Sanghyun Kim

Current Affiliation

Senior Researcher, Dept. of AI Machinery, **2020.10 - Presence**
AI Robot Research Devision,
Korea Institute of Machinery & Materials (KIMM)

Contact Information

Address: 45 Oncheon-ro, Yuseong-gu, Daejeon, Republic of Korea (34186)
E-mail: kim87@kimm.re.kr
Phone: +82-10-9203-4998
WWW: http://ggory15.github.io *(for my projects)*, http://github.com/ggory15 *(for source codes)*

Education

Seoul National University, Seoul, Korea **2012.3 - 2020.2**
Ph.D. of Dept of Trandisciplinary Studies
- Lab: Dynamic Robotic System Lab (DYROS Lab, https://dyros.snu.ac.kr)
- Advisor: Professor Jaeheung Park (park73@snu.ac.kr)
- Thesis: Continuous Task Transition Approach Based on Hierarchical Quadratic Programming for Flexible Prioritization of Robots

Seoul National University, Seoul, Korea **2005.3 - 2012.2**
B.A., Mechanical Engineering, March, 2012

Research Experience

University of Edinburgh, United Kingdom **2020.4 - 2020.9**
Research Associate (Post-doctoral Researcher)
- Lab: Statistical Machine Learning and Motor Control Group (http://web.inf.ed.ac.uk/slmc)
- Advisor: Prof. Sethu Vijayakumar (sethu.vijayakumar@ed.ac.uk)

Centre National de la Recherche Scientifique (CNRS), France **2018.8 - 2019.6**
Visiting Researcher
- Lab: Gepetto Team (http://projects.laas.fr/gepetto)
- Advisor: Dr. Nicolas Mansard (nmansard@laas.fr)
- Funding: Korean government grant

Gwangju Institute of Science and Technology (GIST), Korea **2010.6 - 2010.9**
Student Internship
- Lab: Haptic Team (http://dyconlab.gist.ac.kr)
- Advisor: Prof. Jeha Ryu (ryu@gist.ac.kr)

Research Interests

Hierarchical whole-body control of bipedal robot and mobile-based humanoid
Task and contact transition algorithm for hierarchical controller
Torque-based task space control
Whole-body planning for high redundant robot
Dexterous robot hand control
Manipulation of redundant robotic system

Research Experience

During senior researcher in KIMM

Development of Dismantling Work Technology for Recycling of Variety EV Battery Packs with Human-robot Cooperation **2022 - Presence**
- PI (1,000,000kWon for 5 years, funded by the Ministry of Trade, Industry & Energy (MOTIE, Korea))

Development of Unstaffed Robotic Cafe Solution **2022 - Presence**

- PI (230,000kWon for 2 years, funded by Small and Medium Business Administration, Korea)

Loco-manipulation with Spot-Kinova **2022 - 2022**

- (Ongoing Work) Cooperation Control with Human-Robot and Robot-Robot.
- Implementation of whole-body controller based on *HQP Algorithm*.
  - ✓ Video: https://www.youtube.com/watch?v=6GXwmtdNnLM

Cooperation Control with Mobile Manipulator **2020 - Presence**

- (Ongoing Work) Cooperation Control with Human-Robot and Robot-Robot.
- Implementation of whole-body controller based on *HQP Algorithm*.
  - ✓ Video: https://www.youtube.com/watch?v=6GXwmtdNnLM

During research associate in SLMC Group, University of Edinburgh, United Kingdom

Horizon Planning for Humanoid **2020 - Presence**

- (Ongoing Work) Generating CoM trajectory and whole-body trajectory for uneven terrain [C9, C10].
- Implementation of CoM trajectory generator based on *Receding Horizon Planning*.
  - ✓ Video: https://www.youtube.com/watch?v=csG2uO_foSY
  - ✓ Video: https://www.youtube.com/watch?v=oCsOBHHc9XM

During visiting researcher in Gepetto Team, LAAS-CNRS, France

Whole-body Planning for Humanoid **2018 - 2019**

- (Ongoing Work) Generating contact sequence, CoM trajectory, feet trajectories, and whole-body trajectory for legged robots [C9].
  - ✓ Video: https://youtu.be/JpwigzMQg6E
- Implementation of CoM trajectory generator based on *Time Optimization*.
- Implementation of feet trajectories using the concept of hyper-plane.
- Implementation of Quadratic Programming (QP)-based whole-body planner in C++ and Python:
  - ✓ Video: https://youtu.be/nHiLV89cMG8
  - ✓ Codes: https://github.com/ggory15/tsid_python_binding

Model Predictive Control for Humanoid **2018 - Presence**

- (Ongoing Work) Developing whole-body controller using Differential Dynamic Programming (DDP).
- (Ongoing Work) Implementation of DDP-based controller with the collision avoidance constraint.
  - ✓ (Preliminary) Video : https://youtu.be/rq3dXdt8t0E

During Ph.D. student

Multiple Task Execution Algorithm **2017 - 2020**

- Dynamic task transition algorithm to generate complex behavior.
- Continuous transitions between arbitrary tasks using the activation parameter [J5].
  - ✓ Insertion and removal both equality and inequality tasks without discontinuity of the control input.
  - ✓ Development of avoidance tasks including joint-limit, singularity, and obstacle.
  - ✓ Video : https://youtu.be/-lfnLhmSk3M
  - ✓ Codes: https://ggory15.github.io/tasktransition-project
- (Ongoing Work) Applying the task transition method to operate mobile-based humanoid
  - ✓ Development controller for archiving complex tasks [C8]
  - ✓ Self-collision avoidance algorithm using the concept of attractive force [O1]
  - ✓ Video : https://youtu.be/K8RnMAA0rg4
- (Ongoing Work) Multi-contact transition for humanoids using Gravito-Inertial Wrench Cone (GIWC)

Whole-body Control of Torque-controlled Humanoids **2014 - Presence**

- Design and development of torque-controlled humanoid, DYROS-Red [C2].
  - ✓ EtherCAT and RTX programming for real-time control
  - ✓ High-level controller: Whole-body controller
  - ✓ Low-level controller: Elmo motion controller
  - ✓ Video : https://youtu.be/01E-rKixNfE
- Implementation of whole-body controllers for torque-controlled humanoids.
  - ✓ Using operational-space controller [C2]
  - ✓ Using hierarchical QP-based controller [J4, J6]
  - ✓ Using DDP-based controller
- (Ongoing Work) Development contact force generator with multi-constraints for dynamic balance.

Control of Position-controlled Humanoids **2014 - 2018**

- Design and development of position-controlled humanoid, DYROS-Jet [J2, J4].
  - ✓ RS-232 communication with 200 Hz
  - ✓ High-level controller: Jacobian-based controller
  - ✓ Low-level controller: Robotis controller
  - ✓ Video : https://youtu.be/9UwJQREUjtc
- Implementation of inverse kinematics controllers for position-controlled humanoids
  - ✓ using Jacobian-based inverse kinematics controller [J2, J4, C3, W2]
  - ✓ using Forward And Backward Reaching Inverse Kinematics (FABRIK) [C7]
  - ✓ using Recursive Neural Network (RNN) [C5]
- Disturbance observer to enhance balancing performance [C6]
  - ✓ Feed-forward joint disturbance observer for compliant motion
  - ✓ Video: https://youtu.be/LHGxx0M9ijs

Singularity avoidance algorithm **2016 - 2017**

- Comparative analysis of six representative singularity avoidance algorithms: Damped Pseudo Inverse, Error Damped Pseudo Inverse, Jacobian Transpose, Selectively Damped Inverse, Filtered Inverse, and Task Transition Method

Development of humanoid system for DRC Finals 2015 **2014 - 2016**

- Student leader of Team SNU
  - ✓ Managing the whole framework of robot
  - ✓ Developing the upper-body and lower-body position controller
- No falling down during the competitions and 12th in DRC Finals 2015 [J2, J4, C3, W2]
  - ✓ Video: https://youtu.be/aWpyfKkbzf0

Artificial intelligence robot CPR system **2014 - 2016**

- Robot manipulator to perform CPR in emergency situations [P2, J3]
- Automatic System based biological data from a patient
- Simulation on mannequin and animal test
  - ✓ Video: https://youtu.be/D9saZERvzf8

Robot hand tele-operation control **2012 - 2014**

- Robot hand synergy mapping using multi-factor model [P1, J1, W1]
- Extracting synergy by considering individual characteristic as well as grasping motion
  - ✓ Video: https://youtu.be/QzGgV9KHaZI
- Grasping Force Estimation using sEMG signals [J5]

Tele-opeartion control of ultrasonic examination system **2012 - 2013**

- Tele-operated robotic arm for remote ultra-sound exam
- Automated orientation control for ultrasound
- Contact force feedback using haptic device

✓ Video: https://youtu.be/_OSkL5e70fI

During internship in GIST, Korea

Friction and Gravity Compensator for Surgery Simulator **2010.6 - 2010.9**

- Research and development on the Laparoscopic simulator
- Haptic Feedback using friction and gravity compensator [C1]

Technical skills

Hardware Experience

Human-sized Humanoids

- Torque controlled robot, *DYROS-Red*
- Position controlled robot, *DYROS-Jet*
- Torque controlled robot, *TALOS (PAL Robotics Co.)*
- Position controlled robot, *HRP-2*

Mobile-based Humanoids

- Four-wheeled mobile base, *Husky*, with 7-DoF arm, *Franka Panda*

Manipulator

- 7-DoF arm, *Franka Panda*
- 6-DoF arm, *Roman-3D*
- 6-DoF arm, *Denso Arm*

Software Experience

Programming Skills

- Intermediate C++, Python, and Matlab programming for robotics (Windows, Ubuntu 18.04)
- V-Rep, MuJoCo, Gazebo, and PyBullet for robotic simulation

Libraries

- Math - Eigen, Lapack, MKL
- Optimization - qpOASES, Eiquadprog, IFOPT and IPOPT
- Robot Kinematics and Dynamics: Pinocchio, RBDL
- Others: Boost (in particular, boost-python), FCL

Honors and Awards

Young researcher award from ICROS, 2022.
Best thesis award from Seoul National University, 2020.
Best conference paper award in IEEE/ASME International Conference on Advanced Robotics and Mechatronics, 2019.
Korean government grant for Visiting Scholar of LAAS-CNRS, 2018.
Best paper award in Journal of Korea Robotics Society (JKROS), 2018.
Cum laude from Dept. of Mechanical Engineering at Seoul National University, 2012.

Patents

[P2] **Sanghyun Kim** *et al.* Automatic cardiopulmonary resuscitation device and control method therefor, US Patent, No. 20190029919A1, CN Patent, No. 108697572A, EU Patent, No. 3409258A1, 2019

[P1] **Sanghyun Kim**, Jaeheung Park, Mingon Kim, Jimin Lee, Jounghuem Kwon, Bumjae You. APPARATUS FOR ESTIMATING GRASPING POSTURE AND GRASPING FORCE. Korea Patent, No.10-2016-0075150, 2016.

International Journal Articles

[J10] K. Jang, **S. Kim(*)**, S. Park, J. Kim, and J. Park. Weighted Hierarchical Quadratic Programming: Assigning Individual Joint Weights for Each Task Priority, Intelligent Service Robotics, accepted, 2022 **(*Corresponding Author)**

[J9] S. Hong, K. Jang, **S. Kim**, and J. Park. Regularized Hierarchical Quadratic Program for Real-Time Whole-Body Motion Generation , IEEE/ASME Transactions on Mechatronics, Vol. 26, No.

4, 2021. 08

[J8] J. Sim, S. Kim, S. Park, **S. Kim**, M. Kim, and J. Park. Design of JET Humanoid Robot with Compliant Modular Actuators for Industrial and Service Applications, Applied Science, Vol. 11, No. 13, 2021. 07

[J7] Y. Lee, **S. Kim**, J. Park, N. Tsagarakis, and J. Lee. Whole-body Control Framework based on the Operational Space Formulation under Inequality Constraints via Task-oriented Optimisation, IEEE Access, Vol. 9, pp. 39813-39826, 2021. 03

[J6] K. Jang, **S. Kim**, and J. Park Reactive Self-Collision Avoidance for a Differentially Driven Mobile Manipulator, Sensors, Vol. 21, No. 3, 2021. 02

[J5] **S. Kim**, M. Kim, J. Kim, S, Kim, and J. Park. Grasping Force Prediction by EMG Signals and Arm Posture: Tensor Decomposition Based Approach, Journal of Bionic Engineering, Vol. 16, No. 3, pp. 455-467, 2019.05

[J4] **S. Kim**, K. Jang, S. Park, Y. Lee, S. Y. Lee, and J. Park, Continuous Task Transition Approach for Robot Controller based on Hierarchical Quadratic Programming, IEEE Robotics and Automation Letters (with International Conference on Robotics and Automation 2019), Vol. 4, No. 2, pp. 1603-1610, 2019.05

[J3] **S. Kim**, M. Kim, J. Lee, S. Hwang, J. Chae, B. Park, H. Cho, J. Sim, J. Jung, H. Lee, S. Shin, M. Kim, W. Choi, Y. Lee, S. Park, J. Oh, Y. Lee, S. Lee, M. Lee, S. Yi, K. Chang, N. Kwak, and J. Park. Team SNU's Control Strategies to Enhancing Robot's Capability: Lessons from the DARPA Robotics Challenge Finals 2015, The DARPA Robotics Challenge Finals: Humanoid Robots to the Rescue, Springer, pp. 347-379, 2018.04

[J2] **S. Kim**, M. Kim, J. Lee, S. Hwang, J. Chae, B. Park, H. Cho, J. Sim, J. Jung, H. Lee, S. Shin, M. Kim, W. Choi, Y. Lee, S. Park, J. Oh, Y. Lee, S. Lee, M. Lee, S. Yi, K. Chang, N. Kwak, and J. Park. Team SNU's Control Strategies to Enhancing Robot's Capability: Lessons from the 2015 DARPA Robotics Challenge Finals. Journal of Field Robotics, Vol. 34, No. 2, pp. 359-380, 2017.03

[J1] **S. Kim**, M. Kim, J. Lee, and J. Park. Robot Hand Synergy Mapping Using Multi-factor Model and EMG signal. (with International Symposium on Experimental Robotics 2014), Springer, pp.671-683, 2015.11

International Conference Articles

[C10] J. Wang, T. S. Lembono, **S. Kim**, S. Calinon, S. Vijayakumar and S. Tonneau, Learning to Guide Online Multi-Contact Receding Horizon Planning. The 2022 IEEE/RSJ International Conference on Intelligent Robots and Systems, Kyoto, Japan, 2022.

[C9] J. Wang, **S. Kim**, S. Vijayakumar and S. Tonneau, Multi-Fidelity Receding Horizon Planning for Multi-Contact Locomotion. The 2020 IEEE-RAS International Conference on Humanoid Robots, Munich, Germany, 2021.

[C8] **S. Kim**, K. Jang, S. Park, Y. Lee, S. Y. Lee, and J. Park, Whole-body Control of Non-holonomic Mobile Manipulator Based on Hierarchical Quadratic Programming and Continuous Task Transition. IEEE International Conference on Advanced Robotics and Mechatronics (ARM), Osaka, Japan, 2019, **Best Conference Paper Award**

[C7] **S. Kim**, J. Kim, and J. Park. Real-time Inverse Kinematics Technique for Controlling Humanoid Avatar with Redundant Arm, Ubiquitous Robot 2018, Hawaii, USA, 2018.

[C6] M. Kim, J. Kim, **S. Kim**, J. Sim, and J. Park. Disturbance Observer based Linear Feedback

Controller for Compliant Motion of Humanoid Robot, International Conference on Robotics and Automation (ICRA), Australia, 2018.

[C5] M. Kim, **S. Kim**, and J. Park. Human Motion Imitation for Humanoid by Recurrent Neural Network. The 13th International Conference on Ubiquitous Robots and Ambient Intelligence, Xian, China, 19-22 Aug, 2017.

[C4] J. Jung, J. Kim, **S. Kim**, W. Kwon, S. Na, K. Kim, J. Lee, G. Suh, and J. Park. Application of Robot Manipulator for Cardiopulmonary Resuscitation, International Symposium on Experimental Robotics 2016, Springer, pp. 266-274, 2017.03

[C3] **S. Kim**, M. Kim, J. Lee, S. Hwang, J. Chae, B. Park, H. Cho, J. Sim, J. Jung, H. Lee, S. Shin, M. Kim, N. Kwak, Y. Lee, S. Lee, M. Lee, S. Yi, K. K.C. Chang, and J. Park. Approach of Team SNU to the DARPA Robotics Challenge Finals. 2015 IEEE-RAS International Conference on Humanoid Robots, Seoul, Korea, 3-5 Nov 2015.

[C2] M. Schwartz, S. Hwang, Y. Lee, J. Won, **S. Kim**, and J. Park. Aesthetic Design and Development of Humanoid Legged Robot. The 2014 IEEE-RAS International Conference on Humanoid Robots, Madrid, Spain, 18-20 Nov 2014.

[C1] **S. Kim**, C. Lee, and J. Ryu. Data-driven Haptic Rendering of Friction between Surgical Device and Trocar for Laparoscopic Surgery Simulator, ACCAS 2010, Busan, Korea, 2010.

Domestic Journal Articles

[DJ6] K. Jang, **S. Kim**, S. Park, and J. Park. Unified Framework for Overcoming Motion Constraints of Robots Using Task Transition Algorithm, Journal of Korea Robotics Society, Vol. 13, No. 2, 2018.

[DJ5] J. Kim, **S. Kim**, and J. Park. The Trends of HRI: Focusing on Task Oriented Robot User Interface, Robot and Human, Vol. 14, No. 4, 2017.

[DJ4] **S. Kim** and J. Park. Singularity Avoidance Algorithms for Controlling Robot Manipulator: A Comparative Study, Journal of Korea Robotics Society, Vol. 12, No. 1, 2017. **Best Paper Award**

[DJ3] S. Shin, M. Kim, J. Ahn, **S. Kim**, and J. Park. Development of Tele-operation Interface and Stable Navigation Strategy for Humanoid Robot Driving, Journal of Institute of Control, Robotics and Systems, Vol. 22, No. 11, 2016.

[DJ2] **S. Kim**, B. Park, and J. Park. DRC Finals 2015 – Analysis of Participants, Robot and Human, Vol. 12, No. 4, 2015.

[DJ1] **S. Kim**, C. Lee, J. Kim, and J. Ryu. Approximate Friction and Gravity Compensation in Haptic Laparoscopic Surgery Simulator, Transactions of the KSME, Vol. 35, No. 8, 2010.

Domestic Conference Articles

[DC9] S. Park, K. Jang, S. Kim, **S. Kim**, and J. Park. nverse Kinematics Minimizing JointsTorque with Given Target Wrench, The 15th Korea Robotics Society Annual Conference (KROC), Korea, 2020.

[DC8] S. Y. Lee, S. Park, K. Jang, **S. Kim**, S. Kim, and J. Park. A Comparative Study of Tracking Control with Closed Loop Inverse Kinematics Algorithm, The 14th Korea Robotics Society Annual Conference (KROC), Korea, 2019.

[DC7] J. Jang, **S. Kim**, S. Park, S. Y. Lee, and J. Park Self-collision Avoidance Algorithm for Robot Manipulator using Continuous Task Transition Algorithm, The 14th Korea Robotics Society Annual Conference (KROC), Korea, 2019.

[DC6] K. Jang, **S. Kim**, S. Park, and J. Park, Joint Limit Avoidance of Non-holonomic Mobile Manipulator using Weighting Matrix in Generalized Pseudo-Inverse, Conference on Korean Society for Precision Engineering, Korea, 2017.

[DC5] M. Kim, R. Destenay, **S. Kim**, J. Kwon, K. Yeom, J. Park, and B. You. Avatar Motion Generation by Null-Space Mapping Based on Minimum Number of Markers. 2015 Conference on Information and Control Systems, Sokcho, Korea, 2015.

[DC4] **S. Kim**, M. Kim, and J. Park. Extracting Postural Synergies Using Grasping Taxonomy, The 9th Korea Robotics Society Annual Conference (KROC), Korea, 2014.

[DC3] J. Lee, M. Kim, **S. Kim**, and J. Park. Estimation of Hand Posture and Grasping Force Using Surface EMG, The 9th Korea Robotics Society Annual Conference (KROC), Korea, 2014.

[DC2] **S. Kim**, C. Lee, J. Kim, and J. Ryu. Friction and Gravity Compensation in Haptic Laparoscopic Surgery Simulator, Conference on Korean Society of Mechanical Engineers (KSME), Korea, 2010.

[DC1] **S. Kim**, C. Lee, J. Kim, and J. Ryu. Trocar Friction modelling for Friction and gravity Compensation, Conference on Korean Society of Mechanical Engineers (KSME), Korea, 2010.

Workshops

[W3] **S. Kim**. Learning to Guide Online Multi-Contact Receding Horizon Planning for Locomotion. Invited speaker at Workshop on "KROS locomotion manipulation research group" Pohang, Korea, 18 Aug 2022.

[W2] **S. Kim** and J. Park. Control Strategies of Team SNU for DRC Finals, and Future Directions for Robots in Human Environment. Invited speaker at Workshop on "What did we do for the DARPA Robotics Challenge?, 2015 IEEE-RAS International Conference on Humanoid Robots, Seoul, Korea, 3-5 Nov 2015.

[W1] **S. Kim**, J. Lee, M. Kim, and J. Park. Teleoperated Robot Hand Control using Tensor Decomposition. Full-day Tutorial on Robotics-based Methods for the Identification, Recognition, and Synthesis of Human Motions, IEEE/RSJ International Conference on Intelligent Robots and Systems, Tokyo, Japan, 3 Nov 2013.