Antonio Cicone's Final Report

During my Marie Curie Post-Doctoral research experience I have been working on my three research objectives: further studying from a mathematical standpoint problems related with signal processing analysis; start and continue collaborations with researchers in applied fields; disseminate in Italy and Europe the knowledge on the signal processing methods I worked to so far.

In particular, regarding my first research objective, during my visits in Atlanta, in October-November 2015 and then again in May 2016, besides attending conferences where I have been invited to present my research work, I collaborated with Haomin Zhou.

Making use of ideas from linear algebra and Fourier analysis, we derived an explicit numerical formula for the components produced in the Iterative Filtering decomposition of a discrete signal. We also produced a definition of what stability is in this field of research.

The results of this work are going to be published in a few months in a paper titled: Numerical analysis of the Iterative Filtering algorithm for nonstationary and nonlinear signal decomposition. Furthermore we studied the extension of Iterative Filtering to higher dimensions and applications of such method to real life 2D signals. Results are published in the paper titled Multidimensional iterative Filtering method for the decomposition of high-dimensional non-stationary signals in the journal Cambridge Core in Numerical Mathematics: Theory, Methods and Applications.

During these trips I begun studying also to the analytic and numerical convergence of the Adaptive Local Iterative Filtering technique. I involved in this research project also Stefano Serra-Capizzano and Carlo Garoni during one of my visits to the University of Insubria in Como in April 2016. Thanks to our collaboration we discovered new important results on the a priori convergence of the Adaptive Local Iterative Filtering method. We submitted a paper titled Spectral and convergence analysis of the Discrete ALIF method for publication to the journal Applied and Computational Harmonic Analysis.


I also started several collaborations with other researchers:

Together with Hau-tien Wu, assistant professor in Mathematics department at the University of Toronto, I worked on the application of signal processing techniques to medical signals. In particular we were interested in extracting clean heart and respiratory rates from photoplethysmography. Thanks to the application of a new approach based on the signal processing analysis we were able to achieve this research goal. Results have been published on the journal Frontiers in Physiology in a paper titled How Nonlinear-Type Time-Frequency Analysis Can Help in Sensing Instantaneous Heart Rate and Instantaneous Respiratory Rate from Photoplethysmography in a Reliable Way.

With Pietro Dell'Acqua, post doc at University of L'Aquila, I started studying the boundary extension influences on the decompositions produced by both Iterative Filtering and Adaptive Local Iterative Filtering. The problem under study is completely open, it has important repercussions for most real life applications of these kind of techniques, and the preliminary results we are obtaining are really promising.

Regarding my second research objective I started a collaboration with Mirko Piersanti, physicist working at the University of L'Aquila, working on the time-frequency analysis of the Earth's magnetic field measurements collected at geostationary and ground level. We applied the Iterative Filtering method to decompose the Earth's magnetic field measurements as well as the solar wind data in order to identify hidden features of these signals and correlations between the two.

We submitted a paper for publication in the Journal of Geophysical Research, which is one of the most cited journal in Physics, and we presented two posters at the European Geophysical Union conference in April this year.
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I also started collaborating with a researcher in Engineering, Stefano Sfarra, applying the methods developed during this project to the analysis of thermal images in order to identify damages in buildings or artifacts. Another collaboration is with a Volcanologist from the University of Perugia, Laura Spina. With her we are working on the application of the newly developed decomposition methods to volcanic sounds produced during the emission of magma from a volcano. The goal is to predict what kind of magma will be ejected from the volcano.

Finally, for my third research objective I have been invited as well as I applied to participate to several national and international conferences during which I have been able to present my research on the topics of the founded research project to the Italian, European and American Mathematical community. In December of this year I will travel to New Orleans, USA, to participate to the most important conference in Geophysics, American Geophysics Union conference 2017, where I will have the chance to show the potential of these techniques. Furthermore in January I have been invited to give a plenary talk in India at the M3HPCST 2018 conference.

During my second year I applied, together with my colleague Mirko Piersanti, for an ERC Advanced grant with a project concerning the application of Adaptive Local Iterative Filtering to the analysis of the earth magnetic field. The project did not pass the first evaluation process. In fact the project was evaluated extremely positive. The only problem was that the method was considered too much innovative and the reviewers suggested us to apply it to a few more problems before reapplying for funding. We also applied to the European Space Agency for another application of the method for the analysis of satellites datasets. Also in this case the reviewers considered the project as really promising, but they rejected it for the same reason. More applications have to be studied.

I plan to continue working on applications of these techniques to real life signals and reapply in the future to European funding. At the same time I plan to continue working to the mathematical analysis of these algorithms.

Papers published during the project:


Submitted papers


• Ciccone. Nonstationary signal decomposition for dummies. arxiv.org/abs/1710.04844

Papers in preparation

• Numerical analysis of the Iterative Filtering algorithm for the decomposition of non-stationary and non-linear signals (with Haomin Zhou)
• Fast computation of tight bounds for the joint spectral radius (with Vladimir Yu. Protasov)

Invited Talks and Invited Conference Presentations

• Tecniche di decomposizione di segnali non lineari e non stazionari bidimensionali ed applicazioni. Convegno 2016 del GNCS (Montecatini Terme, Italy). February 2, 2016.
• State of the art and open problems in the decomposition of nonlinear and nonstationary signals. XX Congresso UMI (Siena, Italy). September 10, 2015.

Contributed Lectures at Conferences

• Convergenza numerica e proprietà del metodo Filtraggio Iterativo per lo studio di segnali nonlineari e nonstazionari. Due Giorni di Algebra Lineare Numerica (Como, Italy). February 16-17, 2017.
• A sub-optimal solution for optimal control of linear systems with unmeasurable switching delays. 54th IEEE Conference on Decision and Control (Osaka, Japan). December 15-18, 2015.

Posters

• ALIF: a new promising technique for the decomposition and analysis of nonlinear and nonstationary signals. European Geosciences Union General Assembly 2017 (Vienna, Austria). April 8-13, 2017
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