

Changhyun Choi, Ph.D.

Assistant Professor
Department of Electrical and Computer Engineering
University of Minnesota, Twin Cities
5-157 Keller Hall
200 Union St. SE
Minneapolis, MN 55455
USA

PHONE: +1-612-625-7870
EMAIL: cchoi@umn.edu
URL: <http://www.ece.umn.edu/~cchoi>

Research Interests

Visual perception for robotic manipulation, with a focus on deep learning for object grasping, assembly manipulation, soft manipulators, object pose estimation, visual tracking, and active perception.

Academic Positions

- | | | |
|--------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------|
| 2018-present | Electrical and Computer Eng., University of Minnesota, Twin Cities
<i>Assistant Professor</i>
- Graduate Faculty, Department of Computer Science and Engineering
- Affiliate, MnDRIVE Initiative: Robotics, Sensors and Advanced Manufacturing | Minneapolis, MN, USA |
| 2014-2017 | CSAIL, Massachusetts Institute of Technology
<i>Postdoctoral Associate & Research Scientist</i>
- Advisor: Prof. Daniela Rus
- Visual verification for robotic assembly manipulation
- Visual perception applied to soft robot hands toward flexible robotic assembly
- Object grasping combining 3D deep learning and soft robot hands | Cambridge, MA, USA |
| 2009-2014 | Institute of Robotics and Intelligent Machines (IRIM), Georgia Tech
<i>Graduate Research Assistant</i>
- Advisor: Prof. Henrik I. Christensen
- Model-based visual object tracking for collaborative research with General Motors
- Object pose estimation using 3D point clouds for Boeing assembly robots
- Real-time object pose tracking on GPU | Atlanta, GA, USA |

Education

- Dec 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

- 2018 Best Conference Paper Award (Finalist) & Best Paper Award in Robot Manipulation (Finalist), **IEEE International Conference on Robotics and Automation (ICRA)**
- 2017 Best Reviewer Award, **IEEE International Conference on Robotics and Automation (ICRA)**
- 2008-2013 Graduate Study Abroad Scholarship, **Korea Foundation for Advanced Studies (KFAS)**
- 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**
- 2002 3rd Place in the Small League MiroSot, **FIRA Robot Soccer World Championship**
- Played as a team representative and was in charge of computer vision and artificial intelligence
- 2000-2007 Merit-based Scholarship, **Sungkyunkwan University**
- Tuition waiver award based on academic excellence for 7 semesters

Research Experience

- May-Aug 2012 **Google Summer of Code, Google** Mountain View, CA, USA
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
- 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 fea-

tures in a particle filter

Jun-Aug 2006

Ubiquitous-VR Lab, Gwangju Institute of Science and Technology
Intern Researcher

Gwangju, Korea

- Developed a hand gesture recognition system using a 3D accelerometer
- Employed a support vector machine for gesture classification

Publications

JOURNAL ARTICLES

- 2020 Yang Yang, Hengyue Liang, and **Changhyun Choi**, “A Deep Learning Approach to Grasping the Invisible,” *IEEE Robotics and Automation Letters (RA-L)*, vol. 5, no. 2, pp. 2232–2239, Apr. 2020
- 2018 **Changhyun Choi**, Wilko Schwarting, Joseph DelPreto, and Daniela Rus, “Learning Object Grasping for Soft Robot Hands”, *IEEE Robotics and Automation Letters (RA-L)*, vol. 3, no. 3, pp. 2370-2377, Jul. 2018. **(ICRA Best Paper Award in Robot Manipulation (Finalist))**
- 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

- 2020 Xibai Lou, Yang Yang, and **Changhyun Choi**, “Learning to Generate 6-DoF Grasp Poses with Reachability Awareness”, *IEEE International Conference on Robotics and Automation (ICRA)*, Paris, France, 2020.
- 2020 Joseph DelPreto, Jeffrey Lipton, Lindsay Sanneman, Aidan Fay, Christopher K Fourie, **Changhyun Choi**, Daniela Rus, “Helping Robots Learn: A Human-Robot Master-Apprentice Model Using Demonstrations Via Virtual Reality Teleoperation”, *IEEE International Conference on Robotics and Automation (ICRA)*, Paris, France, 2020.
- 2018 Guy Rosman, **Changhyun Choi**, Mehmet Dogar, John W. Fisher III, Daniela Rus, “Task-specific Sensor Planning for Robotic Assembly Tasks”, *IEEE International Conference on Robotics and Automation (ICRA)*, Brisbane, Australia, 2018. **(ICRA Best Paper Award (Finalist))**
- 2017 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 Papis, 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”, *IEEE International Conference on Robotics and Automation (ICRA)*, Singapore, 2017.
- 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.
- 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.

DISSERTATION

- 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

- 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

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

Spring 19, 20 EE 2361 - Intro. to Microcontrollers, **University of Minnesota** Minneapolis, MN, USA
Instructor SRT: 5.58/6 (Spring 19)
- Taught computer organization, pipelining, instruction fetch/decode execution, opcodes, assembly language programming, arithmetic/logical operations, parallel/serial input/output, buffers, interrupts, using special purpose features, e.g., A/D converters.

Spring 18, Fall 19 EE 5940 - Robot Vision, **University of Minnesota** Minneapolis, MN, USA
Instructor SRT: 5.80/6 (Spring 18)
- Textbook: P. Corke, *Robotics, Vision and Control: Fundamental Algorithms In MATLAB*, Second Edition. New York, Springer, 2017.
- Taught computer vision fundamentals for robotics, vision-based control, convolutional neural network, and reinforcement learning.

Feb-May 2016 **MIT 2.166 - Duckietown, MIT**, 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

Mar 2017 **Faculty Candidate Talk, The Robotics Institute, Carnegie Mellon University** Pittsburgh, PA, USA
- "Soft Manipulation with Vision"

Mar 2017 Faculty Candidate Talk, **University of Minnesota** Minneapolis, MN, USA
- "Soft Manipulation with Vision"

Feb 2017 Faculty Candidate Talk, **Arizona State University** Mesa, AZ, USA
- "Soft Manipulation with Vision"

Feb 2017 Faculty Candidate Talk, **The Ohio State University** Columbus, OH, USA
- "Soft Manipulation with Vision"

Jul 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

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

University Service

2018-present Graduate Committee, Dept. of Electrical and Computer Eng. (ECE)
 2018-present MnDRIVE Vision Committee for establishing a new interdisciplinary Robotics MS Program at UMN

Student Supervision

2018-present Hengyue Liang, Ph.D. student in ECE
 2018-present Xibai Lou, Ph.D. student in ECE
 2019-present Yang Yang, Ph.D. student in CSE
 2020-present Alireza Rezazadeh, Ph.D. student in ECE
 2020-present Houjian Yu, Ph.D. student in ECE
 2019-present Abhinav Mehta, MS student in ECE
 2019-present Yuanhao Liu, MS student in ECE
 2019-present Nickhil Gupta, Undergraduate student in ECE
 - Independent Research (Sep 2019-present)
 2019-present Jeanine Thao, Undergraduate student in ECE
 - NorthStar STEM Alliance Summer Internship, Jun-Aug 2019
 - UROP (Jan-May 2020)
 2018-2019 Stephen Mylabathula, Undergraduate student in ECE (now at Facebook Oculus)
 - UROP (Sep-Dec 2018)
 - Senior Honors Thesis (Jan-May 2019): *Deep Learning Sensor Fusion for Human-Robot Collaboration*

Thesis Committee

ELECTRICAL & COMPUTER ENGINEERING, UNIVERSITY OF MINNESOTA TWIN CITIES

Jun 2020 Hengyue Liang, Ph.D. WPE¹ Prof. Changyun Choi
 - Title: *Reinforcement Learning Applications in Robotic Manipulations with Visual Perception*
 Apr 2020 Xibai Lou, Ph.D. WPE Prof. Changyun Choi
 - Title: *A Survey of Data-Driven Grasp Synthesis Methods*
 Sep 2019 Sayed Abdolrasoul Faraji, Ph.D. WPE Prof. Kia Bazargan
 - Title: *Stochastic Computing: From Concept to Application*

COMPUTER SCIENCE & ENGINEERING, UNIVERSITY OF MINNESOTA TWIN CITIES

Jun 2020 Pallavi Mitra, MS Defense Prof. Junaed Sattar
 - Title: *Monocular Depth Estimation using Adversarial Training*
 May 2020 Wenbo Dong, Ph.D. Thesis Defense Prof. Volkan Isler
 - Title: *A Robotic Vision Approach to Next-Generation Automated Precision Agriculture*

¹WPE: Written Preliminary Exam

Apr 2020	Dengyuan Wang, MS Defense - Title: <i>Haptic Feedback for Virtual Reality Applications With Redirected Walking</i>	Prof. Evan Rosenberg
Feb 2020	Yang Yang, Ph.D. OPE ² - Title: <i>A Deep Learning Approach to Grasping the Invisible</i>	Prof. Changhyun Choi
Mar 2019	Nicolai Haeni, Ph.D. OPE - Title: <i>A Comparative Study of Fruit Detection and Counting Methods for Yield Mapping in Apple Orchards</i>	Prof. Volkan Isler
Jan 2019	Jerald Thomas, Ph.D. OPE - Title: <i>A General Reactive Algorithm for Redirected Walking Using Artificial Potential Functions</i>	Prof. Evan Rosenberg
Dec 2018	Jiawei Mo, Ph.D. OPE - Title: <i>DSVO: Direct Stereo Visual Odometry</i>	Prof. Junaed Sattar
Nov 2018	Song Liu, Ph.D. OPE - Title: <i>SmartLight: Light-weight 3D Indoor Localization Using a Single LED Lamp</i>	Prof. Tian He
Aug 2018	Cheng Peng, Ph.D. OPE - Title: <i>View Selection for Aerial 3D Reconstruction</i>	Prof. Volkan Isler

Professional Service

2018-present	Associate Editor, IEEE Robotics and Automation Letters (RA-L)
2020-present	Associate Editor, IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS)
2018-2019	Associate Editor, IEEE International Conference on Soft Robotics (RoboSoft 2019)
2015, 2016	Reviewer, IEEE Transactions on Robotics (T-RO)
2016-present	Reviewer, IEEE Robotics and Automation Letters (RA-L)
2014, 2015	Reviewer, International Journal of Robotics Research (IJRR)
2015, 2016	Reviewer, Robotics and Autonomous Systems
2017	Reviewer, Computer Vision and Image Understanding
2013, 2014	Reviewer, Image and Vision Computing Journal (IVC)
2018-present	Reviewer, Conference on Robot Learning (CoRL)
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

Jun 2019	Robot Demo, Robotic Object Grasping Demo - Audience: NorthStar STEM Alliance Summer Intern Students	Minneapolis, MN, USA
Apr 2016	Robot Demo, Baxter with Soft Hands , 2016 MIT Open House - Audience: public and K-12 students (more than 40,000 attendees)	Cambridge, MA, USA
Apr 2013, Apr 2014	Robot Demo, National Robotics Week Open House, Georgia Tech - Audience: K-12 students (more than 100 attendees yearly)	Atlanta, GA, USA

²OPE: Oral Preliminary Exam

References

Available upon request.

Last updated • September 7, 2020

<http://www.ece.umn.edu/~cchoi>