

Inrak Choi

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Research Interests

I am interested in designing robotic systems that can physically help people in their daily lives. Past projects include physical user interfaces for VR/AR/Automotive applications, human augmentation with robotic systems, surgical robots, and bio-inspired robots. My research covers a wide range from design, modelling, and simulation of actuators of various driving principles to system-level robot design and evaluation. I often analyze human perception and existing systems in nature and apply the results to robot design.

keywords: human-computer interaction, haptics, robotics

Education

Ph.D. in Mechanical Engineering 2016 – 2019

Stanford University (Stanford, CA)

- Thesis: Handheld Haptic Feedback for Grasping in Virtual Reality
- Thesis Committee: Sean Follmer (advisor), Mark Cutkosky, Allison Okamura, Ken Salisbury
- Cumulative GPA: 3.96 / 4.0

M.S. in Mechanical Engineering 2013 - 2016

Stanford University (Stanford, CA)

- Concentration: Dynamics, Robotics, and Research (Haptics)

B.S. in Mechanical Engineering 2009 - 2013

Korea University (Seoul, Korea)

- Cumulative GPA: 3.88 / 4.0

Employment

Postdoctoral Research Fellow - Mandatory Military Service Nov 2019 - present

Seoul National University Soft Robotics & Bionics Lab (Seoul, Korea)

Advised by Yong-Lae Park, Ph.D.

- This three-year research position replaces actual mandatory military service in South Korea. While much focused on haptics in the PhD years, I developed various actuation and sensing mechanisms that can be widely applied to robots/devices.
- Designed pneumatic jamming-based cellular composites having exceptional strength/stiffness densities for selectively stiffening garments.
- Designed a submillimetre-thick linear three-phase electrostatic actuator package with a hybrid configuration with an electrostatic clutch. The actuator is also capable of noise-free high-resolution position sensing and proprioceptive force sensing utilizing the Moiré effect.
- Developed a robotic tadpole capable of agile escape maneuvers using an inertia-driven actuation.

Graduate Research Assistant

June 2015 – Sep 2019

Stanford University SHAPE Lab (Stanford, CA)

Advised by Sean Follmer, Ph.D.

- Developed handheld/wearable haptic interfaces using various novel kinesthetic and vibrotactile feedback mechanisms and investigated additional pseudo haptic effects through user studies for more realistic VR/AR interaction. Won several awards in top HCI conferences and filed six patents.
- Investigated passive & energy-dissipative mechanisms, such as jamming, braking, and clutching, for lightweight and power-efficient wearable haptic interfaces.
- Led multidisciplinary team collaboration with researchers at MIT Media Lab, Facebook Reality Labs, and Google Research, and Hyundai Motor Company.

Research Intern

Summer 2017

Microsoft Research (Redmond, WA)

- Mentor: Mike Sinclair, Hrvoje Benko, Ph.D., Eyal Ofek, Ph.D., Christian Holz, Ph.D.
- Developed a multifunctional VR haptic controller, CLAW, and quantitatively validated the effectiveness of the device in VR scenarios through human-subject studies. The work has been published to a top HCI conference, CHI, and patented.

Research Intern

Summer 2015

Hansen Medical, Inc. (Mountain View, CA)

Advised by June Park, Ph.D.

- Devised new active guidewire manipulation mechanisms for the Sensei robotic catheter system.
- Wrote two invention disclosures in three months then applied for a patent.

Graduate Research Assistant

Jan 2014 – May 2015

Stanford University Artificial Intelligence Laboratory (Stanford, CA)

Advised by Oussama Khatib, Ph.D.

- Human-friendly robot project. Designed and assembled a wrist and a gripper.
- Implemented macro-mini force control with the hybrid actuation system of pneumatic artificial muscles and electrical dc motors.

Honors and Awards

Best Paper Award. UIST 2017. 2017

Best Paper Award. UIST 2016. 2016

Best Demo Award. UIST 2016. 2016

Distinguished Paper Award. IMWUT 2018 Vol. 2. 2018

Honorable Mention. Fast Company Innovation by Design Awards. 2017

Young Engineers Honor Society. The National Academy of Engineering of Korea. 2011-present

Great Honor Student for Academic Achievement. Korea University. 2009-2013

Presidential Science Scholarship. Korea 2009-2013

Publications

Google Scholar: https://scholar.google.com/citations?user=zHH_LwkAAAAJ&hl=ko&oi=ao

Journal Articles

- [J.1] **I. Choi**, S. Chang, J. Cho, H. Yoo, T. Kim, S. Kim, K. Kim, S. Ahn, K.J. Cho, Y.-L. Park. Proprioception in Soft Actuators: A Review. *(In preparation for IEEE Sensors Journal)*
- [J.2] **I. Choi***, J. Choi*, S. J. Yoon, Y.-L. Park. Agile Maneuvers with a Robotic Tadpole. *(In preparation for Science Robotics)*
* equally contributed.
- [J.3] G. Shin, Y. Choi, B. Jeon, **I. Choi**, Y.-L. Park. Bi-stable Electromagnetic Soft Actuators (BELSA) Using a High Density Multi-Layered Liquid Metal Coil for Robotic Applications. *(Written for Science Robotics)*
- [J.4] **I. Choi***, S. J. Yoon*, Y.-L. Park. Linear Synchronous Electrostatic Actuator with Moiré-Effect Optical Sensing and Braking Mode. *(Written for IEEE Transactions on Robotics)*
* equally contributed.
- [J.5] B. Do, **I. Choi**, and S. Follmer. An All-Soft Variable Impedance Actuator Enabled by Embedded Layer Jamming. *IEEE/ASME Transactions on Mechatronics. (Minor revision)*
- [J.6] **I. Choi***, J. Kwon*, M. Park, J. Moon, B. Jeong, P. Pathak, J. Ahn, and Y.-L. Park. Sandwich Jamming Structures with Cellular Cores and Rubber-Laminated Face Sheets for Assistive and Protective Wearables. *Advanced Materials Technologies*. 2022.
* equally contributed.
- [J.7] **I. Choi**, E. J. Gonzalez, and S. Follmer. Hybrid Actuation with Unidirectional Clutches for Handheld Haptic Controllers. *IEEE Robotics and Automation Letters*, 2021.
- [J.8] **I. Choi**, Y. Zhao, E. J. Gonzalez, and S. Follmer. Augmenting Perceived Softness of Haptic Proxy Objects through Transient Vibration and Visuo-Haptic Illusion in Virtual Reality. *IEEE Transactions on Visualization and Computer Graphics*, 2020.
- [J.9] A. Dementyev, J. Hernandez, **I. Choi**, S. Follmer, and J. Paradiso. 2018. Epidermal Robots: Wearable Sensors That Climb on the Skin. *Proc. ACM Interact. Mob. Wearable Ubiquitous Technol.* 2.3: 1-22, 2018. **Distinguished Paper Award (Top 4%)**
- [J.10] **I. Choi**, N. Corson, L. Peiros, E. W. Hawkes, S. Keller, and S. Follmer. A Soft, Controllable, High Force Density Linear Brake Utilizing Layer Jamming. *IEEE Robotics and Automation Letters*, 2018.

Refereed Conference Articles

**Top conferences in the research area of Human Computer Interaction. Papers in these conferences have an acceptance rate of 15-25%, refereed by 4-5 experts.*

- [C.1] **I. Choi**, E. Ofek, H. Benko, M. Sinclair, and C. Holz. CLAW: A Multifunctional Handheld Haptic Controller for Grasping, Touching, and Triggering in Virtual Reality. In Proceedings of the 2018 CHI Conference on Human Factors in Computing Systems, Montreal, QC, Canada, 2018.
*
- [C.2] **I. Choi**, H. Culbertson, M. R. Miller, A. Olwal, and S. Follmer. Grability: A Wearable Haptic Interface for Simulating Weight and Grasping in Virtual Reality. In Proceedings of the 30th Annual ACM Symposium on User Interface Software & Technology, 2017. **Best Paper Award (Top 1%)**
- [C.3] H.-L. C. Kao, D. Ajilo, O. Anilionyte, A. Dementyev, **I. Choi**, S. Follmer, and C. Schmandt. Exploring interactions and perceptions of kinetic wearables. In Proceedings of the 2017 Conference on Designing Interactive Systems, 2017.
- [C.4] A. Dementyev, H.-L. C. Kao, **I. Choi**, D. Ajilo, M. Xu, J. A. Paradiso, C. Schmandt, and S. Follmer. Rovables: Miniature On-Body Robots as Mobile Wearables. In Proceedings of the 29th Annual ACM Symposium on User Interface Software & Technology, 2016. **Best Paper Award (Top 1%)**
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- [C.5] **I. Choi**, E. W. Hawkes, D. L. Christensen, C. J. Ploch, and S. Follmer. Wolverine: A Wearable Haptic Interface for Grasping in Virtual Reality. In Proceedings of the 2016 IEEE/RSJ International Conference on Intelligent Robots and Systems, 2016.

Demos & Posters

- [D.1] **I. Choi**, E. Ofek, H. Benko, M. Sinclair, and C. Holz. Demonstration of CLAW: A Multifunctional Handheld VR Haptic Controller. In Adjunct proceedings of the 2018 CHI Conference on Human Factors in Computing Systems, Montreal, QC, Canada, 2018.
- [D.2] M. Sinclair, E. Ofek, C. Holz, **I. Choi**, E. Whitmire, E. Strasnick, H. Benko. Three Haptic Shape-Feedback Controllers for Virtual Reality. IEEE Virtual Reality, 2018
- [D.3] A. Dementyev, J. Hernandez, S. Follmer, **I. Choi**, and J. Paradiso. SkinBot: A Wearable Skin Climbing Robot. In Adjunct proceedings of the 30th Annual ACM Symposium on User Interface Software & Technology, 2017.
- [D.4] **I. Choi** and S. Follmer. Wolverine, ACM Interactions, Demo Hour, Jan/Feb 2017.
- [D.5] **I. Choi** and S. Follmer. Wolverine: A Wearable Haptic Interface for Grasping in Virtual Reality. In Adjunct proceedings of the 29th Annual ACM Symposium on User Interface Software & Technology (UIST 2016) **Best Demo Award (Top 3)**

Patents

- [P.1] **I. Choi**, J. Park, and A. Kokish, "Active Drive for Guidewire Manipulation," 2022. (U.S. Patent: 11,241,559)
- [P.2] B. H. Do, **I. Choi**, S. Follmer, "Soft Variable Impedance Actuator Using Embedded Jamming Layer," 2022. (U.S. Appl. No.: 63/310642)

- [P.3] S. Lee, S. Follmer, and **I. Choi**, "Vehicle and Method of Controlling the same," 2022. (U.S. Appl. No.: 16/991,559)
- [P.4] S. Lee, S. Follmer, and **I. Choi**, "Input Device and Vehicle Including the same, and Method of Controlling Input Device," 2022. (U.S. Appl. No.: 16/991,539)
- [P.5] C. Holz, E. Ofek, M. J. Sinclair, H. Benko, **I. Choi**, and E. Whitmire, "Controller with haptic feedback," 2020. (U.S. Patent: 10,617,942)
- [P.6] **I. Choi**, H. Culbertson, and S. Follmer, "Gravity: A Wearable Haptic Interface for Simulating Weight and Grasping in Virtual Reality," 2020. (U.S. Patent: 10,852,872)
- [P.7] E. W. Hawkes, **I. Choi**, and S. Follmer, "Wolverine: A Wearable Haptic Interface for Grasping in Virtual Reality," 2019. (U.S. Patent: 10,248,201)
- [P.8] **I. Choi**, "A Device for Removing the Snow of Vinyl House," 2008. (Korea Utility Model Appl. No. 20-2008-0000167)

Teaching Experience

<p>Dynamic Systems, Vibrations and Control (ME 161/261) Stanford University (Stanford, CA) Course Assistant with instructor Paul Mitiguy, Ph.D.</p>	<p>2014, 2015, and 2016</p>
<p>Advanced Dynamics & Computation (ME 331A) Stanford University (Stanford, CA) Course Assistant with instructor Paul Mitiguy, Ph.D.</p>	<p>2014 and 2015</p>
<p>Advanced Dynamics, Simulation & Control (ME 331B) Stanford University (Stanford, CA) Course Assistant with instructor Paul Mitiguy, Ph.D.</p>	<p>2014 and 2015</p>
<p>Experimental Robotics (CS 225A) Stanford University (Stanford, CA) Course Assistant with instructor Oussama Khatib, Ph.D.</p>	<p>2015</p>
<p>Introduction to Robotics (CS 223A) Stanford University (Stanford, CA) Course Assistant with instructor Oussama Khatib, Ph.D.</p>	<p>2015</p>

Academic Service

Reviewer

More than 40 papers in HCI / VR / Haptics / Robotics such as ToH, SoRo, TMECH, Actuators, IEEE VR, UIST, CHI, ICRA, IROS, RA-L, IJHCI, Haptics Symposium, Eurohaptics, TOMM, BioRob, ISMAR, IMWUT.

Selected Media Coverage

BBC Click "Robot seeks out skin cancer with suction" October 15, 2018

Digital Trends "MIT's Creepy-crawly Robot can Help Monitor Your Health" October 1, 2018

New Scientist " This robot crawls over your body and scans your skin with a microscope" September 28, 2018

Gizmodo "Microsoft Wants You to Touch the VR World With a Giant CLAW." March 12, 2018

The Register "Microsoft floats feelers for fake worlds." March 8, 2018

Engadget "Microsoft's mad scientists are making AR more tactile." March 12, 2018

Co.Design Fast Company "Crazy Microsoft Is The Best Microsoft." March 9, 2018

Road to VR "Microsoft Shows New Research in Haptics With 'CLAW' VR Controller Prototype." March 13, 2018

Recode "These tiny, wearable robots can cling to your clothes and drive around your body." October 19, 2016

The Verge "These robots will crawl over your clothes for some reason." October 21, 2016

Engadget "Tiny body-roaming robots could be the future of wearables." October 19, 2016

Digital Trends "Get a grip, bub: Wolverine haptic device lets you grasp objects in VR." October 27, 2016

Futurism "Meet Wolverine, the Tech That Lets You Grab Objects in Virtual Reality." October 26, 2016

Motherboard "Haptic Feedback Prototype Lets You Grasp Objects in VR" October 23, 2016

IEEE Spectrum "Video Friday: Robot Toes, Wolverine Haptic Hand, and More From IROS 2016" October 21, 2016

Skills

- **Hardware design** rapid prototyping, CAD (mainly SolidWorks), machining, system-level design of haptic interfaces and robotic systems
- **Simulation** COMSOL, MATLAB, LTspice, non-linear pneumatic actuators, electromagnetic actuators, multi-layer composites, non-linear dynamic systems including friction and damping, analog circuits
- **Theoretical modelling** pneumatic, electrostatic, and electromagnetic actuators made of soft/flexible materials, kinematics and dynamics of multi-linkage robotic systems.
- **Mechatronics** circuits, PCB (mainly Altium), closed-loop control, actuators and sensors
- **User study** quantitative & qualitative study design, statistical analysis (R, SPSS)
- **Programming** C++, MATLAB
- **Spoken languages** Korean - native, English – Fluent