MECHANICAL ENGINEERING

PNRR Ammin/Mespac - AI-BOOST / Artificial Intelligence to go BeyOnd earth Observation SaTellite limits

Funded By	Politecnico di TORINO [P.iva/CF:00518460019] - MESPAC S.r.l. [P. IVA. 12704170013]
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Context of the research activity	The role of monitoring and data gathering in science and technology is continuously increasing. Within this context, the proposed research requires the integration of SatEOs, in-situ data, and AI algorithms to increase the time- and spatial-resolution. The main field of application is ocean monitoring, needed for design and operation of offshore renewable energy systems. Progetto co-finanziato nell'ambito del PNRR - Bando NODES - CUP E13B22000020001
Objectives	The research activity falls within an industrial collaboration with MESPAC s.r.l., that is co-funding part the project through the industrial PhD call of Spoke 1, NODES. Earth observation satellite data inherently suffer from limitations in spatial and temporal resolution due to the orbits of the satellites themselves. This limitation restricts their application only to cases where the subsequent revisit time is acceptable, excluding many industrial fields with more stringent requirements (e.g., offshore wind power). This research activity envisions bridging this gap between satellite data supply and industrial demand through artificial intelligence algorithms for gap-filling, which increase the spatial and temporal resolution of the data while maintaining high accuracy. Promising results have been achieved using surrogate models such as Kriging (specifically, Gaussian Process Regression) applied to marine variables like wave height and period (relevant for offshore wind power) using public satellite datasets (Copernicus). The achieved results confirm the great potential of this approach and motivate further research and development activities to enhance the algorithm's performance and broaden its applications. Specifically, the following three research objectives (ob.) are intended to be pursued: 1. Applicability mapping: While the effectiveness of gap-filling algorithms depends on identification and training strategies (see ob.2), a fundamental role is played by the stochastic characteristics of spatial and temporal correlation of the variables measured by satellites. The first research

	objective is, therefore, to formulate a rigorous and repeatable methodology to assess which variables are compatible with the developed digital tools. Achieving this objective ensures the multiplication of the application fields of the strategies developed during the doctoral program, thereby increasing their impacts and industrial implications. The primary focus is to consider additional meteorological and marine variables such as wave direction, wind intensity and direction, and marine currents. The analysis and results of this mapping are intertwined with the development of artificial intelligence algorithms in the next point. 2. Development of new surrogate models: The Kriging strategy is promising as it not only provides data estimation where measurements are missing (gap-filling) but also delivers a confidence interval. The doctoral objective is to select and possibly define ad-hoc the most effective mathematical architectures (kernels) depending on the nature of the considered data. Additionally, new co-Kriging techniques must be developed to handle multi-source data with non-homogeneous uncertainty, as well as to include additional data layers to improve fitting (e.g., bathymetry or topography). 3. Integration of in-situ measurements: While the estimation of uncertainty is inherent in Kriging-like strategies, actual validation requires the integration of in-situ measurements. Furthermore, in the presence of multiple in-situ sensors, data fusion strategies can be developed to improve the identification and training of surrogate models.

Skills and competencies for the development of the activity	The candidate should be familiar with the following aspects: - Artificial intelligence and machine learning - Offshore renewable energy applications Moreover, the candidate should be able to interact in a collaborative working environment.