UNIVERSITÀ
DI PARMA

Location: Department of Engineering and Architecture, University of Parma, Parma, Italy

Intelligent Bio-Inspired Systems (IBIS) Lab

Social Web, Intelligent and Distributed systems Engineering (SoWide) Lab

Supervisor: Stefano Cagnoni (https://personale.unipr.it/en/ugovdocenti/person/16857)

Project: *Using Evolutionary Computation and Machine Learning Algorithms to explain Deep Neural Nets results*

Stefano Cagnoni

Stefano Cagnoni graduated in Electronic Engineering at the University of Florence in 1988. He has been a Ph.D. student and a post-doc until 1997, working in the Bioengineering Lab of the Department of Electronic Engineering. He received a Ph.D. degree in Bioengineering in 1993 from the same institution.

In 1994, he was a visiting scientist at the Whitaker College Biomedical Imaging and Computation Laboratory at the Massachusetts Institute of Technology. He held a post-doc position at the University of Florence in 1995 and 1996. Since 1997 he has been with the Department of Computer Engineering of the University of Parma, where he has been Associate Professor since 2004.

As concerns basic research, his main research interests are in the field of soft computing, with particular regard to evolutionary computation.

As concerns applied research, his main topics of interest are the application of the above-mentioned techniques to problems in pattern recognition and computer vision.

Besides actively participating in EvoNET, the EU-funded network of excellence in evolutionary computation from 1997 to 2005, when the project was officially closed, he has developed applications of evolutionary algorithms to image processing and image understanding problems.

He has also studied the coevolution of heterogeneous systems, aimed, as a long-term goal, at defining co-evolutionary algorithms based on the definition of ecosystems in which different populations evolve cooperatively and self-organize to optimize specific parts of a problem at hand.

His research has also been focused on the theory and applications of Particle Swarm Optimization (PSO). In particular, as regards applications, he has studied computer vision algorithms in which PSO is used to detect and track objects/people and defined a highly efficient massively parallel implementation of PSO on graphics hardware.

In the last five years, he has applied evolutionary and swarm intelligence methods to speed up the detection of relevant variable sets in complex systems or, more in general, in systems described by many variables.

Stefano Cagnoni's research activity has been carried out within projects financed by MIUR, CNR, ASI, and ENEA and part of contracts managed directly or within regional technology transfer projects between his group and firms in the province Parma or Emilia Romagna. He has co-managed a project funded by the Italian Railway Network Society (RFI) to develop an inspection system for train pantographs which originated a patent whose rights have been acquired by a multinational corporation that has further developed the project up to an industrial product level.

He has been awarded a grant from the EU Marie Sklodowska Curie Actions for a four-year research education project in "Medical Imaging using Bio-Inspired and Soft Computing." (2009-2013).

From 1999 to 2018, he has been chairman of a yearly European event dedicated to evolutionary computation applications to image analysis and signal processing (now a track of the EvoApplication conference). In 2001 and 2002, he was General Chair of EvoWorkshops (presently known as EvoApplications), the joint European conference on the Applications of Evolutionary Computation. He is currently a member of the SPECIES Executive Board.

From 2005 to 2020, he has co-chaired MedGEC, a workshop on medical applications of evolutionary computation held concurrently with GECCO (Genetic and Evolutionary Computation Conference). Co-editor of the special issues of "EURASIP Journal of Applied Signal Processing" (July 2003), "Pattern Recognition Letters" (2006), "Evolutionary Computation" (2008), "Applied Soft Computing" (2020) dedicated to "Genetic and Evolutionary Computation for Image Analysis, Signal Processing, and Pattern Recognition." He organized the "EvoNET Summer School on Evolutionary Computation" in Parma in 2003. He has been Editor-in-chief of the "Journal of Artificial Evolution and Applications" (2007-2009).

He was the recipient of the "Evostar 2009 Award", awarded by SPECIES to recognize the most outstanding contribution to Evolutionary Computation.

As of April 2021, his H-Index is 29 (Google) / 20 (Scopus).

Project Description

Although Machine Learning applications in the medical field and, in particular, in the diagnostic sector, have achieved excellent results, many doubts regarding their reliability and practical applicability are raised by medical personnel due to the difficult interpretation and explanation of their decisions.
The problem is deeply felt and debated in the field of Artificial Intelligence and has become the subject of a large number of projects at European and world level.
For example, in the page reporting the position statements of the most distinguished members of Claire, the largest European networking initiative among researchers in Artificial Intelligence, we find the following statements:

"Next generation AI systems must become more socially-aware, explainable and responsible"; "Statistical machine learning has made some amazing advances, but we are now beginning to see its limitations, especially regarding explainability, or rather the lack of it"; "…reasoning and learning processes need to be traceable and explainable in human terms"

The proposed project starts from the observation that the functions by which, when possible, the decision-making models generated by Machine Learning methods, and in particular Deep Learning, can be expressed are too complicated to be interpreted directly in order to derive causal relationships or hypothesis on these relationships.
On the other hand, the use of attention maps, which is by far the currently most frequently used methodology to try to explain the decisions of Deep networks, especially in the field of image interpretation and analysis, has recently been questioned for its insufficient selectivity. It has in fact been verified that completely comparable attention patterns can be associated with images of a very different nature, being linked more to the pose of the framed subject than to the actual content of the image. Additionally, a problem exists, linked to the high risk of making correct decisions based on the use of spurious or random correlations in models, such as Deep networks, which base their performance on a very high number of degrees of freedom (variables) that determine its functioning.

A possible approach to the solution of these problems can be represented by what, from an information theory point of view, can be considered a sampling of the networks' response or, from a clinical-diagnostic point of view, the response to a series of 'What if…?' questions that can be formulated expressing a hypothesis by defining instances that we consider representative of paradigmatic situations and to which we can give an answer by observing the corresponding output produced by the model.
However, the input space (clinical data) is typically large, while the number of possible states that we can imagine exploring 'manually' to validate the model or to formulate new hypotheses on the correlation between these states and some pathology of interest can only be extremely limited. Nor can the idea of sampling the entire space exhaustively (or in any case very dense) be admissible at the other extreme.
A more complete characterization of the model can be obtained through meta-heuristics capable of generating and evaluating an extremely large number of clinical states, or even from generative-type models, widely documented in the literature on Deep Learning. Through an approach of this type applied to networks that map clinical states on the corresponding pathologies, it is possible, for example, to extract the clinical states that are most likely associated with a certain pathology, effectively answering the question 'which contributing causes can lead to the onset disease x? 'or' what clinical signs are typically associated with disease x? '

It is foreseeable that this research may select a very significant number of 'examples', many of which will be very different from the cases typically faced in clinical practice. A subsequent clustering of these data will still allow the identification of a limited number of 'classes' that the extracted data represent. The latter can be critically analyzed by a medical expert who will recognize:
i. known associations, confirming the correctness of the network response;
ii. associations that are not plausible or acceptable, in which case one could add negative examples of this type to the training set, in order to correct the response of the model;
iii. situations that are not known or documented, but plausible, corresponding to new possible clinical hypotheses to be verified, which would constitute the most stimulating result from a researcher's viewpoint.

The proposed approach, although designed for the clinical application described above, in fact has general characteristics that make it applicable to the most varied contexts in which learning processes are activated on a large amount of data. The system is in fact able to enrich the intelligent systems thus obtained, oriented to classification or prediction, by introducing an advanced a posteriori analysis of the input / output associations (causal relationships) that the learning system has been able to extract.

We are willing to add an allowance of 1000 Euros/month to extend the student's stay for up to two more months.

PARMA (visit https://en.unipr.it/living-parma for more)

A friendly city for modern living

Busy but not chaotic, tidy but not dull, beautiful, Parma is an ideal place to live in.
Parma is a lovely medium-sized city of 196,000 inhabitants**.** It is located in Emilia-Romagna, a Northern Italy region enclosed, to the North, by the charming plains of the Po river and, to the South, by the woods of the Apennines.
In Parma, the high quality of living is immediately perceivable thanks to its florid economic activities, its excellent food industry, and the Emilian way of life**.** Nevertheless, Parma is also famous for its art and history, with its magnificent Cathedral and Baptistery and the masterpieces of the local painters Correggio and Parmigianino.
Parma is a welcoming and friendly city where life is easy-going, and bicycles are the perfect means to move around: have a ride or a stroll through the charming streets of the city center with their fashionable shops and cafés to enjoy this lovely atmosphere!

Much to see, do and discover

A city immersed in art, Parma offers a wide range of cultural and entertainment opportunities all year round: about twenty theatres and cinemas, exhibitions, events, museums, art galleries, etc., and last but not least, concerts and music performances at its magnificent and renowned **Teatro Regio opera house.**
Music has a leading role in the city, especially for opera and the composer **Giuseppe Verdi**, who was born near Parma. To celebrate its great *Maestro*, every year, Parma organizes the **Verdi Festival** offering a complete program of concerts and performances, as well as meetings and workshops dedicated to Verdi's music.
International jazz and theatre festivals, rock concerts, art shows, and galleries are always available to attend. Just choose any of the events that Parma offers throughout the year, and you will realize that **cultural life never stops**.
Let us not forget the last acknowledgments obtained by Parma: the label of "The **Creative City of Gastronomy**" awarded by UNESCO in 2015, and the title of "**Capital of Culture 2020**", obtained in February 2018

Parma hosted Evostar in 2018 (http://evostar.org/2018)!

http://en.unipr.it is the web site of the University of Parma (UNIPR)

Parma is close to many historical cities: Milan (1.5 h by train), Bologna (1h), Florence (2h), Turin (2.5 h) as well as almost equally far from both the Tyrrhenian (Versilia) and the Adriatic Sea (Ravenna, Rimini).

Our lab is in The Faculty of Engineering Research Center of the University of Parma, located in the University Campus, about 6 km (15-20 minutes by bus, a little more by bicycle) from the town center.