PhD in Information Technology and Electrical Engineering
Università degli Studi di Napoli Federico II

PhD Student: Viviana Morlando

Cycle: XXXV

Training and Research Activities Report

Year: First

Viviana Morlando

Tutor: Fabio Ruggiero

Fabio Ruggiero

Date: 21/10/2020

1. Information:

- **PhD student: Viviana Morlando**
- **DR number: DR993891**
- **Date of birth: 26/06/1996**
- **Master Science degree: Automation Engineering University: Università degli Studi di Napoli Federico II**
- **Doctoral Cycle: XXXV**
- **Scholarship type: *DIETI PRIN 2017 "PRINBOT"***
- **Tutor: Fabio Ruggiero**

2. Study and training activities:

Activity	Type[1]	Hours	Credits	Dates	Organizer	Certificate[2]
Numerical methods for modeling, simulation and control for soft robots or robots in interaction with deformable environment	Seminar	1	0.2	14/01/2020	Fanny Ficuciello	Y
Computational Biology: Large scale data analysis to understand the molecular bases of human diseases	Seminar	1	0.2	09/04/2020	Michele Ceccarelli	Y
Elettromagnetismo e salute	Seminar	1	0.2	09/04/2020	Rita Massa	N
How to get published with IEEE	Seminar	2	0.4	20/04/2020	Eszter Lukacs	Y
Innovation management, entrepreneurship and intellectual property	Course	18	5	05/05/2020 - 05/06/2020	Pierluigi Rippa	Y

Activity	**Type[1]**	**Hours**	**Credits**	**Dates**	**Organizer**	**Certificate[2]**
Large Scale Training of Deep Neural Networks	Seminar	2	0.4	06/05/2020	Giuseppe Fiameni	N
La programmazione europea e la ricerca. Nuovi scenari della programmazione europea dopo il 2020 - La gestione di un progetto di ricerca.	Seminar	2	0.4	13/05/2020	Filippo Ammirati	N
Health 4.0 – La rapidità della medicina e la velocità del cambiamento del nostro mondo organizzato	Seminar	2	0.4	14/05/2020	Paolo Netti	N
Realtà Virtuale e salute reale. Health 4.0 – Dal bit alla mente: spazi virtuali per la salute	Seminar	2	0.4	15/05/2020	Valentino Megale	N
Virtual Seminars on 'Sensing'	Seminar	4	0.8	20/05/2020	Carlo Forestiere	Y
EECI- International Graduate School on Control 2020- M10 Model Predictive Control	Doctoral School	21	3	8/06/2020-11/06/2020	Eduardo F. Camacho	Y
Exploring Autonomy in Robotic Flexible Endoscopy	Seminar	2	0.4	12/06/2020	Fanny Ficuciello	Y
"Linear regression in PyTorch" and "Convolutional Neural Networks". Part of the Webinar series on Deep Learning for CINI AIIS Labs.	Seminar	2	0.4	29/06/2020	Giuseppe Fiameni	N
Machine Learning	Course	20	4	6-17/07/2020	Carlo Sansone	Y
Field and service robotics	Course	48	6	March-July	Fabio Ruggiero	Y

Activity	Type[1]	Hours	Credits	Dates	Organizer	Certificate[2]
Robotics Lab	Course	48	6	March-July	Vincenzo Lippiello	Y
"Efficient Data Loading with DALI" and "Mixed Precision Training using Apex". Part of the	Seminar	1	0.2	01/07/2020	Giuseppe Fiameni	N
"Multi-GPU Training using Horovod" , "Deploying Models with TensorRT" and "Profiling with NVTX". Part of the Webinar series on Deep Learning for CINI AIIS Labs.	Seminar	2	0.4	02/07/2020	Giuseppe Fiameni	N

1) Courses, Seminar, Doctoral School, Research, Tutorship
2) Choose: Y or N

2.1. Study and training activities - credits earned

	Courses	Seminars	Research	Tutorship	Total
Bimonth 1	0	0	10	0	10
Bimonth 2	0	0.2	8.8	0	9
Bimonth 3	0	0.8	4.2	0	5
Bimonth 4	8	3.2	1.2	0	12.4
Bimonth 5	16	0.6	4	0	20.6
Bimonth 6	0	0	6	0	6
Total	24	4.8	34.2	0	63
Expected	30 - 70	10 - 30	80 - 140	0 – 4.8	

3. Research activity:

My scholarship is associated with the project PRIN 2017 "PRINBOT - Grapevine Recognition and Winter Pruning Automation Based on Innovative Robots (20172HHNK5_002)", which aims to develop innovative robotic technologies for grapevine winter pruning automation. My research activity focuses on controlling legged robotic systems, to develop a control architecture for a legged locomotion platform endowed with a robotic arm, able to walk on different kinds of terrain and perform manipulation tasks.

One of the main objectives of service robotics is developing autonomous systems able to move in unstructured environments and cooperate with humans in daily life tasks or replace them in potentially dangerous situations. Regarding autonomous locomotion, significant differences exist between wheeled systems and legged ones. While wheeled robots can move at high speeds, useful to cover a large space in a short time, they encounter severe difficulties in traversing uneven terrain and environments that were designed for human use, like steps and stairs. These problems can be solved using legged robots, which can walk through challenging terrain, adapt their foothold to its irregularities, and overcome obstacles lifting the leg.

An essential choice during the design of a legged system regards the number of legs [1], influencing the speed, the dynamicity of the gait, and retaining balance. The problem addressed by the project associated with this Ph.D. research focuses on quadruped robots, since they have higher stability than biped robots and, at the same time, their legs are more manageable to coordinate than robots with six or more legs. Anyway, a control framework developed for a quadruped robot can be adapted to biped or systems with more legs.

Different control solutions were proposed over the years to achieve dynamic locomotion for a quadruped robot. Some of them use a reduced dynamic model [2], which does not allow them to achieve fast and dynamic walking. For this reason, the best approach is considering the full dynamic of the robot using a whole-body control or a model predictive control (MPC).
While the first one allows the decoupling of the motion planning from the controller [3-5], the last one can stabilize the robot by predicting the movements over a finite horizon [6,7], despite the difficulty of the nonlinearity of the legged robots dynamic. In both cases, there is the possibility of online re-planning that contributes to coping with the roughness of the terrain and all the external disturbances. Indeed, since this kind of robots have started to be recently used in tasks such as inspection or patrolling, where the environment is confined or full of obstacles, the robot needs not only to retain its balance and adapt its foothold to the slope and the roughness of the terrain but also to reject external disturbances.

In some cases, these disturbances are considered with the use of an observer. However, the literature reports observers that take in account only the disturbances applied directly either on the center of mass or on the support legs [5,8], without considering a more comprehensive range of disturbances present in more complex situations.

The research of this first Ph.D. year has been focused on the study of the state of the art of the locomotion of legged robots, and the development of a whole-body controller based on the decoupling of the centroidal's dynamics (the dynamics of the center of mass) from the legs' ones, composed of a quadratic problem (QP) that modules the ground reaction forces in order to retain balance during the locomotion.
Moreover, as a solution of the problem regarding external disturbances, the study and the realization of a momentum-based observer inspired by the one in [9] has been faced. Differently from other observers, this one takes into account also the disturbances acting on legs that are still swinging, so that the robot is able to work under challenging conditions such as in difficult atmosphere situations or in narrow spaces where it is easy to have a collision between a leg that is still moving and the environment. The observer's estimation has been combined with the whole-body controller to be tested in the "Gazebo simulator", where the platform used is DogBot, provided by React Robotics (https://reactrobotics.com).

In the future, this observer might be used within legged manipulation scenarios, where the legged robot is equipped with a manipulator's arm. In this case, the observer would allow decoupling the manipulation task from the locomotion one.

References:

[1] Kajita, Shuuji, and Christian Ott. "Limbed Systems." *Springer handbook of robotics*. Springer, Cham, 2016. 419-442.

[2] N. Dini and V. J. Majd, "An mpc-based two-dimensional push recovery of a quadruped robot in trotting gait using its reduced virtual model," Mechanism and Machine Theory, vol. 146, p. 103737, 2020.

[3] C. D. Bellicoso, F. Jenelten, P. Fankhauser, C. Gehring, J. Hwangbo, and M. Hutter, "Dynamic locomotion and whole-body control for quadrupedal robots," in 2017 IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS). IEEE, 2017, pp. 3359–3365.

[4] C. D. Bellicoso, F. Jenelten, C. Gehring, and M. Hutter, "Dynamic locomotion through online nonlinear motion optimization for quadrupedal robots," IEEE Robotics and Automation Letters, vol. 3, no. 3, pp. 2261–2268, 2018.

[5] S. Fahmi, C. Mastalli, M. Focchi, and C. Semini, "Passive whole-body control for quadruped robots: Experimental validation over challenging terrain," IEEE Robotics

[6] G. Bledt, P. M. Wensing, and S. Kim, "Policy-regularized model predictive control to stabilize diverse quadrupedal gaits for the mit cheetah," in 2017 IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS). IEEE, 2017, pp. 4102–4109.

[7] M. Neunert, M. St¨auble, M. Giftthaler, C. D. Bellicoso, J. Carius, C. Gehring, M. Hutter, and J. Buchli, "Whole-body nonlinear model predictive control through contacts for quadrupeds," IEEE Robotics and Automation Letters, vol. 3, no. 3, pp. 1458–1465, 2018.

[8] M. Focchi, R. Orsolino, M. Camurri, V. Barasuol, C. Mastalli, D. G. Caldwell, and C. Semini, "Heuristic planning for rough terrain locomotion in presence of external disturbances and variable perception quality," in Advances in Robotics Research: From Lab to Market. Springer, 2020, pp. 165–209.

[9] F. Ruggiero, J. Cacace, H. Sadeghian, and V. Lippiello, "Passivitybased control of vtol uavs with a momentum-based estimator of external wrench and unmodeled dynamics," Robotics and Autonomous Systems, vol. 72, pp. 139–151, 2015.

4. Research products:

Viviana Morlando, Ainoor Teimoorzadeh, Fabio Ruggiero, "Whole-body Control with Disturbance Rejection through Momentum-based Observer for Quadruped Robots", submitted to : "Robotics and Automation Letters (IEEE RAL)", 2020

5. Attended conferences and seminars

- 2020 IEEE International Conference on Robotics and Automation, ICRA 2020, Virtual Conference, May 31- August 31, I didn't presented a paper.
- IEEE ICRA Workshop: Towards Real-World Deployment of Legged Robots, ICRA 2020, Virtual Workshop, June 22-July 3.

6. Activity abroad:

None

7. Tutorship

Tutorship for two B.Sc. theses: Paolino De Risi and Antonio Zampa.
I'm currently tutoring a M.Sc. student, Salvatore Punzo, for his thesis.