# Changhyun Choi, Ph.D.

Postdoctoral Associate
Computer Science & Artificial Intelligence Lab (CSAIL)
Massachusetts Institute of Technology (MIT)
32 Vassar St, 32-379
Cambridge, MA 02139
USA

PHONE: +1-678-488-1023
EMAIL: cchoi@csail.mit.edu
URL: http://people.csail.mit.edu/cchoi

## Research Interests

Visual perception for robotic manipulation, with a focus on deep learning for object grasping, 3D object recognition and pose estimation, visual tracking, active perception, visual verification, and 3D registration.

## Current Position

2014-present **CSAIL, Massachusetts Institute of Technology**   Cambridge, MA, USA
*Postdoctoral Associate*
- Advisor: Prof. Daniela Rus
- Designing vision algorithms for soft manipulators
- Developing a novel visual verification approach for robotic assembly manipulation
- Advancing active sensor planning for multi-robot assembly

## Education

Aug. 2014   **PH.D. in Robotics**, College of Computing, Georgia Institute of Technology   Atlanta, GA, USA
- Dissertation: "Visual Object Perception in Unstructured Environments"
- Advisor: Prof. Henrik I. Christensen
- Thesis Committee: Prof. Dieter Fox, James M. Rehg, Irfan Essa, Anthony Yezzi
- GPA: 4.0/4.0

Feb. 2008   **B.S. in** Electrical and Computer Engineering, Sungkyunkwan University   Suwon, Korea
- Thesis: "Real-time 3D Object Pose Estimation and Tracking for Natural Landmark Based Visual Servo" (appeared in IROS'08)
- Advisor: Prof. Sukhan Lee
- GPA: 4.42/4.5 (*Summa cum Laude*)
- Computer science specialization with an emphasis on computer vision and robotics

## Honors & Awards

**2008-2013**  Graduate Study Abroad Scholarship, Korea Foundation for Advanced Studies (KFAS) Seoul, Korea
- Full financial support, including tuition and stipend, up to five years for Ph.D. study

**2008**  *Summa cum Laude*, with highest honor in engineering, Sungkyunkwan University  Suwon, Korea

**2002**  3rd Place in the Small League MiroSot, FIRA Robot Soccer World Championship  Seoul, Korea
- Played as a team representative and was in charge of computer vision and artificial intelligence

**2000-2007**  Merit-based Scholarship, Sungkyunkwan University  Suwon, Korea
- Tuition waiver award based on academic excellence for 7 semesters

## Research Experience

**2011-2014**  Robotics and Intelligent Machines (RIM), Georgia Institute of Technology  Atlanta, GA, USA
*Graduate Research Assistant*
- Advisor: Prof. Henrik I. Christensen
- Funding: Boeing Company
- Designed and implemented an object pose estimation using 3D point clouds for assembly robots

**May-Aug. 2012**  Google Summer of Code, Google  Mountain View, CA, USA[1]
*Student Developer*
- Organization: Point Cloud Library (PCL)
- Designed and implemented a 3D edge extraction algorithm which detects various types of edges from geometric structure and photometric textures of a given organized scene point cloud

**May-Aug. 2011**  Imaging Group, Mitsubishi Electric Research Labs (MERL)  Cambridge, MA, USA
*Research Intern*
- Advisor: Dr. Yuichi Taguchi and Dr. Oncel Tuzel
- Designed and implemented a voting-based pose estimation algorithm using a 3D depth sensor

**2009-2011**  Robotics and Intelligent Machines (RIM), Georgia Institute of Technology  Atlanta, GA, USA
*Graduate Research Assistant*
- Advisor: Prof. Henrik I. Christensen
- Funding: General Motors
- Designed and implemented a model-based visual object tracking for the collaborative research with General Motors – Interaction and Learning for Autonomous Assembly Robots

**Mar.-Jul. 2008**  Imaging Media Research Center, Korea Institute of Science and Technology (KIST)  Seoul, Korea
*Commissioned Research Scientist*
- Supervisor: Dr. Ig-jae Kim and Dr. Hyoung-gon Kim
- Developed a 3D reconstruction software using Internet photos based on Noah Snavely's work
- Developed an automatic geotagging software using Internet photos

**2007-2008**  Intelligent System Research Center, Sungkyunkwan University  Suwon, Korea
*Undergraduate Research Assistant*
- Designed and implemented a real-time 3D pose tracking method using KLT and SIFT keypoints
- Partially contributed to implementing an object recognition algorithm fusing multiple visual features in a particle filter

**Jun.-Aug. 2006**  Ubiquitous-VR Lab, Gwangju Institute of Science and Technology  Gwangju, Korea
*Intern Researcher*
- Developed a hand gesture recognition system using a 3D accelerometer
- Employed a support vector machine for gesture classification

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[1]The work had been done while I was staying in Atlanta, Georgia, USA.

# Publications

### Journal Articles

2016    **Changhyun Choi**, Henrik I. Christensen, "RGB-D Object Pose Estimation in Unstructured Environments," *Robotics and Autonomous Systems*, Jan. 2016.

2015    Mehmet Dogar, Ross A. Knepper, Andrew Spielberg, **Changhyun Choi**, Henrik I. Christensen, Daniela Rus, "Multi-Scale Assembly with Robot Teams," *International Journal of Robotics Research (IJRR)*, Jul. 2015.

2012    **Changhyun Choi**, Henrik I. Christensen, "Robust 3D visual tracking using particle filtering on the special Euclidean group: A combined approach of keypoint and edge features," *International Journal of Robotics Research (IJRR)*, vol. 31, no. 4, pp. 498-519, Apr. 2012.

### Refereed Conference Papers

2016    **Changhyun Choi**, Joseph DelPreto, Daniela Rus, "Using Vision for Pre- and Post-grasping Object Localization for Soft Hands," in *Proceedings of International Symposium on Experimental Robotics (ISER)*, Tokyo, Japan, 2016.

2016    **Changhyun Choi**, Daniela Rus, "Probabilistic Visual Verification for Robotic Assembly Manipulation," in *Proceedings of IEEE International Conference on Robotics and Automation (ICRA)*, Stockholm, Sweden, 2016.

2014    Mehmet Dogar, Ross A. Knepper, Andrew Spielberg, **Changhyun Choi**, Henrik I. Christensen, Daniela Rus, "Towards Coordinated Precision Assembly with Robot Teams," in *Proceedings of International Symposium on Experimental Robotics (ISER)*, Marrakech and Essaouira, Morocco, 2014.

2013    **Changhyun Choi**, Henrik I. Christensen, "RGB-D Object Tracking: A Particle Filter Approach on GPU," in *Proceedings of IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS)*, Tokyo Big Sight, Japan, 2013.

2013    **Changhyun Choi**, Alexander J. B. Trevor, Henrik I. Christensen, "RGB-D Edge Detection and Edge-based Registration," in *Proceedings of IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS)*, Tokyo Big Sight, Japan, 2013.

2012    **Changhyun Choi**, Henrik I. Christensen, "3D Pose Estimation of Daily Objects Using an RGB-D Camera," in *Proceedings of IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS)*, Vila Moura, Algarve, Portugal, 2012.

2012    **Changhyun Choi**, Henrik I. Christensen, "3D Textureless Object Detection and Tracking: An Edge-based Approach," in *Proceedings of IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS)*, Vila Moura, Algarve, Portugal, 2012.

2012    **Changhyun Choi**, Yuichi Taguchi, Oncel Tuzel, Ming-Yu Liu, and Srikumar Ramalingam, "Voting-Based Pose Estimation for Robotic Assembly Using a 3D Sensor," in *Proceedings of IEEE International Conference on Robotics and Automation (ICRA)*, St. Paul, MN, USA, 2012.

2011    **Changhyun Choi**, Henrik I. Christensen, "Robust 3D Visual Tracking Using Particle Filtering on the SE(3) Group," in *Proceedings of IEEE International Conference on Robotics and Automation (ICRA)*, Shanghai, China, 2011.

2010    **Changhyun Choi**, Henrik I. Christensen, "Real-time 3D Model-based Tracking Using Edge and Keypoint Features for Robotic Manipulation," in *Proceedings of IEEE International Conference on Robotics and Automation (ICRA)*, Anchorage, AK, USA, 2010.

2009    **Changhyun Choi**, Henrik I. Christensen, "Cognitive Vision for Efficient Scene Processing and Object Categorization in Highly Cluttered Environments," in *Proceedings of IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS)*, St. Louis, MO, USA, 2009.

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| 2008 | **Changhyun Choi**, Seung-Min Baek and Sukhan Lee, "Real-time 3D Object Pose Estimation and Tracking for Natural Landmark Based Visual Servo," in *Proceedings of IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS)*, Nice, France, 2008. |

## Under Review

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| submitted | **Changhyun Choi**, Wilko Schwarting, Joseph DelPreto, and Daniela Rus, "Object Grasping with Soft Hands: A 3D CNN Approach". |
| submitted | Guy Rosman, **Changhyun Choi**, Mehmet Dogar, John W. Fisher III, Daniela Rus, "Task-specific Sensor Planning for Robotic Assembly Tasks". |
| submitted | Liam Paull, Jacopo Tani, Heejin Ahn, Javier Alonso-Mora, Luca Carlone, Michal Cap, Yu Fan Chen, **Changhyun Choi**, Jeff Dusek, Yajun Fang, Daniel Hoehener, Shih-Yuan Liu, Michael Novitzky, Igor Franzoni, Okuyama, Jason Pazis, Guy Rosman, Valerio Varricchio, Hsueh-Cheng Wang, Dmitry Yershov, Hang Zhao, Michael Benjamin, Christopher Carr, Maria Zuber, Sertac Karaman, Emilio Frazzoli, Domitilla Del Vecchio, Daniela Rus, Jonathan How, John Leonard, Andrea Censi, "Duckietown: an Open, Inexpensive and Flexible Platform for Autonomy Education and Research". |

## Dissertation

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| 2014 | **Changhyun Choi**, "Visual Object Perception in Unstructured Environments," *Robotics Ph.D., School of Interactive Computing, College of Computing, Georgia Institute of Technology*, Dec. 2014. |

## Workshop Papers

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| 2016 | **Changhyun Choi**, Joseph DelPreto, Daniela Rus, "Using Vision for Pre- and Post-grasping Object Localization for Soft Hands," in *IROS workshop: Evaluation and Benchmarking of Underactuated and Soft Robotic Hands*, Daejeon, South Korea, 2016. |
| 2011 | Hye Yeon Nam, **Changhyun Choi**, and Sam Mendenhall, "Artistic Robot: Please smile," in *ICRA workshop: Robots and Art - Frontiers in Human-Centered Robotics as Seen by the Arts*, Shanghai, China, 2011. |
| 2009 | **Changhyun Choi**, Jacob Huckaby, John G. Rogers III, Alexander J. B. Trevor, James P. Case, and Henrik I. Christensen, "Towards Semantic Perception for Mobile Manipulation," in *IROS workshop: Semantic Perception for Mobile Manipulation*, St. Louis, MO, USA, 2009. |

## Patents

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| 2013 | Yuichi Taguchi, Oncel Tuzel, Srikumar Ramalingam, **Changhyun Choi**, Ming-Yu Liu, "Voting-Based Pose Estimation for 3D Sensors," US Patent, 20130156262, 2013. |

# Teaching Experience

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| Feb. - May 2016 | MIT 2.166 - Duckietown, Spring 2016 | Cambridge, MA, USA |
| | *Co-instructor* | |
| | - Co-designed the course materials for the graduate course focusing on self-driving vehicles and high-level autonomy. | |
| | - Taught computer vision for autonomous driving, such as camera model, projective geometry, camera calibration, and object recognition. | |

## Invited Talks

July 2014  GRASP Special Seminar, University of Pennsylvania      Philadelphia, PA, USA
- "Visual Object Perception in Unstructured Environments"

May 2014  School of Information & Communication Engineering, Sungkyunkwan University   Suwon, Korea
- "Visual Object Perception in Unstructured Environments"

Nov. 2013  School of Mechanical & Aerospace Engineering, Seoul National University      Seoul, Korea
- "Model-based Object Pose Estimation and Tracking using 2D and 3D Visual Information"

Oct. 2012  PCL (Point Cloud Library) Tutorial at IROS 2012      Vila Moura, Portugal
- "3D Edge Detection and Registration"

Aug. 2011  KORUS Summer School, Sungkyunkwan University      Suwon, Korea
- "Vision for Service Robots"

Oct. 2009  International Cognitive Vision Workshop at IROS 2009      St. Louis, MO, USA
- "Cognitive Vision for Efficient Scene Processing and Object Categorization in Highly Cluttered Environments"

## Professional Service

2015-present  Reviewer, IEEE Transactions on Robotics (T-RO)
2016-present  Reviewer, IEEE Robotics and Automation Letters (RA-L)
2014-present  Reviewer, International Journal of Robotics Research (IJRR)
2015-present  Reviewer, Robotics and Autonomous Systems
2013-2014  Reviewer, Image and Vision Computing Journal (IVC)
2012-present  Reviewer, IEEE International Conference on Robotics and Automation (ICRA)
2010-present  Reviewer, IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS)
2012  Tracking Chair, International Symposium on Mixed and Augmented Reality (ISMAR)

## Outreach

Apr. 2016  Robot Demo, Baxter with Soft Hands, 2016 MIT Open House      Cambridge, MA, USA

## References

Available upon request.