

Humanoid Robot Falling: Fall Detection, Damage Prevention, and Recovery Actions

Dimitrios Kanoulas¹, Jinoh Lee², Abderrahmane Kheddar³, Yohei Kakiuchi⁴

Abstract—Research on humanoid robots has focused mainly on reliable perception, planning, and control methods for completing challenging tasks. The DARPA Robotics Challenge 2015 showed that when the tether is removed, legged robots may inevitable fall over during a task in an unstructured environment; either when they walk on a flat or rough terrain, or when they are cutting a wall with a drill, opening a door, and turning a valve. In a lot of cases if a humanoid robot falls over, it may end up with a serious damage for itself or the environment. If not, the robot in a real world scenario should recover, stand up, and complete the task. Being able to detect such a fall, apply the appropriate actions to prevent a big damage both on the robot and the environment around it, and recover if possible, are necessary for a real world application, where humanoid robots will need to deal with even rougher terrain and more complicated manipulation tasks under significant uncertainty either for static or dynamically changing environments.

This workshop provided a platform for researchers from all areas in robotics to disseminate and exchange ideas, evaluating their advantages and drawbacks. This included from the mechanical design and biomechanics to the perception, planning, and whole-body control methods on real robots and simulations for fall detection, damage prevention, and recovery actions in a falling over scenario. The aim was to foster collaboration among researchers that are working on humanoid robots to advance the very limited state-of-the-art work in this area.

I. TOPICS OF INTEREST

- mechanical design for a falling scenario and soft robotics
- robotic simulation for falling
- exteroceptive and proprioceptive perception for fall detection
- fall planning and recovery
- damage prevention control
- collision avoidance and self-collision avoidance
- reactive behaviors and emergency behaviors
- biomechanical analysis of human fall detection

*This workshop is supported by the European Commission H2020 projects: ICT-23-2014 CogIMon (no. 644727) and ICT-23-2014 CO-MANOID (no. 645097).

¹Dimitrios Kanoulas is with the Humanoids and Human Centered Mechatronics, Istituto Italiano di Tecnologia (IIT), Via Morego 30, 16163, Genova, Italy. Dimitrios.Kanoulas@iit.it

²Jinoh Lee is with the Department of Advanced Robotics, Istituto Italiano di Tecnologia (IIT), Via Morego 30, 16163, Genova, Italy. Jinoh.Lee@iit.it

³Abderrahmane Kheddar is with the University of Montpellier-CNRS LIRMM, Interactive Digital Humans, Montpellier, France. kheddar@lirmm.fr

⁴Yohei Kakiuchi is with the Department of Mechano-Informatics, the University of Tokyo, 7-3-1 Hongo, Bunkyo-ku, Tokyo, 113-8656, Japan. youhei@jsk.t.u-tokyo.ac.jp

- whole-body control fall/recovery strategies

url: <https://iros2018wsfallingrobots.wordpress.com>

II. SPEAKERS

- Dr. Abderrahmane Kheddar – University of Montpellier-CNRS LIRMM, France.
- Prof. Amy Lavers – Univ. of Illinois at Urbana-Champaign, USA.
- Dr. Shuuji Kajita – AIST, Japan.
- Dr. Yohei Kakiuchi – JSK, Japan.
- Dr. Jinoh Lee – IIT, Italy.
- Dr. Libo Meng (Prof. Z. Yu, Prof. Q. Huang) – Beijing Inst. of Tech., China.
- Prof. Sven Behnke – Univ. of Bonn, Germany.

ACKNOWLEDGMENT

This workshop is supported by the following IEEE RAS Technical Committees:

- 1) IEEE RAS Technical Committee on Humanoids Robotics as confirmed as confirmed by the Technical Committee co-chairs Katsu Yamane, Giorgio Metta, and Tomomichi Sugihara.
- 2) IEEE RAS Technical Committee on Algorithms for Planning and Control of Robot Motion as confirmed by the Technical Committee co-chairs Sertac Karaman and Lydia Tapia.
- 3) IEEE RAS Technical Committee on Robotics and Automation in Nuclear Facilities, as confirmed by the Technical Committee co-chairs William R. Hamel, Hajime Asama, Raja Chatila, and Yoshihiko Nakamura. IEEE RAS Technical Committee on Whole-Body Control, as confirmed by the Technical Committee co-chairs Federico Moro, Jaeheung Park, and Luis Sentis.

This workshop is supported by the following RSJ Special Interest Group:

- 1) RSJ Special Interest Group on Humanoid Robotics, as confirmed by Tomomichi Sugihara.

We would also like to thank Prof. Ambarish Goswami, who, as in our previous workshop event on this topic, helped a lot on the organization. His priceless support on the topic, given that he is one of the first to study humanoid robot falling strategies, was very important.

IEEE/RSJ International Conference on Intelligent Robots and Systems

IROS2018.org / October 1 – 5, 2018 / Municipal Conference Centre / Madrid, Spain



Half-Day Workshop

Humanoid Robot Falling: Fall Detection,

Monday, October, 1st (AM)

**Damage Prevention,
and Recovery Actions**

IROS 2018, Madrid, Spain

Monday, October 1, 2018

2nd Full-Day Workshop on:

Humanoid Robot Falling: *Fall Detection,*

Damage Prevention,

and Recovery Actions.

Dimitrios Kanoulas, Jinh Lee, Abderrahmane Kheddar, Yohei Kakiuchi

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Slides: <https://iros2018wsfallingrobots.wordpress.com/program>

Photos: <https://iros2018wsfallingrobots.wordpress.com/2018/10/10/thanks>

1. Introduction

1.1 Objectives

Webpage: <https://iros2018wsfallingrobots.wordpress.com>

Facebook: <https://www.facebook.com/fallingrobots>

Video: <https://youtu.be/ZepZZCoozh4>

Research on humanoid robots has focused mainly on reliable perception, planning, and control methods for completing challenging tasks. The DARPA Robotics Challenge 2015 showed that when the tether is removed, **legged robots may inevitable fall over** during a task in an unstructured environment; either when they walk on a flat or rough terrain, or when they are cutting a wall with a drill, opening a door, and turning a valve. In a lot of cases if a humanoid robot falls over, it may end up with a serious damage for itself or the environment. If not, the robot in a real world scenario should recover, stand up, and complete the task. Being able to **detect** such a fall, apply the appropriate actions to **prevent** a big damage both on the robot and the environment around it, and **recover** if possible, are necessary for a real world application, where humanoid robots will need to deal with even rougher terrain and more complicated manipulation tasks under significant uncertainty either for static or dynamically changing environments.

This workshop will provide a platform for researchers from **all areas in robotics** to disseminate and exchange ideas, evaluating their advantages and drawbacks. This will include **from the mechanical design and biomechanics to the perception, planning, and whole-body control methods on real robots and simulations** for fall detection, damage prevention, and recovery actions in a falling over scenario. The aim is to foster collaboration among researchers that are working on humanoid robots to advance the very limited state-of-the-art work in this area.

We organize a **half-day workshop** consisting of a mixture of **presentations** on topics including design, sensing, perception, planning, biomechanics, and motion generation for humanoid robots designed to work indoors and outdoors. To stimulate interaction, we will also organize a **poster session** to encourage the participation of young researchers and promote the discussion with the speakers and the audience. Moreover we will allocate adequate time for questions and discussion to make the workshop as interactive as possible.

This workshop is the second to be organized on this topic, after our first successful attempt in ICRA 2016 (“Legged Robot Falling: Fall Detection, Damage Prevention, and Recovery Actions”), with a bigger focus on humanoid robots. This workshop is related also to the IROS’15 workshop on “The Path to Success: Failures in Real Robots” and the ICRA’15 workshop on “Dynamic Locomotion and Balancing of Humanoids: State of the Art and Challenges”, which were focused more on analyzing the cause of a fall, the fall recovery for toy-robots, and balancing. This **workshop** will focus on the action to follow an inevitable fall after it has been detected. We believe that such a workshop will attract a large number of participants and promote interaction and collaboration, given the emergent interest in humanoid failures rising also from the DRC 2015 results.

Dr. Ambarish Goswami
comments on the WS



The “fall” problem must be solved to one’s satisfaction before humanoid robots can be made a household product.

The “fall” problem is scientifically rich and can be used as the springboard for a large set of associated mathematical problems such as very special kinds of path planning, trajectory planning, optimal control, impulsive control, impedance control, and the list can go on.

1.2 Topics of interest

- mechanical design for a falling scenario and soft robotics
- robotic simulation for falling
- exteroceptive and proprioceptive perception for fall detection
- fall planning and recovery
- damage prevention control
- collision avoidance and self-collision avoidance
- reactive behaviors and emergency behaviors
- biomechanical analysis of human fall detection
- whole-body control fall/recovery strategies

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1.4 Acknowledgement

This workshop is supported by:



COGIMON
Cognitive Interaction in Motion



1. The ICT-23-2014 **CogIMon** EU H2020 project (no. 644727): <https://cogimon.eu>

2. The ICT-23-2014 **COMANOID** EU H2020 project (no. 645097): www.comanoid.eu

1.5 Organizers



Dr. Dimitrios Kanoulas



Dr. Jinoh Lee [IIT, Italy]



*Dr. Abderrahmane Kheddar [CNRS,
France]*



Dr. Yohei Kakiuchi [JSK, Japan]

Dr. Dimitrios Kanoulas, Italy (primary contact)

Address: Via Morego, 30, Genoa, Liguria 16163, Italy.

Affiliation: Humanoids and Human Centered Mechatronics, Istituto Italiano di Tecnologia (IIT)

Email: Dimitrios.Kanoulas@iit.it

URL: <http://dkanou.github.io>

Dr. Jinoh Lee, Italy

Address: Via Morego, 30, Genoa, Liguria 16163, Italy.

Affiliation: Department of Advanced Robotics, Istituto Italiano di Tecnologia (IIT)

Email: Jinoh.Lee@iit.it

URL: <https://www.iit.it/people/jinoh-lee>

Prof. Abderrahmane Kheddar, Japan/France

Address: 860 rue de St Priest, Montpellier cedex 5, 34095, France.

Affiliation: CNRS & CNRS-AIST Joint Robotic Laboratory (JRL)

Email: kheddar@lirmm.fr

URL: http://www.lirmm.fr/lirmm_eng/users/utilisateurs-lirmm/equipes/idh/abderrahmane-kheddar

Dr. Yohei Kakiuchi, Japan

Address: Building No. 2, Hongo Campus, 7-3-1, Hongo, Bukyo-ku, Tokyo, 113-8656, Japan

Affiliation: JSK Robotics Laboratory, Univ. of Tokyo

Email: youhei@jsk.t.u-tokyo.ac.jp

URL: <http://www.jsk.t.u-tokyo.ac.jp/~youhei>

2. Program

2.1 Program Schedule

09:00– 09:15 Dr. Dimitrios Kanoulas — HHCM, IIT

Title: “Introduction to the workshop” [[slides](#)]

09:15 – 09:45 Dr. Shuuji Kajita — AIST, Japan.

[Drs. R. Cisneros, M. Benallegue, T. Sakaguchi, M. Morisawa, S. Nakaoka, H. Kaminaga, I. Kumagai, K. Kaneko, F. Kanehiro]

Title: “Airbag System Developments for Humanoid Falling” [[slides](#)]

09:45 – 10:15 Prof. Amy Lavers — Univ. of Illinois at Urbana-Champaign, USA.

Title: “Human Fall Strategies: The Bartenieff Principle of Weight Shift From the Pelvic Core and Its Role in Producing an Expressive Bipedal Walker” [[slides](#)]

10:15 – 10:45 Dr. Abderrahmane Kheddar — CNRS & CNRS-AIST, France.

Title: “Humanoid Falls with Active Postural Reshaping and Adaptive Compliance” [[slides](#)]

10:45 – 11:30 Coffee Break & Poster Session with Spotlight Talks

- Junhyung Kim, Jaehoon Sim, and Jaeheung Park
Title: “Humanoid fall recovery strategy using air thrust” [[poster](#), [paper](#)]
- Noel Maalouf, Imad H. Elhaji, Elie Shammas, and Daniel Asmar
Title: “Imitating Humans: Stable Humanoid Gait Design Based on Energy Exchange” [[poster](#), [paper](#)]
- H. Jafari, M. Pauelsen, U. Röijezon, L. Nyberg, G. Nikolakopoulos and T. Gustafsson
Title: “On Internal Modeling of the Upright Postural Control in Elderly” [[poster](#), [paper](#)]
- Juan A. Castano, Chengxu Zhou, and Nikos G. Tsagarakis
Title: “Heuristic Fall Recovery Strategy for a Wheel-Legged Quadruped Robot” [[poster](#)]

11:30 – 12:00 Dr. Yohei Kakiuchi (Prof. Masayuki Inaba) — JSK, Univ. of Tokyo, Japan.

Title: “Humanoid Robot Design with Robustness for Falling Down” [[slides](#)]

12:00 – 12:30 Dr. Jino Lee — IIT, Italy.

Title: “Rolling! Energy Control Concepts for Humanoid Falls.” [[slides](#)]

12:30 – 13:00 Dr. Libo Meng (Profs. Z. Yu, Q. Huang) — Beijing Inst. of Tech., China.

Title: “Humanoid Falling Study on BHR-6P” [[slides](#)]

13:00 – 13:30 Prof. Sven Behnke — Univ. of Bonn, Germany.

Title: “Push Recovery, Fall Survival, and Getting-up of NimRo Humanoid Soccer Robots” [[slides](#)]

13:30 – 14:00 Closing Remarks

2.2 Invited Speakers

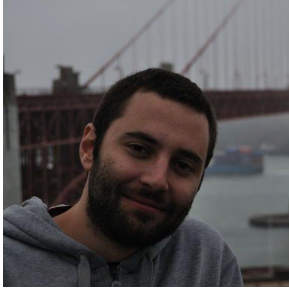
- Dr. Abderrahmane Kheddar — *University of Montpellier-CNRS LIRMM, France.*
- Prof. Amy Lavers — *Univ. of Illinois at Urbana-Champaign, USA.*
- Dr. Shuuji Kajita — *AIST, Japan.*
- Dr. Yohei Kakiuchi — *JSK, Japan.*
- Dr. Jinoh Lee — *Istituto Italiano di Tecnologia (IIT), Italy.*
- Dr. Libo Meng (Prof. Z. Yu, Prof. Q. Huang) — *Beijing Inst. of Tech., China.*
- Prof. Sven Behnke — *Univ. of Bonn, Germany.*

2.3 Poster Presentations

1. Junhyung Kim , Jaehoon Sim, and Jaeheung Park — *Seoul National University, Republic of Korea.*
2. Noel Maalouf, Imad H. Elhadj, Elie Shammas, and Daniel Asmar — *American University of Beirut, Lebanon.*
3. H. Jafari, M. Pauelsen, U. Röjjezon, L. Nyberg, G. Nikolakopoulos and T. Gustafsson — *Lulea University of Technology, Sweden.*
4. Juan A. Castano, Chengxu Zhou, and Nikos G. Tsagarakis — *Istituto Italiano di Tecnologia, Italy.*

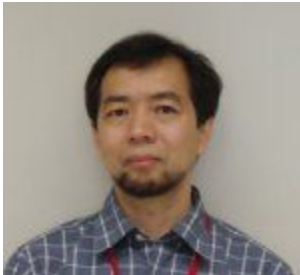
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Title: “Introduction to the workshop” [[slides](#)]

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3.2 Prof. Amy Lavers — *Univ. of Illinois at Urbana-Champaign, USA.*



Title: “Human Fall Strategies: The Bartenieff Principle of Weight Shift From the Pelvic Core and Its Role in Producing an Expressive Bipedal Walker” [[slides](#)]

3.3 Dr. Abderrahmane Kheddar — CNRS & CNRS-AIST, France.



Title: "Humanoid Falls with Active Postural Reshaping and Adaptive Compliance" [slides]

3.4 Dr. Yohei Kakiuchi — JSK, Japan.



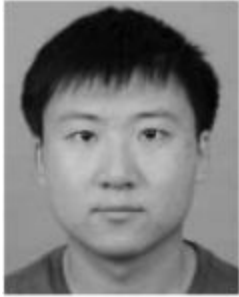
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3.7 Prof. Sven Behnke — *Univ. of Bonn, Germany.*



Title: “Push Recovery, Fall Survival, and Getting-up of NimbRo Humanoid Soccer Robots” [[slides](#)]

4. Posters and Short Papers

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Title: “*Humanoid fall recovery strategy using air thrust*” [[poster](#), [paper](#)]

4.2 Noel Maalouf, Imad H. Elhajj, Elie Shamma, and Daniel Asmar — *American University of Beirut, Lebanon.*

Title: “*Imitating Humans: Stable Humanoid Gait Design Based on Energy Exchange*” [[poster](#), [paper](#)]

4.3 H. Jafari, M. Pauelsen, U. Röijezon, L. Nyberg, G. Nikolakopoulos and T. Gustafsson — *Lulea University of Technology, Sweden.*

Title: “*On Internal Modeling of the Upright Postural Control in Elderly*” [[poster](#), [paper](#)]

4.4 Juan A. Castano, Chengxu Zhou, and Nikos G. Tsagarakis — *Istituto Italiano di Tecnologia, Italy.*

Title: “*Heuristic Fall Recovery Strategy for a Wheel-Legged Quadruped Robot*” [[poster](#)]