SSM
Scuola Superiore Meridionale

MERC PhD Project Proposal 2023/2024

Title of the research project:

The Human Exodus: Predicting Human Migration due to Environmental Change

Keywords (up to five)

Collective Behavior, Dynamical Systems, Human Behavior, Network Science, Time-Series Analysis

Supervisors (at least two from two different areas):

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Project description (max 5000 characters)

Every year and at every age humans move. They move to improve their lives – as the Romans put it, “ubi bene, ibi Patria” (‘where one is well-off, there is one’s country’) – sometimes to survive. Recently, environmental catastrophes such as droughts, floods, earthquakes, and wildfire have triggered social unrest and mass migration of people who have seen their food security threatened,

homes destroyed, businesses compromised, and lives at risk (Davis et al. 2015). About 150 million people from 20 countries in Sub-Saharan Africa, South Asia, and Latin America are expected to be displaced by 2050.

The interdependencies between environmental conditions and human mobility underlying environmental migrations are not well understood, and no reliable model exists to predict what the future to come. Grounded in prior research (Porfiri and Ruiz, 2020 and De Lellis, Ruiz, and Porfiri, 2021), this project promises a mathematically-principled understanding of when people migrate and of which patterns they follow. As part of the project, the student will:

i) Enrich the existing database on internal migrations in Bangladesh from Davis et al. (Davis et al., 2018) to other Countries, like the United States of America or the South of Europe, including expressed desire to migrate from Twitter databases (Zegheny et al., 2014).
ii) Expand on the spatial statistical framework by Porfiri and Ruiz (Porfiri and Ruiz, 2020) to account for time effects, thereby honing a spatio-temporal statistical tool to explain environmental migrations.
iii) Construct a network representation encoding economics, infrastructure, access to services, and desire to migrate. This network will be the basis to refine the mathematical model by De Lellis et al. (De Lellis, Ruiz Marín and Porfiri, 2021) toward elucidating existing trends and helping forecast the impact of further changes in the future. Several modeling choices will be examined, from Boolean representations to continuous descriptions.
iv) Identify the most vulnerable shares of the populations, whose livelihood will be affected the most by future migration patterns. Different vulnerability metrics will be considered to assess the effect that additional migration flows potentially have on the socioeconomic fabric in the target Countries. Possible metrics include the network-based indices introduced by De Lellis and Porfiri, 2021, and by De Lellis et al., 2021, and could help policy makers to enhance our preparedness to future migration flows.

The team has experience in the Bangladesh dataset, which refers to human migration due to the effect of sea level rise. Extensive and detailed data on population and housing, as well as data on the distribution and internal migration within Bangladesh, are readily available for 1961-2015 in databases managed by various Bangladeshi government agencies. In addition, the U.N. has published records on internal migration in Bangladesh. By deepening the analysis of this dataset, the student will gain insight into the principles underpinning environmental migrations, before translating to other geographic, environmental, and social contexts. We are particularly keen toward migration patterns in Europe, exploring the effect of the recent conflicts in Ukraine and Palestine that might have accelerated some of the expected changes in the world population. Toward this aim, the student will acquire data from official sources, as the displacement tracking matrix collected by the International Organization for Migration (IOM), and complement them by scraping the Internet to gain information from geo-localized data through social media.

Explaining when people migrate and which patterns they follow in response to environmental change are highly non-trivial questions. For example, there is evidence that mass migration in Syria in 2011 was triggered by an antecedent regional drought. However, the drought was followed by food insecurity, loss of livelihoods, economic crisis, increased inequality, and social unrest, and it is not clear which of these factors directly caused migration. This question of “causation” is crucial for translating knowledge across human migrations, thereby leading to experimentally-based models. This approach to understand and predict human migrations includes the construction of large

databases, the development of new mathematical and statistical tools, and the application of novel parametric models to infer causality.

Models of human mobility are standard tools to predict planned migrations. In this view, migrants plan their move mainly to improve their economic status. Environmental migrants, however, often respond to a set of drivers that are not necessarily economic in nature: instead, they move in response to urgent and abruptly emerging threats, which are mediated by the socioeconomic and political fabric of their place of origin. These elements are at the heart of the recent model developed by De Lellis et al. (De Lellis, Ruiz Marín and Porfiri, 2021), inspired by the seminal work by Simini et al. (Simini et al., 2021). At the same time, humans are not molecules in a gas, as posited in statistical mechanics-based models of migration: humans act in response to emotions, individual preferences, social interactions, and changes in the environment they live in. None of these factors have been yet included in mathematical models. As of today, a theory of environmental migrations accounting for non-economic drivers, policy, and socio-behavioral processes is missing. This project will make strides to fill this fundamental gap in knowledge through effective network models.

Relevance to the MERC PhD Program (max 2000 characters)

Understanding the impact of environmental change on human migration dynamics is a crucial challenge for sovereign governments and international institutions, which requires a truly interdisciplinary effort at the interface of complex systems and human behavior. Therefore, this projects ideally fits the spirit of the MERC PhD program, with respect to its criteria of excellence, interdisciplinary nature, and transformative potential.

Methodologically, this project will represent an invaluable opportunity to sharpen the modeling skills of the students and to learn powerful statistical tools to test and validate models from available data, without the possibility of performing ad hoc experiments. The student will be guided by three supervisors from US, Italy, and Spain, and they will have the opportunity to learn mathematical and statistical tools that are at the frontier of knowledge. Furthermore, they will learn how to make meaningful predictions with confidence level associated with them. Along with theory, the student will be trained in data collection, spanning rigorous exploration of official sources and internet scraping from social media. By working on a concrete dataset, the student will have the opportunity to appreciate how the concepts and the scientific approach learned at the MERC PhD school translate to the solution of real-world complex problems.

Key references

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-De Lellis P., & Porfiri M., (2021) Detection of Influential Nodes in Network Dynamical Systems from Time-Series, IEEE Transactions on Control of Network Systems, doi.org//10.1109/TCNS.2021.3061953.
-De Lellis P., Ruiz Marín, M., & Porfiri, M. (2021). Modeling human migration under environmental change: a case study of the effect of sea level rise in Bangladesh. Earth's Future, in press.
-Porfiri, M., & Ruiz Marín, M. (2020). An information-theoretic approach to study spatial dependencies in small datasets. Proceedings of the Royal Society A, 476(2242), 20200113.

-Simini, F., González, M. C., Maritan, A., & Barabási, A.-L. (2012). A universal model for mobility and migration patterns. Nature, 484(7392), 96–100.
-Zagheni, E., Garimella, V. R. K., Weber, I., & State, B. (2014). Inferring international and internal migration patterns from twitter data. In Proceedings of the 23rd International Conference on World Wide Web (pp. 439-444).

Joint supervision arrangements

The supervisors are close friends who are excited about the project and discuss science on a regular basis, multiple times per week. As such, students will be part of a vibrant team, where discussions continuously happen in an organic and natural manner. The frequency of meetings and the supervisor to meet will depend on the stage of the research carried out by the student and on the very need they will have. We expect that there will be periods when meeting twice per month with all the group will be sufficient, for instance, when the student is learning and studying some methodology or the state of the art, and other periods when one-on-one meetings with any of the supervisors should happen two or three times per week, for example, when dealing with the development of new models or algorithms.

Location and length of the study period abroad (min 12 months)

The New York University (NYU) Tandon School of Engineering is the engineering and applied sciences school of NYU. Tandon is the second oldest private engineering and technology school in the United States. Located in the Brooklyn Tech Triangle, ten minutes walking to the Brooklyn Bridge and connected with subway or NYU to any of the other NYU schools in the City. Prof. Porfiri is an Institute Professor (the highest distinction at NYU Tandon), with tenured appointments in Biomedical Engineering and Mechanical and Aerospace Engineering. Prof. Porfiri's laboratory, the Dynamical Systems Laboratory (DSL), was founded fifteen years ago with the vision of creating an interdisciplinary space with fundamental research in dynamical systems with clear societal impact. The laboratory is housed between the Center for Urban Science and Progress (CUSP) and the Department of Mechanical Engineering. MERC students joining the project will have office space in the newly renovated CUSP building and access to any of the DSL facilities. At the DSL, they will be fully integrated in any of the lab activities, such as seminars, workshops, focused courses for professional developments, and collaborative efforts within and outside the group.

Technical University of Cartagena (UPCT) offers several different study programs across engineering, economics, and business sciences. The historical city of Cartagena belongs to the autonomous province of Murcia. Cartagena is located in the southeast of Spain, right at the Mediterranean Sea. The combination of tradition and modernity gives UPCT a vibrant, adventurous and innovative character. Prof. Ruiz is the principal investigator of the excellence research group Economic Modelling and Non-Parametric Statistic (EMODs), an interdisciplinary research group specialized in the analysis and applications of nonlinear time series, complex networks and spatial processes. MERC students joining the project will have office space and access to any of the UPCT facilities.

Ideally, we would like the student to spend 18 to 24 months abroad to ensure ample opportunities for training and full integration with the supervisors' research teams. How to split the time between US and Spain will be discussed based on student preferences; we also anticipate that, under normal circumstances, Prof. Porfiri visits the Technical University of Cartagena regularly and so does Prof. Ruiz visits NYU.

Any other useful information

Models of human migrations can be seen as an instance of coevolving complex networks. In this respect, the outputs of this project are of interest also with respect to the scope of the collaborative project ACROSS, funded by the Compagnia di San Paolo, Instituto Banco di Napoli, programme STAR 2018, which deals with the analysis and control of emerging properties in evolving network dynamical systems. ACROSS is led by Dr. De Lellis, in cooperation with the research groups of the other two supervisors, Dr. Porfiri and Dr. Ruiz Marín. We expect a virtuous cycle between the outputs of ACROSS and those of this project, since the student could benefit on the analysis, methods and results already achieved within ACROSS.

CUSP is a Tandon research center dedicated to the application of science, technology, engineering, and mathematics in the service of urban communities across the globe. CUSP was founded in 2012 as a partnership between NYU and NYC, motivated by a rapid trend of urbanization that will see 68% of the world's population live in cities by 2050. Using NYC as a living laboratory, CUSP contributes foundational knowledge and novel technologies for increasing our understanding of urban processes and solving complex urban problems, from ensuring the health and wellness of urban populations, to making our cities more accessible and inclusive, to supporting local governments to be more responsive to citizens' needs. CUSP members include faculty and researchers from computer and data science; civil, electrical, biomedical, and mechanical engineering; human-technology design and interaction; applied mathematics and statistics; public health and policy; and the social sciences. CUSP has a large number of ongoing partnerships with city agencies, non-profits, industry, academic organizations, and start-ups that will provide project-based internship opportunities for trainees. These convergent research activities and synergistic connections with NYC put CUSP at the forefront of fundamental and applied research in urban accessibility, a priority of NYC's administration.

Prof. Porfiri is the inaugural director of the CUSP Interdisciplinary Doctoral Concentration, which, like MERC, offers a collaborative environment for excellence in interdisciplinary research. MERC students will be integrated in doctoral activities at CUSP, thereby promoting collaborations with other junior researchers. As an example of potential synergies, Prof. Porfiri is one of the key investigators of several National Science Foundation Projects on networks and human behaviour, which bring along a team of experts across several disciplines in rewarding intellectual activities. MERC students will be welcome to be involved in these activities, participate in related meetings, and attend lectures and seminars.