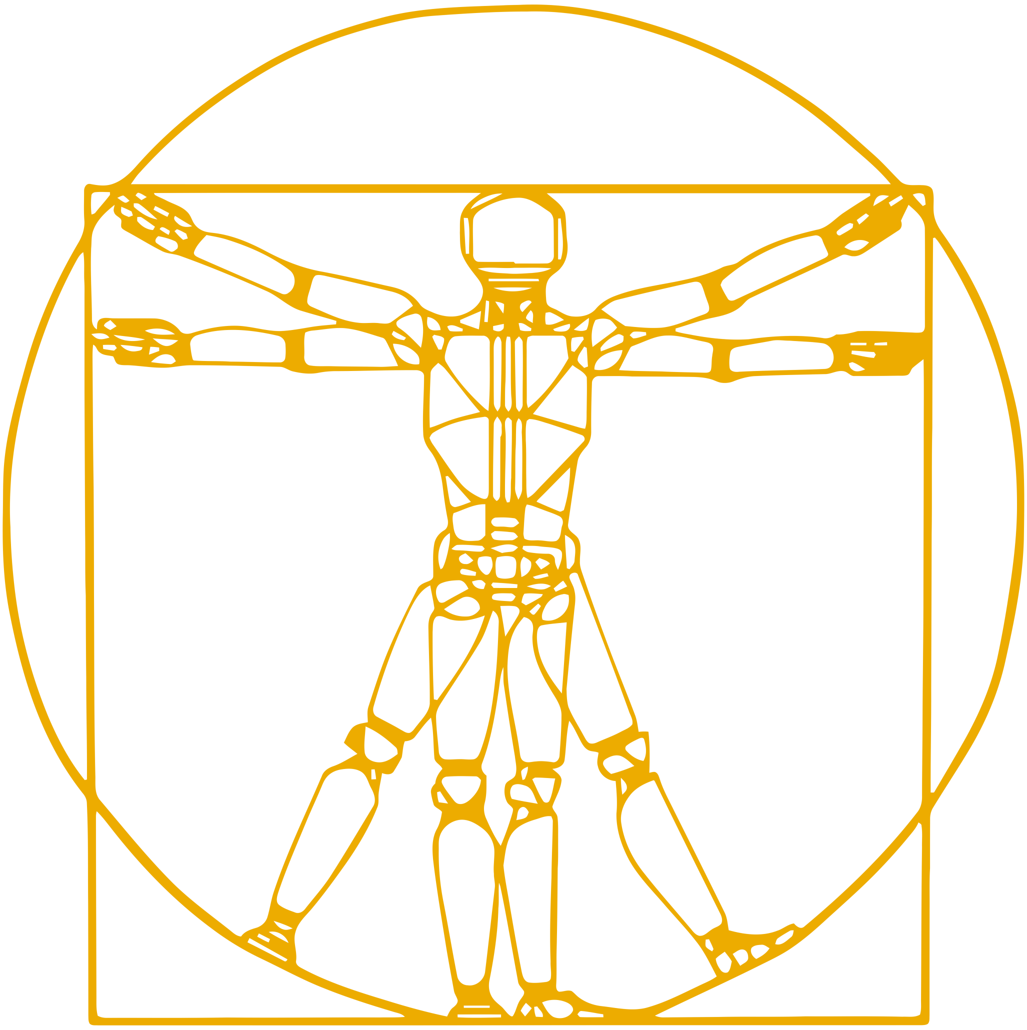
ROBOTICS
SCIENCE AND SYSTEMS



Conference Booklet

July 12–16, 2014
University of California, Berkeley
Berkeley, California, USA
www.roboticsconference.org

Preface

Welcome to RSS 2014 at UC Berkeley – the 10th incarnation of the RSS conference!

RSS continues to attract some of the best work from across the whole spectrum of robotics research. This year we have 57 papers being presented by authors from all around the world. Of the 57 papers, 6 will be presented through long talks, and 51 will be presented through short talks. All 57 papers will in addition be presented through interactive sessions. The RSS 2014 proceedings, available at www.roboticsproceedings.org, will be indexed by INSPEC and we are in the fortunate position to announce that all earlier RSS proceedings will also be indexed by INSPEC retroactively. Recently, we also launched the RSS Foundation website www.roboticsfoundation.org, which features the foundation's goals, procedures and policies, and open letters to the RSS community.

In addition to the presentations of peer-reviewed papers, the program features 5 outstanding invited speakers: Nancy Amato, Genevieve Bell, Brad Nelson, Andrew Ng, and Chris Urmson; 2 early career spotlight presenters: Julie Shah and Ashutosh Saxena. Also included are streaming of the world cup final on Sunday; a celebration of 10 years of RSS on Monday evening; a bay cruise conference banquet on Tuesday evening; lunchtime tours of the UC Berkeley robotics labs and an evening at Google on Wednesday.

This year's RSS was made possible by many invisible hands that gave their support and put in long hours and hard work: the organizing committee, our sponsors, the area chairs, the many reviewers, the student volunteers, and so many more. Special thanks to everybody who contributed! Berkeley is well known for its wealth of cafes and restaurants. We strongly encourage you to try to explore its many exciting neighborhoods: Southside, Northside, Downtown, Gourmet Ghetto, and Elmwood.

The RSS conference has seen solid growth in participation over the years, but the growth of the conference accelerated at a whole new level this year, with a doubling of the number of conference registrations as compared to last year. We look forward to hosting all of you, and if we can help you with anything during the conference, please do not hesitate to reach out to the local organizing committee — we wear the gold T-shirts!

Pieter Abbeel, Sachin Patil, Lydia Kavraki, Dieter Fox

Contents

Conference and Local Information

General Information

About the University of California, Berkeley

The University of California, Berkeley (also referred to as UC Berkeley; Berkeley; California; or simply Cal), is a public research university located in Berkeley, California. The university occupies 1,232 acres on the eastern side of the San Francisco Bay with the central campus resting on 178 acres. Berkeley is the flagship institution of the 10 campus University of California system.

Established in 1868 as the result of the merger of the private College of California and the public Agricultural, Mining, and Mechanical Arts College in Oakland, Berkeley is the oldest institution in the UC system and offers approximately 350 undergraduate and graduate degree programs in a wide range of disciplines. Berkeley has been charged with providing both “classical” and “practical” education for the state’s people. Berkeley co-manages three United States Department of Energy National Laboratories, including the Los Alamos National Laboratory, the Lawrence Livermore National Laboratory, and the Lawrence Berkeley National Laboratory for the U.S. Department of Energy.

About the City of Berkeley

Berkeley (pronounced burk-lee) is a city on the east shore of the San Francisco Bay in northern Alameda County, California, that is named after the eighteenth-century bishop and philosopher George Berkeley. Berkeley borders the cities of Albany, Oakland, and Emeryville and Contra Costa County including unincorporated Kensington as well as the San Francisco Bay. According to the United States Census Bureau the city’s 17.7 square miles area includes 10.5 square miles of land and 7.2 square miles water, most of it part of the San Francisco Bay. Its population at the 2010 census was determined to be 112,580 and it is one of the most politically liberal cities in the United States.

Berkeley is the site of the oldest campus in the University of California system – the University of California, Berkeley – and of the Lawrence Berkeley National Laboratory that the university manages and operates.

Berkeley is served by Amtrak (Capitol Corridor), AC Transit, BART (Ashby, Downtown Berkeley Station and North Berkeley) and bus shuttles operated by major employers including UC Berkeley and Lawrence Berkeley National Laboratory. The Eastshore Freeway (Interstate 80 and Interstate 580) runs along the bay shoreline. Berkeley also hosts car sharing networks run by City CarShare, Uhaul Car Share, and Zipcar. Several ”pods” (points of departure where cars are kept) exist throughout the city, in several downtown locations, at the Ashby and North Berkeley BART stations, and at various other locations in Berkeley (and other cities in the region).

Berkeley has a number of distinct neighborhoods. Surrounding the University of California campus are the most densely populated parts of the city. West of the campus is Downtown Berkeley, the city’s traditional commercial core; home of the civic center, the city’s only public high school, the busiest BART station in Berkeley, as well as a major transfer point for AC Transit buses. South of the campus is the Southside neighborhood, mainly a student ghetto, where much of the university’s student housing is located. The busiest stretch of Telegraph Avenue is in this neighborhood. North of the campus is the quieter Northside neighborhood, which has a wide variety of cafes and dining options. North of Downtown is the North Berkeley neighborhood, which has been nicknamed the ”Gourmet Ghetto” because of the concentration of well-known restaurants and other food-related businesses. In the southeastern corner of the city is the Claremont District, home to the Claremont Hotel; and the Elmwood District, with a small shopping area on College Avenue. West of Elmwood is South Berkeley, known for its weekend flea market at the Ashby Station. Along the shoreline of the San Francisco Bay at the foot of University Avenue is the Berkeley Marina.

Registration

The registration desk will be located in the lobby of Wheeler Hall on the first floor that is accessible through the south-side entrance of the building. Student volunteers will be present at the desk and will provide you with a registration packet consisting of your name tag, a printed conference booklet, conference t-shirt, instructions on how to setup wireless access, and tickets to the conference banquet and the Dinner & Demos event at Google HQ.

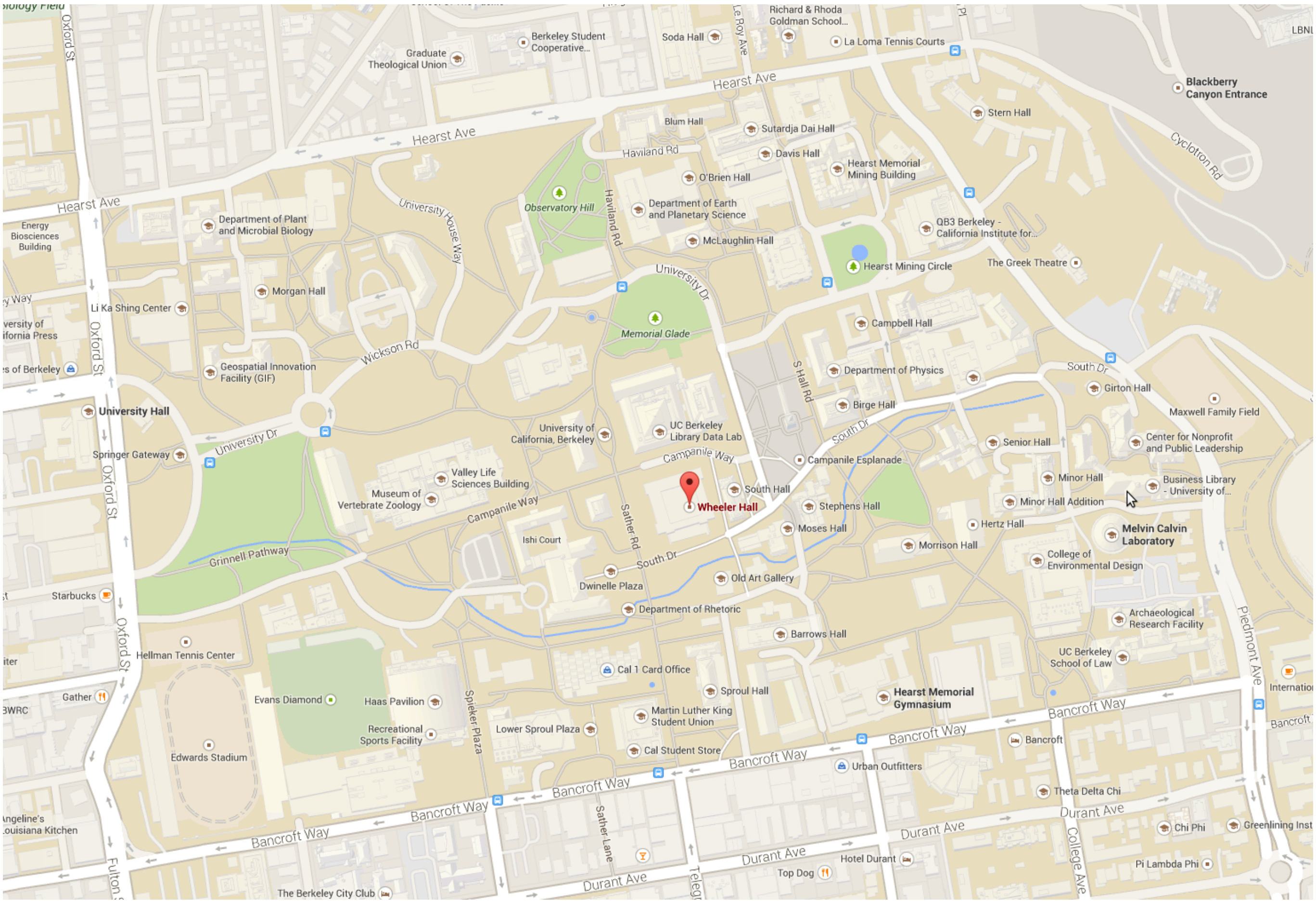
Wireless Internet Access

The registration package will include instructions and access credentials for wireless access. If you have difficulties setting up your wireless access, please contact any of the volunteers or the registration desk.

Help and Emergencies

In case of an emergency at the conference, you can seek assistance from any of the conference volunteers (who will wear gold t-shirts) or seek assistance at the registration desk. For medical emergencies at the conference, please call 911.

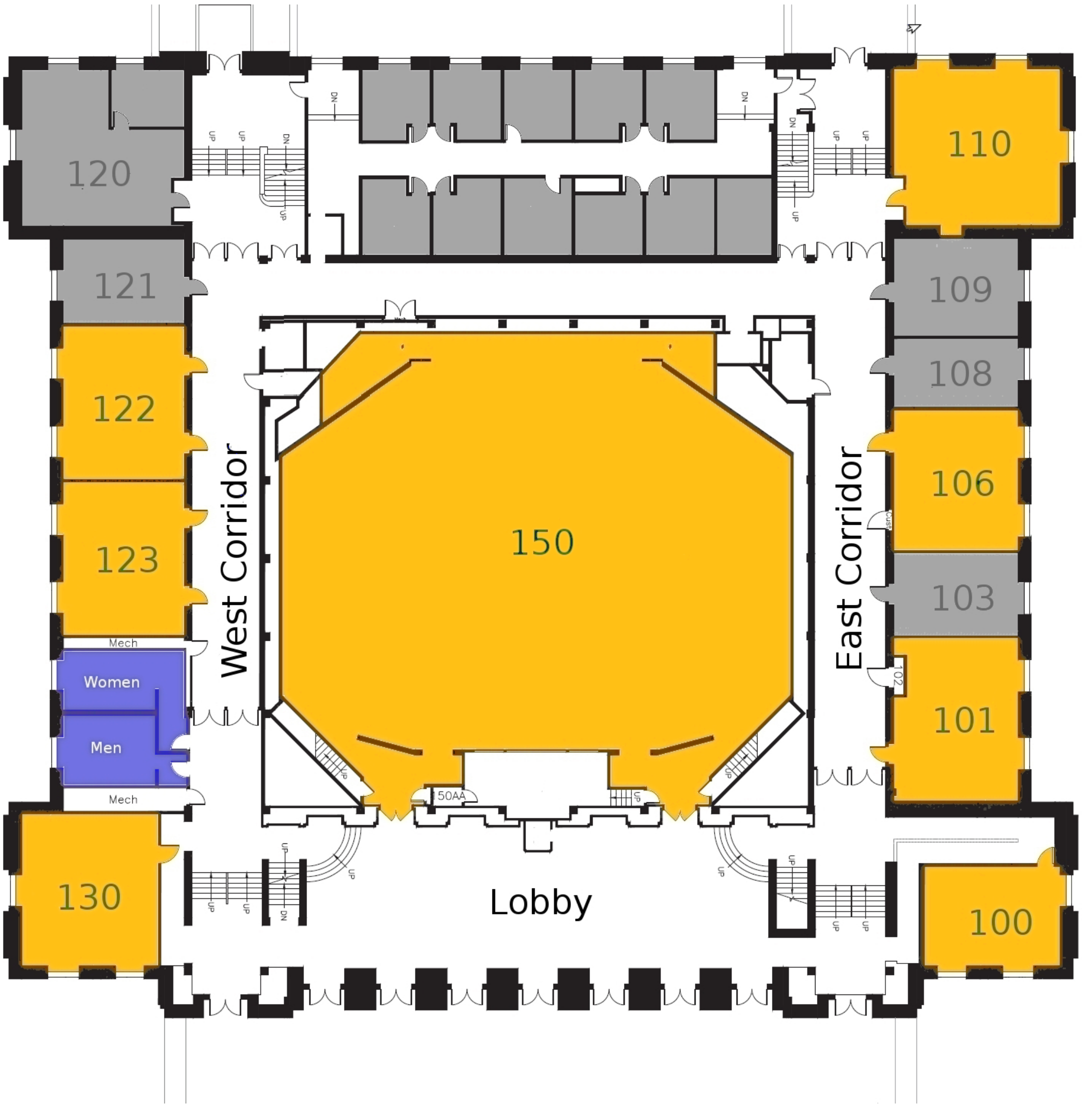
Conference and Workshops Venues



The conference and workshops will take place in Wheeler Hall on the UC Berkeley campus.

1st Floor – Conference and Workshops Venue

Saturday, July 12 to Wednesday, July 16



Legend:

- Gold: Rooms in use
- Blue: Restrooms
- Gray: Rooms not in use

The registration desk will be located in the lobby of Wheeler Hall.

Please see Technical Program for conference and workshop room assignments.

Basement Floor – Workshops Venue

Saturday, July 12 to Sunday, July 13

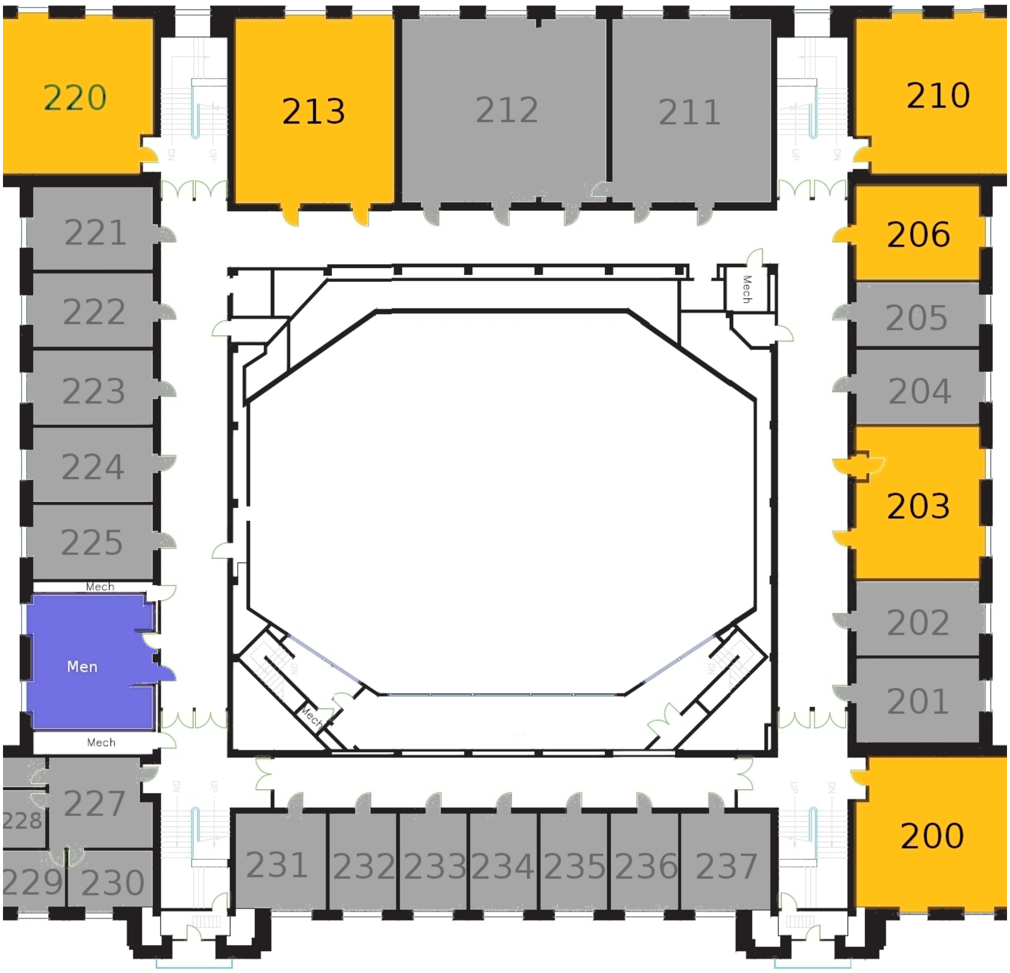
Legend:

- Gold: Rooms in use
- Blue: Restrooms
- Gray: Rooms not in use

Please see Technical Program for workshop room assignments.

2nd Floor – Workshops Venue

Saturday, July 12 to Sunday, July 13



Legend:

- Gold: Rooms in use
- Blue: Restrooms
- Gray: Rooms not in use

Please see Technical Program for workshop room assignments.

Special Events

Celebration of 10 years of RSS (Sponsored by Anki)

We will celebrate the 10th edition of RSS with cake and drinks. Anki will have demos of the Anki Drive game for RSS attendees to try out.

Conference Banquet

The conference banquet will be held on a cruise on the San Francisco Bay. Enjoy a splendid sunset on the water with magnificent views of the city of San Francisco, accompanied by a delicious seasonal dinner and drinks. Transportation will be provided. Buses will pick us up from Berkeley at 6pm and take us to Pier 3 in San Francisco, where we will board the San Francisco Belle. Buses will pick us up from Pier 3 around 10pm, and we'll be back in Berkeley around 10:30pm.

Dinner & Demos at Google HQ

On the last day of the conference, Google will be hosting a special evening event for RSS attendees at the Google Headquarters in Mountain View. In order to attend this event, you need to have registered for it when you registered for the conference. An additional badge will be issued to registered attendees. You can look forward to a night of hosted dinner and demos from some of the Google teams working on robotics, machine learning, and computer vision. Teams that will be present include the Self-Driving Car team, Project Loon, Google Glass, Streetview, and more. Transportation will be provided. Buses will pick us up from Berkeley at 5pm and take us to Mountain View. Storage for luggage will be provided at the venue. Buses will bring us back to Berkeley around 10pm.

Drink and Food Suggestions

Lunch

We recommend the Southside, Northside, and Downtown neighborhoods for lunch in terms of proximity to the conference venue. We have provided below a sampling of lunch places in each of these neighborhoods, along with the type of food and price category.

1) Southside (0.3 miles from Wheeler Hall)

1	Cheese 'N' Stuff	Sandwiches	$
2	Montague's Gourmet Sandwiches	Sandwiches	$
3	Tivoli Caffe	Pizza, Sandwiches	$
4	Gypsy's Trattoria Italiano	Italian	$
5	Julie's Cafe	Sandwiches, Salads	$
6	KoJa Kitchen	Asian Fusion, Japanese	$
7	Crepes A-Go Go	Creperie	$
8	Chipotle Mexican Grill	Mexican	$
9	Free House	Burgers, Salads, Sandwiches	$$
10	Henry's	Burgers, Salads, Sandwiches	$$

2) Northside (0.5 miles from Wheeler Hall)

1	Northside Cafe	Breakfast, Sandwiches	$
2	Urbann Turbann	Rice/Naan Wraps with Indian Curries	$
3	D'Yar	Mediterranean	$
4	The Pho Bar	Vietnamese	$$
5	Cafe Nefeli	Mediterranean	$
6	Bongo Burger	Burgers, Salads	$
7	Celia's Mexican	Mexican	$$
8	Stuffed Inn	Sandwiches	$
9	Jasmine Thai	Thai	$$
10	Hummingbird Cafe	Sandwiches, Mediterranean	$

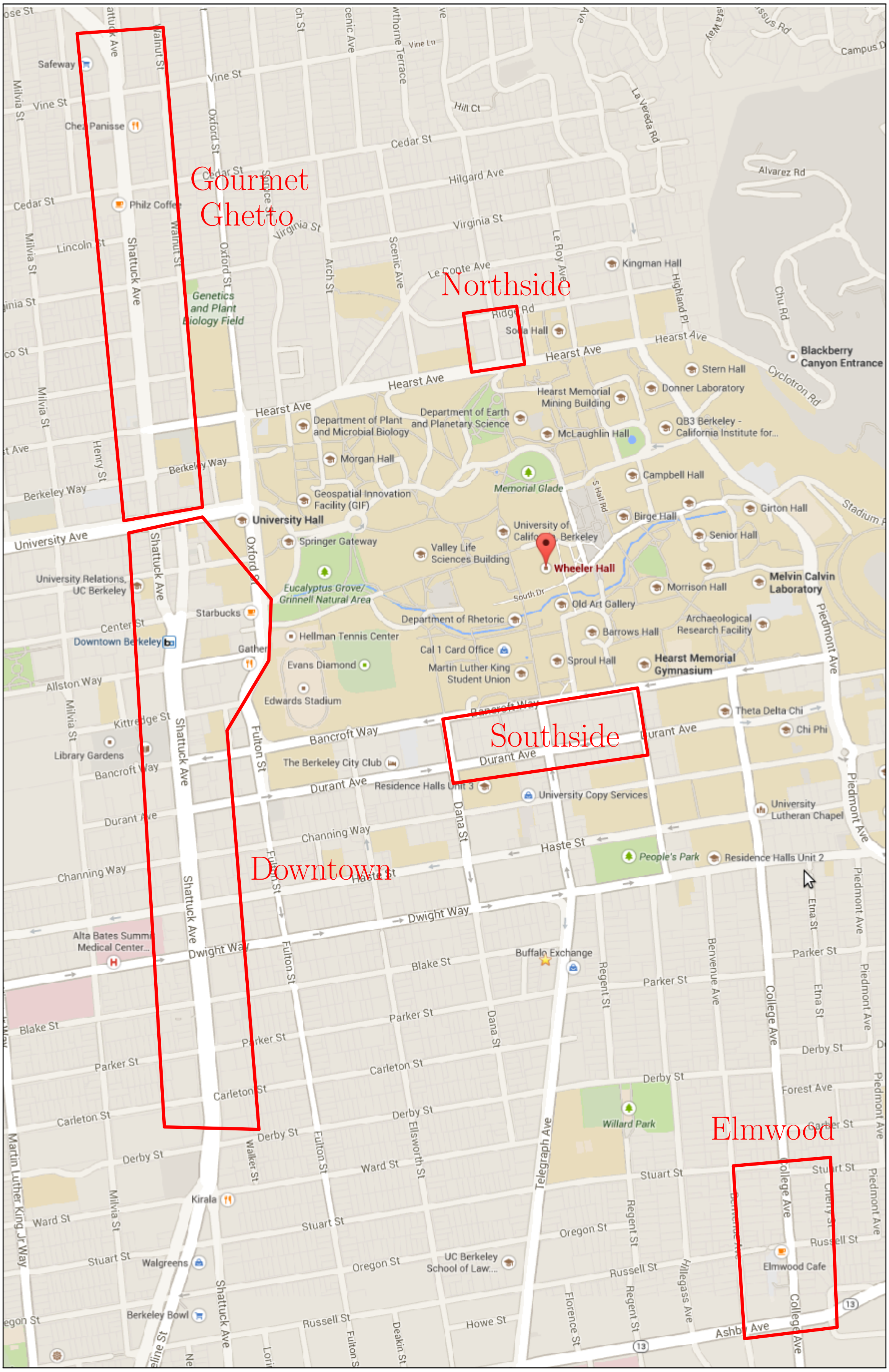
3) Downtown (1 mile from Wheeler Hall)

1	Slow	Sandwiches	$
2	Platano	Latin American	$$
3	Brazil Cafe	Brazilian, Sandwiches	$
4	PIQ Bakery	Italian, Bakery	$
5	Sandwich Spot	Sandwiches	$
6	Gecko Gecko	Thai	$$
7	Athineon	Mediterranean	$$
8	Sliver	Pizza, Sandwiches	$
9	Toss Noodle Bar	Asian Fusion	$
10	Suya African Caribbean Grill	African, Caribbean	$

Dinner

There are a plethora of dining options available in the Berkeley neighborhoods listed on the map. We have provided below a sampling of dinner places that we like. This list is by no means comprehensive and we encourage you to check out dining options on Yelp! or Google maps as well. We recommend that you reserve a table in advance, especially on Saturday and Sunday.

1	Gather	American, Drinks	$$	Downtown
2	Jupiter	America, Drinks, Brewery	$$	Downtown
3	Comal	Mexican, Drinks	$$	Downtown
4	Five	American, Drinks	$$$	Downtown
5	Cesar	Tapas Bar	$$$	Gourmet Ghetto
6	Cheese Board	Pizza	$	Gourmet Ghetto
7	Cha-Am	Thai	$$	Gourmet Ghetto
8	Chez Panisse	French	$$$$	Gourmet Ghetto
9	Taste of the Himalayas	Indian, Nepalese	$$	Gourmet Ghetto
10	Henry's	American, Drinks	$$	Southside
11	Free House	American, Drinks	$$	Southside
12	Kiraku	Japanese Tapas	$$	Southside
13	Wood Tavern	American, Drinks	$$$	Elmwood
14	Rangoon Super Stars	Burmese	$$	Elmwood
15	Ici	Ice-cream	$	Elmwood


Gourmet Ghetto
Northside
Southside
Downtown
Elmwood
Safeway
Chez Panisse
Philz Coffee
Genetics and Plant Biology Field
Shattuck Ave
Walnut St
Oxford St
Vine St
Cedar St
Hilgard Ave
Virginia St
Le Conte Ave
Ridge Rd
Soda Hall
Hearst Ave
Kingman Hall
Stern Hall
Donner Laboratory
Hearst Memorial Mining Building
Department of Earth and Planetary Science
Department of Plant and Microbial Biology
McLaughlin Hall
QB3 Berkeley - California Institute for...
Morgan Hall
Campbell Hall
Memorial Glade
Geospatial Innovation Facility (GIF)
University Hall
Birge Hall
Girton Hall
Senior Hall
University of California, Berkeley
Springer Gateway
Valley Life Sciences Building
Wheeler Hall
Eucalyptus Grove/ Grinnell Natural Area
Morrison Hall
Melvin Calvin Laboratory
Old Art Gallery
Department of Rhetoric
Archaeological Research Facility
University Relations, UC Berkeley
Starbucks
Downtown Berkeley
Hellman Tennis Center
Barrows Hall
Cal 1 Card Office
Sproul Hall
Hearst Memorial Gymnasium
Evans Diamond
Martin Luther King Student Union
Edwards Stadium
Bancroft Way
Durant Ave
Theta Delta Chi
Chi Phi
The Berkeley City Club
Residence Halls Unit 3
University Copy Services
University Lutheran Chapel
Channing Way
Haste St
People's Park
Residence Halls Unit 2
Dwight Way
Alta Bates Summit Medical Center
Buffalo Exchange
Blake St
Parker St
Carleton St
Derby St
Willard Park
Telegraph Ave
College Ave
Piedmont Ave
Ward St
Stuart St
Kirala
Walgreens
Oregon St
UC Berkeley School of Law
Russell St
Berkeley Bowl
Elmwood Cafe
Ashby Ave
Martin Luther King Jr Way
Blackberry Canyon Entrance
Cyclotron Rd
University Ave
Library Gardens

	Saturday	Sunday	Monday	Tuesday	Wednesday
08:00	08:30 Breakfast 8:30 Workshops SAT1-SAT14 120 min	8:00 Workshops SUN1-SUN14 Breakfast starts at 8:00 120 min	08:30 Breakfast 08:45 Welcome 15 min	08:30 Breakfast	08:30 Breakfast
09:00			09:00 Chris Urmson 60 min	09:00 Brad Nelson 60 min	09:00 Andrew Ng 60 min
10:00	10:30 Break 30 min	10:00 Break 20 min 10:20 Workshops SUN1-SUN14 90 min	10:00 Short Talks 35 min 10:35 Break 55 min	10:00 Short Talks 35 min 10:35 Break and Posters 55 min	10:00 Short Talks 42 min 10:40 Break and Posters 58 min
11:00	11:00 Workshops SAT1-SAT14 90 min	11:50 Lunch Break 190 min World Cup Final Streaming in Main Auditorium	11:30 Talks 1 long + 6 short 65 min	11:30 Talks 1 long + 6 short 65 min	11:40 Forum 30 min
12:00	12:30 Lunch Break 90 min		12:35 Lunch Break 85 min	12:35 Lunch Break and Lab Tours 85 min	12:10 Lunch Break and Lab Tours 110 min
13:00					
14:00	14:00 Workshops SAT1-SAT14 90 min		14:00 Genevieve Bell 60 min	14:00 Talks 2 long + 6 short 90 min	14:00 Nancy Amato 60 min
15:00	15:30 Break 30 min	15:00 Workshops SUN1-SUN14 90 min	15:00 Short Talks 30 min 15:30 Break and Posters 75 min	15:30 Break and Posters 75 min	15:00 Early Career Spotlights 60 min
16:00	16:00 Workshops SAT1-SAT14 120 min	16:30 Break 30 min	16:45 Talks 1 long + 7 short 75 min	16:45 Talks 1 long + 6 short 75 min	16:00 Awards 15 min 16:15 Farewell 45 min
17:00		17:00 Workshops SUN1-SUN14 120 min			17:00 Buses Depart for Google. The end-time at Google is 9:30pm, estimated time to be back in Berkeley 10:40pm. at Google
18:00			18:00 Celebration of 10 years of RSS 90 min	18:00 Buses Depart for Banquet at San Francisco Bay	
19:00					
20:00					
21:00					

Note: Unless otherwise noted, all conference activities are in Wheeler Hall. The workshops are in various Wheeler Hall classrooms. The conference sessions are in the main auditorium, 150 Wheeler Hall.

Saturday, July 12: Workshops SAT1-SAT14

ID	Room	Title	Organizers
SAT1	123	5th Workshop on Formal Methods for Robotics and Automation	H. Kress-Gazit, C. Belta
SAT2	200	5th Workshop on RGB-D Perception: Reconstruction and Recognition	H. Koppula, J. Xiao, A. Saxena, J. Leonard
SAT3	130	Autonomous Control, Adaptation, and Learning for Underwater Vehicles	G. Hollinger, M. Hsieh, F. Hover, R. Smith
SAT4	110	DARPA Robotics Challenge: Lessons Learned and What's Next	M. Fallon and S. Kuindersma
SAT5	20	Distributed Control and Estimation for Robotic Vehicle Networks	N. Ahmed, S. Martinez, J. Cortes
SAT6	210	Human versus Robot Grasping and Manipulation—How Can We Close the Gap?	O. Brock, D. Berenson, J. Mainprice, M. Roa, C. Eppner
SAT7	101	Human–Robot Collaboration for Industrial Manufacturing	A. Sauppe, M. Gombolay, J. Shah, B. Mutlu
SAT8	203	Moral, Ethical, and Legal Issues in Robotics	J. Gillula, J. Urban
SAT9	220	Non-parametric Learning in Robotics	R. Triebel, L. Spinello
SAT10	213	Optimization Techniques for Motion Generation in Robotics	A. Escande, K. Mombaur
SAT11	106	Resource-efficient Integration of Planning and Perception for True Autonomous Operation of Micro Air Vehicles (MAVs)	D. Burschka, M. Suppa, R. Siegwart, K. Schmid, M. Achtelik
SAT12	122	Robot Makers: The Future of Digital Rapid Design and Fabrication of Robots	A. Mehta, M. Tolley, N. Bezzo, C. Onal
SAT13	206	Workshop on Robotics Methods for Structural and Dynamic Modeling of Molecular Systems	L. Tapia, J. Corts, J. J. Cheng, A. Shehu, K. Manavi
SAT14	100	Workshop on Women in Robotics	J. Pineau, A. Tomaz, M. Bennewitz, L. Takayama

Sunday, July 13: Workshops SUN1-SUN14

ID	Room	Title	Organizers
SUN1	100	Affordances in Vision for Cognitive Robotics	K. M. Varadarajan, M. Vincze, T. Darrell, J. Gall
SUN2	122	Communication-aware Robotics: New Tools for Multi-Robot Networks, Autonomous Vehicles, and Localization	D. Rus, S. Gil, N. Ayanian, S. Kumar
SUN3	210	Constrained decision-making in robotics: models, algorithms, and applications	S Carpin, M. Pavone
SUN4	220	Dynamic Locomotion	A. Ames, K. Sreenath
SUN5	24	Guaranteed Safety for Uncertain Robotic Systems	J. Gillula, S. Kaynama
SUN6	203	Humans and Sensing in Cyber-Physical Systems	A. Aswani, R. Vasudevan
SUN7	200	Information-based Grasp and Manipulation Planning	S. Patil, R. Platt Jr.
SUN8	123	Learning Plans with Context from Human Signals	D. Bagnell, A. Jain, J. Peters, A. Saxena
SUN9	206	Managing Software Variability in Robot Control Systems	D. Brugali, C. Schlegel[1]
SUN10	110	Next-Generation Robotics: Academia, Start-ups and Industry	S. Chitta, I. Sucan, T. Kroeger
SUN11	213	Self-Driving Vehicles: Technology and Policy	J. Leonard, J. Levinson
SUN12	106	Advances on Soft Robotics	C. Laschi, F. Iida, J. Rossiter, L. Margheri
SUN13	130	Workshop on Multi-View Geometry in Robotics (MVIGRO 2014)	V. Indelman, L. Carlone, F. Dellaert
SUN14	101	Workshop on Robotic Monitoring	A. Breitenmoser, J. Muller, J. Das, R. Smith, C. Detweiler

Monday Morning, July 14

Start	Length			Interactive session ID
08:45	15	Welcome		
09:00	60	Invited Talk: Realizing Self-Driving Cars	Chris Urmson	
10:00		p01: Batch Continuous-Time Trajectory Estimation as Exactly Sparse Gaussian Process Regression	Tim Barfoot, Chi Hay Tong, Simo Sarkka	A1
		p14: Combining 3D Shape, Color, and Motion for Robust Anytime Tracking	David Held, Jesse Levinson, Sebastian Thrun, Silvio Savarese	A2
		p46: Decision-Making Authority, Team Efficiency and Human Worker Satisfaction in Mixed Human-Robot Teams	Matthew Gombolay, Reymundo Gutierrez, Giancarlo Sturla, Julie Shah	A3
		p32: Stiction Compensation in Agonist-Antagonist Variable Stiffness Actuators	Luca Fiorio, Francesco Romano, Alberto Parmiggiani, Giulio Sandini, Francesco Nori	A4
		p51: Simultaneous Compliance and Registration Estimation for Robotic Surgery	Siddharth Sanan, Stephen Tully, Andrea Bajo, Nabil Simaan, Howie Choset	A5
10:35	55	Coffee Break		
11:30	25	p44: Vision-based Landing Site Evaluation and Trajectory Generation Toward Rooftop Landing	Vishnu Desaraju, Nathan Michael, Martin Humenberger, Roland Brockers, Stephan Weiss, Larry Matthies	B1
11:55		p12: Correct High-level Robot Behavior in Environments with Unexpected Events	Kai Weng Wong, Rudiger Ehlers, Hadas Kress-Gazit	B2
		p38: Persistent Monitoring of Stochastic Spatio-temporal Phenomena with a Small Team of Robots	Sahil Garg, Nora Ayanian	B3
		p25: Modeling and Controlling Friendliness for An Interactive Museum Robot	Chien-Ming Huang, Takamasa Iio, Satoru Satake, Takayuki Kanda	B4
		p57: Efficient Visual-Inertial Navigation using a Rolling-Shutter Camera with Inaccurate Timestamps	Chao Guo, Dimitrios Kottas, Ryan DuToit, Ahmed Ahmed, Ruipeng Li, Stergios Roumeliotis	B5
		p53: Dynamically Feasible Motion Planning through Partial Differential Flatness	Suresh Ramasamy, Guofan Wu, Koushil Sreenath	B6
		p47: Sky Segmentation with Ultraviolet Images Can Be Used for Navigation	Thomas Stone, Michael Mangan, Paul Ardin, Barbara Webb	B7
12:35	95	Lunch Break		

Monday Afternoon, July 14

Start	Length			Interactive session ID
14:00	60	Invited Talk: The Pre-history of Robots	Genevieve Bell	
15:00		p06: Hierarchical Semantic Labeling for Task-Relevant RGB-D Perception	Chenxia Wu, Ian Lenz, Ashutosh Saxena	C1
		p56: Multi-Heuristics A*	Sandip Aine, Siddharth Swaminathan, Venkatraman Narayanan, Victor Hwang, Maxim Likhachev	C2
		p50: Learning Articulated Motions from Visual Demonstration	Sudeep Pillai, Matthew Walter, Seth Teller	C3
		p10: An Analysis of Deceptive Robot Motion	Anca Dragan, Rachel Holladay, Siddhartha Srinivasa	C4
15:30	75	Coffee Break and Posters (A1-A5, B1-B7, C1-C4)		
16:45	25	p43: Semantic Localization Via the Matrix Permanent	Nikolay Atanasov, Menglong Zhu, Kostas Daniilidis, George Pappas	D1
17:10		p17: The Multi-Agent Navigation Transformation: Tuning-Free Multi-Robot Navigation	Savvas Loizou	D2
		p45: An Automata-Theoretic Approach to the Vehicle Routing Problem	Cristian Vasile, Calin Belta	D3
		p02: Effective Task Training Strategies for Instructional Robots	Allison Sauppe, Bilge Mutlu	D4
		p35: Learning to Locate from Demonstrated Searches	Paul Vernaza, Anthony Stentz	D5
		p15: Modeling High-Dimensional Humans for Activity Anticipation using Gaussian Process Latent CRFs	Yun Jiang, Ashutosh Saxena	D6
		p16: Manhattan and Piecewise-Planar Constraints for Dense Monocular Mapping	Alejo Concha, Wajahat Hussain, Luis Montano, Javier Civera	D7
		p29: Appearance-based Active, Monocular, Dense Reconstruction for Micro Aerial Vehicles	Christian Forster, Matia Pizzoli, Davide Scaramuzza	D8
18:00	90	Reception		

Tuesday Morning, July 15

Start	Length			Interactive session ID
09:00	60	Invited Talk: Swimming Microrobots	Brad Nelson	
10:00		p27: Bio-Artificial Synergies for Grasp Posture Control of Supernumerary Robotic Fingers	Faye Wu, Harry Asada	E1
		p13: Six-Degrees-of-Freedom Remote Actuation of Magnetic Microrobots	Eric Diller, Joshua Giltinan, Guo Zhan Lum, Zhou Ye, Metin Sitti	E2
		p37: 5-DOF Manipulation of an Untethered Magnetic Device in Fluid using a Single Permanent Magnet	Arthur Mahoney, Abbott Jake	E3
		p04: Automatic Generation of Reduced CPG Control Networks for Locomotion of Arbitrary Modular Robot Structures	Stephane Bonardi, Massimo Vespignani, Rico Moeckel, Jesse Van den Kieboom, Soha Pouya, Alexander Sproewitz, Auke Ijspeert	E4
		p42: Cogging Torque Ripple Minimization via Position Based Characterization	Matthew Piccoli, Mark Yim	E5
10:35	55	Coffee Break and Posters (D1-D8, E1-E5)		
11:30	25	p18: A Novel Type of Compliant, Underactuated Robotic Hand for Dexterous Grasping	Raphael Deimel, Oliver Brock	F1
11:55		p34: Pre- and Post-Contact Policy Decomposition for Planar Contact Manipulation Under Uncertainty	Michael Koval, Nancy Pollard, Siddhartha Srinivasa	F2
		p22: Modeling Robot Discrete Movements with State-varying Stiffness and Damping: A framework for integrated motion generation and impedance control	Mohammad Khansari, Klas Kronander, Aude Billard	F3
		p49: Robust Policies via Meshing for Metastable Rough Terrain Walking	Cenk Oguz Saglam, Katie Byl	F4
		p39: Probably Approximately Correct MDP Learning and Control With Temporal Logic Constraints	Jie Fu, Ufuk Topcu	F5
		p08: Self-Calibration and Visual SLAM with a Multi-Camera System on a Micro Aerial Vehicle	Lionel Heng, Gim Hee Lee, Marc Pollefeys	F6
		p26: Control of Robotic Mobility-On-Demand Systems: a Queueing-Theoretical Perspective	Rick Zhang, Marco Pavone	F7
12:35	55	Lunch Break		

Tuesday Afternoon, July 15

Start	Length			Interactive session ID
14:00	25	p54: Multiscale Topological Trajectory Classification with Persistent Homology	Florian Pokorny, Majd Hawasly, Subramanian Ramamoorthy	G1
14:25	25	p24: Asking for Help Using Inverse Semantics	Stefanie Tellex, Ross Knepper, Adrian Li, Daniela Rus, Nicholas Roy	G2
14:50		p07: LOAM: Lidar Odometry and Mapping in Real-time	Ji Zhang, Sanjiv Singh	G3
		p52: Combining the Benefits of Function Approximation and Trajectory Optimization	Igor Mordatch, Emo Todorov	G4
		p20: Enhanced 3D Kinematic Modeling of Wheeled Mobile Robots	Neal Seegmiller, Alonzo Kelly	G5
		p05: Tell Me Dave: Context-Sensitive Grounding of Natural Language to Manipulation Instructions	Dipendra Kumar Misra, Jaeyong Sung, Kevin Lee, Ashutosh Saxena	G6
		p40: Nonlinear Graph Sparsification for SLAM	Mladen Mazuran, Tipaldi Gian Diego, Spinello Luciano, Wolfram Burgard	G7
		p21: Fully Decentralized Task Swaps with Optimized Local Searching	Lantao Liu, Nathan Michael, Dylan Shell	G8
15:30	75	Coffee Break and Posters (F1-F7, G1-G8)		
16:45	25	p48: Robot Programming by Demonstration with Interactive Action Visualizations	Sonya Alexandrova, Maya Cakmak, Kaijen Hsiao, Leila Takayama	H1
17:10		p36: An Online Sparsity-Cognizant Loop-Closure Algorithm for Visual Navigation	Yasir Latif, Guoquan Huang, John Leonard, Jose Neira	H2
		p23: Scene Signatures: Localised and Point-less Features for Localisation	Colin McManus, Ben Upcroft, Paul Newmann	H3
		p31: Active Reward Learning	Christian Daniel, Malte Viering, Jan Metz, Oliver Kroemer, Jan Peters	H4
		p03: Learning to Recognize Human Activities from Soft Labeled Data	Ninghang Hu, Zhongyu Lou, Gwenn Englebienne, Ben Krose	H5
		p33: Planning Single-arm Manipulations with n-Arm Robots	Benjamin Cohen, Mike Phillips, Maxim Likhachev	H6
		p28: Robust and Agile 3D Biped Walking with Steering Capability Using a Footstep Predictive Approach	Salman Faraji, Soha Pouya, Auke Ijspeert	H7
18:00		Buses Depart for Banquet		

Wednesday, July 16

Start	Length			Interactive session ID
09:00	60	Invited Talk: Deep Learning: Machine Learning via Large-scale Brain Simulations	Andrew Ng	
10:00		p41: Open-vocabulary Object Retrieval	Sergio Guadarrama, et al.	I1
		p19: State Representation Learning in Robotics: Using Prior Knowledge about Physical Interaction	Rico Jonschkowski, Oliver Brock	I2
		p55: Conditioned Basis Array Factorization: An Approach to Gait Pattern Extraction	Chaohui Gong, Matthew Travers, Henry Astley, Lu Li, Joseph Mendelson, David Hu, Daniel Goldman, Howie Choset	I3
		p11: Online Trajectory Planning in Dynamic Environment for Surgical Task Automation	Takayuki Osa, Naohiko Sugita, Mamoru Mitsuishi	I4
		p09: Articulated Pose Estimation via Over-parametrization and Noise Projection	Jonathan Brookshire, Seth Teller	I5
		p30: DART: Dense Articulated Real-Time Tracking	Tanner Schmidt, Richard Newcombe, Dieter Fox	I6
10:42	58	Coffee Break and Posters (H1-H7, I1-I6)		
11:40	30	Forum		
12:10	110	Lunch		
14:00	60	Invited Talk: Using Motion Planning to Study Protein Motions	Nancy Amato	
15:00	30	Early Career Spotlight	Julie Shah	
15:30	30	Early Career Spotlight	Ashutosh Saxena	
16:00	15	Awards and Wrap-Up		
16:15	45	Coffee and Farewell		
17:00		Evening at Google		

Monday, July 14, 09:00

Chris Urmson

Realizing Self-Driving Cars

Self-driving vehicles are coming. They will save lives, save time and offer mobility to those who otherwise don't have it. Eventually they will reshape the way we live in, and move through, our communities and cities. Or so the story goes. Is this a 50 year pipe dream, or a near term reality? A dedicated team at Google has spent the last five years moving self-driving vehicles closer to a reality. New algorithms, increased processing power, innovative sensors and massive amounts of data enable our vehicles to see further, understand more and handle a wide variety of challenging driving scenarios. Our vehicles have driven over a half million miles on highways, suburban and urban streets. Through this journey, we've learned a lot; not just about how to drive, but about interacting with drivers, users and others on the road, and about what it takes to bring in incredibly complex system to fruition. I'll share some fun stories and lessons along with our vision for how these vehicles will become a reality.

Chris Urmson
Google [x]

Biography Chris Urmson leads Google's self-driving car program where the team's vehicles have driven over a half million miles. Prior to joining Google, Chris was on the faculty of the Robotics Institute at Carnegie Mellon University where his research focused on motion planning and perception for robotic vehicles. During his time at Carnegie Mellon, he worked with house size trucks, drove robots around in deserts and served as the Director of Technology for the team that won the 2007 DARPA Urban Challenge. He earned his PhD in 2005 from Carnegie Mellon and his B.Sc. in Computer Engineering from the University of Manitoba in 1998.

Monday, July 14, 14:00

Genevieve Bell

The Pre-history of Robots

Genevieve Bell is a well known anthropologist, working at the intersection of culture and technology. Australian by birth, Bell runs one of Intel's premier research and development labs in the United States. In this talk, she unpacks the relationship between technology and anxiety, tracing out the origins of our socio-technical fears. Drawing on cultural, literary and historical accounts, Bell makes the case that we have an opportunity to re-imagine the ways in which we encounter and make sense of new digital technologies.

Genevieve Bell
Intel

Biography Dr. Genevieve Bell is an anthropologist and researcher with 15 years of experience driving innovation in the high tech industry. As the Director of Interaction and Experience Research in Intel Labs, Bell leads a team of social scientists, interaction designers, human factors engineers and computer scientists. This organization researches new computing experiences that are centered around people's needs and desires. This foundationally shapes and then helps to create new Intel technologies and products. In this team and her prior roles, Bell has fundamentally altered the way Intel envisions and plans its products so that they are centered on people's needs rather than simply silicon capabilities. In addition to leading this increasingly important area at Intel, Bell is an accomplished industry commentator on the intersection of culture and technology and has been extensively featured in publications that include Wired, Forbes, The Atlantic, Fast Company, and the Wall Street Journal. In August 2013, Fast Company declared her to be one of the top 25 smartest women on Twitter, where she goes by the handle, @feraldata. She is a regular public speaker and panelist at technology conferences worldwide, sharing myriad insights gained from her extensive international field work and research. In 2010, Bell was named one of Fast Company's inaugural '100 Most Creative People in Business.' Bell is a passionate advocate for the advancement of women in technology and in 2012 was inducted into the Women In Technology International (WITI) hall of fame, as well being honored by the Anita Borg Institute as the 2013 Woman of Vision for Leadership. Her first book, 'Divining the Digital Future: Mess and Mythology in Ubiquitous Computing,' was co-written with Prof. Paul Dourish of the University of California at Irvine and released in April 2011. Bell is also the recipient of several patents for consumer electronics innovations. A native of Australia, Bell moved to the United States for her undergraduate studies and graduated from Bryn Mawr in 1990 with a bachelor's degree in anthropology. She then earned a master's degree and a doctorate in cultural anthropology from Stanford University where she also taught as an acting lecturer in the Department of Anthropology from 1996-1998. With a father who was an engineer and a mother who was an anthropologist, perhaps Bell was fated to ultimately work for a technology company, joining Intel in 1998. Bell is currently an Intel Fellow.

Tuesday, July 15, 09:00

Brad Nelson

Swimming Microrobots

Nature has inspired numerous microrobotic locomotion designs that are suitable for propulsion generation at low Reynolds numbers. This talk first reviews various swimming methods with a particular focus on helical propulsion inspired by E. coli bacteria. To actuate swimming microrobots, various magnetic actuation methods have been proposed, such as rotating fields, oscillating fields, and field gradients. These methods can be categorized into force-driven or torque-driven actuation. It can be shown that torque-driven approaches scale better to the micro- and nano-scale than force-driven approaches. The implementation of swarm or multi-agent control will also be discussed. The use of multiple microrobots may be beneficial for in vivo as well as in vitro applications, and the frequency-dependent behavior of helical microrobots allows individual agents to be decoupled from within small groups. Finally, an elegant commercial application of microrobots originally inspired by helical swimmers will be presented.

Brad Nelson
ETH Zurich

Biography Brad Nelson is the Professor of Robotics and Intelligent Systems at ETH Zurich. His primary research focus is on microrobotics and nanorobotics emphasizing applications in biology and medicine. He received mechanical engineering degrees from the University of Illinois (B.S. 1984) and the University of Minnesota (M.S. 1987) and a Ph.D. in Robotics (School of Computer Science) from Carnegie Mellon University (1995). He has worked as an engineer at Honeywell and Motorola and served as a United States Peace Corps Volunteer in Botswana, Africa. He was an Assistant Professor at the University of Illinois at Chicago (1995-1998) and an Associate Professor at the University of Minnesota (1998-2002). He became a Full Professor at ETH Zurich in 2002. Prof. Nelson has received a number of awards including more than a dozen Best Paper Awards at major robotics conferences and journals. He was named to the 2005 ”Scientific American 50,” Scientific American magazine’s annual list recognizing fifty outstanding acts of leadership in science and technology from the past year for his efforts in nanotube manufacturing. His laboratory won the 2007 and 2009 RoboCup Nanogram Competition, both times the event has been held. He is a European Research Council Advanced Grantee (2011) and his lab appears in the 2012 Guinness Book of World Records for the ”Most Advanced Mini Robot for Medical Use.” In 2013 he was listed as an ISI Highly Cited Researcher. He serves on the editorial boards of several journals, has chaired several international workshops and conferences, has served as the head of the ETH Department of Mechanical and Process Engineering, the Chairman of the ETH Electron Microscopy Center (EMEZ), and is a member of the Research Council of the Swiss National Science Foundation.

Wednesday, July 16, 09:00

Andrew Ng

Deep Learning: Machine Learning via Large-scale Brain Simulations

Machine learning is a very successful technology, but applying it to a new problem usually means spending a long time hand designing the input features to feed to the learning algorithm. This is true for applications in vision, audio, and text/NLP. To address this, researchers in machine learning have recently developed "deep learning" algorithms, which can automatically learn feature representations from unlabeled data, thus bypassing most of this time-consuming engineering. These algorithms are based on building massive artificial neural networks that were loosely inspired by cortical (brain) computations. In this talk, I describe the key ideas behind deep learning, and also discuss the computational challenges of getting these algorithms to work. I'll also present a few case studies, and report on the results from a project that I led at Google to build massive deep learning algorithms, resulting in a highly distributed neural network trained on 16,000 CPU cores, and that learned by itself to discover high level concepts such as common objects in video.

Andrew Ng
Stanford University

Biography Andrew Ng's research is in the areas of machine learning and artificial intelligence. Through building very large-scale cortical (brain) simulations, he is developing algorithms that can learn to sense and perceive without needing to be explicitly programed. Using these techniques, he has developed sophisticated computer vision algorithms, as well as a variety of highly capable robots, such as by far the most advanced autonomous helicopter controller, that is able to fly spectacular aerobatic maneuvers. His group at Stanford University (together with Willow Garage) also developed ROS, which is today by far the most widely used open-source robotics software platform. In 2011, he taught an online Machine Learning class to over 100,000 students, leading to the founding of Coursera, which is today the world's largest MOOC platform. Ng has also been named to the 2013 "Time 100" list of the most influential people in the world.

Wednesday, July 16, 14:00

Nancy Amato

Using Motion Planning to Study Protein Motions

Protein motions, ranging from molecular flexibility to large-scale conformational change, play an essential role in many biochemical processes. For example, some devastating diseases such as Alzheimer's and bovine spongiform encephalopathy (Mad Cow) are associated with the misfolding of proteins. Despite the explosion of structural and functional data, our understanding of protein movement is still very limited because it is difficult to measure experimentally and computationally expensive to simulate. In this talk, we describe how techniques developed for motion planning in robotics have been adapted and applied to model and analyze protein motions and to reason about the structure, flexibility and interactions of proteins and other biomolecules. These techniques adapt sampling-based methods developed for robotic configuration spaces to construct approximate maps of a protein's potential energy landscape which can be used, e.g., to generate transitional motions of a protein to the native state from unstructured conformations or between specified conformations. For example, we show how our map-based tools for modeling and analyzing folding landscapes can capture subtle folding differences between protein G and its mutants, NuG1 and NuG2.

Nancy Amato
Texas A&M University

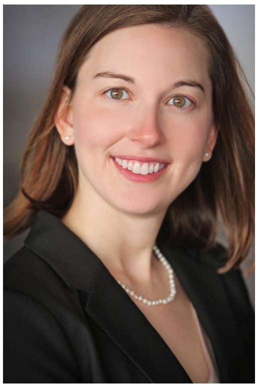
Biography Nancy M. Amato is Unocal Professor and Interim Department Head of the Department of Computer Science and Engineering at Texas A&M University where she co-directs the Parasol Lab. She received undergraduate degrees in Mathematical Sciences and Economics from Stanford University, and M.S. and Ph.D. degrees in Computer Science from UC Berkeley and the University of Illinois at Urbana-Champaign. Her main areas of research focus are motion planning and robotics, computational biology and geometry, and parallel and distributed computing. She was Editor-in-Chief of the IEEE/RSJ IROS Conference Paper Review Board from 2011-2013, has served on the editorial boards of the IEEE Transactions of Robotics and Automation, IEEE Transactions on Parallel and Distributed Computing, and is an elected member of the Administrative Committee of the IEEE Robotics and Automation Society. She was co-Chair of the NCWIT Academic Alliance (2009-2011), is a member of the Computing Research Association's Committee on the Status of Women in Computing Research (CRA-W) and of the Coalition to Diversity Computing (CDC). She was an AT&T Bell Laboratories PhD Scholar, received an NSF CAREER Award, is a Distinguished Speaker for the ACM Distinguished Speakers Program, and was a Distinguished Lecturer for the IEEE Robotics and Automation Society. She received the 2013 IEEE Hewlett-Packard/Harriet B. Rigas Award, and a University-level teaching award and the Betty M. Unterberger Award for Outstanding Service to Honors Education at Texas A&M. She is a AAAS Fellow and an IEEE Fellow.

Wednesday, July 16, 15:00

Julie A. Shah

Integrating Robots into Team-Oriented Environments

Recent advances in computation, sensing, and hardware enable robotics to perform an increasing percentage of traditionally manual tasks in manufacturing. Yet, often the assembly mechanic cannot be removed entirely from the process. This provides new economic motivation to explore opportunities where human workers and industrial robots may work in close physical collaboration. In this talk, I will present the development of new algorithmic techniques for collaborative plan execution that scale to real-world industrial applications. I also discuss the design of new models for robot planning, which use insights and data derived from the planning and execution strategies employed by successful human teams, to support more seamless robot participation in human work practices. This includes models for human-robot team training, which involves hands-on practice to clarify sequencing and timing of actions, and for team planning, which includes communication to negotiate and clarify allocation and sequencing of work. The aim is to support both the human and robot workers in co-developing a common understanding of task responsibilities and information requirements, to produce more effective human-robot partnerships.



Julie A. Shah
MIT

Biography Julie Shah is an Assistant Professor in the Department of Aeronautics and Astronautics at MIT and leads the Interactive Robotics Group of the Computer Science and Artificial Intelligence Laboratory. Shah received her SB (2004) and SM (2006) from the Department of Aeronautics and Astronautics at MIT, and her PhD (2010) in Autonomous Systems from MIT. Before joining the faculty, she worked at Boeing Research and Technology on robotics applications for aerospace manufacturing. She has developed innovative methods for enabling fluid human-robot teamwork in time-critical, safety-critical domains, ranging from manufacturing to surgery to space exploration. Her group draws on expertise in artificial intelligence, human factors, and systems engineering to develop interactive robots that emulate the qualities of effective human team members to improve the efficiency of human-robot teamwork. Shah is the recipient of a 2014 NSF CAREER Award, and her work was recognized by the Technology Review as one of the 10 Breakthrough Technologies of 2013. She has received international recognition in the form of best paper awards and nominations from the International Conference on Automated Planning and Scheduling, the American Institute of Aeronautics and Astronautics, the IEEE/ACM International Conference on Human-Robot Interaction, and the International Symposium on Robotics.

Wednesday, July 16, 15:30

Ashutosh Saxena

Scaling Robotics: Perception, Planning and Language

For building future robotic applications, robots need to learn from multi-modal data such as images, videos, 3D point-clouds, video game logs and natural language. How can such robot learning be scaled to thousands and even millions of examples?
In this talk, I will present learning algorithms that start learning from large-scale unsupervised datasets, and through different forms of human feedback learn about concepts such as object affordances and basic physics. Through a few examples, I will show that such learning is very effective in performing a variety of tasks including 3D scene labeling, human activity detection and ancipatoon, grasping and path planning, language understanding, and so on.

Ashutosh Saxena
Cornell University

Biography Ashutosh Saxena is an assistant professor in the Computer Science department at Cornell University. His research interests include machine learning, robotics and computer vision. He received his MS in 2006 and Ph.D. in 2009 from Stanford University with Prof. Andrew Ng, and his B.Tech. in 2004 from Indian Institute of Technology (IIT) Kanpur. He was named a co-chair of IEEE technical committee on robot learning and is an associate editor of IEEE Transactions of Robotics. He was a recipient of National Talent Scholar award in India and Google Faculty award in 2011. He was named a Alred P. Sloan Fellow in 2011, named a Microsoft Faculty Fellow in 2012, received a NSF Career award in 2013, and received Early Career Spotlight Award at RSS 2014. He has developed learning algorithms for capturing rich context from multi-modal data such as images, videos, 3D point clouds and natural language. His algorithms have enabled several robots to perform a variety of tasks, for example: his single image depth estimation (Make3D) algorithm has enabled aerial robots to fly; his human behavior modeling algorithm ('hallucinating humans') has enabled robots to detect objects in 3D scenes, anticipate human actions, and underwrite non-prime financial lending; his co-active learning algorithm has enabled manipulators to plan user preferred motions. His robots (such as STAIR, POLAR and Kodiak) perform household chores such as unload items from a dishwasher, arrange a disorganized house, and cook simple kitchen recipes. His work has received a lot of attention in the popular press such as the frontage of New York Times, BBC, ABC, New Scientist, Discovery Science, Wired Magazine and many others.

Workshops on Saturday, July 12

SAT1 *5th Workshop on Formal Methods for Robotics and Automation*
Hadas Kress-Gazit (Cornell), Calin Belta (Boston University)
Saturday, Room 123

Abstract: How can we guarantee robots will never cause harm? How can we prove that complicated mechanical systems, controlled by computers and programmed by people will always behave as expected, under changing conditions and in a variety of uncertain environments? How do we formalize what such behaviors are?

Guaranteeing safety, predictability and reliability of robots is crucial for the assimilation of such systems into society, be it at home or in the workplace. While every robotics researcher working with or on a robot is aware of safety issues, only recently the robotics community has begun looking at ways to either formally prove or guarantee by design different behavioral properties such as safety and correctness. The results that will be presented in the workshop combine and extend ideas from automata theory, logic, model checking, hybrid systems and control and they pave the way toward creating robotic "formal methods" – a body of work that will ultimately result in provable correct robotic systems.

This full day workshop brings together leading researchers from the robotics, formal methods and hybrid systems communities, as well as researchers from industry. We will discuss the state of the art, existing tools, and challenges that must be addressed in order to create safe and reliable systems that can be proven to be correct, either by design or by verification. This workshop follows the successful workshops held at ICRA 2009, 2010, CAV 2011 and RSS 2013.

Workshop homepage[2]

SAT2 *5th Workshop on RGB-D Perception: Reconstruction and Recognition*
Hema Koppula (Cornell), Jianxiong Xiao (Princeton), Ashutosh Saxena (Cornell), John Leonard (MIT)
Saturday, Room 200

Abstract: RGB-D 2014 is a full-day workshop to be held in conjunction with the Robotics Science and Systems (RSS) conference 2014, in Berkeley, July 12, 2014. We seek to bring together ongoing research efforts on RGB-D cameras in robotics as well as contributions from related fields such as computer vision, graphics and machine learning.

The recent advances in RGB-D sensors, such as Kinect, have been transforming robotics research and applications. There have been a large number of research efforts in algorithms and application of RGB-D perception for enabling robots to operate in unstructured real-world environments. Some of the key challenges in this direction are to understand humans and their environments, which is key for robots to operate and perform various tasks in human environments. Our workshop welcomes high-quality work on all topics related to robotics and RGB-D. We will particularly promote and encourage contributions in the direction of applying RGB-D perception to understand human environments and activities, which enable robots to perform various tasks such as detection, navigation, manipulation and observation in human environments.

Workshop homepage[3]

SAT3 *Autonomous Control, Adaptation, and Learning for Underwater Vehicles*
Geoff Hollinger (Oregon State University), Ani Hsieh (Drexel University), Franz Hover (MIT), Ryan Smith (Fort Lewis College)
Saturday, Room 130

Abstract: There has been a steady increase in the deployment of autonomous underwater and surface vehicles (AUVs and ASVs) for applications such as hazardous waste mitigation, inspection and recovery of marine structures, environmental monitoring, and tracking of various biological, chemical, and physical processes. These emerging applications require solving unique challenges that arise when working in the underwater environment. The lack of reliable wireless communications between robots and a base station or with other robots makes remote control difficult; underwater vehicle dynamics are tightly coupled with the environmental dynamics making controls hard; and wellunderstood perception technologies do not always apply to the underwater environment. These challenges, in addition to our limited understanding of the complexities of the fluidic environment, make closed-loop control, online learning, and adaptive decision making challenging at best.

[2] http://verifiablerobotics.com/RSS14/index.html
[3] http://www.cs.cornell.edu/~hema/rgbd-workshop-2014/

The purpose of this workshop is to bring together experts in the highly interdisciplinary field of autonomous underwater robotics to bridge the gap between (1) modeling and prediction for closed-loop control and (2) online learning and adaptation in highly dynamic and uncertain environments. Specifically we would like to highlight new work that lies at the intersection of robotics, control theory, artificial intelligence, machine learning, ocean science, and transport theory that addresses issues in modeling and prediction of the underwater environment. The techniques developed in this workshop will lead to improvements in control, learning, and adaptation for underwater systems that are paramount to achieving prolonged persistent autonomy in these environments.

Workshop homepage[4]

SAT4 *DARPA Robotics Challenge: Lessons Learned and What's Next*
Maurice Fallon (MIT), Scott Kuindersma (MIT)
Saturday, Room 110

Abstract: Over the last 2 years, the DARPA Robotics Challenge (DRC) has driven the development of robot systems and software capable of assisting humans in responding to natural and man-made disasters—a problem that demands beyond-state-of-the-art approaches to manipulation, locomotion, perception, and human-robot interaction (HRI). The December 2013 DRC Trials demonstrated to the world robots capable of manipulating doors and valves, cutting through walls, climbing ladders, driving vehicles, and traversing challenging terrain, all aided by a remote operator using only feedback from the robot sensors suite over a limited, field-realistic communications link. The participating teams represented some of the most advanced robotics research organizations in the world.

This workshop is intended to be a forum where participants and organizers can share with the greater RSS community their lessons learned and what to expect for the DRC Finals. We will particularly encourage speakers to share research ideas inspired by the project and share what they perceive as the major open problems. Topics will include advances in perception, estimation, control, and HRI.

Workshop homepage[5]

SAT5 *Distributed Control and Estimation for Robotic Vehicle Networks*
Nisar Ahmed (University of Colorado, Boulder), Sonia Martinez (UCSD), Jorge Cortes (UCSD)
Saturday, Room 20

Abstract: Applications for autonomous multi-vehicle networks have grown significantly in recent years, and have stimulated research on distributed strategies for optimal/robust cooperative autonomy in multi-vehicle systems. Ideally, distributed approaches not only perform as well as centralized methods, but also lead to better scalability, naturally parallelized computation, and resilience to communication loss and hardware failures. In practice, it is usually convenient to assume that distributed control and distributed estimation problems can be treated separately. While state-of-the-art techniques for distributed planning (e.g. graph-based trajectory generation, consensus-/graph-based task allocation) and perception (e.g. multi-robot SLAM/SAM, Bayesian/consensus sensor fusion for cooperative tracking) can be combined with good results, the assumed "separation principle" is heuristic and leaves open many questions: how should off-the-shelf solutions for different parts of the same problem be jointly selected or modified to work best together, and what guarantees (if any) are there for optimal/robust behavior? Alternative integrated approaches have also emerged for multi-vehicle systems (e.g. distributed optimization, model predictive control, reinforcement learning), which formally capture and exploit subtle yet important dynamic linkages between the control and estimation problems. However, these approaches raise their own questions: are the assumptions/approximations required for analytical and computational tractability reasonable for general applications, and how can state-of-the-art planning/perception methods for individual mobile robots be leveraged?

This workshop will bring together control/planning and estimation/perception specialists from the robotics and controls communities who are interested in autonomous multi-vehicle networks to: (i) discuss these and other related research questions; (ii) promote new ideas for unifying distributed control and estimation, while improving awareness of state-of-the-art techniques; and (iii) foster interactions for developing theoretical ideas and practical applications.

Workshop homepage[6]

[4] http://drexelsaslab.appspot.com/workshops/rss2014/index.html
[5] http://drcworkshop.csail.mit.edu/
[6] https://sites.google.com/site/rss2014dceworkshop

SAT6 *Human versus Robot Grasping and Manipulation—How Can We Close the Gap?*
Oliver Brock (Technische Universitat Berlin), Dmitry Berenson (WPI), Jim Mainprice (WPI), Maximo Roa (DLR), Clemens Eppner (Technische Universitat Berlin)
Saturday, Room 210

Abstract: Grasping and manipulation are easy for humans: they quickly acquire visual information, process the scene, decide how to grasp, and execute the required motion, even under difficult conditions and with previously unseen objects. Several decades of robotics research did not enable us to transfer comparable abilities to robots. This workshop will bring together leading researchers from the human and the robotics sides of grasping research.

Workshop homepage[7]

SAT7 *Human–Robot Collaboration for Industrial Manufacturing*
Allison Sauppe (University of Wisconsin-Madison), Matthew Gombolay (MIT), Julie Shah (MIT), Bilge Mutlu (University of Wisconsin-Madison)
Saturday, Room 101

Abstract: This workshop aims to bring together researchers in academia and industry to develop strategies and identify practical limitations for effective human-robot collaboration in manufacturing. Traditionally, robots have been caged off from human activity; however, improvements in advanced robotic technology are opening up the possibility of one-to-one collaboration between human workers and their robotic counterparts. Already, the introduction of automation in manufacturing has resulted in an improvement in quality and productivity. However, developing robotic systems that can serve as effective teammates remains a challenge in both academia and industry.

Robot systems capable of effectively collaborating with humans requires the coordination of a number of subsystems, such as the mechanical manipulation of the robot's joints, social behavior of the robot, planning and coordinating algorithms, and safety mechanisms. The goal of this workshop is to bring together researchers and industry practitioners to forge interdisciplinary collaborations that translate academic advancements into real systems. We believe that this workshop will provide a forum where practitioners can discuss challenges in implementing human-robot systems and researchers can relate the state of the art in robotic technology.

Workshop homepage[8]

SAT8 *Moral, Ethical, and Legal Issues in Robotics*
Jeremy Gillula (UC Berkeley), Jennifer Urban (UC Berkeley)
Saturday, Room 203

Abstract: The widespread use of robotic systems outside the controlled environments in which they have traditionally been found – from autonomous cars on public roads, to drones in the US airspace, to in-home service robots – generates a wide array of moral, ethical, and legal issues that robotics researchers have not had to deal with in the past. For example:

What are the privacy implications of ubiquitous robotics? What happens when society is filled with mobile sensor platforms that can affect their environment?

What are the liability and other legal issues surrounding autonomous systems? Who is responsible when a robot manufactured by company A, running software developed by developer B, owned by person C, and operating at the behest of person D, causes an accident?

What are the ethical and moral issues surrounding ubiquitous robotics? What happens when robots can prevent some accidents a human couldn't avoid, but not all? How should a robot faced with an emminent accident decide how to minimize damage (and is this even an issue given existing technology)? And most importantly:

Why should robotics researchers even care?

The purpose of this workshop is to attempt to bring roboticists, lawyers, ethicists, and philosophers to the same table in order to generate discussion about these sorts of issues. By doing so we hope each side can help educate the other: lawyers and ethicists can explain to roboticists what the important legal and ethical issues of robotics research are (and why they should care), and roboticists can help lawyers and ethicists understand the technical details and limitations of robotics research (and which issues are actually important, given the current level of technology). This workshop will include a large amount of time dedicated to Q&A and discussion, so if you are interested in learning more about the ethical and legal side of robotics, we invite you to attend!

Workshop homepage[9]

[7] http://www.mobilemanipulation.org/rss2014
[8] http://hci.cs.wisc.edu/workshops/RSS2014/
[9] http://hybrid.eecs.berkeley.edu/workshops/2014/RSS/law-ethics/

SAT9 *Non-parametric Learning in Robotics*
Rudolph Triebel (Technical University of Munich), Luciano Spinello (University of Freiburg)
Saturday, Room 220

Abstract: The growing interest in non-parametric machine learning methods is driven by their flexibility and expressive power on one side and by their efficiency when applied to large data sets on the other side. The latter is particularly interesting for robotic learning tasks, and recent achievements show the potential that these methods can have in practice.

In this workshop, we will present non-parametric learning methods including Gaussian Processes, Spectral Learning, Dirichlet Processes, Deep Learning, and we will show potential applications in robotics. Renowed experts in the field will present their work, and there will be ample opportunities for interaction and discussion. The aims are to draw further attention of the robotics community to these novel methods, and to highlight their benefits over standard, parametric learning techniques.

Workshop homepage[10]

SAT10 *Optimization Techniques for Motion Generation in Robotics*
Adrien Escande (CNRS/AIST Joint Robotics Laboratory), Katja Mombaur (University of Heidelberg)
Saturday, Room 213

Abstract: Numerical optimization and optimal control algorithms have become more and more powerful in recent years which also made them increasingly interesting to generate motions in robotics. Optimization provides the possibility to easily handle redundant mechanisms, to assign the degrees of freedom of the robot to multiple and possibly concurrent tasks, to enforce hard constraints corresponding to physical limitations, etc., to name just a few. Optimization is used in numerous schemes for generalized inverse kinematics, linear and non-linear control, direct and inverse optimal control, trajectory optimization, planning, etc., with already impressive achievements. However, the increasing complexity of robot models and problems, and the need for fast computations still yield hard challenges and call for many more developments.

There are an important number of optimization algorithms and numerous ways to formulate a robotics problem. Efficient, state-of-the-art motion generation methods are the result of a careful choice of both the formulation and the solver, possibly tailoring the optimization methods for the specific problem class.

The goal of this workshop is to give, via a mix of invited talks, posters and discussions, an overview of optimization tools and techniques used in robotics and the variety of applications. We plan to gather roboticists who require optimization methods for their robots or have already developed dedicated algorithms for robotic problems and researchers from the optimization community have already applied their algorithms to robotics problems or are interested in doing so.

Workshop homepage[11]

SAT11 *Resource-efficient Integration of Planning and Perception for True Autonomous Operation of Micro Air Vehicles (MAVs)*
Darius Burschka (TU Munich), Michael Suppa (DLR), Roland Siegwart (ETH Zürich), Korbinian Schmid (DLR), Markus Achtelik (ETH Zürich)
Saturday, Room 106

Abstract: The wide availability of small and cheap flying platforms (e.g. quadrotors) in combination with advances in embedded systems, high density batteries and lightweight sensors has made small UAS very attractive for a wide range of applications like area surveillance, asset inspection, mapping or search and rescue. The compact size and small weight also make them easier to deploy, both due to their high portability and because obtaining an operational permit is typically easier for such systems.

A disadvantage of using compact, low-power sensors is often their slower speed and lower accuracy making them unsuitable for direct capture and control of high dynamic motion. On the other hand, the inherent instability of some systems (e.g. helicopters or quadrotors), their limited on-board resources and payload, their multi-DOF design and the uncertain and dynamic environment they operate in, present unique challenges both in achieving robust low level control and in implementing higher level functions, like navigation, exploration or object tracking. These challenges can be exacerbated in search and rescue missions where the lack of communications infrastructure and the need for beyond-line-of-sight flying creates the need for operating at a higher degree of autonomy.

[10] http://ais.informatik.uni-freiburg.de/nonparam_rss14/index.html
[11] http://www.orb.uni-hd.de/conferences-workshops/RSS2014

The perceptual evaluation of high dynamic motion can be improved through fusion of proprioceptive (e.g. inertial) and exteroceptive (e.g. vision) sensors, through the use of internal environment representations and/or through the coordinated use of multiple platforms. Perception and action need to be strongly coupled to allow long-term stabilization in the face of challenging platform dynamics, external disturbances, sensor uncertainty and on-board failures. The same is true between perception and navigation/planning to achieve both the necessary reactive behaviors (e.g. for obstacle avoidance or for formation keeping), as well as the execution of goal-oriented tasks.

The goal of the workshop is to collect current state-of-the art solutions to the aforementioned issues. Our key interests lie in the latest developments in the area of robust integration of perception with control and planning of the highly dynamic motion of resource-limited flying platforms. We are also interested in new developments in the field of internal environment representation and collaborative approaches in perception and exploration.

After the great success of the last RSS workshop, we aim to bring together again researchers working on aspects of sensor data processing and fusion for robust navigation of flying platforms. The goal is to provide an opportunity to compare and discuss the current state-of-the-art approaches and solutions to the aforementioned problems. We encourage video and live presentations of the approaches during the conference. We aim to organize a panel at the end of the workshop to discuss current challenges in the field and to foster collaborations between the research groups.

Workshop homepage[12]

SAT12 *Robot Makers: The Future of Digital Rapid Design and Fabrication of Robots*
Ankur Mehta (MIT), Mike Tolley (Harvard), Nicola Bezzo (UPenn), Cagdas Onal (WPI)
Saturday, Room 122

Abstract: A future enriched by personal on-demand programmable robots will require multi-disciplinary advancements across a range of research areas. New algorithms and programming languages will be necessary to define, evaluate, and optimize behavioral specifications and designs. New paradigms and tools will be needed for on-demand design generation. And new fabrication methods will be needed to realize custom electromechanical devices. Within this workshop, we aim to bring together researchers pushing forward the state of the art in these and related fields. Through talks and discussions, this workshop will seek to identify key issues facing the realization of custom cyber-physical systems; by gathering like-minded researchers together, we can address these issues and begin to develop a roadmap for upcoming research. This interactive, multi-prong, cross-disciplinary workshop will define and advance the future of robot making.

Workshop homepage[13]

SAT13 *Workshop on Robotics Methods for Structural and Dynamic Modeling of Molecular Systems*
Lydia Tapia (University of New Mexico), Juan Cortes (LAAS/CNRS), Jianlin Jack Cheng (Missouri), Amarda Shehu (George Mason) Kasra Manavi (University of New Mexico)
Saturday, Room 206

Abstract: Biological macromolecules such as proteins or RNA, at the atomic scale, can be seen as extremely complex mobile systems. The development of methods for modeling the structure and the motion of such systems is essential to better understand their physiochemical properties and biological functions. In recent years, many computer scientists in Robotics and Artificial Intelligence (AI) have made significant contributions to modeling biological systems. Research expertise in planning, search, learning, evolutionary computation, constraint programming, machine learning, data mining is being used to make great progress on molecular motion, structure prediction, and design.

This workshop will explore the many connections between robotics and molecular modeling and will feature keynote speakers who work in robotics, learning, and computational structural biology. Participation is encouraged through paper submission and poster presentations. We will focus on interdisciplinary approaches to predict molecular structures, to simulate their motions, and to analyze structure-dynamics-function relationships. For example, probabilistic search techniques, originally developed for robot motion planning, have been used to model protein structure and flexibility. Recent results have shown exciting promise at exploring high-dimensional and complex molecular motions. Also, search algorithms, optimization techniques, and geometry methods stemming from the AI and robotics community research have produced a large and recent body of literature.

Interaction between the sub-communities of robotics, AI, and molecular modeling will be promoted through the sharing views, methods, and findings. Biological topics will be well explained so that they can be well understood even by non-experts.

Workshop homepage[14]

[12] http://rss2014_uav.visual-navigation.com/
[13] http://www.seas.upenn.edu/~nicbezzo/RoMa2014/
[14] https://cs.unm.edu/amprg/rss14workshop/

SAT14 *Workshop on Women in Robotics*
Joelle Pineau (McGill University), Andrea Tomaz (Georgia Institute of Technology), Maren Bennewitz (University of Freiburg), Leila Takayama (Google)
Saturday, Room 100

Abstract: Robotics is undergoing tremendous growth in recent years, over a wide range of important areas, from transportation, to manufacturing, entertainment, space exploration, health-care and education. While the field is progressing forward, both in research findings and industrial markets, the percentage of female roboticists continues to lag far behind their male counterparts. By organizing the first Workshop on Women in Robotics, we aim to: (1) raise visibility of women in robotics by presenting invited talks by women that are leaders in the field, (2) strengthen the community and provide an opportunity for networking by providing an event dedicated to women in robotics, (3) foster mentorship of junior female researchers via a poster session and travel awards.

Workshop homepage[15]

[15] `http://www.cs.mcgill.ca/~jpineau/rss14-wir.html`

Workshops on Sunday, July 13

SUN1 *Affordances in Vision for Cognitive Robotics*
Karthik Mahesh Varadarajan (Technical University of Vienna), Markus Vincze (Technical University of Vienna), Trevor Darrell (University of California, Berkeley), Jürgen Gall (University of Bonn)
Sunday, Room 100

Abstract: Based on the Gibsonian principle of defining objects by their function, "affordances" have been studied extensively by psychologists and visual perception researchers, resulting in the creation of numerous cognitive models. These models are being increasingly revisited and adapted by computer vision and robotics researchers to build cognitive models of visual perception and behavioral algorithms in recent years. This workshop attempts to explore this nascent, yet rapidly emerging field of affordance based cognitive robotics while integrating the efforts and language of affordance communities not just in computer vision and robotics, but also psychophysics and neurobiology by creating an open affordance research forum, feature framework and ontology called AfNet (theaffordances.net). In particular, the workshop will focus on emerging trends in affordances and other human-centered function/action features that can be used to build computer vision and robotic applications. The workshop also features contributions from researchers involved in traditional theories to affordances, especially from the point of view of psychophysics and neuro-biology. Avenues to aiding research in these fields using techniques from computer vision and cognitive robotics will also be explored.

The workshop also seeks to address key challenges in robotics with regard to functional form descriptions. While affordances describe the function that each object or entity affords, these in turn define the manipulation schema and interaction modes that robots need to use to work with objects. These functional features, ascertained through vision, haptics and other sensory information also help in categorizing objects, task planning, grasp planning, scene understanding and a number of other robotic tasks. Understanding various challenges in the field and building a common language and framework for communication across varied communities in are the key goals of the proposed workshop. Through the course of the workshop, we also envisage the establishment of a working group for AfNet. An initial version is available online at www.theaffordances.net. We hope the workshop will serve to foster greater collaboration between the affordance communities in various fields.

Workshop homepage[16]

SUN2 *Communication-aware Robotics: New Tools for Multi-Robot Networks, Autonomous Vehicles, and Localization*
Daniela Rus (MIT), Stephanie Gil (MIT), Nora Ayanian (USC), Swarun Kumar (MIT)
Sunday, Room 122

Abstract: Recent advances in communication are enabling teams of robots to achieve new and exciting capabilities. Of current interest in the robotics literature are multi-agent teams for their applications to distributed exploration, search and rescue, and in the near future, global connectivity. The effectiveness of these coordinated systems inherently depends on communication infrastructure and hinges on the assumption of adequate inter-agent communication. This necessitates the development of robust communication tools with guaranteed performance in real-world environments.

Emerging technologies in the communications field include using information exchange as a virtual sensor to be used by autonomous cars in future networked cities, leveraging WiFi to "see through walls" to track people or objects behind occlusions, and processing of wireless signals for the purpose of localization in an environment. From providing the necessary communication quality guarantees to achieve coordination tasks amongst robot teams in real-world environments, to using wireless signals as sensors for localization and/or tracking, cutting edge advancements in communication are becoming a critical component of future robotic systems. The potential for robotic systems that are tightly coupled with the newest and most capable tools in communication is pressing. However, in order for us to achieve these goals we must encourage collaboration between the largely independent fields of communication and robotics.

The goal of this full day workshop is to bring together leaders of both fields to discuss recent and targeted advances in communication for robotic systems, identify the major needs and challenges in translating these capabilities to practical arenas, and encourage an exchanging of ideas from robotics and communication experts to tackle these challenges towards development of high performing and reliable networked multi-agent systems for the real-world.

Workshop homepage[17]

[16] `http://affordances.info/workshops/RSS.html/`
[17] `http://groups.csail.mit.edu/drl/wiki/index.php?title=RSS_2014_Proposed_Workshop/`

SUN3 *Constrained Decision-making in Robotics: Models, Algorithms, and Applications*
Stefano Carpin (University of California, Merced), Marco Pavone (Stanford University)
Sunday, Room 210

Abstract: As the complexity of robotic tasks grows, robotic decision makers increasingly face the problem of trading off different objectives. For example, a rescue robot might be required to plan trajectories so as to maximize the probability of success to reach a victim and, at the same time, minimize the duration of the traversal (a task often contrasting the one of ensuring safety). A natural framework for this class of problems is constrained decision-making, whereby a decision maker seeks to optimize a given cost function (often stochastic) while keeping other costs (usually involving risk assessments) below given bounds. In the last decade, the operations research community has made significant strides on the topics of constrained decision-making (notoriously more challenging than the unconstrained counterpart) and risk assessments in dynamic scenarios. The result is a comprehensive theory and a set of algorithmic tools for (risk)-constrained decision-making. Yet, despite their relevance, these results have seen limited application within the robotics domain. Accordingly, the objective of this workshop is threefold:

(1) To convene together, arguably for the first time, researchers working in the areas of decision-making, risk theory, and robotics to facilitate a joint discussion on (risk)-constrained decision-making in robotics.

(2) To inform robotic researchers about the state of the art in constrained decision-making and modern risk theory.

(3) To formulate a research agenda on the topics of risk modeling for robotics applications, algorithmic approaches for robotic decision-making under constraints, and application of these results to robotic planning.

Workshop homepage[18]

SUN4 *Dynamic Locomotion*
Aaron Ames (Texas A& M), Koushil Sreenath (CMU)
Sunday, Room 220

Abstract: Locomotion has received great interest in recent years, especially during the ongoing DARPA Robotics Challenge (DRC). Legged locomotion is challenging because it combines the challenges of dealing with periodic motions, high degree-of-freedom systems, nonlinear and hybrid dynamics, underactuation, and unilateral constraints. This has led to most approaches approaches that appear in practice, e.g., at the DRC, to be predominantly flat-footed, slow and quasi-static. The goal of this workshop is to put together leaders in dynamic locomotion, from controls, dynamics and robotics communities, to foster a platform for exchanging ideas to enable complex experimental robots to exhibit dynamic locomotion.

Workshop homepage[19]

SUN5 *Guaranteed Safety for Uncertain Robotic Systems*
Jeremy Gillula (UC Berkeley), Shahab Kaynama (UC Berkeley)
Sunday, Room 24

Abstract: Automated systems are increasingly being used in uncontrolled environments by people who are not robotics experts: autonomous automobiles are being driven on public roads, robotic surgery systems are becoming standard in hospitals, and the FAA will soon pass rules allowing UAVs to fly in US airspace, just to name a few. A common theme among these and other examples is that a modern robot's workspace is less likely to be a meticulously designed factory floor, and more likely to be an everyday place like a road or a small business. In order to enable robots to successfully make this transition, however, we must be able to guarantee that the robots we create are safe even in the face of uncertainty.

This workshop will thus focus on how to design algorithms for guaranteeing safety for uncertain robotic (and other cyberphysical) systems. Since uncertainty can take many forms (from probabilistic or noisy dynamics, to uncertain measurements or obstacles, to adversarial disturbances) a wide array of different methods will be presented and discussed. The goal of the workshop is to bring together researchers with a wide variety of different approaches in order to maximize the sharing of ideas and identify the commonalities present in existing methods, as well as discuss future research challenges which, once solved, will enable pervasive safe robotics to become a reality even in the face of uncertainty.

Workshop homepage[20]

[18] http://robotics.ucmerced.edu/RSS2014Workshop
[19] http://www.dynamiclocomotion.org/
[20] http://hybrid.eecs.berkeley.edu/workshops/2014/RSS/safety

SUN6 *Humans and Sensing in Cyber-Physical Systems*
Anil Aswani (UC Berkeley), Ram Vasudevan (MIT)
Sunday, Room 203

Abstract: Sensor limitations, natural disasters, and adversarial users pose unique challenges during the design of networked robotic systems interacting with the environment. Traditional models of uncertainty for these cyber-physical systems utilize stochasticity, game theory, or worst-case analysis, but integration of such models into the design and validation process of cyber-physical systems has languished due to computational and theoretical limitations. This workshop will cover some of the current work in the field of integrating sensors and humans with cyber-physical systems and its application to infrastructure and automation systems.

Workshop homepage[21]

SUN7 *Information-based Grasp and Manipulation Planning*
Sachin Patil (UC Berkeley), Robert Platt Jr. (Northeastern University)
Sunday, Room 200

Abstract: In order for robots to perform grasping and manipulation tasks robustly in the presence of environmental uncertainty, it is important to be able to reason about the acquisition of perceptual knowledge and to perform information gathering actions as necessary. This is especially important today because many recently developed inexpensive robots sacrifice actuator accuracy and performance for cost savings. In order for this tradeoff to work, it is necessary to make up for actuator error with improved perceptual capabilities.

This workshop will focus on the intersection between grasping/manipulation and planning under uncertainty. One the one hand, we are interested in planning algorithms that enable a robot to reason about how to obtain relevant information in the context of performing a task. On the other, we are looking for ways that these planning algorithms can make robot grasping and manipulation more robust. We envision a robot manipulation system that gains information by interacting with objects (touching, pushing, changing viewing perspective, etc.) in order to perform grasping, placement, insertion, assembly, or other tasks more robustly.

This workshop will bring together researchers working in sensing and perception, grasp and motion planning, and information/belief space planning to discuss the current state of the art and identify new research opportunities.

Workshop homepage[22]

SUN8 *Learning Plans with Context from Human Signals*
Drew Bagnell (CMU), Ashesh Jain (Cornell), Jan Peters (TU Darmstadt), Ashutosh Saxena (Cornell)
Sunday, Room 123

Abstract: This workshop aims at a broader audience and will bring together people from machine learning, planning and HRI communities.

Human environments such as homes, warehouses and offices are very rich with the context of the objects and humans present and the task to be performed. Robots should incorporate this rich context and plan human-preferred motions. Furthermore, the robots should learn from different kinds of human feedback, which can range from optimal demonstrations to sub-optimal incremental signals. From an HRI perspective, signals come in various forms and we need new machine learning techniques to use these signals for meaningful motion planning. Through this workshop we bring together people from the areas of machine learning, planning and HRI to discuss how robots can learn to plan and act in context-rich human environments.

Workshop homepage[23]

[21] `http://ieor.berkeley.edu/~aaswani/rss14_cps/`
[22] `http://rll.berkeley.edu/RSS2014Workshop`
[23] `http://learningplans.cs.cornell.edu/`

SUN9 *Managing Software Variability in Robot Control Systems*
Davide Brugali (University of Bergamo), Christian Schlegel (Fakultät Informatik Hochschule Ulm)
Sunday, Room 206

Abstract: Sensing, planning, controlling, and reasoning, are human like capabilities that can be artificially replicated in an autonomous robot as software systems, which implement data structures and algorithms devised on a large spectrum of theories, from probability theory, mechanics, and control theory to ethology, economy, and cognitive sciences. Software plays a key role in the development of robotic systems as it is the medium to embody intelligence in the machine. In this scenario, software development is increasingly becoming the bottleneck of robotic system engineering and calls for new approaches and tools that support and promote the software reuse. The routine use of existing solutions in the development of new systems is a key attribute of every mature engineering discipline. While systematic software reuse is a state of the practice development approach in various application domains, such as telecommunications, factory automation, automotive, and avionics, it is still a research issue in Robotics. The tutorial presents a set of model-driven tools that support variability modeling, composition, and resolution of robot software control systems built on popular robotic component-based middlewares and runtime infrastructures. The tools simplify systems configuration and application deployment by system integrators without advanced skills in software development.

Workshop homepage[24]

SUN10 *Next-Generation Robotics: Academia, Start-ups and Industry*
Sachin Chitta (SRI International), Ioan Sucan (Google Inc.), Torsten Kroeger (Stanford University)
Sunday, Room 110

Abstract: This full-day workshop is intended to bring before the RSS audience speakers from industry and start-ups. In the morning session, industry experts from different domains including automation, manufacturing, automobile, aerospace, healthcare will talk about the next-generation of problems for robotics to address. They will talk about the need for new types of robots and capabilities, the research directions that academia could take and the potential for greater industry-academic collaboration. In the afternoon session, founders and other members from start-ups in Robotics will talk about their experience in creating start-ups and bringing new technology to the market, the opportunities for new companies to emerge in the field and the lessons learned. Audience participation will be encouraged through panel discussions in each of the sessions with the opportunity for the audience to interact with the panelists.

Workshop homepage[25]

SUN11 *Self-Driving Vehicles: Technology and Policy*
John Leonard (MIT), Jesse Levinson (Stanford)
Sunday, Room 213

Abstract: The goal of this workshop is to explore the fast-changing topic of self-driving vehicles, from the perspectives of robotics research and policy. Led by the efforts of Google and many leading automobile manufacturers, interest in the field of self-driving vehicles has surged in the past several years. This workshop will solicit contributions in the core technologies of mobile robotics that underpin self-driving vehicles, including: sensors, localization, mapping, path-planning and control, and human-machine interfaces. We will also bring in policy experts to discuss some of the potential legal and economic impacts of this transformative technology.

Workshop homepage[26]

[24] `http://robotics.unibg.it/tcsoft/rss2014/`
[25] `http://moveit.ros.org/rss-2014-workshop/`
[26] `http://jleonard.scripts.mit.edu/sdv/`

SUN12 *Advances on Soft Robotics*
Cecilia Laschi (Scuola Superiore Sant'Anna), Fumiya Iida (ETH), Jonathan Rossiter (University of Bristol), Laura Margheri (Scuola Superiore Sant'Anna)
Sunday, Room 106

Abstract: This one day Workshop will gather experts across multiple fields in the scientific community of soft robotics. The workshop is organized to be part of the series of scientific events planned in the framework of RoboSoft Coordination Action (European Commission funded project under FP7-ICT-2013-C, Future and Emerging Technologies FET-Open scheme, `http://www.robosoftca.eu/`) aimed at bringing together researchers to enable the step-change in technologies and standards needed to advance soft robotics.

Invited talks, contributed paper talks and roundtable sessions will discuss the development of general theories, new and non-conventional approaches and techniques for most of the technologies involved in soft robotics, like smart soft materials, soft (muscle-like) actuators, soft sensors, modelling and control of soft robots, energy harvesting, design principles for soft robotics and morphological computation. Thanks to the high interdisciplinarity of the field of soft robotics the event will gather together researchers of different scientific background and potential stakeholders.

Workshop homepage[27]

SUN13 *Workshop on Multi-View Geometry in Robotics (MVIGRO 2014)*
Vadim Indelman (GaTech), Luca Carlone (GaTech), Frank Dellaert (GaTech)
Sunday, Room 130

Abstract: Following up on the success and the broad participation in MVIGRO 2013, this workshop brings together researchers from the robotics and computer vision communities, to discuss recent advances in multiple view geometry with application to robotics. Multi-view geometry plays a key role in many areas of robotics and ongoing research includes different fields such as visual servoing and control, surveillance, indoor and outdoor vision-aided navigation, simultaneous localization and mapping (SLAM), cooperative localization, detection of moving objects and operation in dynamic environments. While the research field witnessed a proliferation of excellent contributions and working solutions, some challenges still stand on the way to fully autonomous robots. Examples of these challenges are long-term robust operation (e.g. autonomous driving), ability to deal with dynamic, deformable, and cluttered environments (e.g., robot-assisted surgery or navigation in human populated environments), and high level scene understanding (e.g., object recognition and tracking). Harnessing the full potential of multiple view geometry can address these challenges, enhancing the societal impact of robotics.

This workshop aims to bring forward the latest breakthroughs and cutting edge research on multiple view geometry in robotics, as well as discuss challenges and future research directions.

Workshop homepage[28]

SUN14 *Workshop on Robotic Monitoring*
Andreas Breitenmoser (USC), Jorg Muller (USC), Jnaneshwar Das (USC), Ryan Smith (USC), Carrick Detweiler (University of Nebraska-Lincoln Lincoln)
Sunday, Room 101

Abstract: The goal of this workshop is to bring together researchers from various fields to present and discuss recent advances in robotic monitoring. Limited sensing capabilities while monitoring vast areas pose fundamental challenges in the deployment and coordination of autonomous mobile robots. Intelligent algorithms can facilitate efficient robotic monitoring by adaptively selecting the most interesting regions to observe and by leveraging the coordinated planning and control of (complementary heterogeneous) teams of robots. The underlying state estimation, planning, and information-theoretic decision making algorithms must be integrated into robust real-world robotic systems. By this workshop, we want to stimulate the exchange of recent achievements in theory and application among researchers working in environmental monitoring, industrial inspection, persistent coverage and surveillance, and other related fields. We hope that this will lead the way toward advancing and integrating existing and new techniques for effective robots and cyber-physical systems in monitoring tasks.

Workshop homepage[29]

[27] `http://www.robosoftca.eu/events/RSS2014-workshop`
[28] `http://www.cc.gatech.edu/events/mvigro/`
[29] `http://cinaps.usc.edu/rss2014/`

Paper Abstracts

A1 *Batch Continuous-Time Trajectory Estimation as Exactly Sparse Gaussian Process Regression*
Tim Barfoot (University Toronto), Chi Hay Tong (University of Oxford), Simo Sarkka (Aalto University)

Abstract: In this paper, we revisit batch state estimation through the lens of Gaussian process (GP) regression. We consider continuous-discrete estimation problems wherein a trajectory is viewed as a one-dimensional GP, with time as the independent variable. Our continuous-time prior can be defined by any linear, time-varying stochastic differential equation driven by white noise; this allows the possibility of smoothing our trajectory estimates using a variety of vehicle dynamics models (e.g., 'constant-velocity'). We show that this class of prior results in an inverse kernel matrix (i.e., covariance matrix between all pairs of measurement times) that is exactly sparse (block-tridiagonal) and that this can be exploited to carry out GP regression (and interpolation) very efficiently. Though the prior is continuous, we consider measurements to occur at discrete times. When the measurement model is also linear, this GP approach is equivalent to classical, discrete-time smoothing (at the measurement times). When the measurement model is nonlinear, we iterate over the whole trajectory (as is common in vision and robotics) to maximize accuracy. We test the approach experimentally on a simultaneous trajectory estimation and mapping problem using a mobile robot dataset.

Paper link[30]

A2 *Combining 3D Shape, Color, and Motion for Robust Anytime Tracking*
David Held (Stanford University), Jesse Levinson (Stanford University), Sebastian Thrun (Stanford University), Silvio Savarese (Stanford University)

Abstract: Although object tracking has been studied for decades, real-time tracking algorithms often suffer from low accuracy and poor robustness when confronted with difficult, real-world data. We present a tracker that combines 3D shape, color (when available), and motion cues to accurately track moving objects in real-time. Our tracker allocates computational effort based on the shape of the posterior distribution. Starting with a coarse approximation to the posterior, the tracker successively refines this distribution, increasing in tracking accuracy over time. The tracker can thus be run for any amount of time, after which the current approximation to the posterior is returned. Even at a minimum runtime of 0.7 milliseconds, our method outperforms all of the baseline methods of similar speed by at least 10%. If our tracker is allowed to run for longer, the accuracy continues to improve, and it continues to outperform all baseline methods. Our tracker is thus anytime, allowing the speed or accuracy to be optimized based on the needs of the application.

Paper link[31]

A3 *Decision-Making Authority, Team Efficiency and Human Worker Satisfaction in Mixed Human-Robot Teams*
Matthew Gombolay (MIT), Reymundo Gutierrez (MIT), Giancarlo Sturla (MIT), Julie Shah (MIT)

Abstract: In manufacturing, advanced robotic technology has opened up the possibility of integrating highly autonomous mobile robots into human teams. However, with this capability comes the issue of how to maximize both team efficiency and the desire of human team members to work with robotic counterparts. We hypothesized that giving workers partial decision-making authority over a task allocation process for the scheduling of work would achieve such a maximization, and conducted an experiment on human subjects to test this hypothesis. We found that an autonomous robot can outperform a worker in the execution of part or all of the task allocation ($p < 0.001$ for both). However, rather than finding an ideal balance of control authority to maximize worker satisfaction, we observed that workers preferred to give control authority to the robot ($p < 0.001$). Our results indicate that workers prefer to be part of an efficient team rather than have a role in the scheduling process, if maintaining such a role decreases their efficiency. These results provide guidance for the successful introduction of semi-autonomous robots into human teams.

Paper link[32]

A4 *Stiction Compensation in Agonist-Antagonist Variable Stiffness Actuators*
Luca Fiorio (Istituto Italiano di Tecnologia), Francesco Romano (Istituto Italiano di Tecnologia), Alberto Parmiggiani (Istituto Italiano di Tecnologia), Giulio Sandini (Istituto Italiano di Tecnologia), Francesco Nori (Istituto Italiano di Tecnologia)

Abstract: In the last decade new actuator designs have been presented trying to introduce at mechanical level the advantages of compliance. Ranging from serial elastic actuators to different designs of variable stiffness actuators, various prototypes have been proposed and implemented on robots, thus allowing performance of novel and challenging tasks. Nevertheless some of these new devices often are affected by the drawbacks related to friction. In particular, static friction due to its discontinuous nature, can produce undesired behaviors that are rather difficult to compensate. In this paper we present a novel kind of passive variable stiffness actuator based on agonist-antagonist configuration. The specific design we adopted improves the capability of the system in mechanically compensating the external disturbances, but on the

[30] http://www.roboticsproceedings.org/rss10/p01.html
[31] http://www.roboticsproceedings.org/rss10/p14.html
[32] http://www.roboticsproceedings.org/rss10/p46.html

other hand intensifies the effect of stiction during the co-contraction of the agonist and antagonist side of the actuator. The consequence is the appearance of a set of neutral equilibrium configurations of the output joint that we named “dead-band”. This issue is tackled analytically investigating the propagation and the distribution of the stiction components within the whole system. The result is a condition over the spring potential energies that is exploited to properly design the new non-linear springs. Eventually experimental tests are conducted on the real actuator, showing the effectiveness of our analytical approach.

Paper link[33]

A5 *Simultaneous Compliance and Registration Estimation for Robotic Surgery*
Siddharth Sanan (Carnegie Mellon University), Stephen Tully (Medrobotics), Andrea Bajo (Vanderbilt University), Nabil Simaan (Vanderbilt University), Howie Choset (Carnegie Mellon University)

Abstract: Leveraging techniques pioneered by the SLAM community, we present a new filtering approach called simultaneous compliance and registration estimation or CARE. CARE is like SLAM in that it simultaneously determines the pose of a surgical robot while creating a map, but in this case, the map is a compliance map associated with a preoperative model of an organ as opposed to just positional information like landmark locations. The problem assumes that the robot is forcefully contacting and deforming the environment. This palpation has a dual purpose: 1) it provides the necessary geometric information to align or register the robot to *a priori* models, and 2) with palpation at varying forces, the stiffness/compliance of the environment can be computed. By allowing the robot to palpate its environment with varying forces, we create a force balanced spring model within a Kalman filter framework to estimate both tissue and robot position. The probabilistic framework allows for information fusion and computational efficiency. The algorithm is experimentally evaluated using a continuum robot interacting with two bench-top flexible structures.

Paper link[34]

B1 *Vision-based Landing Site Evaluation and Trajectory Generation Toward Rooftop Landing*
Vishnu Desaraju (Carnegie Mellon University), Nathan Michael (Carnegie Mellon University), Martin Humenberger (JPL), Roland Brockers (JPL), Stephan Weiss (JPL) Larry Matthies (JPL)

Abstract: Autonomous landing is an essential function for micro air vehicles (MAVs) for many scenarios. We pursue an active perception strategy that enables MAVs with limited onboard sensing and processing capabilities to concurrently assess feasible rooftop landing sites with a vision-based perception system while generating trajectories that balance continued landing site assessment and the requirement to provide visual monitoring of an interest point. The contributions of the work are twofold: (1) a perception system that employs a dense motion stereo approach that determines the 3D model of the captured scene without the need of geo-referenced images, scene geometry constraints, or external navigation aids; and (2) an online trajectory generation approach that balances the need to concurrently explore available rooftop vantages of an interest point while ensuring confidence in the landing site suitability by considering the impact of landing site uncertainty as assessed by the perception system. Simulation and experimental evaluation of the performance of the perception and trajectory generation methodologies are analyzed independently and jointly in order to establish the efficacy of the proposed approach.

Paper link[35]

B2 *Correct High-level Robot Behavior in Environments with Unexpected Events*
Kai Weng Wong (Cornell University), Rudiger Ehlers (University of Bremen), Hadas Kress-Gazit (Cornell University)

Abstract: Synthesis of correct-by-construction robot controllers from high-level specifications has the advantage of providing guaranteed robot behavior under different environments. Typically, when such controllers are synthesized, assumptions that the user makes about the behavior of the environment, if any, are incorporated into the resulting controller. In practice, however, the environment assumptions may be unknown to the user, thus preventing the application of synthesis. Even if environment assumptions are available, they may not hold during the robot’s execution due to modeling errors or unforeseen anomalous operating conditions. In this paper, we address both of these problems. We present an approach for synthesizing controllers that include built-in recovery transitions, enabling the robot to make progress towards its goals in the event of environment assumption violation, whenever possible. Furthermore, we present a process for automatically augmenting a specification with environment assumptions that are computed from the robot’s observations at runtime. We start with a set of candidate assumptions that is updated whenever violated at runtime.

Paper link[36]

[33] http://www.roboticsproceedings.org/rss10/p32.html
[34] http://www.roboticsproceedings.org/rss10/p51.html
[35] http://www.roboticsproceedings.org/rss10/p44.html
[36] http://www.roboticsproceedings.org/rss10/p12.html

B3 *Persistent Monitoring of Stochastic Spatio-temporal Phenomena with a Small Team of Robots*
Sahil Garg (University of Southern California), Nora Ayanian (University of Southern California)

Abstract: This paper presents a solution for persistent monitoring of real-world stochastic phenomena, where the underlying covariance structure changes sharply across time, using a small number of mobile robot sensors. We propose an adaptive solution for the problem where stochastic real-world dynamics are modeled as a Gaussian Process (GP). The belief on the underlying covariance structure is learned from recently observed dynamics as a Gaussian Mixture (GM) in the low-dimensional hyper-parameters space of the GP and adapted across time using Sequential Monte Carlo methods. Each robot samples a belief point from the GM and locally optimizes a set of informative regions by greedy maximization of the submodular entropy function. The key contributions of this paper are threefold: adapting the belief on the covariance using Markov Chain Monte Carlo (MCMC) sampling such that particles survive even under sharp covariance changes across time; exploiting the belief to transform the problem of entropy maximization into a decentralized one; and developing an approximation algorithm to maximize entropy on a set of informative regions in the continuous space. We illustrate the application of the proposed solution through extensive simulations using an artificial dataset and multiple real datasets from fixed sensor deployments, and compare it to three competing state-of-the-art approaches.

Paper link[37]

B4 *Modeling and Controlling Friendliness for An Interactive Museum Robot*
Chien-Ming Huang (University of Wisconsin - Madison), Takamasa Iio (ATR), Satoru Satake (ATR), Takayuki Kanda (ATR)

Abstract: Advances in robotic technologies have enabled interactive robots to utilize humanlike social behaviors to interact with people in public places such as museums. While these behaviors have shown promise in engaging people, they have been designed and applied to users uniformly. Humans, however, behave differently according to their relationships with others. Behavioral changes, from neutral to friendly, contribute to the development of interpersonal relationships. Friendliness, in particular, plays an important role in the early development of a relationship. In this work, we explore how an interactive robot might nonverbally express a variety of friendly behaviors in a museum scenario. Four behavioral variables—response time, approach speed, individual distance, and attentiveness—contributing to perceived friendliness were modeled and implemented for the interactive museum robot. The results of our study showed that people perceived the differences in the designed robot behaviors and related those differences to the friendliness of the robot to varying degrees. This work serves as a building block toward the development of human-robot relationships and has implications on designing friendly behaviors for interactive robots.

Paper link[38]

B5 *Efficient Visual-Inertial Navigation using a Rolling-Shutter Camera with Inaccurate Timestamps*
Chao Guo (University of Minnesota), Dimitrios Kottas (University of Minnesota), Ryan DuToit (University of Minnesota), Ahmed Ahmed (University of Minnesota), Ruipeng Li (University of Minnesota), Stergios Roumeliotis (University of Minnesota)

Abstract: In order to develop Vision-aided Inertial Navigation Systems (VINS) on mobile devices, such as cell phones and tablets, one needs to consider two important issues, both due to the commercial-grade underlying hardware: (i) The unknown and varying time offset between the camera and IMU clocks (ii) The rolling-shutter effect caused by CMOS sensors. Without appropriately modelling their effect and compensating for them online, the navigation accuracy will significantly degrade. In this work, we introduce a linear-complexity algorithm for fusing inertial measurements with time-misaligned, rolling-shutter images using a highly efficient and precise linear interpolation model. As a result, our algorithm achieves a better accuracy and improved speed compared to existing methods. Finally, we validate the superiority of the proposed algorithm through simulations and real-time, online experiments on a cell phone.

Paper link[39]

[37] `http://www.roboticsproceedings.org/rss10/p38.html`
[38] `http://www.roboticsproceedings.org/rss10/p25.html`
[39] `http://www.roboticsproceedings.org/rss10/p57.html`

B6 *Dynamically Feasible Motion Planning through Partial Differential Flatness*
Suresh Ramasamy (Carnegie Mellon University), Guofan Wu (Carnegie Mellon University), Koushil Sreenath (Carnegie Mellon University)

Abstract: Differential flatness is a property which substantially reduces the difficulty involved in generating dynamically feasible trajectories for underactuated robotic systems. However, there is a large class of robotic systems that are not differentially flat, and an efficient method for computing dynamically feasible trajectories does not exist. In this paper we introduce a weaker but more general form of differential flatness, termed partial differential flatness, which enables efficient planning of dynamic feasible motion plans for an entire new class of systems. We provide several examples of underactuated systems which are not differentially flat, but are partially differentially flat. We also extend the notion of partial differential flatness to hybrid systems. Finally, we consider the infamous cart-pole system and provide a concrete example of designing dynamically feasible trajectories in the presence of obstacles.

Paper link[40]

B7 *Sky Segmentation with Ultraviolet Images Can Be Used for Navigation*
Thomas Stone (University of Edinburgh), Michael Mangan (University of Edinburgh), Paul Ardin (University of Edinburgh), Barbara Webb (University of Edinburgh)

Abstract: Inspired by ant navigation, we explore a method for sky segmentation using ultraviolet (UV) light. A standard camera is adapted to allow collection of outdoor images containing light in the visible range, in UV only and in green only. Automatic segmentation of the sky region using UV only is significantly more accurate and far more consistent than visible wavelengths over a wide range of locations, times and weather conditions, and can be accomplished with a very low complexity algorithm. We apply this method to obtain compact binary (sky vs non-sky) images from panoramic UV images taken along a 2km route in an urban environment. Using either sequence SLAM or a visual compass on these images produces reliable localisation and orientation on a subsequent traversal of the route under different weather conditions.

Paper link[41]

C1 *Hierarchical Semantic Labeling for Task-Relevant RGB-D Perception*
Chenxia Wu (Cornell University), Ian Lenz (Cornell University), Ashutosh Saxena (Cornell University)

Abstract: Semantic labeling of RGB-D scenes is very important in enabling robots to perform mobile manipulation tasks, but different tasks may require entirely different sets of labels. For example, when navigating to an object, we may need only a single label denoting its class, but to manipulate it, we might need to identify individual parts. In this work, we present an algorithm that produces hierarchical labelings of a scene, following is-part-of and is-type-of relationships. Our model is based on a Conditional Random Field that relates pixel-wise and pair-wise observations to labels. We encode hierarchical labeling constraints into the model while keeping inference tractable. Our model thus predicts different specificities in labeling based on its confidence—if it is not sure whether an object is Pepsi or Sprite, it will predict soda rather than making an arbitrary choice. In extensive experiments, both offline on standard datasets as well as in online robotic experiments, we show that our model outperforms other state-of-the-art methods in labeling performance as well as in success rate for robotic tasks.

Paper link[42]

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[41] http://www.roboticsproceedings.org/rss10/p47.html
[42] http://www.roboticsproceedings.org/rss10/p06.html

C2 *Multi-Heuristics A**
Sandip Aine (IIIT-Delhi, India), Siddharth Swaminathan (Carnegie Mellon University), Venkatraman Narayanan (Carnegie Mellon University), Victor Hwang (Carnegie Mellon University), Maxim Likhachev (Carnegie Mellon University)

Abstract: The performance of heuristic search (such as A*) based planners depends heavily on the quality of the heuristic function used to focus the search. These algorithms work fast and generate high-quality solutions, even for high-dimensional problems, as long as they are given a well-designed heuristic function. Consequently, the research in developing an efficient planner for a specific domain becomes the design of a good heuristic function. However, for many domains, it is hard to design a single heuristic function that captures all the complexities of the problem. Furthermore, it is hard to ensure that heuristics are admissible and consistent, which is necessary for A* like searches to provide guarantees on completeness and bounds on suboptimality. In this paper, we develop a novel heuristic search, called Multi-Heuristic A* (MHA*), that takes in multiple, arbitrarily inadmissible heuristic functions in addition to a single consistent heuristic, and uses all of them simultaneously to search for a complete and bounded suboptimal solution. This simplifies the design of heuristics and enables the search to effectively combine the guiding powers of different heuristic functions. We support these claims with experimental analysis on several domains ranging from inherently continuous domains such as full-body manipulation and navigation to inherently discrete domains such as the sliding tile puzzle.

Paper link[43]

C3 *Learning Articulated Motions from Visual Demonstration*
Sudeep Pillai (MIT), Matthew Walter (MIT), Seth Teller (MIT)

Abstract: Many functional elements of human homes and workplaces consist of rigid components which are connected through one or more sliding or rotating linkages. Examples include doors and drawers of cabinets and appliances; laptops; and swivel office chairs. A robotic mobile manipulator would benefit from the ability to acquire kinematic models of such objects from observation. This paper describes a method by which a robot can acquire an object model by capturing depth imagery of the object as a human moves it through its range of motion. We envision that in future, a machine newly introduced to an environment could be shown by its human user the articulated objects particular to that environment, inferring from these ”visual demonstrations” enough information to actuate each object independently of the user. Our method employs sparse (markerless) feature tracking, motion segmentation, component pose estimation, and articulation learning; it does not require prior object models. Using the method, a robot can observe an object being exercised, infer a kinematic model incorporating rigid, prismatic and revolute joints, then use the model to predict the object's motion from a novel vantage point. We evaluate the method's performance, and compare it to that of a previously published technique, for a variety of household objects.

Paper link[44]

C4 *An Analysis of Deceptive Robot Motion*
Anca Dragan (Carnegie Mellon University), Rachel Holladay (Carnegie Mellon University), Siddhartha Srinivasa (Carnegie Mellon University)

Abstract: Much robotics research explores how robots can clearly communicate true information. Here, we focus on the counterpart: communicating false information, or hiding information altogether – in one word, deception. Robot deception is useful in conveying intentionality, and in making games against the robot more engaging. We study robot deception in goal-directed motion, in which the robot is concealing its actual goal. We present an analysis of deceptive motion, starting with how humans would deceive, moving to a mathematical model that enables the robot to autonomously generate deceptive motion, and ending with a study on the implications of deceptive motion for human-robot interactions.

Paper link[45]

D1 *Semantic Localization Via the Matrix Permanent*
Nikolay Atanasov (University of Pennsylvania), Menglong Zhu (University of Pennsylvania), Kostas Daniilidis (University of Pennsylvania), George Pappas (University of Pennsylvania)

Abstract: Most approaches to robot localization rely on low-level geometric features such as points, lines, and planes. In this paper, we use object recognition to obtain semantic information from the robot's sensors and consider the task of localizing the robot within a prior map of landmarks, which are annotated with semantic labels. As object recognition algorithms miss detections and produce false alarms, correct data association between the detections and the landmarks on the map is central to the semantic localization problem. Instead of the traditional vector-based representations, we use random finite sets to represent the object detections. This allows us to explicitly incorporate missed detections, false alarms, and data association in the sensor model. Our second contribution is to reduce the problem of computing the likelihood of a set-valued observation to the problem of computing a matrix permanent. It is this crucial transformation that enables us to solve the semantic localization problem with a polynomial-time approximation to the set-based Bayes filter. The performance of our approach is

[43] `http://www.roboticsproceedings.org/rss10/p56.html`
[44] `http://www.roboticsproceedings.org/rss10/p50.html`
[45] `http://www.roboticsproceedings.org/rss10/p10.html`

demonstrated in simulation and in a real environment using a deformable-part-model-based object detector. Comparisons are made with the traditional lidar-based geometric Monte-Carlo localization.

Paper link[46]

D2 *The Multi-Agent Navigation Transformation: Tuning-Free Multi-Robot Navigation*
Savvas Loizou (Cyprus University of Technology)

Abstract: This paper proposes a novel methodology for decentralized multi-robot navigation with multiple arbitrarily shaped obstacles in 2-dimensional environments. The proposed methodology is based on the novel concepts of the Navigation Transformation and the Harmonic Function based Navigation Functions. A version of the Navigation Transformation - the Multi-Agent Navigation Transformation - is proposed in this paper to map geometrically complex topologies resulting from moving workspace entities to simple topologies enabling the construction of Harmonic Function based Navigation Functions. The resulting vector field is guaranteed to be free of local minima by construction. A construction of a candidate Multi-Agent Navigation Transformation is proposed. In addition to the theoretical guarantees, the effectiveness of the proposed methodology is demonstrated through non-trivial computer simulations utilizing the proposed construction.

Paper link[47]

D3 *An Automata-Theoretic Approach to the Vehicle Routing Problem*
Cristian Vasile (Boston University), Calin Belta (Boston University)

Abstract: We propose a new formulation and algorithms for the Vehicle Routing Problem (VRP). To accommodate persistent surveillance missions, which require executions in infinite time, we define Persistent VRP (P-VRP). The vehicles consume a resource, such as gas or battery charge, which can be replenished when they visit replenish stations. The mission specifications are given as rich, temporal logic statements about the sites, their service durations, and the time intervals in which services should be provided. We define a temporal logic, called Time-Window Temporal Logic (TWTL), whose formulae allow for simple, intuitive descriptions of such specifications. Two different optimization criteria are considered. The first is the infinite-time limit of the duration needed for the completion of a surveillance round. The second penalizes the long-term average of the same quantity. The proposed algorithms, which are based on concepts and tools from formal verification and optimization, generate collision-free motion plans automatically from the temporal logic statements and vehicle characteristics such as maximum operation time and minimum replenish time. Illustrative simulations and experimental trials for a team of quadrotors involved in persistent surveillance missions are included.

Paper link[48]

D4 *Effective Task Training Strategies for Instructional Robots*
Allison Sauppe (University of Wisconsin - Madison), Bilge Mutlu (University of Wisconsin - Madison)

Abstract: From teaching in labs to training for assembly, a key role that robots are expected to play is to instruct their users in completing physical tasks. While task instruction requires a wide range of capabilities, such as effective use of verbal and nonverbal language, a fundamental requirement for an instructional robot is to provide its students with task instructions in a way that maximizes their understanding of and performance in the task. In this paper, we present an autonomous instructional robot system and investigate how different instructional strategies affect user performance and experience. We collected data on human instructor-trainee interactions in a pipe-assembly task. Our analysis identified two key instructional strategies: (1) grouping instructions together and (2) summarizing the outcome of subsequent instructions. We implemented these strategies into a humanlike robot that autonomously instructed its users in the same pipe-assembly task. To achieve autonomous instruction, we also developed a repair mechanism that enabled the robot to correct mistakes and misunderstandings. An evaluation of the instructional strategies in a human-robot interaction study showed that employing the grouping strategy resulted in faster task completion and increased rapport with the robot, although it also increased the number of task breakdowns. Our model of instructional strategies and study findings offer strong implications for the design of instructional robots.

Paper link[49]

[46] http://www.roboticsproceedings.org/rss10/p43.html
[47] http://www.roboticsproceedings.org/rss10/p17.html
[48] http://www.roboticsproceedings.org/rss10/p45.html
[49] http://www.roboticsproceedings.org/rss10/p02.html

D5 *Learning to Locate from Demonstrated Searches*
Paul Vernaza (Carnegie Mellon University), Anthony Stentz (Carnegie Mellon University)

Abstract: We consider the problem of learning to locate targets from demonstrated searches. In this concept, a human demonstrates tours of environments that are assumed to minimize the human's expected time to locate the target, given the person's latent prior over potential target locations. The latent prior is then learned as a function of environmental features, enabling a robot to search novel environments in a way that would be deemed efficient by the teacher. We present novel approaches to solve both the inference problem of planning an expected- time-optimal tour given a prior and the learning problem of deducing the prior from observed tours. Our learning algorithm is inspired by and similar to maximum margin planning (MMP), although it differs in key ways. On the inference side, we advance the state-of-the-art by proposing a novel graph-based search method incorporating heuristics obtained via efficiently- solved relaxations of the problem. An application to a home assistant scenario is discussed, and experimental results are given validating our methods in this domain.

Paper link[50]

D6 *Modeling High-Dimensional Humans for Activity Anticipation using Gaussian Process Latent CRFs*
Yun Jiang (Cornell University), Ashutosh Saxena (Cornell University)

Abstract: For robots, the ability to model human configurations and temporal dynamics is crucial for the task of anticipating future human activities, yet requires conflicting properties: On one hand, we need a detailed high-dimensional description of human configurations to reason about the physical plausibility of the prediction; on the other hand, we need a compact representation to be able to parsimoniously model the relations between the human and the environment. We therefore propose a new model, GP-LCRF, which admits both the high-dimensional and low-dimensional representation of humans. It assumes that the high-dimensional representation is generated from a latent variable corresponding to its low-dimensional representation using a Gaussian process. The generative process not only defines the mapping function between the high- and low-dimensional spaces, but also models a distribution of humans embedded as a potential function in GP-LCRF along with other potentials to jointly model the rich context among humans, objects and the activity. Through extensive experiments on activity anticipation, we show that our GP-LCRF consistently outperforms the state-of-the-art results and reduces the predicted human trajectory error by 11.6%.

Paper link[51]

D7 *Manhattan and Piecewise-Planar Constraints for Dense Monocular Mapping*
Alejo Concha (University of Zaragoza), Wajahat Hussain (University of Zaragoza), Luis Montano (University of Zaragoza), Javier Civera (University of Zaragoza)

Abstract: Abstract—This paper presents a variational formulation for real-time dense 3D mapping from a RGB monocular sequence that incorporates Manhattan and piecewise-planar constraints in indoor and outdoor man-made scenes. The state-of-the-art variational approaches are based on the minimization of an energy functional composed of two terms, the first one accounting for the photometric compatibility in multiple views, and the second one favoring smooth solutions. We show that the addition of a third energy term modelling Manhattan and piecewise-planar structures greatly improves them accuracy of the dense visual maps, particularly for low-textured man-made environments where the data term can be ambiguous. We evaluate two different methods to provide such Manhattan and piecewise-planar constraints based on 1) multiview superpixel geometry and 2) multiview layout estimation and scene understanding. Our experiments include the largest map produced by variational methods from a RGB sequence and demonstrate a reduction in the median depth error up to a factor 5x.

Paper link[52]

D8 *Appearance-based Active, Monocular, Dense Reconstruction for Micro Aerial Vehicles*
Christian Forster (University of Zurich), Matia Pizzoli (University of Zurich), Davide Scaramuzza (University of Zurich)

Abstract: In this paper, we investigate the following problem: given the image of a scene, what is the trajectory that a robot-mounted camera should follow to allow optimal dense depth estimation? The solution we propose is based on maximizing the information gain over a set of candidate trajectories. In order to estimate the information that we expect from a camera pose, we introduce a novel formulation of the measurement uncertainty that accounts for the scene appearance (i.e., texture in the reference view), the scene depth and the vehicle pose. We successfully demonstrate our approach in the case of real-time, monocular reconstruction from a micro aerial vehicle and validate the effectiveness of our solution in both synthetic and real experiments. To the best of our knowledge, this is the first work on active, monocular dense reconstruction, which chooses motion trajectories that minimize perceptual ambiguities inferred by the texture in the scene.

Paper link[53]

[50] http://www.roboticsproceedings.org/rss10/p35.html
[51] http://www.roboticsproceedings.org/rss10/p15.html
[52] http://www.roboticsproceedings.org/rss10/p16.html
[53] http://www.roboticsproceedings.org/rss10/p29.html

E1 *Bio-Artificial Synergies for Grasp Posture Control of Supernumerary Robotic Fingers*
Faye Wu (MIT), Harry Asada (MIT)

Abstract: A new type of wrist-mounted robot, the Supernumerary Robotic (SR) Fingers, is proposed to work closely with the human hand and aid the human in performing a variety of prehensile tasks. For people with diminished functionality of their hands, these robotic fingers could provide the opportunity to live with more independence and work more productively. A natural and implicit coordination between the SR Fingers and the human fingers is required so the robot can be transformed to act as part of the human body. This paper presents a novel control algorithm, termed "Bio-Artificial Synergies", which enables the SR and human fingers to share the task load together and adapt to diverse task conditions. Through grasp experiments and data analysis, postural synergies were found for a seven-fingered hand comprised of two SR Fingers and five human fingers. The synergy-based control law was then extracted from the experimental data using Partial Least Squares (PLS) regression and tested on the SR Finger prototype as a proof of concept.

Paper link[54]

E2 *Six-Degrees-of-Freedom Remote Actuation of Magnetic Microrobots*
Eric Diller (University of Toronto), Joshua Giltinan (Carnegie Mellon University), Guo Zhan Lum (Carnegie Mellon University), Zhou Ye (Carnegie Mellon University), Metin Sitti (Carnegie Mellon University)

Abstract: Existing remotely-actuated microrobots powered by magnetic coils far from the workspace exhibit a maximum of only five-degrees-of-freedom (DOF) actuation, as a driving torque about the magnetization axis is not achievable. This lack of orientation control limit the effectiveness of existing microrobots for precision tasks of object manipulation and orientation for advanced medical, biological and micro-manufacturing applications. This paper presents a novel magnetic actuation method that allows these robots to achieve full six-DOF actuation by allowing for a non-uniform magnetization profile within the microrobot body. This non-uniform magnetization results in additional rigid-body torques to be induced from magnetic forces via a moment arm. A general analytical model presents the working principle for continuous and discrete magnetization profiles. Using this model, microrobot design guidelines are introduced which guarantee six-DOF actuation capability. Several discrete magnetization designs which possess reduced coupling between magnetic forces and induced rigid-body torques are also presented. A simple permanent-magnet decoupled prototype is fabricated and used to quantitatively demonstrate the accuracy of the analytical model in a constrained-DOF environment and qualitatively for free motion in a viscous liquid three-dimensional environment. Results show that desired forces and torques can be created with high precision and limited parasitic actuation, allowing for full six-DOF actuation using limited feedback control.

Paper link[55]

E3 *5-DOF Manipulation of an Untethered Magnetic Device in Fluid using a Single Permanent Magnet*
Arthur Mahoney (University of Utah), Abbott Jake (University of Utah)

Abstract: This paper presents a three degree-of-freedom (3-DOF) closed-loop position and 2-DOF open-loop orientation control method for an untethered mockup magnetic capsule endoscope in fluid with a single permanent magnet positioned by a commercial robotic manipulator and a 3-DOF capsule-position localization system. Using traditional methods known to roboticists, we study the kinematics of untethered magnetic manipulation using a single permanent magnet as the end-effector of a robot manipulator. We present a control method that maintains 5-DOF control of a magnetic capsule when the robot manipulator is not near a kinematic singularity, and seamlessly enables a capsule's position to be controlled when the manipulator nears a kinematic singularity by sacrificing control over the capsule's orientation. We demonstrate the method's robustness to a control rate of 25 Hz, reduced localization rates down to 30 Hz, and the presence of manipulator singularities. 5-DOF manipulation of an untethered device has been previously demonstrated by electromagnetic systems only. This work has applications for robotic capsule endoscopy of a fluid-distended stomach.

Paper link[56]

[54] http://www.roboticsproceedings.org/rss10/p27.html
[55] http://www.roboticsproceedings.org/rss10/p13.html
[56] http://www.roboticsproceedings.org/rss10/p37.html

E4 *Automatic Generation of Reduced CPG Control Networks for Locomotion of Arbitrary Modular Robot Structures*
Stephane Bonardi (Biorobotics Laboratory - EPFL), Massimo Vespignani (Biorobotics laboratory - EPFL), Rico Moeckel(Biorobotics laboratory - EPFL), Jesse Van den Kieboom (Biorobotics laboratory - EPFL), Soha Pouya (Biorobotics laboratory - EPFL), Alexander Sproewitz (Biorobotics laboratory - EPFL), Auke Ijspeert (Biorobotics laboratory - EPFL)

Abstract: The design of efficient locomotion controllers for arbitrary structures of reconfigurable modular robots is challenging because the morphology of the structure can change dynamically during the completion of a task. In this paper, we propose a new method to automatically generate reduced Central Pattern Generator (CPG) networks for locomotion control based on the detection of bio-inspired sub-structures, like body and limbs, and articulation joints inside the robotic structure. We demonstrate how that information, coupled with the potential symmetries in the structure, can be used to speed up the optimization of the gaits and investigate its impact on the solution quality (i.e. the velocity of the robotic structure and the potential internal collisions between robotic modules). We tested our approach on three simulated structures and observed that the reduced network topologies in the first iterations of the optimization process performed significantly better than the fully open ones.

Paper link[57]

E5 *Cogging Torque Ripple Minimization via Position Based Characterization*
Matthew Piccoli (University of Pennsylvania), Mark Yim (University of Pennsylvania)

Abstract: Smooth motion is critical to some robotic applications such as haptics or those requiring high precision force control. These systems are often direct-drive, so any torque ripple in the motor output must be minimal. Unfortunately, low inherent torque ripple motors are expensive. Low cost brushless DC motors are becoming more prevalent, especially from the hobby RC community. These motors often have the required high torque density; however, they also have significant torque ripple. This paper presents a system that is low cost using a method for anticogging - the compensation of cogging torque in low cost, high torque motors. While other methods exist to compensate for current-based torque ripple (mutual or reluctance torque), none have addressed cogging torque, except by adding expensive force sensors. This paper presents two methods that use a position sensor (already present for servo motors) to map cogging torque to rotor position. The map is played back according to position reported from the sensor to cancel the cogging torque. The design and testing of a low cost haptic arm using anticogging shows validation; however, the approach is much broader, and can be applied to any precision force application. Test results on eleven different motors show an average removal of 69% of torque ripple with no added cost in robotic servo applications.

Paper link[58]

F1 *A Novel Type of Compliant, Underactuated Robotic Hand for Dexterous Grasping*
Raphael Deimel (TU Berlin), Oliver Brock (TU Berlin)

Abstract: We built a highly compliant, underactuated, robust and at the same time dexterous anthropomorphic hand. We evaluate its dexterous grasping capabilities by implementing the comprehensive Feix taxonomy of human grasps and by assessing the dexterity of its opposable thumb using the Kapandji test. We also illustrate the hand's payload limits and demonstrate its grasping capabilities in real-world grasping experiments. To support our claim that compliant structures are beneficial for dexterous grasping, we compare the dimensionality of control necessary to implement the diverse grasp postures with the dimensionality of the grasp postures themselves. We find that actuation space is smaller than posture space and explain the difference with the mechanic interaction between hand and grasped object. Additional desirable properties are derived from using soft robotics technology: the hand is robust to impact and blunt collisions, inherently safe, and not affected by dirt, dust, or liquids. Furthermore, the hand is simple and inexpensive to manufacture.

Paper link[59]

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[59] http://www.roboticsproceedings.org/rss10/p18.html

F2 *Pre- and Post-Contact Policy Decomposition for Planar Contact Manipulation Under Uncertainty*

Michael Koval (Carnegie Mellon University), Nancy Pollard (Carnegie Mellon University), Siddhartha Srinivasa (Carnegie Mellon University)

Abstract: We consider the problem of using real-time feedback from contact sensors to create closed-loop pushing actions. To do so, we formulate the problem as a partially observable Markov decision process (POMDP) with a transition model based on a physics simulator and a reward function that drives the robot towards a successful grasp. We demonstrate that it is intractable to solve the full POMDP with traditional techniques and introduce a novel decomposition of the policy into pre- and post-contact stages to reduce the computational complexity. Our method uses an offline point-based solver on a variable-resolution discretization of the state space to solve for a post-contact policy as a pre-computation step. Then, at runtime, we use an A* search to compute a pre-contact trajectory. We prove that the value of the resulting policy is within a bound of the value of the optimal policy and give intuition about when it performs well. Additionally, we show the policy produced by our algorithm achieves a successful grasp more quickly and with higher probability than a baseline policy.

Paper link[60]

F3 *Modeling Robot Discrete Movements with State-varying Stiffness and Damping: A framework for integrated motion generation and impedance control*

Mohammad Khansari (EPFL), Klas Kronander (EPFL), Aude Billard (EPFL)

Abstract: Successful execution of many robotic tasks requires precise control of robot motion and its interaction with the environment. In robotics these two problems are mainly studied separately in the domain of robot motion generation and interaction control, respectively. Existing approaches rely on two control loops: a motion generator (planner) that provides a reference trajectory in the outer loop, and an active impedance controller that tracks the reference trajectory in the inner loop. Ensuring stability of the closed-loop system for this control architecture is non-trivial. In this paper, we propose a single-loop control architecture that performs motion generation and interaction control at once. We model robot discrete motions with a time-invariant dynamical system, which is expressed as a nonlinear combination of a set of linear spring-damper systems. This formulation represents the nominal motion and the impedance properties with a single set of parameters, simplifying stability analysis of the closed-loop system. We provide sufficient conditions to ensure global asymptotic stability of this system for movements in free-space, and its passivity during persistent contact with a passive environment. We validate our approach in simulation using the 7-DoF KUKA LWR-IV robot.

Paper link[61]

F4 *Robust Policies via Meshing for Metastable Rough Terrain Walking*

Cenk Oguz Saglam (UCSB), Katie Byl (UCSB)

Abstract: In this paper, we present and verify methods for developing robust, high-level policies for metastable (i.e., rarely falling) rough-terrain robot walking. We focus on simultaneously addressing the important, real-world challenges of (1) use of a tractable mesh, to avoid the curse of dimensionality and (2) maintaining near-optimal performance that is robust to uncertainties. Toward our first goal, we present an improved meshing technique, which captures the step-to-step dynamics of robot walking as a discrete-time Markov chain with a small number of points. We keep our methods and analysis generic, and illustrate robustness by quantifying the stability of resulting control policies derived through our methods. To demonstrate our approach, we focus on the challenge of optimally switching among a finite set of low-level controllers for underactuated, rough-terrain walking. Via appropriate meshing techniques, we see that even terrain-blind switching between multiple controllers increases the stability of the robot, while lookahead (terrain information) makes this improvement dramatic. We deal with both noise on the lookahead information and on the state of the robot. These two robustness requirements are essential for our methods to be applicable to real high-DOF robots, which is the primary motivation of the authors.

Paper link[62]

[60] `http://www.roboticsproceedings.org/rss10/p34.html`
[61] `http://www.roboticsproceedings.org/rss10/p22.html`
[62] `http://www.roboticsproceedings.org/rss10/p49.html`

F5 *Probably Approximately Correct MDP Learning and Control With Temporal Logic Constraints*
Jie Fu (University of Pennsylvania), Ufuk Topcu (University of Pennsylvania)

Abstract: We consider synthesis of controllers that maximize the probability of satisfying given temporal logic specifications in unknown, stochastic environments. We model the interaction between the system and its environment as a Markov decision process with initially unknown transition probabilities. The solution we develop builds on the so-called model-based probably approximately correct Markov decision process (PAC-MDP) method. The algorithm attains an ε-approximately optimal policy with probability $1-\delta$ using samples (i.e. observations), time and space that grow polynomially with the size of the MDP, the size of the automaton expressing the temporal logic specification, $1/\varepsilon$, $1/\delta$ and a finite time horizon. In this approach, the system maintains a model of the initially unknown MDP, and constructs a product MDP based on its learned model and the specification automaton that expresses the temporal logic constraints. During execution, the policy is iteratively updated using observation of the transitions taken by the system. The iteration terminates in finitely many execution steps. With high probability, the resulting policy is such that, for any state, the difference between the probability of satisfying the specification under this policy and the optimal one is within a predefined bound.

Paper link[63]

F6 *Self-Calibration and Visual SLAM with a Multi-Camera System on a Micro Aerial Vehicle*
Lionel Heng (ETH Zurich), Gim Hee Lee (ETH Zurich), Marc Pollefeys (ETH Zurich)

Abstract: The use of a multi-camera system enables a robot to obtain a surround view, and thus, maximize its perceptual awareness of its environment. An accurate calibration is a necessary prerequisite if vision-based simultaneous localization and mapping (vSLAM) is expected to provide reliable pose estimates for a micro aerial vehicle (MAV) with a multi-camera system. On our MAV, we set up each camera pair in a stereo configuration. We propose a novel vSLAM-based self-calibration method for a multi-sensor system that includes multiple calibrated stereo cameras and an inertial measurement unit (IMU). Our self-calibration estimates the transform with metric scale between each camera and the IMU. Once the MAV is calibrated, the MAV is able to estimate its global pose via a multi-camera vSLAM implementation based on the generalized camera model. We propose a novel minimal and linear 3-point algorithm that uses inertial information to recover the relative motion of the MAV with metric scale. Our constant-time vSLAM implementation with loop closures runs on-board the MAV in real-time. To the best of our knowledge, no published work has demonstrated real-time on-board vSLAM with loop closures. We show experimental results in both indoor and outdoor environments. The code for both the self-calibration and vSLAM is available as a set of ROS packages at `https://github.com/hengli/vmav-ros-pkg`.

Paper link[64]

F7 *Control of Robotic Mobility-On-Demand Systems: a Queueing-Theoretical Perspective*
Rick Zhang (Stanford University), Marco Pavone (Stanford University)

Abstract: In this paper we present and analyze a queueing-theoretical model for autonomous mobility-on-demand (MOD) systems where robotic, self-driving vehicles transport customers within an urban environment and rebalance themselves to ensure acceptable quality of service throughout the entire network. We cast an autonomous MOD system within a closed Jackson network model with passenger loss. It is shown that an optimal rebalancing algorithm minimizing the number of (autonomously) rebalancing vehicles and keeping vehicles availabilities balanced throughout the network can be found by solving a linear program. The theoretical insights are used to design a robust, real-time rebalancing algorithm, which is applied to a case study of New York City. The case study shows that the current taxi demand in Manhattan can be met with about 8,000 robotic vehicles (roughly 70% of the size of the current taxi fleet operating in Manhattan). Finally, we extend our queueing-theoretical setup to include congestion effects, and we study the impact of autonomously rebalancing vehicles on overall congestion. Collectively, this paper provides a rigorous approach to the problem of system-wide coordination of autonomously driving vehicles, and provides one of the first characterizations of the sustainability benefits of robotic transportation networks.

Paper link[65]

G1 *Multiscale Topological Trajectory Classification with Persistent Homology*
Florian Pokorny (KTH Royal Institute of Tech.), Majd Hawasly (University of Edinburgh), Subramanian Ramamoorthy (University of Edinburgh)

Abstract: Topological approaches to studying equivalence classes of trajectories in a configuration space have recently received attention in robotics since they allow a robot to reason about trajectories at a high level of abstraction. While recent work has approached the problem of topological motion planning under the assumption that the configuration space and obstacles within it are explicitly described in a noise-free manner, we focus on trajectory classification and present a sampling-based approach which can handle noise, which is applicable to general configuration spaces and which relies only on the availability of collision free samples. Unlike previous sampling-based approaches in robotics which use graphs to capture information about the path-connectedness of a configuration space, we construct a multiscale approximation of

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[64] `http://www.roboticsproceedings.org/rss10/p08.html`
[65] `http://www.roboticsproceedings.org/rss10/p26.html`

neighborhoods of the collision free configurations based on filtrations of simplicial complexes. Our approach thereby extracts additional homological information which is essential for a topological trajectory classification. By computing a basis for the first persistent homology groups, we obtain a multiscale classification algorithm for trajectories in configuration spaces of arbitrary dimension. We furthermore show how an augmented filtration of simplicial complexes based on a cost function can be defined to incorporate additional constraints. We present an evaluation of our approach in 2, 3, 4 and 6 dimensional configuration spaces in simulation and using a Baxter robot.

Paper link[66]

G2 *Asking for Help Using Inverse Semantics*
Stefanie Tellex (Brown), Ross Knepper (MIT), Adrian Li (University of Cambridge), Daniela Rus (MIT), Nicholas Roy (MIT)

Abstract: Robots inevitably fail, often without the ability to recover autonomously. We demonstrate an approach for enabling a robot to recover from failures by communicating its need for specific help to a human partner using natural language. Our approach automatically detects failures, then generates targeted spoken-language requests for help such as “Please give me the white table leg that is on the black table.” Once the human partner has repaired the failure condition, the system resumes full autonomy. We present a novel inverse semantics algorithm for generating effective help requests. In contrast to forward semantic models that interpret natural language in terms of robot actions and perception, our inverse semantics algorithm generates requests by emulating the human’s ability to interpret a request using the Generalized Grounding Graph framework. To assess the effectiveness of our approach, we present a corpus-based online evaluation, as well as an end-to-end user study, demonstrating that our approach increases the effectiveness of human interventions compared to static requests for help.

Paper link[67]

G3 *LOAM: Lidar Odometry and Mapping in Real-time*
Ji Zhang (Carnegie Mellon University), Sanjiv Singh (Carnegie Mellon University)

Abstract: We propose a real-time method for odometry and mapping using range measurements from a 2-axis lidar moving in 6-DOF. The problem is hard because the range measurements are received at different times, and errors in motion estimation can cause mis-registration of the resulting point cloud. To date, coherent 3D maps can be built by off-line batch methods, often using loop closure to correct for drift over time. Our method achieves both low-drift and low-computational complexity without the need for high accuracy ranging or inertial measurements. The key idea in obtaining this level of performance is the division of the complex problem of simultaneous localization and mapping, which seeks to optimize a large number of variables simultaneously, by two algorithms. One algorithm performs odometry at a high frequency but low fidelity to estimate velocity of the lidar. Another algorithm runs at a frequency of an order of magnitude lower for fine matching and registration of the point cloud. Combination of the two algorithms allows the method to map in real-time. The method has been evaluated by a large set of experiments as well as on the KITTI odometry benchmark. The results indicate that the method can achieve accuracy at the level of state of the art offline batch methods.

Paper link[68]

G4 *Combining the Benefits of Function Approximation and Trajectory Optimization*
Igor Mordatch (University of Washington), Emo Todorov (University Washington)

Abstract: Neural networks have recently solved many hard problems in Machine Learning, but their impact in control remains limited. Trajectory optimization has recently solved many hard problems in robotic control, but using it online remains challenging. Here we leverage the high-fidelity solutions obtained by trajectory optimization to speed up the training of neural network controllers. The two learning problems are coupled using the Alternating Direction Method of Multipliers (ADMM). This coupling enables the trajectory optimizer to act as a teacher, gradually guiding the network towards better solutions. We develop a new trajectory optimizer based on inverse contact dynamics, and provide not only the trajectories but also the feedback gains as training data to the network.

Paper link[69]

[66] `http://www.roboticsproceedings.org/rss10/p54.html`
[67] `http://www.roboticsproceedings.org/rss10/p24.html`
[68] `http://www.roboticsproceedings.org/rss10/p07.html`
[69] `http://www.roboticsproceedings.org/rss10/p52.html`

G5 *Enhanced 3D Kinematic Modeling of Wheeled Mobile Robots*
Neal Seegmiller (Carnegie Mellon University), Alonzo Kelly (Carnegie Mellon University)

Abstract: Most fielded wheeled mobile robots (WMRs) today use basic 2D kinematic motion models in their planning, control, and estimation systems. On uneven or low traction terrain, or during aggressive maneuvers, higher fidelity models are required which account for suspension articulations, wheel slip, and liftoff. In this paper we present a simple, algorithmic method to construct 3D kinematic models for any WMR configuration. We also present a novel enhancement to predict the effects of slip on body-level motion. Extensive experimental results are presented to validate our model formulation. We show odometry improvement by calibrating to data logs and modeling 3D articulations. We also show comparable predictive accuracy of our enhanced kinematic model to a full dynamic model, at much lower computational cost.

Paper link[70]

G6 *Tell Me Dave: Context-Sensitive Grounding of Natural Language to Manipulation Instructions*
Dipendra Kumar Misra (Cornell University), Jaeyong Sung (Cornell University), Kevin Lee (Cornell University), Ashutosh Saxena (Cornell University)

Abstract: We consider performing a sequence of mobile manipulation tasks with instructions given in natural language (NL). Given a new environment, even a simple task such as of boiling water would be performed quite differently depending on the presence, location and state of the objects. We start by collecting a dataset of task descriptions in free-form natural language and the corresponding grounded task-logs of the tasks performed in an online robot simulator. We then build a library of verb-environment- instructions that represents the possible instructions for each verb in that environment—these may or may not be valid for a different environment and task context. We present a model that takes into account the variations in natural language, and ambiguities in grounding them to robotic instructions with appropriate environment context and task constraints. Our model also handles incomplete or noisy NL instructions. Our model is based on an energy function that encodes such properties in a form isomorphic to a conditional random field. In evaluation, we show that our model produces sequences that perform the task successfully in a simulator and also significantly outperforms the state-of-the-art. We also verify by executing our output instruction sequences on a PR2 robot.

Paper link[71]

G7 *Nonlinear Graph Sparsification for SLAM*
Mladen Mazuran (University of Freiburg), Tipaldi Gian Diego (University of Freiburg), Spinello Luciano (University of Freiburg), Wolfram Burgard (University of Freiburg)

Abstract: In this paper we present a novel framework for nonlinear graph sparsification in the context of simultaneous localization and mapping. Our approach is formulated as a convex minimization problem, where we select the set of nonlinear measurements that best approximate the original distribution. In contrast to previous algorithms, our method does not require a global linearization point and can be used with any nonlinear measurement function. Experiments performed on several publicly available datasets demonstrate that our method outperforms the state of the art with respect to the Kullback-Leibler divergence and the sparsity of the solution.

Paper link[72]

G8 *Fully Decentralized Task Swaps with Optimized Local Searching*
Lantao Liu (Carnegie Mellon University), Nathan Michael (Carnegie Mellon University), Dylan Shell (Texas A&M University)

Abstract: Communication constraints dictated by hardware often require a multi-robot system to make decisions and take actions locally. Unfortunately, local knowledge may impose limits that run antithetical to global optimality in a decentralized optimization problem. This paper redesigns the task-swap mechanism recently introduced in an anytime assignment algorithm to tackle the problem of decentralized task allocation for large scale multi-robot systems. We propose a fully decentralized approach that allows local search processes to execute concurrently while minimizing interactions amongst the processes, needing neither global broadcast nor a multi-hop communication protocol. The formulation is analyzed in a novel way using tools from group theory and the optimization duality theory to show that the convergence of local searching processes is related to a shortest path routing problem on a graph subject to the network topology. Simulation results show that this fully decentralized method converges quickly while sacrificing little optimality.

Paper link[73]

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[71] http://www.roboticsproceedings.org/rss10/p05.html
[72] http://www.roboticsproceedings.org/rss10/p40.html
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H1 *Robot Programming by Demonstration with Interactive Action Visualizations*
Sonya Alexandrova (University of Washington), Maya Cakmak (University of Washington), Kaijen Hsiao (Bosch Research), Leila Takayama (Google[X])

Abstract: Existing approaches to Robot Programming by Demonstration (PbD) require multiple demonstrations to capture task information that lets robots generalize to unseen situations. However, providing these demonstrations is cumbersome for end-users. In addition, users who are not familiar with the system often fail to demonstrate sufficiently varied demonstrations. We propose an alternative PbD framework that involves demonstrating the task once and then providing additional task information explicitly, through interactions with a visualization of the action. We present a simple action representation that supports this framework and describe a system that implements the framework on a two-armed mobile manipulator. We demonstrate the power of this system by evaluating it on a diverse task benchmark that involves manipulation of everyday objects. We then demonstrate that the system is easy to learn and use for novice users through a user study in which participants program a subset of the benchmark. We characterize the limitations of our system in task generalization and end-user interactions and present extensions that could address some of the limitations.

Paper link[74]

H2 *An Online Sparsity-Cognizant Loop-Closure Algorithm for Visual Navigation*
Yasir Latif (Universidad de Zaragoza), Guoquan Huang (MIT), John Leonard (MIT), Jose Neira (University of Zaragosa)

Abstract: It is essential for a robot to be able to detect revisits or loop closures for long-term visual navigation. A key insight is that the loop-closing event inherently occurs sparsely, i.e., the image currently being taken matches with only a small subset (if any) of previous observations. Based on this observation, we formulate the problem of loop-closure detection as a sparse, convex l-1-minimization problem. By leveraging on fast convex optimization techniques, we are able to efficiently find loop closures, thus enabling real-time robot navigation. This novel formulation requires no offline dictionary learning, as required by most existing approaches, and thus allows online incremental operation. Our approach ensures a global, unique hypothesis by choosing only a single globally optimal match when making a loop-closure decision. Furthermore, the proposed formulation enjoys a flexible representation, with no restriction imposed on how images should be represented, while requiring only that the representations be close to each other when the corresponding images are visually similar. The proposed algorithm is validated extensively using public real-world datasets.

Paper link[75]

H3 *Scene Signatures: Localised and Point-less Features for Localisation*
Colin McManus (University of Oxford), Ben Upcroft (Queensland University of Technology), Paul Newmann (University of Oxford)

Abstract: This paper is about localising across extreme lighting and weather conditions. We depart from the traditional point-feature-based approach as matching under dramatic appearance changes is a brittle and hard thing. Point feature detectors are fixed and rigid procedures which pass over an image examining small, low-level structure such as corners or blobs. They apply the same criteria applied all images of all places. This paper takes a contrary view and asks what is possible if instead we learn a bespoke detector for every place. Our localisation task then turns into curating a large bank of spatially indexed detectors and we show that this yields vastly superior performance in terms of robustness in exchange for a reduced but tolerable metric precision. We present an unsupervised system that produces broad-region detectors for distinctive visual elements, called scene signatures, which can be associated across almost all appearance changes. We show, using 21km of data collected over a period of 3 months, that our system is capable of producing metric localisation estimates from night-to-day or summer-to-winter conditions.

Paper link[76]

[74] http://www.roboticsproceedings.org/rss10/p48.html
[75] http://www.roboticsproceedings.org/rss10/p36.html
[76] http://www.roboticsproceedings.org/rss10/p23.html

H4 *Active Reward Learning*

Christian Daniel (TU Darmstadt), Malte Viering (TU Darmstadt), Jan Metz (TU Darmstadt), Oliver Kroemer (TU Darmstadt), Jan Peters (TU Darmstadt)

Abstract: While reward functions are an essential component of many robot learning methods, defining such functions remains a hard problem in many practical applications. For tasks such as grasping, there are no reliable success measures available. Defining reward functions by hand requires extensive task knowledge and often leads to undesired emergent behavior. Instead, we propose to learn the reward function through active learning, querying human expert knowledge for a subset of the agent's rollouts. We introduce a framework, wherein a traditional learning algorithm interplays with the reward learning component, such that the evolution of the action learner guides the queries of the reward learner. We demonstrate results of our method on a robot grasping task and show that the learned reward function generalizes to a similar task.

Paper link[77]

H5 *Learning to Recognize Human Activities from Soft Labeled Data*

Ninghang Hu (University of Amsterdam), Zhongyu Lou (University of Amsterdam), Gwenn Englebienne (University of Amsterdam), Ben Krose (University of Amsterdam)

Abstract: An activity recognition system is a very important component for assistant robots, but training such a system usually requires a large and correctly labeled dataset. Most of the previous works only allow training data to have a single activity label per segment, which is overly restrictive because the labels are not always certain. It is, therefore, desirable to allow multiple labels for ambiguous segments. In this paper, we introduce the method of "soft labeling", which allows annotators to assign multiple, weighted, labels to data segments. This is useful in many situations, e.g. when the labels are uncertain, when part of the labels are missing, or when multiple annotators assign inconsistent labels. We treat the activity recognition task as a sequential labeling problem. Latent variables are embedded to exploit sub-level semantics for better estimation. We propose a novel method for learning model parameters from soft-labeled data in a max-margin framework. The model is evaluated on a challenging dataset (CAD-120), which is captured by a RGB-D sensor mounted on the robot. To simulate the uncertainty in data annotation, we randomly change the labels for transition segments. The results show significant improvement over the state-of-the-art approach.

Paper link[78]

H6 *Planning Single-arm Manipulations with n-Arm Robots*

Benjamin Cohen (University of Pennsylvania), Mike Phillips (Carnegie Mellon University), Maxim Likhachev (Carnegie Mellon University)

Abstract: Many robotic systems are comprised of two or more arms. Such systems range from dual-arm household manipulators to factory floors populated with a multitude of industrial robotic arms. While the use of multiple arms increases the productivity of the system and extends dramatically its workspace, it also introduces a number of challenges. One such challenge is planning the motion of the arm(s) required to relocate an object from one location to another. This problem is challenging because it requires reasoning over which arms and in which order should manipulate the object, finding a sequence of valid handoff locations between the consecutive arms and finally choosing the grasps that allow for successful handoffs. In this paper, we show how to exploit the characteristics of this problem in order to construct a planner that can solve it effectively without sacrificing guarantees on completeness. We analyze our approach experimentally on a number of simulated examples ranging from a 2-arm system operating at a table to a 3-arm system working at a bar and to a 4-arm system in a factory setting.

Paper link[79]

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H7 *Robust and Agile 3D Biped Walking with Steering Capability Using a Footstep Predictive Approach*
Salman Faraji (Biorobotics laboratory - EPFL), Soha Pouya (Biorobotics laboratory - EPFL), Auke Ijspeert (Biorobotics laboratory - EPFL)

Abstract: In this paper, we formulate a novel hierarchical controller for walking of torque controlled humanoid robots. Our method uses a whole body optimization approach which generates joint torques, given Cartesian accelerations of different points on the robot. Over such variable translation, we can plan our desired foot trajectories in Cartesian space between starting and ending positions of the foot on the ground. On top level, we use the simplified Linear Inverted Pendulum Model to predict the future motion of the robot. With LIPM, we derive a formulation where the whole system is described by the state of center of mass and footstep locations serve as discrete inputs to this linear system. We then use model predictive control to plan optimal future footsteps which resemble a reference plan, given desired sagittal and steering velocities determined by the high-end user. Using simulations on a kid-size torque controlled humanoid robot, the method tolerates various disturbances such as external pushes, sensor noises, model errors and delayed communication in the control loop. It can perform robust walking over slopes and uneven terrains blindly and turn rapidly at the same time. Our generic dynamics model-based method does not depend on any off-line optimization, being suitable for typical torque controlled humanoid robots.

Paper link[80]

I1 *Open-vocabulary Object Retrieval*
Sergio Guadarrama (University of California, Berkeley), Erik Rodner (International Computer Science Institute), Kate Saenko (University of Massachussetts, Lowell), Ning Zhang (University of California, Berkeley), Ryan Farrell (University of California, Berkeley), Jeff Donahue (University of California, Berkeley), Trevor Darrell (University of California, Berkeley)

Abstract: In this paper, we address the problem of retrieving objects based on open-vocabulary natural language queries: Given a phrase describing a specific object, e.g., "the corn flakes box", the task is to find the best match in a set of images containing candidate objects. When naming objects, humans tend to use natural language with rich semantics, including basic-level categories, fine-grained categories, and instance-level concepts such as brand names. Existing approaches to large-scale object recognition fail in this scenario, as they expect queries that map directly to a fixed set of pre-trained visual categories, e.g. ImageNet synset tags. We address this limitation by introducing a novel object retrieval method. Given a candidate object image, we first map it to a set of words that are likely to describe it, using several learned image-to-text projections. We also propose a method for handling open-vocabularies, i.e., words not contained in the training data. We then compare the natural language query to the sets of words predicted for each candidate and select the best match. Our method can combine category- and instance-level semantics in a common representation. We present extensive experimental results on several datasets using both instance-level and category-level matching and show that our approach can accurately retrieve objects based on extremely varied open-vocabulary queries. The source code of our approach will be publicly available together with pre-trained models at `http://openvoc.berkeleyvision.org` and could be directly used for robotics applications.

Paper link[81]

I2 *State Representation Learning in Robotics: Using Prior Knowledge about Physical Interaction*
Rico Jonschkowski (TU Berlin), Oliver Brock (TU Berlin)

Abstract: State representations critically affect the effectiveness of learning in robots. In this paper, we propose a robotics-specific approach to learning such state representations. Robots accomplish tasks by interacting with the physical world. Physics in turn imposes structure on both the changes in the world and on the way robots can effect these changes. Using prior knowledge about interacting with the physical world, robots can learn state representations that are consistent with physics. We identify five robotic priors and explain how they can be used for representation learning. We demonstrate the effectiveness of this approach in a simulated slot car racing task and a simulated navigation task with distracting moving objects. We show that our method extracts task-relevant state representations from high-dimensional observations, even in the presence of task-irrelevant distractions. We also show that the state representations learned by our method greatly improve generalization in reinforcement learning.

Paper link[82]

I3 *Conditioned Basis Array Factorization: An Approach to Gait Pattern Extraction*
Chaohui Gong (Carnegie Mellon University), Matthew Travers (Carnegie Mellon University), Henry Astley (Georgia Tech), Lu Li (Carnegie Mellon University), Joseph Mendelson (Zoo ATL), David Hu (Georgia Tech), Daniel Goldman (Georgia Tech), Howie Choset (Carnegie Mellon University)

Abstract: Snakes locomote through sophisticated coordinated motions of their many degrees of freedom (DoFs). The exhibited regularity of their body undulation implies the existence of low dimensional representations of snake gaits. We posit that investigating the underlying motion patterns will lead to insights for understanding how animals control low-level joint motions in a coupled fashion to achieve behavior-

[80] `http://www.roboticsproceedings.org/rss10/p28.html`
[81] `http://www.roboticsproceedings.org/rss10/p41.html`
[82] `http://www.roboticsproceedings.org/rss10/p19.html`

level control targets. To study snake motions in a concise way, we develop a novel modal decomposition algorithm called conditioned basis array factorization (CBAF). Unlike most modal decomposition algorithms, CBAF uses analytical bases which can be identified with temporal, spatial, and behavioral (e.g., moving in a straight line, turning, etc.) components of snake motions. Applying CBAF to shape change data collected from a series of snake behaviors results in analytical representations of the recorded motions. These analytical representations provide insight into biological system models, as well as generate families of gaits for snake robots. Although this work focuses on snakes, the generality of the analysis techniques suggest that a similar approach can be used as an effective motion generation technique for any system whose locomotion is kinematic in nature.

Paper link[83]

I4 *Online Trajectory Planning in Dynamic Environment for Surgical Task Automation*
Takayuki Osa (University of Tokyo), Naohiko Sugita (University of Tokyo), Mamoru Mitsuishi (University of Tokyo)

Abstract: Automation of robotic surgery has the potential to improve the performance of surgeons and the quality of the life of patients. However, the automation of surgical tasks has challenging problems that must be resolved. One such problem is the adaptive online trajectory planning based on the state of the surrounding dynamic environment. This study presents a framework for online trajectory planning in a dynamic environment for automatic assistance in robotic surgery. In the proposed system, a demonstration under various states of the environment is used for learning. The distribution of the demonstrated trajectory over the environmental conditions is modeled using a statistical model. The trajectory, under given environmental conditions, is computed as a conditional expectation using the learned model. Because of its low computational cost, the proposed scheme is able to generalize and plan a trajectory online in a dynamic environment. To design the motion of the system to track the planned trajectory in a stable and smooth manner, the concept of a sliding mode control was employed; its stability was proved theoretically. The proposed scheme was implemented on a robotic surgical system and the performance was verified through experiments and simulations. These experiments and simulations verified that the developed system successfully planned and updated the trajectories of the learned tasks in response to the changes in the dynamic environment.

Paper link[84]

I5 *Articulated Pose Estimation via Over-parametrization and Noise Projection*
Jonathan Brookshire (MIT), Seth Teller (MIT)

Abstract: We describe an algorithm to estimate the pose of a generic articulated object. Our algorithm takes as input a description of the object and a potentially incomplete series of observations; it outputs an on-line estimate of the object's configuration. This task is challenging because: (1) the distribution of object states is often multi-modal; (2) the object is not assumed to be under our control, limiting our ability to predict its motion; and (3) rotational joints make the state space highly non-linear. The proposed method represents three principal contributions to address these challenges. First, we use a particle filter implementation which is unique in that it does not require a reliable state transition model. Instead, the method relies primarily on observations during particle proposal, using the state transition model only at singularities. Second, our particle filter formulation explicitly handles missing observations via a novel proposal mechanism. Although existing particle filters can handle missing observations, they do so only by relying on good state transition models. Finally, our method evaluates noise in the observation space, rather than state space. This reduces the variability in performance due to choice of parametrization, and effectively handles non-linearities caused by rotational joints. We compare our method to a baseline implementation without these techniques and demonstrate, for a fixed error, more than an order-of-magnitude reduction in the number of required particles, an increase in the number of effective particles, and an increase in frame rate. Source code for the method is available at `http://rvsn.csail.mit.edu/articulated`.

Paper link[85]

I6 *DART: Dense Articulated Real-Time Tracking*
Tanner Schmidt (University of Washington), Richard Newcombe (University of Washington), Dieter Fox (University of Washington)

Abstract: This paper introduces DART, a general framework for tracking articulated objects composed of rigid bodies chained together through a kinematic chain. DART can track a broad set of objects encountered in indoor environments, including furniture, tools, human bodies, human hands, and robot manipulators. To achieve the efficiency required for robust tracking, DART extends the signed distance function representation to articulated objects and takes full advantage of highly parallelized GPU algorithms for data association and pose optimization. We demonstrate the capabilities of DART on different types of objects that each have required dedicated tracking techniques in the past (human hand, robot interacting with object).

Paper link[86]

[83] `http://www.roboticsproceedings.org/rss10/p55.html`
[84] `http://www.roboticsproceedings.org/rss10/p11.html`
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