Dynamic Networks:
a hands-on course

Davide A. Cucci*[1], Jan Skaloud[1] and Ismael Colomina[2]

[1]Geodetic Engineering Laboratory, Ecole polytechnique fédérale de Lausanne, Switzerland
[2]GeoNumerics , Castelldefels, Spain

1 Background

Dynamics Networks (DNs) is a powerful technique for solving arbitrary sensor fusion problems, such as those arising in navigation and mapping applications. For instance, in photogrammetry, all the available sensor readings are processed together, being those image observations, raw inertial readings, GNSS position/velocity fixes, in a single joint-adjustment step. Another example is the use of DNs for trajectory determination of terrestrial mobile mapping systems where, in addition, trajectory crossovers can be implicitly used to constrain the solution. All this has considerable advantages in terms of quality of the results and ease of use with respect to conventional methodologies.

DNs were introduced by I. Colomina and its collaborators in 2004 [3, 12]. The authors studied further its benefits in mobile laser scanning [10] and in real airborne-gravimetry campaign [11]. In 2017, the authors presented a comprehensive description without simplifications in 3-D space, while evaluating the approach in aerial photogrammetry with UAVs [7]. This contribution was regognized with the U.V. Helava award for the best paper of the year in the journal of the International Society of Photogrammetry and Remote Sensing[1]. In 2019, DNs were invited at the Photogrammetric Week, Stuttgart, a well renown venue supporting the continuous interchange between scientists, developers and practitioners: two presentations covered the theory and the benefits of the method [8] and advanced applications in terrestrial-aerial photogrammetry [2]. More recently, DNs were employed to estimate a high-frequency trajectory that is later employed in direct geo-referencing of LiDAR point-clouds by fusing image observations [9] and 3D point-to-point correspondences [1].

The availability of open-source DNs solvers, including online graphical user interfaces maintained by the authors [5, 6, 4], makes nowadays possible for researchers and for practitioners to apply DNs to research and production projects in the field of aerial photogrammetry and LiDAR geo-referencing and to extend the presented approach to other application scenarios.

2 Content and objectives

The course has three main objectives:

1. provide a comprehensive overview on the theory behind DNs, covering in details the differences with respect to conventional Assisted Aerial Triangulation (AAT) processing,
2. teach the users how to process real aerial photogrammetry and airborne laser scanning projects with the open-source DNs solver developed by the authors,
3. promote open science with excellent quality data (image, navigation and control data) for scientific purposes.

At the end of the course, the participants will have a well founded understanding of the DN's principles with initial experience on real-world projects to successfully apply and extend DNs to their use cases. This will be achieved with theoretical presentations and via hands-on exercises employing provided software and data.

*davide.cucci@epfl.ch

[1]U.V. Helava award 2017: `https://www.isprs.org/society/awards/helava/2017.aspx`

3 Prerequisites and intended audience

The participants should be familiar with the problem of sensor orientation and with the principles and the operational steps of conventional aerial/terrestrial photogrammetry pipelines, including

1. fundamentals of GNSS/inertial processing (e.g., Kalman filtering/smoothing with commercial software),
2. practice with aerial triangulation software (e.g., Agisoft Metashape or Pix4D),

The course will be based on `ODyN`, an Online Dynamic Network solver which will be introduced at the ISPRS 2022 congress [5].

4 Tentative program

The course will span half a day and includes presentations and guided exercises that the participants can follow on their laptop with the provided material. The course agenda is presented below:

1. Integrated Sensor Orientation (ISO): GNSS, and GNSS/inertial and bundle-adjustment (J. Skaloud, 30 min),
2. DNs: motivations and theory (I. Colomina / J. Skaloud), 30 min,
3. Hands-on part 1. Aerial photogrammetry in UAVs with DNs (D.A. Cucci, 1h30),
4. Hands-on part 2. Airborne LiDAR geo-referencing using 3D point-to-point correspondences (D.A. Cucci, 1h),
5. Advanced DNs applications (I. Colomina, 30 min).

References

[1] A. Brun, D. A. Cucci, and J. Skaloud. Lidar point–to–point correspondences for rigorous registration of kinematic scanning in dynamic networks. *arXiv preprint arXiv:2201.00596*, 2022.

[2] I. Colomina. Mapkite: A tandem drone and terrestrial corridor mapping system and method. 57th Photogrammetric Week, September, 9-13, Stuttgart, 2019.

[3] I. Colomina and M. Blázquez. A unified approach to static and dynamic modelling in photogrammetry and remote sensing. *ISPRS International Archives at Photogrammetry, Remote Sensing and Spatial Information Sciences*, 35:B1, 2004.

[4] D. A. Cucci. ROAMFREE: Robust Odometry Applying Multi-sensor Fusion to Reduce Estimation Errors. `https://github.com/AIRLab-POLIMI/ROAMFREE`, 2014.

[5] D. A. Cucci. ODyN: An online dynamic network solver for photogrammetry and lidar geo-referencing. *ISPRS Annals of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, 2022.

[6] D. A. Cucci and M. Matteucci. Position tracking and sensors self-calibration in autonomous mobile robots by gauss-newton optimization. In *Robotics and Automation (ICRA), 2014 IEEE International Conference on*, pages 1269–1275. IEEE, 2014.

[7] D. A. Cucci, M. Rehak, and J. Skaloud. Bundle adjustment with raw inertial observations in UAV applications. *ISPRS Journal of Photogrammetry and Remote Sensing*, 130:1–12, 2017.

[8] D. A. Cucci and J. Skaloud. Joint adjustment of raw inertial data and image observations: Methods and benefits. 57th Photogrammetric Week, September, 9-13, Stuttgart, 2019.

[9] K. Mouzakidou, D. A. Cucci, and J. Skaloud. On the benefit of concurrent adjustment of active and passive optical sensors with GNSS & raw inertial data. *ISPRS Annals of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, 2022.

[10] D. Rouzaud and J. Skaloud. Rigorous integration of inertial navigation with optical sensors by dynamic networks. *Navigation*, 58(2):141–152, 2011.

[11] J. Skaloud, I. Colomina, M. E. Parés, M. Blázquez, J. Silva, and M. Chersich. A method of airborne gravimetry by combining strapdown inertial and new satellite observations via dynamic networks. In J. T. Freymueller and L. Sánchez, editors, *International Symposium on Earth and Environmental Sciences for Future Generations*, pages 111–122, Cham, 2018. Springer International Publishing.

[12] A. Térmens and I. Colomina. Network approach versus state-space approach for strapdown inertial kinematic gravimetry. In *Gravity, Geoid and Space Missions*, pages 107–112. Springer, 2005.