



NATIONAL PH.D. PROGRAM IN AUTONOMOUS SYSTEMS

A nonlinear dynamical approach to the symptoms graph

Ph.D. candidate

Iacopo CAPOROSSO

Cycle XL

Tutors

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1. Description of the research program

Recently a group of psychologists proposed the use of graphs to represent mental disorders (called symptoms graph), in which the graph's nodes represent the symptoms of the mental illness and the edges are the connections between them. One of the main results they obtained is that a necessary condition for having a mental disorder is the strong connectivity of the symptoms graph.

In my master thesis I introduced the evolution over time in the symptoms graph assuming some simplifications: the adjacency matrix is fixed and the external triggers that activates one or more symptoms appears only once (at beginning). I obtained a linear dynamical system in which the variables are the symptoms of the mental disorder which can be either active, setting the variable 1, or inactive, setting the variable 0. Performing numerical simulations (using a Matlab code) and using synchronization's theory, the conclusion is that a peculiar case for which one can talk about recovery from a mental disorder is reaching a consensus under a certain threshold.

In my thesis the symptoms graph has been constructed analyzing transcribed therapy sessions, in my PHD I propose to use NLP's techniques to let the symptoms graph be constructed in an automated way. In order to built the required data collection to train the artificial intelligence, agreements with Scuola di Psicoterapia Integrativa Interdisciplinare (SPII) of Florence were made in order to obtain complete and transcribed therapy paths to be analyzed.

The second task that I propose to investigate in my PHD is the relationship between the psychological concept of hysteresis and its mathematical counterpart. A psychological definition of hysteresis can be the tendency of the individuals to keep performing some behaviors, even if some parameters are changed. Borsboom and Cramer found that if the graph reacting to the symptoms' activation due to an external trigger becomes strongly connected, the symptoms keep staying active even if the external trigger (the modification on the nearby patient) disappears. Whereas, in dynamical systems' theory, the hysteresis can be defined as a sort of delay in responding to the perturbations in relation with the previous state.

The study will be divided following these steps, at the first the discrete time linear system developed in my thesis will be expanded in continuous time, supposing that the activation function of every symptom depends in a linear way (to maintain the adjacency matrix structure) to the others. Then we perturb the system adding a nonlinear term in one symptom with the claim of finding necessary conditions on the adjacency matrix and on the nonlinear term to have an hysterical regime in the perturbed system. As a final result, the generalization of it, adding the nonlinear term in a general number of symptoms will be study.

2. Schedule of the research activities

First academic year planned

	Description	Period	Activity abroad
Study the relevant literature	Analyze the the state of art of the relevant literature in matter of psychological complex systems and machine learning techniques.	1-12 months	NO
Application to my model	Expand the existing linear model introducing nonlinearity to better describe the evolution over time of a mental disorder from a theoretical point of view.	1-12 months	NO

Second academic year planned

	Description	Period	Activity abroad
Data collection and collaboration with Prometeo	<ul style="list-style-type: none"> • Collaboration with the company Prometeo (up to 6 months) • Collections of transcribed therapy paths to let the construction of the symptoms graph be automatized. 	1-12 month	NO
Validation of the model	Collaboration with psychologists to validate the proposed model	9 month	NO
Period abroad	Studying similar model based on different hypothesis	3 months	YES (to be acknowledge)

Third academic year planned

	Description	Period	Activity abroad
Analysis of the results	Analysis of the results obtained with the aim of developing a more adherent with reality model	3 months	YES (to be acknowledge)
Writing the PHD thesis	Writing the PHD thesis	1-12 months	NO

3. Training and research activities plan

First academic year planned

	Description	Period	Final Exam	ECTS
A. Ph.D. courses	Complex Network Theory: theory, methods and applications	March	Yes	2
	Linear Algebra for control applications	Feb-Mar	Yes	2
	Introduction to Autonomous Systems	June	Yes	1
B. Master's degree courses	Programming for data science	Nov- Jen	Yes	6
C. Soft skill courses	Partecipation to one soft skill courses according to availability	1-12 months	Yes	2
D. Participation to seminars	Participation to at least four seminars according to availability.	1-12 months	No	7,5
E. Participation to international congresses or workshops	Participation to at least one international congresses or workshops according to availability.	1-12 months	No	2
F. Presentation of research products at international congresses or workshops	Presentation of the results obtained to at least one international congresses or workshops.	1-12 months	No	2
	TOTAL OF ECTS FOR TRAINING ACTIVITIES			24,5
G. Individual research activity	Research activities in the field of networked systems and NLP's techniques.	1-12 months	No	15,5
H. Supervision of students	Supervision of Students under the guidance of the tutor.	1-12 months	No	5
I. Integrative teaching activities	Integrative didactive activities to be carried out under the supervision of the tutor.	1-12 months	No	5
J. Preparation of manuscripts for conferences or journals	Verbalization of the results obtained, in the form of a paper for a conference or a journal.	1-12 months	No	10
	TOTAL OF ECTS FOR RESEARCH ACTIVITIES			35,5
	TOTAL OF ECTS			60

Second academic year planned

	Description	Period	Final Exam	ECTS
A. Ph.D. courses	Participation to at least four PhD courses according to availability.	1-12 months	Yes	7
B. Master's degree courses				
C. Soft skill courses	Participation to one soft skill course according to availability	1-12 months	No	2
D. Participation to seminars	Participation to at least two seminars according to availability.	1-12 months	No	3
E. Participation to international congresses or workshops	Participation to at least one international congresses or workshops according to availability.	1-12 months	No	2
F. Presentation of research products at international congresses or workshops	Presentation of the results obtained to at least one international congresses or workshops.	1-12 months	No	2
	TOTAL OF ECTS FOR TRAINING ACTIVITIES			16
G. Individual research activity	Research activities in the field of networked systems and NLP's techniques.	1-12 months	No	17
H. Supervision of students	Supervision of Students under the guidance of the tutor.	1-12 months	No	7
I. Integrative teaching activities	Integrative didactive activities to be carried out under the supervision of the tutor.	1-12 months	No	10
J. Preparation of manuscripts for conferences or journals	Verbalization of the results obtained, in the form of a paper for a conference or a journal.	1-12 months	No	10
	TOTAL OF ECTS FOR RESEARCH ACTIVITIES			44
	TOTAL OF ECTS			60

Third academic year planned

	Description	Period	Final Exam	ECTS
A. Ph.D. courses				
B. Master's degree courses				
C. Soft skill courses				
D. Participation to seminars	Participation to at least two international congresses or workshops according to availability.	1-12 months	No	4
E. Participation to international congresses or workshops	Participation to at least two international congresses or workshops according to availability.	1-12 months	No	4
	TOTAL OF ECTS FOR TRAINING ACTIVITIES			8
G. Individual research activity	Research activities in the field of networked systems and NLP's techniques.	1-12 months	No	20
H. Supervision of students	Supervision of Students under the guidance of the tutor.	1-12 months	No	12
I. Integrative teaching activities	Integrative didactive activities to be carried out under the supervision of the tutor.	1-12 months	No	10
J. Preparation of manuscripts for conferences or journals	Verbalization of the results obtained, in the form of a paper for a conference or a journal.	1-12 months	No	10
	TOTAL OF ECTS FOR RESEARCH ACTIVITIES			52
	TOTAL OF ECTS			60

4. List of the publications written by the candidate in the triennium

Master Thesis of M.Sc. Program in Applied Mathematics

Caporossi I., A dynamical approach to the symptoms graph, University of Siena (July 18-th 2024)

International Conference Proceedings

Caporossi I., Vitanza E., Mocenni C., A nonlinear dynamical model of the symptoms graph, Conference of complex systems CCS2024, Exeter, September 1-st - 7-th 2024 (postere presentation)

