacles and drop-offs using stereo and motion cues for safe local motion. *IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS-08)*, 2008.
- S. Ramamoorthy and B. J. Kuipers. Trajectory generation for dynamic bipedal walking through qualitative model based manifold learning. *Int. Conf. Robotics and Automation (ICRA-08)*, 2008. Best Paper Award finalist (top 4).
- B. Kuipers. An intellectual history of the Spatial Semantic Hierarchy. In Margaret E. Jefferies and Wai K. Yeap (Eds.), *Robotics and Cognitive Approaches to Spatial Mapping*, Springer-Verlag, 2008.
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- M. MacMahon, B. Stankiewicz and B. Kuipers. 2006. Walk the talk: connecting language, knowledge, action in route instructions. *National Conference on Artificial Intelligence (AAAI-06)*, Boston, MA, 16-20 July 2006.
- B. J. Oommen, G. Raghunath and B. Kuipers. 2006. Learning from stochastic teachers and stochastic compulsive liars. *IEEE Trans. Systems, Man and Cybernetics, Part B: Cybernetics* **36**(4): 820–834.
- A. Murarka, J. Modayil and B. Kuipers. 2006. Local safety maps for a wheelchair robot using vision and lasers. *Third Canadian Conference on Computer and Robot Vision*, Quebec City, Canada. (Best Student Paper Award)

- B. Kuipers, P. Beeson, J. Modayil and J. Provost. 2006. Bootstrap learning of foundational representations. *Connection Science* **18**(2): 145–158, special issue on Developmental Robotics.
- J. Provost, B. Kuipers, and R. Miikkulainen. 2006. Developing navigation behavior through self-organizing distinctive state abstraction. *Connection Science* **18**(2): 159–172, special issue on Developmental Robotics.
- B. Kuipers. 2005. Consciousness: Drinking from the firehose of experience. *National Conference on Artificial Intelligence (AAAI-05)*.
- P. Beeson, N. K. Jong, and B. Kuipers. 2005. Towards autonomous topological place detection using the extended Voronoi graph. *IEEE Int. Conf. on Robotics and Automation (ICRA-05)*.
- J. Modayil and B. Kuipers. 2004. Bootstrap learning for object discovery. *IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS-04)*.
- J. Modayil, P. Beeson and B. Kuipers. 2004. Using the topological skeleton for scalable global metrical map-building. *IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS-04)*.
- F. Savelli and B. Kuipers. 2004. Loop closing and planarity in topological map building. *IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS-04)*.
- B. Kuipers, J. Modayil, P. Beeson, M. MacMahon, and F. Savelli. 2004. Local metrical and global topological maps in the hybrid spatial semantic hierarchy. *IEEE International Conference on Robotics and Automation (ICRA-04)*.
- E. Remolina and B. Kuipers. 2004. Towards a general theory of topological maps. *Artificial Intelligence* **152**: 47–104.
- B. Kuipers, D. Tecuci, and B. Stankiewicz. 2003. The skeleton in the cognitive map: a computational and empirical exploration. *Environment and Behavior* **35**(1): 80–106.
- S. Ramamoorthy and B. Kuipers. Qualitative heterogeneous control of higher order systems. In A. Pnueli and O. Maler (Eds.), *Hybrid Systems: Computation and Control*, Lecture Notes in Computer Science (LNCS 2623), Springer Verlag, 2003, pages 417–434.
- B. Kuipers and P. Beeson. 2002. Bootstrap learning for place recognition. *Proceedings of the National Conference on Artificial Intelligence (AAAI-2002)*, AAAI/MIT Press, 2002, pages 174–180.
- B. Kuipers and S. Ramamoorthy. 2002. Qualitative modeling and heterogeneous control of global system behavior. In C. J. Tomlin and M. R. Greenstreet (Eds.), *Hybrid Systems: Computation and Control*, Lecture Notes in Computer Science (LNCS 2289), Springer Verlag, 2002, pages 294–307.
- B. Kuipers. The Spatial Semantic Hierarchy. 2000. *Artificial Intelligence* **119**: 191–233.
- H. Kay, B. Rinner and B. Kuipers. 2000. Semi-quantitative system identification. *Artificial Intelligence* **119**: 103–140.
- B. Rinner and B. Kuipers. 1999. Monitoring piecewise continuous behaviors by refining semi-quantitative trackers. In *Proceedings of the Sixteenth International Joint Conference on Artificial Intelligence (IJCAI-99)*, Stockholm, Sweden, August 1999.

- D. J. Clancy and B. J. Kuipers. 1998. Qualitative simulation as a temporally-extended constraint satisfaction problem. *Proceedings of the 15th National Conference on Artificial Intelligence (AAAI-98)*, AAAI/MIT Press, 1998.
- D. J. Clancy and B. Kuipers. 1997. Model decomposition and simulation: a component based qualitative simulation algorithm. *Proceedings of the 14th National Conference on Artificial Intelligence (AAAI-97)*, AAAI/MIT Press, 1997.
- D. J. Clancy and B. Kuipers. 1997. Static and dynamic abstraction solves the problem of chatter in qualitative simulation. *Proceedings of the 14th National Conference on Artificial Intelligence (AAAI-97)*, AAAI/MIT Press, 1997.
- D. M. Pierce and B. Kuipers. 1997. Map learning with uninterpreted sensors and effectors. *Artificial Intelligence* **92**: 169–227.
- B. Shults and B. Kuipers. 1997. Proving properties of continuous systems: qualitative simulation and temporal logic. *Artificial Intelligence* **92**: 91–129.
- B. J. Kuipers. 1994. *Qualitative Reasoning: Modeling and Simulation with Incomplete Knowledge*. Cambridge, MA: MIT Press.
- B. J. Kuipers and K. Åström. 1994. The composition and validation of heterogeneous control laws. *Automatica* **30**(2): 233–249.
- H. Kay & B. Kuipers. 1993. Numerical behavior envelopes for qualitative simulation. *Proceedings of the National Conference on Artificial Intelligence (AAAI-93)*, AAAI/MIT Press, 1993.
- W. W. Lee & B. Kuipers. 1993. A qualitative method to construct phase portraits. *Proceedings of the National Conference on Artificial Intelligence (AAAI-93)*, AAAI/MIT Press, 1993.
- B. J. Kuipers. Reasoning with qualitative models. 1993. *Artificial Intelligence* **59**: 125-132.
- B. J. Kuipers. Qualitative simulation: then and now. 1993. *Artificial Intelligence* **59**: 133-140.
- P. Fouché & B. Kuipers. 1992. Reasoning about energy in qualitative simulation. *IEEE Transactions on Systems, Man, and Cybernetics* **22**(1): 47-63.
- B. J. Kuipers, C. Chiu, D. T. Dalle Molle & D. R. Throop. 1991. Higher-order derivative constraints in qualitative simulation. *Artificial Intelligence* **51**: 343-379.
- D. Dvorak & B. Kuipers. 1991. Process monitoring and diagnosis: a model-based approach. *IEEE Expert* **6**(3): 67-74, June 1991.
- B. J. Kuipers & Y.-T. Byun. 1991. A robot exploration and mapping strategy based on a semantic hierarchy of spatial representations. *Journal of Robotics and Autonomous Systems* **8**: 47-63.
- B. J. Kuipers. 1989. Qualitative reasoning: modeling and simulation with incomplete knowledge. *Automatica* **25**: 571-585, July 1989.
- D. T. Dalle Molle, B. J. Kuipers, and T. F. Edgar. 1988. Qualitative modeling and simulation of dynamic systems. *Computers and Chemical Engineering* **12**: 853-866, 1988.
- B. J. Kuipers and T. Levitt. 1988. Navigation and mapping in large scale space. *AI Magazine*, vol. 9, no. 2, Summer 1988, pp. 25-43.

- B. J. Kuipers, A. J. Moskowitz, and J. P. Kassirer. Critical decisions under uncertainty: representation and structure. *Cognitive Science* **12**: 177-210, 1988.
- A. J. Moskowitz, B. J. Kuipers, and J. P. Kassirer. Dealing with uncertainty, risks, and tradeoffs: a cognitive science approach. *Annals of Internal Medicine* **108**: 435-449, 1988.
- B. J. Kuipers. 1986. Qualitative simulation. *Artificial Intelligence* **29**: 289 - 338, 1986.
- B. J. Kuipers. 1984. Commonsense reasoning about causality: deriving behavior from structure. *Artificial Intelligence* **24**: 169-203.
- B. J. Kuipers and J. P. Kassirer. 1984. Causal reasoning in medicine: analysis of a protocol. *Cognitive Science* **8**: 363-385, 1984.
- B. J. Kuipers. 1982. The 'Map in the Head' metaphor. *Environment and Behavior* **14**: 202-220, 1982.
- B. J. Kuipers. 1979. On representing common sense knowledge. In N. V. Findler (Ed.), *Associative Networks: The Representation and Use of Knowledge by Computers*. New York: Academic Press, 1979.
- B. J. Kuipers. 1978. Modeling spatial knowledge. *Cognitive Science* **2**: 129-153, 1978.

## ACADEMIC HONORS

- 2011 Best Student Paper Award for C. Xu, J. Liu and B. Kuipers, "Motion segmentation by learning homography matrices from motor signals." *Canadian Conf. Computer and Robot Vision (CRV-11)*.
- 2010 Best Educational Video Award, AAAI Video Competition (AIVC 2010), for J. Mugan and B. Kuipers, "The Qualitative Learner of Action and Perception, QLAP." Video available at: <http://www.youtube.com/watch?v=xJ0g-NoerZ0>
- Best Paper Award finalist (top 4) for S. Ramamoorthy and B. J. Kuipers, "Trajectory generation for dynamic bipedal walking through qualitative model based manifold learning." *IEEE International Conference on Robotics and Automation (ICRA)*, 2008.
- 2007 AAAI Classic Paper Award, Honorable Mention for "A robust, qualitative method for robot spatial learning" by Benjamin Kuipers and Yung-Tai Byun, as one of the most influential papers from the seventh National Conference on Artificial Intelligence, held in 1988.
- Best Student Paper Award. A. Murarka, J. Modayil and B. Kuipers, "Local safety maps for a wheelchair robot using vision and lasers." *Third Canadian Conference on Computer and Robot Vision*, 2006.
- Artificial Intelligence* honored two papers (1984 and 1986) as among the 25 most cited papers in the first 50 volumes of the journal [*Artificial Intelligence* **59**, 1993].
- Number of published papers reprinted in Readings volumes or other edited collections: 17.
- Best Paper Award in Machine Reasoning. R. Rajagopalan and B. Kuipers, "The Figure Understander: a system for integrating text and diagram input to a knowledge base." *Industrial and Engineering Applications of Artificial Intelligence and Expert Systems Conference (IEA/AIE)*, 1994.
- NSF Creativity Award, 1992: "Qualitative Methods for Robot Exploration" (IRI-8904454). "This two-year extension for special creativity is based on outstanding scientific/technical progress achieved to date under this grant."

1988 AAAI Best Paper Award nominee (top 10). B. J. Kuipers & Y.-T. Byun, "A robust qualitative method for spatial learning in unknown environments." *National Conference on Artificial Intelligence (AAAI)*, 1988.

College of Natural Sciences Teaching Excellence Award, 2004.

Guest Professor, University of Science and Technology of China, Hefei, China, May 2002.

Fellow, Institute of Electrical and Electronics Engineers, 1999.

Endowed Professorship in Computer Sciences (No. 3), from 1997.

David Bruton, Jr. Centennial Professorship in Computer Sciences (No. 1), 1992-97.

Fellow, American Association for Artificial Intelligence, 1992.

Computer Sciences Faculty Fellowship (No. 1), 1987-92.

Sigma Xi, student member 1970, full member 1976.

Phi Beta Kappa, Swarthmore College, 1970.

Danforth Graduate Fellowship, 1970.

National Science Foundation Graduate Fellowship, 1970.

National Merit Scholar, 1966.

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