WG3 – Some perspectives after 4 years of g2net

Luigia Petre and *Andrea Chincarini*

- 25 (**15**) members
  - **Dr. Francesca Badaracco**
  - **Dr. Eng. Mateusz Bawaj**
  - Dr. Valerio Boschi
  - Prof. Peter Butka
  - Sotirios Chatzis
  - **Dr. Andrea Chincarini**
  - Alessio Cirone
  - **Dr. Jan Harms**
  - **Dr. 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**

Our focus

- GW detectors → uniquely complex instruments
  - specific and new challenges in terms of control and noise issues
  - currently running + 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

Our main events

- 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)
    - Sqeezed 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 1/2 of participants
      - ECI
    - About 1/3 of 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 (Diego Bersanetti)
  - Squeezed light benches and optical alignment issues (Fiodor Sorrentino)
  - Non stationary noise removal from GW data (Gabriele Vajente)
  - Newtonian Noise Cancellation Strategies and Optimisation Problems (Francesca Badaracco)
  - Glitch removal in ground-based GW detectors (Marco Cavaglia)
- Control Aspects in Future GW Detectors
  - Einstein Telescope (Luca Naticchioni, Stefan Hild)
  - LISA (Natalia Korsakova)
  - Robotics for GW detectors (Fabio Bonsignorio)
- Emerging ML solutions to GW Detectors Control
  - Towards a neural network based sensing & control for GW observatories (Nikhil Mukund)
  - Combinatorial optimization for sensor placement with deep reinforcement learning (Conor Muldoon)
  - Newtonian noise subtraction in 2G and 3G detectors using neural networks (Soumen Koley)

WG3 → Machine Learning for Advanced Control Techniques
Luigia Petre
Andrea Chincarini