

WG3 → Machine Learning for Advanced Control Techniques

Luigia Petre and Andrea Chincarini



Who are we

- 25 (**15**) members
 - **Francesca Badaracco, Dr. Eng. Mateusz Bawaj, Dr. Valerio Boschi, Prof. Peter Butka, Sotirios Chatzis, Dr. Andrea Chincarini, Alessio Cirone, Dr. Jan Harms, Alberto Iess, Dr. Natalia Korsakova, Dr. Luca Longo, Dr. Nikhil Mukund, Dr. Conor Muldoon, Franco Maria Nardini, Dr. Eng. Andrea Paoli, Dr. Luigia Petre, Luca Rei, Dr. Maria Tringali, Dr. Catia Trubiani, Dr. Gabriele Vajente, Rob Walet, Andrei Utina, Dr. Catalin Leordeanu, Prof. Marco Cavaglia, Dr Agata Trovato**
- WG3 email: wg3-g2net@ego-gw.it
- Our slack channel
 - <https://app.slack.com/client/TT226125S/CT51XP57Y>
 - Working plan, meeting notes, slides, links to seminar recordings
- Our gitlab repo
 - <https://gitlab.com/g2net/wg3-g2net>
 - Links to videos of scientific presentations → since April 2020
 - Slides of scientific presentations
- We met regularly for a while
 - Last Friday of the month, at 14:00 CET



Our focus

- Use of Machine Learning (ML) in control and noise mitigation for scientific experiments
 - Gravitational Wave (GW) detectors
- GW detectors → uniquely complex instruments
 - specific and new challenges in terms of control and noise issues
 - both currently running and the space-borne foreseen detectors
- Significant adaptation and ingenuity in ML approaches
 - seldom used as textbook cases
 - often coupled with simulations
 - burden with heavy experimental constraints
- We need diverse expertise and interaction
- Our goal → develop ML algorithms
 - as part of the detectors' feedback-control systems
 - for the feed-forward cancellation of noise



Our tasks

1. ML for glitch removal
2. Newtonian noise cancellation with ML
3. Data pre-processing with reinforcement learning
4. Deep learning for noise removal
5. Laser cavity control to optimise locking time and stability



What happened since the last MC meeting in October 2021

- Seminar in December 2021
- Planned out the WG3 paper
- Planned out the Turku meeting



Some history of WG3

- Fall 2019 → Andrea and Luigia appointed as new chairs
- 2020 → Re-started monthly seminars
 - Jan 2020 → reconvention meeting
 - Feb 2020 → Natalia Korsakova, LISA, FR
 - March 2020 → Andrea Chincarini, INFN, IT
 - April 2020 → Luigia Petre, ÅA, FI
 - May 2020 → Eftim Zdravevski, North Macedonia
 - June 2020 → Jan Harms, GSSI, IT
 - September 2020 → Filip Morawski, Warsaw, Poland
 - October 2020 → Mateusz Bawaj, Univ of Perugia, IT
 - November 2021 → Michal Bejger, Warsaw, Poland
 - Jan 2021 → Velimir Ilic, Belgrade, Serbia
 - Feb 2021 → Nikhil Mukund, Max Plank Institute, Germany
 - May 2021 → Jade Powell (ML for GW data), Melbourne, Australia
 - <https://iopscience.iop.org/article/10.1088/2632-2153/abb93a>
 - June 2021 → Marco Cavaglia, Missouri University of Science and Technology, US
 - December 2021 → Mateusz Bawaj about Differentiable Programming



Our main events

- Monthly online seminar
- Online workshop
 - 22-23 March 2021
 - <https://indico.ego-gw.it/event/172/>
- Online Training School
 - August 30– September 2 2021
 - <https://indico.ego-gw.it/event/217/>
- WG2-3 hybrid workshop
 - June 8, 2022
 - <https://indico.ego-gw.it/event/409/>



WG3 workshop

- Speakers

- Diego Bersanetti, INFN Genova (IT)
 - Interferometer Cavities: locking strategies and improvement possibilities
- Francesca Badaracco, GSSI (IT) & UCLouvain (Belgium)
 - Surrogate Wiener filtering for the prediction and optimized cancellation of Newtonian noise at Virgo
- Rob Walet, Nikhef (The Netherlands)
 - The experiment of the table top interferometer
- Gabriele Vajente, LIGO Laboratory Caltech (US)
 - Non stationary noise removal from LIGO data
- Fiodor Sorrentino, INFN Genova (IT)
 - Squeezed light benches and optical alignment issues
- Marco Cavaglia, Missouri University of Science and Technology (US)
 - Glitch removal in ground-based gravitational-wave interferometric detectors

- 31 registered participants

- All presentations recorded



WG3 Training School (1/2)

- 7 speakers
 - 5 from Europe, 1 from UK and 1 from US
 - Dr Francesca Badaracco, UCLouvain, Belgium
 - Topic: Newtonian Noise Cancellation Strategies and Optimisation Problems
 - Dr Luca Naticchioni, INFN, Italy
 - Topic: Einstein Telescope site characterisation measures and their impact on the third generation GW detectors
 - Prof Stefan Hild, Maastricht University, The Netherlands
 - Topic: Einstein Telescope: technical & scientific challenges for the future GW detectors
 - Dr Razvan Pascanu, DeepMind, UK
 - Topic: Deep learning Taxonomy
 - Prof Marco Cavaglia, Missouri Univeristy of Science and Technology, US
 - Topic: Fractal analysis for interferometer control
 - Dr Natalia Korsakova, Artemis, France
 - Topic: LISA talk on disentanglement
 - Dr Fabio Bonsignorio, HeronRobotics
 - Topic: Possible Utilization of Intelligent Robotics Technologies in GW detection and in the Einstein Telescope
- Each lecturer → 2-hour slot for their lecture and interaction with participants
- We recorded each slot



WG3 Training school (2/2)

- 39 registered participants
 - 1 Early Career Investigator (ECI) speaker
 - 1 International Partner Country (IPC) speaker
 - 4 /9 women involved in the organisation
 - Francesca, Natalia, Luigia, Agata
 - Isa helped a lot
 - Our estimation
 - About half of the participants
 - ECI
 - About one third of the participants
 - women



WG3 contributes to

- *Deliverable 7?*
 - *Report on Design study for application for **robots** to adaptively monitor seismic noise around GW detectors*
- **Deliverable 9**
 - Report on solution to be adopted to address the impact on **Newtonian Noise** in GW data records
- **Deliverable 10**
 - Report on the application of ML methods in the **control systems** for GW detectors
- *Deliverable 11?*
 - *Report on new ML method application in **seismological problems** for GW detection and related experiments*



Some statistics since September 2019

1. Number of publications → 10
2. Number of online meetings → 14
3. Number of STSM grants → 3+1
4. Presentations → 14
5. Online workshops → 1
6. Training schools → 1
7. Hybrid meetings → 1



Proud of

- Small community of people interested in our topics
 - Andrea Chincarini, Rob Walet, Conor Muldoon, Andrei Utina, Diego Bersanetti, Fiodor Sorrentino, Marco Cavaglia, Gabriele Vajente, Francesca Badaracco, Luca Naticchioni, Mateusz Bawaj, Nikhil Mukund, Natalia Korsakova
- Understanding the big picture and where it is going
 - GW detectors, ML solutions, control systems
 - Control strategies in GW detectors
 - Control Aspects in Future GW Detectors
 - Emerging ML solutions to GW Detectors Control



Zoom in

- Control strategies in GW detectors
 - Lock acquisition and loss
 - Squeezed light benches and optical alignment issues
 - Non stationary noise removal from GW data
 - Newtonian Noise Cancellation Strategies and Optimisation Problems
 - Glitch removal in ground-based GW detectors
- Control Aspects in Future GW Detectors
 - Einstein Telescope
 - LISA
 - Robotics for GW detectors
- Emerging ML solutions to GW Detectors Control
 - Automatic pre-alignment using Deep Neural Networks
 - Towards a neural network based sensing & control for GW observatories
 - Combinatorial optimization for sensor placement with deep reinforcement learning





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