POLITECNICO DI MILANO

PhD in MODELLI E METODI MATEMATICI PER L'INGEGNERIA / MATHEMATICAL MODELS AND METHODS IN ENGINEERING - 39th cycle

PNRR 118 PNRR Research Field: NONPARAMETRIC ESTIMATION AND PREDICTIVE METHODS AND ALGORITHMS FOR THE REMOTE COMPOSITIONAL MAPPING OF NEAR-EARTH ASTEROIDS AND PLANETS

Monthly net income of PhDscholarship (max 36 months)
€ 1325.0
In case of a change of the welfare rates during the three-year period, the amount could be modified.

Context of the research activity	
Motivation and objectives of the research in this field	The world conventional deposits of rare critical materials at the basis of many wide-spread IT, energy, and pharmaceutical technologies are quickly getting closer to exhaustion (World Economic Forum &Accenture, 2017, Digital Transformation Initiative: Mining and Metals Initiative) that will generate in 2030 generating a global shortage that would stop the production of technologies like smart phones, flat screens, laptops, and medicines with dramatic impacts on all layers of society. This high and increasing demand of rare materials comes also with a strong concentration, instability, and insecurity in the supply. Private mining operators together with national governments or agencies are pushing investments towards new possible solutions. Among these, space mining (i.e., mining materials from extraterrestrial bodies close to the Earth) is considered nowadays the only economically, environmentally, and socially sustainable alternative on the long term due to: - Very reduced environmental impact - Massive reduction in transportation costs - The extraordinary abundance of materials in some extra-terrestrial sites. Global space mining market size is indeed expected to reach US$ 7.8 Billion by 2028 with the first mining initiatives operating on the Moon in 2030. However, a direct non-educated inspection of these large celestial bodies would be

	completely unfeasible from an economic point of view. Consistently with this scenario, the final objective of this research program is overcoming this economic and technological bottleneck by providing mineralogic maps of these extraterrestrial bodies. Thanks to synthetic extraterrestrial rocks that will be generated by the Petrology and Volcanology Research Group at the UniPG and to the advanced algorithms that will be developed at Polimi, it will be possible to transform public iper-spectral satellite data of some relevant areas of Moon, Mars, Mercury, and Bennu in real mineralogic maps that could fully enable prospecting activities of mining fields in space which could both strongly reducing the critical material supply dependence of EU countries from big non-EU exporting countries and supporting the full accomplishment of the European Green Deal. The research program embraces the following Missions and Components of the PNRR: M1 Digitalizzazione, innovazione, competitività, cultura e turismo M1C2: Digitalizzazione, innovazione e competitività nel sistema produttivo - Favorire la transizione digitale e l?innovazione del sistema produttivo incentivando gli investimenti in tecnologie avanzare, ricerca e innovazione; - Rafforzare la partecipazione allo sviluppo dell'economia dello spazio e i sistemi di osservazione della Terra per il monitoraggio dei territori. M2: Rivoluzione verde e transizione ecologica M2C1: Agricoltura sostenibile ed economia circolare - Migliorare la capacità di gestione efficiente e sostenibile dei rifiuti e il paradigma dell'economia circolare.
Methods and techniques that will be developed and used to carry out the research	The PhD student research activity will focus on the development of innovative supervised learning algorithms in the framework of nonparametric statistics. This kind of framework has never been introduced before in this field and it will be made possible by the possibility of training the algorithms using the data related to the synthetically generated extra-terrestrial rocks produced by the Petrology and Volcanology Research Group at the University Perugia. Differently from the gold standard of the field the newly developed approach will be **fully supervised and disruptive with respect to literature**. The PhD student is

	indeed expected to **develop and apply innovative estimation and predictive methods and algorithms** at the intersection of **high-dimensional and Functional Data Analysis**, and **Resampling Methods** (bootstrap estimation, permutation tests, and conformal prediction) with the aim of identifying predictive algorithms able to directly **infer the abundancies of mineral in a new rock sample directly from its spectrum**. The algorithms will indeed consist of nonlinear mathematical maps taking a rock spectrum as input and **providing the estimated composition as output together with a probabilistically valid uncertainty quantification of the estimated abundances**. To successfully complete this research program, four activities are planned: •**theoretical development and characterization** of the new algorithms; •**efficient implementation** of the new algorithms in an open-source language; •**validation of the new algorithms** on computer-generated data; •**surface mineralogic mapping** of extra-terrestrial rock bodies. Prior experience (at least at a MSc level) in the analysis of high-dimensional data (e.g., functional or raster data) and in resampling methods (e.g., bootstrap methods, permutational methods, conformal predictions) is appreciated although not mandatory. Due to the strong multi-disciplinarity of the research program, very good communication skills in both Italian and English supporting the interaction with researchers of different fields is appreciated.
Educational objectives	From the training point of view, the research project is aimed at the professional growth of a researcher which, at the end of the PhD, will be provided with both theoretical and applied competences in the modeling and analysis of high-dimensional and possibly spatially dependent data with an ability of fruitfully interacting with colleagues (also from other disciplines) from academia and industry.
Job opportunities	At the end of the PhD program, the candidate will be

	suited for positions in advanced national and international research centers both in academia (in research groups working in the field of mathematical modeling, statistics, machine learning or remote sensing) and the private sector (not exclusively in companies focusing on remote sensing technologies but also in many industrial, financial, and marketing firms that find part of their current core business in big data analytics).
Composition of the research group	2 Full Professors 4 Associated Professors 3 Assistant Professors 18 PhD Students
Name of the research directors	Prof. Simone Vantini

Contacts
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Additional support - Financial aid per PhD student per year (gross amount)	
Housing - Foreign Students	--
Housing - Out-of-town residents (more than 80Km out of Milano)	--

Scholarship Increase for a period abroad	
Amount monthly	662.5 €
By number of months	6

National Operational Program for Research and Innovation	
Company where the candidate will attend the stage (name and brief description)	
By number of months at the company	0
Institution or company where the candidate will spend the period abroad (name and brief description)	Institute of Mathematics - EPFL
By number of months abroad	6

Additional information: educational activity, teaching assistantship, computer availability, desk availability, any other information
Educational activities (purchase of study books and material, funding for participation to courses, summer schools, workshops and conferences): financial aid per PhD student per year1st year: max 1.800,47 euros 1st year: max 1.800,47 euros 2nd year: max 1.800,47 euros 3rd year: max 1.800,47 euros

The PhD students are encouraged to take part in activities related to teaching, within the limits allowed by the regulations.1 individual PC per student +several shared PC. Access to one cluster with 32 processors and 384 GB RAM, and to several multi-processor servers