

MAXIM LIKHACHEV

RESEARCH ASSISTANT PROFESSOR

Computer and Information Science

University of Pennsylvania

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EDUCATION

09/01 – 09/05 **Carnegie Mellon University** **Pittsburgh, PA**

Ph.D., Computer Science, M.S., Computer Science

Thesis Title: “Search-based Planning for Large Dynamic Environments”

Advisors: Sebastian Thrun and Geoff Gordon

Thesis Committee: Geoff Gordon (co-chair), Sebastian Thrun (co-chair),
Manuel Blum, Sven Koenig

05/94 - 07/99 **Stevens Institute of Technology** **Hoboken, NJ**

M.E., Electrical Engineering/Digital Signal Processing

GPA: 4.0/4.0

B.S., Major: Mathematics, Minor: Computer Science

Major GPA: 4.0/4.0 Minor GPA: 4.0/4.0 Cumulative GPA: 3.9/4.0

RESEARCH INTERESTS

Artificial Intelligence and Robotics: graph search-based planning, real-time planning, planning under uncertainty, planning for single and multi-agent systems including unmanned ground and aerial vehicles, mobile manipulators, articulated robots and teams of tightly-coupled robots

ACADEMIC PROFESSIONAL EXPERIENCE

04/09 – presently University of Pennsylvania Philadelphia, PA
Research Assistant Professor

09/07 – 04/09 University of Pennsylvania Philadelphia, PA
Research Associate

09/05 – 09/07 Carnegie Mellon University Pittsburgh, PA
Postdoctoral Fellow – worked under the supervision of Professor Tony Stentz and also was part of Tartanracing team that won the DARPA Urban Challenge in 2007 (the third DARPA Grand Challenge competition)

09/01 – 09/05 Carnegie Mellon University Pittsburgh, PA
Graduate Research Assistant – worked under the supervision of Professors Sebastian Thrun and Geoff Gordon.

09/99 – 09/01 Georgia Institute Of Technology Atlanta, GA
Graduate Research Assistant – worked under the supervision of Professors Sven Koenig and Ron Arkin

NON-ACADEMIC PROFESSIONAL EXPERIENCE

01/97 – 07/01 Intel Corporation, Parsippany, NJ
DSP Engineer II
Researched and implemented voice quality improvement algorithms for the use in telecommunication systems.

TEACHING EXPERIENCE

01/09 – 05/09 University of Pennsylvania Philadelphia, PA
Co-Instructor for graduate Advanced Robotics class (MEAM 620)

01/08 – 05/08 University of Pennsylvania Philadelphia, PA
Co-Instructor for graduate Advanced Robotics class (MEAM 620)

09/04 – 12/04 Carnegie Mellon University Pittsburgh, PA
Graduate Teaching Assistant for a Ph.D.-level graduate Machine Learning class (instructors: Andrew Moore and Ziv Bar-Joseph)

01/03 – 05/03 Carnegie Mellon University Pittsburgh, PA
Graduate Teaching Assistant for an undergraduate Artificial Intelligence class (instructor: Jaime Carbonell)

HONORS AND AWARDS

- ◆ Best poster award at NVIDIA GPU Technology Conference, 2009
- ◆ Part of the Tartanracing team that won the 1st place in the Urban Challenge competition sponsored by DARPA in 2007
- ◆ Doctoral Fellowship (Carnegie Mellon University, 2001-2005)
- ◆ Stevens Cooperative Education Program Award for Academic Excellence (Stevens Institute of Technology, 1997)
- ◆ Charles I. Petschek Scholarship Award for a strong interest in mathematics (Stevens Institute of Technology, 1995)
- ◆ Distinguished Scholar Award (Brookdale Community College, 1995)
- ◆ National Dean's List (all semesters)
- ◆ Bachelor of Science with High Honor

FUNDING

- ◆ "II-EN: Mobile Manipulation," NSF Infrastructure grant, PI: M. Likhachev, Co-PIs: K. Daniilidis, K. J. Kuchenbecker, D. D.Lee, J. Shi, \$298K, 2009
- ◆ "Development of Standardized Library of Planning Algorithms and New Planning Algorithms for Manipulation Tasks," granted by Willow Garage, PI: M. Likhachev, \$110K, 2009

- ◆ “Decentralized Reasoning in Reduced Information Spaces,” ONR BAA 08-019 MURI program starting in 2009, 3 base plus 2 option years, lead institution: CMU, PI at UPenn: M. Likhachev, Co-PI: Jianbo Shi, anticipated funding for UPENN for the base 3 years: \$1.05M, 2009
- ◆ “ANTIDOTE: Adaptive Networks for Threat and Intrusion Detection Or TErmination,” ONR BAA 08-019 MURI program starting in 2009, 3 base plus 2 option years, lead institution: USC, PI at UPenn: V. Kumar, Co-PI: M. Likhachev, R. Ghrist, anticipated funding for UPENN for the base 3 years: \$1.35M, 2009
- ◆ “Real-time Determination and Prediction of Aircraft Trajectories Using Limited Sensor Data,” NAVAIR Phase I STTR, PI for the project: Dragonfly Pictures Inc., PI at UPenn: M. Likhachev, \$100K total, 2009
- ◆ “Rapid Complex Mapping” funded by SPARWAR, PI: Sarnoff, subcontracted to UPenn, funding for UPenn: \$100K, PI: K. Daniilidis, Co-PI: J. Shi and M. Likhachev, 2009
- ◆ “Detecting and Tracking Multiple Moving Objects from a Moving Platform,” DARPA Phase I SBIR, PI for the project: Dragonfly Pictures Inc., PI at UPenn: M. Likhachev, Co-PI: J. Shi, \$100K total, 2009
- ◆ “Micro Autonomous Systems Technologies (MAST),” 10-year program starting at 2008, funded by ARL, Co-PI
- ◆ “Development of Standardized Library of Planning Algorithms and New Planning Algorithms for Manipulation Tasks,” granted by Willow Garage, PI: M. Likhachev, \$110K, 2008
- ◆ “Autonomous Landing Site Selection and Confirmation for Unmanned Helicopters,” granted by Dragonfly Pictures Inc., PI: M. Likhachev, \$75K, 2008
- ◆ “Path Planning for Unmanned Helicopters Navigating Urban Environments,” granted by Dragonfly Pictures Inc., PI: M. Likhachev, \$97K, 2008
- ◆ “Path Planning in Dynamic Environments,” DARPA Phase I SBIR, PI for the project: Dragonfly Pictures Inc., PI at UPenn: M. Likhachev, \$100K total, 2008
- ◆ “Search and Rescue with Unmanned Helicopters,” Army Phase I SBIR, PI for the project: Dragonfly Pictures Inc., PI at UPenn: M. Likhachev, Co-PI at Upenn: V. Kumar, \$70K total, 2008

PUBLICATIONS

Journal and Magazine Articles, Book Chapters:

1. Maxim Likhachev and Dave Ferguson, “*Planning Long Dynamically-Feasible Maneuvers for Autonomous Vehicles*,” The International Journal of Robotics Research (IJRR), (to appear), 2009
2. Maxim Likhachev and Anthony Stentz, “*Path Clearance*,” IEEE Robotics and

- Automation Magazine (RAM), Special Issue on Cooperative Control of Multiple Heterogeneous Unmanned Aerial Vehicles for Coverage and Surveillance, (to appear), 2009
3. Maxim Likhachev and Anthony Stentz, "***Probabilistic Planning with Clear Preferences on Missing Information***," Artificial Intelligence Journal (AIJ), Volume 173(5-6), pp. 696-721, 2009
 4. Dave Ferguson, Thomas Howard, and Maxim Likhachev, "***Motion Planning in Urban Environments***," Journal of Field Robotics (JFR), 25(11-12), pp. 939-960, 2008
 5. Chris Urmson et al., "***Autonomous Driving in Urban Environments: Boss and the Urban Challenge***," Journal of Field Robotics (JFR), Special Issue on the 2007 DARPA Urban Challenge, Part I, 25 (8), pp. 425-466, June 2008
 6. Maxim Likhachev, Dave Ferguson, Geoff Gordon, Anthony Stentz, and Sebastian Thrun, "***Anytime Search in Dynamic Graphs***," Artificial Intelligence Journal (AIJ), Volume 172(14), pp. 1613-1643, 2008
 7. Sven Koenig and Maxim Likhachev, "***Fast Replanning for Navigation in Unknown Terrain***," Transactions on Robotics (and Automation), Volume 21(3), pp. 354-363, 2005
 8. Sven Koenig, Maxim Likhachev, and David Furcy, "***Lifelong Planning A****," Artificial Intelligence Journal (AIJ), 155(1-2), pp. 93-146, 2004
 9. Maxim Likhachev and Sven Koenig, "***Lifelong Planning for Mobile Robots***," Lecture Notes in Artificial Intelligence, Vol. 2466: Advances in Plan-Based Control of Robotic Agents, M. Beetz, J. Hertzberg, M. Ghallab, and M. Pollack (Eds.), Springer, pp. 140-156, 2002

Research Overview Publications:

- ◆ Sven Koenig, Maxim Likhachev, Yaxin Liu, and David Furcy, "***Incremental Heuristic Search in Artificial Intelligence***," Artificial Intelligence Magazine, 25(2), pp. 99-112, 2004.

Full-length Publications at Conferences:

1. Jennifer King and Maxim Likhachev, "***Efficient Cost Computation in Cost Map Planning for Non-Circular Robots***," Proceedings of the IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS), 2009.
2. Alex Nash, Sven Koenig and Maxim Likhachev, "***Incremental Phi*: Incremental Any-Angle Path Planning on Grids***," Proceedings of the International Joint Conference on Artificial Intelligence (IJCAI), 2009.
3. Aleksandr Kushleyev and Maxim Likhachev, "***Time-bounded Lattice for Efficient Planning in Dynamic Environments***," Proceedings of the IEEE International Conference on Robotics and Automation (ICRA), 2009.
4. Paul Vernaza, Maxim Likhachev, Subhrajit Bhattacharya, Sachin Chitta, Aleksandr Kushleyev and Daniel D. Lee, "***Search-based Planning for a Legged Robot over Rough Terrain***," Proceedings of the IEEE International Conference on Robotics and Automation (ICRA), 2009.
5. Dave Ferguson, Thomas Howard, and Maxim Likhachev, "***Motion Planning in Urban Environments: Part I***," Proceedings of the IEEE/RSJ International

- Conference on Intelligent Robots and Systems (IROS), 2008
6. Dave Ferguson, Thomas Howard, and Maxim Likhachev, "***Motion Planning in Urban Environments: Part II***," Proceedings of the IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS), 2008
 7. Maxim Likhachev and Dave Ferguson, "***Planning Long Dynamically-Feasible Maneuvers for Autonomous Vehicles***," Proceedings of the Robotics: Science and Systems Conference (RSS), 2008
 8. Maxim Likhachev and Anthony Stentz, "***R* Search***," Proceedings of the National Conference on Artificial Intelligence (AAAI), 2008
 9. Dave Ferguson, Chris Baker, Maxim Likhachev and John Dolan, "***A Reasoning Framework for Autonomous Urban Driving***," Proceedings of the IEEE Intelligent Vehicles Symposium (IV), oral presentation, 2008
 10. Maxim Likhachev and Anthony Stentz, "***Information Value-Driven Approach to Path Clearance with Multiple Scout Robots***," Proceedings of the IEEE International Conference on Robotics and Automation (ICRA), 2008
 11. Maxim Likhachev and Anthony Stentz, "***Goal Directed Navigation with Uncertainty in Adversary Locations***," Proceedings of the IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS), 2007
 12. Sven Koenig, Maxim Likhachev and Xiaoxun Sun, "***Speeding up Moving-Target Search***," Proceedings of the International Joint Conference on Autonomous Agents and Multiagent Systems (AAMAS), 2007
 13. Maxim Likhachev and Anthony Stentz, "***Path Clearance Using Multiple Scout Robots***," Proceedings of the Army Science Conference (ASC), 2006
 14. Maxim Likhachev and Anthony Stentz, "***PPCP: Efficient Probabilistic Planning with Clear Preferences in Partially-Known Environments***," Proceedings of the National Conference on Artificial Intelligence (AAAI), 2006
 15. Sven Koenig and Maxim Likhachev, "***Real-Time Adaptive A****," Proceedings of the International Joint Conference on Autonomous Agents and Multiagent Systems (AAMAS), 2006
 16. H. Brendan McMahan, Maxim Likhachev, and Geoff Gordon, "***Bounded Real-Time Dynamic Programming: RTDP with monotone upper bounds and performance guarantees***," Proceedings of the International Conference on Machine Learning (ICML), 2005
 17. Maxim Likhachev, Dave Ferguson, Geoff Gordon, Anthony Stentz, and Sebastian Thrun, "***Anytime Dynamic A*: An Anytime, Replanning Algorithm***," Proceedings of the International Conference on Automated Planning and Scheduling (ICAPS), 2005
 18. Maxim Likhachev, and Sven Koenig, "***A Generalized Framework for Lifelong Planning A****," Proceedings of the International Conference on Automated Planning and Scheduling (ICAPS), 2005
 19. Maxim Likhachev, Geoff Gordon and Sebastian Thrun, "***Planning for Markov Decision Processes with Sparse Stochasticity***," Advances in Neural Information Processing Systems 17 (NIPS), MIT Press, Cambridge, MA, 2005
 20. Maxim Likhachev, Geoff Gordon and Sebastian Thrun, "***ARA*: Anytime A* with Provable Bounds on Sub-Optimality***," Advances in Neural Information Processing Systems 16 (NIPS), MIT Press, Cambridge, MA, 2004
 21. Maxim Likhachev and Sven Koenig, "***Speeding up the Parti-Game Algorithm***,"

- Advances in Neural Information Processing Systems 15 (NIPS), MIT Press, Cambridge, MA, 2003
22. Maxim Likhachev and Sven Koenig, "**Incremental Replanning for Mapping**," Proceedings of the IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS), Vol. 1, pp. 667-672, 2002
 23. Sven Koenig and Maxim Likhachev, "**D* Lite**," Proceedings of the National Conference on Artificial Intelligence (AAAI), pp. 476-483, 2002
 24. Maxim Likhachev, Michael Kaess, and Ronald C. Arkin, "**Learning Behavioral Parameterization Using Spatio-Temporal Case-Based Reasoning**," Proceedings of the IEEE International Conference on Robotics and Automation (ICRA), Vol. 2, pp. 1282-1289, 2002
 25. J. Brian Lee, Maxim Likhachev, and Ronald C. Arkin, "**Selection of Behavioral Parameters: Integration of Discontinuous Switching via Case-Based Reasoning with Continuous Adaptation via Learning Momentum**," Proceedings of the IEEE International Conference on Robotics and Automation (ICRA), Vol. 2, pp. 1275-1281, 2002
 26. Sven Koenig and Maxim Likhachev, "**Incremental A***," Advances in Neural Information Processing Systems 14 (NIPS), MIT Press, Cambridge, MA, 2002
 27. Maxim Likhachev and Ronald C. Arkin, "**Spatio-Temporal Case-Based Reasoning for Behavioral Selection**," Proceedings of the IEEE International Conference on Robotics and Automation (ICRA), Vol. 2, pp. 1627-1634, 2001
 28. Maxim Likhachev and Ronald C. Arkin, "**Robotic Comfort Zones**," Proceedings of SPIE: Sensor Fusion and Decentralized Control in Robotic Systems III Conference, Vol. 4196, pp. 27-41, 2000

Short-length Publications at Conferences:

- ◆ Mark Henderson, Joseph T. Kider Jr., Maxim Likhachev and Alla Safonova, "**High-Dimensional Planning on the GPU**," NVIDIA GPU Technology Conference, 2009 (Best Poster Award).
- ◆ Dave Ferguson and Maxim Likhachev, "**Efficiently Using Cost Maps For Planning Complex Maneuvers**," Proceedings of ICRA Workshop on Planning with Cost Maps, 2008.
- ◆ Maxim Likhachev and Sven Koenig, "**Incremental Heuristic Search in Games: The Quest for Speed**," Proceedings of the Artificial Intelligence and Interactive Digital Entertainment Conference (AIIDE), Poster Abstract, 2006
- ◆ Dave Ferguson, Maxim Likhachev and Anthony Stentz, "**A Guide to Heuristic-based Path Planning**," Proceedings of ICAPS Workshop on Planning under Uncertainty for Autonomous Systems, 2005
- ◆ Sven Koenig and Maxim Likhachev, "**A New Principle for Incremental Heuristic Search: Theoretical Results**," Proceedings of the International Conference on Automated Planning and Scheduling (ICAPS), Poster Abstract, 2005
- ◆ Sven Koenig and Maxim Likhachev, "**Adaptive A***," Proceedings of the International Joint Conference on Autonomous Agents and Multiagent Systems (AAMAS), Poster Abstract, 2005

PATENTS

- ◆ Patent 7,136,813 (issued 11/14/2006, filed 09/25/2005), "**Probabilistic networks for detecting signal content**," (Intel Corporation).

INVITED TALKS AND TUTORIALS

- ◆ Tutorial "Real-Time Planning in Dynamic and Partially-Known Domains" at ICAPS (together with Sven Koenig), 2009
- ◆ Tutorial "Real-Time Planning in Dynamic and Partially-Known Domains" at IJCAI (together with Sven Koenig), 2009
- ◆ Internal talk "Solving Hard Planning Problems in Robotics with Simple Graph Searches" at GRASP seminar at University of Pennsylvania, 2008
- ◆ Invited talk "Solving Hard Planning Problems in Robotics with Simple A*-like searches" at the First International Symposium on Search Techniques in Artificial Intelligence and Robotics (at AAAI conference), 2008
- ◆ Invited talk "Planning Long Dynamically-Feasible Complex Maneuvers for Autonomous Vehicles" at NREC, CMU, 2008
- ◆ Invited talk "Challenges of Planning in Dynamic Cluttered Environments" at DARPA sponsored workshop on Cognitive Mobile Robotics, 2008
- ◆ Invited talk "Pushing the Limits of Search-based Planning" at Intel Research, Pittsburgh, 2007
- ◆ Invited talk "Search-based Planning under Time Constraints and under Uncertainty" at NREC, CMU, 2007
- ◆ Invited talk "Search-based Planning under Time Constraints and under Uncertainty" at State University of New York, Stony Brook, 2007
- ◆ Invited talk "Fast Replanning" at ICAPS Summer School on Artificial Intelligence Planning 2006 (together with Sven Koenig)
- ◆ Invited talk "Search-based Planning for Large Dynamic Environments" at Palo Alto Research Center (PARC) 2005
- ◆ Part of the tutorial "Greedy On-Line Planning" given by Sven Koenig and Anthony Stentz at AAAI 2005
- ◆ Part of the tutorial "Greedy On-Line Planning" given by Sven Koenig and Anthony Stentz at ICRA 2005

PROFESSIONAL SERVICES

- ◆ **Member of Program Committee for:** Robotics: Science and Systems (RSS) Conference 2010, National Conference on Artificial Intelligence (AAAI) 2010, International Joint Conferences on Artificial Intelligence (IJCAI) 2009, Symposium on Combinatorial Search (SoCS) 2009, National Conference on Artificial Intelligence (AAAI) 2008 (PC member at both the main track and Physically-grounded AI track), Workshop "Search in Artificial Intelligence and Robotics" at AAAI'08, Workshop "Path Planning on Costmaps" at ICRA'08, International Conference on Machine Learning (ICML) 2007

- ◆ **Chair for:** Workshop “Bridging the Gap Between the Task and Motion Planning” at the National Conference on Artificial Intelligence (AAAI), 2010(co-chair), Workshop “Bridging the Gap Between the Task and Motion Planning” at the International Conference on Automated Planning and Scheduling (ICAPS), 2009 (co-chair)
- ◆ **Session Chair for:** National Conference on Artificial Intelligence (AAAI) 2008, IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS), 2007
- ◆ **Reviewer for the following journals:** International Journal of Robotics Research (IJRR) 2009, IEEE Transactions on Robotics (TRO) 2009, Journal of Artificial Intelligence Research (JAIR) 2008, Artificial Intelligence Journal (AIJ) 2008, Journal of Intelligent and Robotic Systems (JINT) 2008, Artificial Intelligence Journal (AIJ) 2007, Artificial Intelligence Journal (AIJ) 2006, Journal of Artificial Intelligence Research (JAIR) 2006 (2 papers), IEEE Transactions on Robotics (TRO) 2006, Journal of Machine Learning Research (JMLR) 2005, Journal of Artificial Intelligence Research (JAIR) 2005, IEEE Transactions on Robotics (TRO) 2005, IEEE Transactions on Robotics and Automation (TRA) 2003, IEEE Transactions on Robotics and Automation (TRA) 2002.
- ◆ **Reviewer for the following conferences:** IEEE International Conference on Intelligent Robots and Systems (IROS) 2010, IEEE International Conference on Intelligent Robots and Systems (IROS) 2009, IEEE International Conference on Robotics and Automation (ICRA) 2009, American Control Conference (ASC) 2009, IEEE International Conference on Robotics and Automation (ICRA) 2008, IEEE Multi-conference on Systems and Control (MSC) 2008, IEEE International Conference on Robotics and Automation (ICRA) 2007, International Joint Conference on Artificial Intelligence (IJCAI) 2007 (5 papers), Robotics: Science and Systems (RoSS) 2006, International Joint Conference on Artificial Intelligence (IJCAI) 2005, International Conference on Intelligent Autonomous Systems (IAS) 2005 (2 papers), IEEE International Conference on Robotics and Automation (ICRA) 2005, International Joint Conference on Artificial Intelligence (IJCAI) 2003, Advances in Neural Information Processing Systems (NIPS) 2002 (6 papers).

TECHNICAL SKILLS

- ◆ Programming Languages: C/C++, Fortran 77, Lisp, Scheme, Matlab, Intel Assembly, Motorola DSP Assembly, FoxPro.
- ◆ Platforms: UNIX, Windows

LANGUAGES

Fluent in English & Russian. Some knowledge of Latvian language.

INTERESTS AND ACTIVITIES

Fishing, downhill skiing, the history of old silver

REFERENCES

Professor Sebastian Thrun	Professor Geoff Gordon
Computer Science Department	School of Computer Science
Stanford University,	Carnegie Mellon University,

thrun@stanford.edu

ggordon+@cs.cmu.edu

Professor Anthony Stentz
Robotics Institute
Carnegie Mellon University,
tony+@cmu.edu

Professor Sven Koenig
Computer Science Department
University of Southern California,
skoenig@usc.edu

CITIZENSHIP STATUS

Citizenship of USA, Top Security Clearance