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On the statistical analysis of intra course dynamics in university system networks

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Summary: The movements of students between the faculties of the University of Bologna represent a complex evolving network. We aim to infer on the dynamics and the structural mechanisms that lead the evolution and topology of this complex system by mapping the database of the University containing relevant information about students during four academic years (2004-2008). Empirical measurements allow us to discover the topological characteristics of the network at a given moment, as well as their evolution in time. The results highlight stable 'attraction' and 'escape' nodes within the University network and provide a simple description of the student movements and preferences.

Keywords: Graph theory, Social network analysis, Escape and attraction Poles.

1. Introduction

A complex evolving network is built with the aim of inferring the dynamical evolution of students' movements between courses in the University Systems.

An interesting case of study is given by Bologna University (Stracqualursi and Monari, 2006), whose internal movements highlight a wide network, characterized by stable 'attraction' and 'escape' nodes which provide a simple description of student dynamics and preferences. Empirical measurements allow us to discover the topological characteristics of the network at a given time and the principal variables affecting it.

In this paper we examine the transfer network in the 2007-2008 academic years, characterized by a noticeable increase in the number of degree courses due to new rules introduced by Italian Government (D.M. 270/20) which transformed once again the Italian university organization. The main consequence was an increase in student transfers from *old* courses (many of which definitively closed) to *new* ones.

The idea is to describe the movements of students between faculties (or courses) within the University of Bologna by means of a network and to represent it as a graph. Our interest is to identify *attraction nodes*, that is courses which tend to attract students from other faculties, and *escape nodes*, including courses having a high out-transfer rate. The present analysis considers only *in* or *out* transfers between the faculties or courses of Bologna University.

In this paper, transfers between Bologna University and other Universities are not considered since lack of data doesn't allow to build an Italian system network.

Particularly, in section 2 we introduce some elements on statistical complex network theory; in section 3 we build the course networks in several academic years using specific measurements that help to discover the variables influencing the network structure; in section 4 we propose a network model for explaining the topology of observed network and a micro model to forecast the evolution of the networks in time.

2. The complex networks

In some complex systems the principal characteristics are not described by points but by relations between them. For example, in biology the cell is best described as a complex network of elements connected by chemical reactions (Barabási and Oltvai, 2004); the Internet is a complex network of routers and computers linked by various physical or wireless links; fads and ideas spread on the social network, whose nodes are human beings and whose edges represent various social relationships; the World Wide Web is an enormous virtual network of Web pages connected by hyperlinks (Barabási, 2001).

Traditionally, the studies on complex networks have been the territory of graph theory, that has its origins in the eighteenth century in the work of Leonard Euler, the early work concentrating on small graphs with a high degree of regularity (Bollobás, 1985).

In mathematical terms, a graph is a pair of sets $\mathbf{S}\{\mathbf{A},\mathbf{E}\}$, where $\mathbf{A}$ is a set of N nodes (or vertices) $A_{1,}A_2,...,A_N$ and $\mathbf{E}$ is a set of edges (or links) that connect two elements of $\mathbf{A}$. Graphs are usually represented as a set of dots, each corresponding to a node, two of these dots being joined by a line if the corresponding nodes are connected.

In the twentieth century, graph theory has become more statistical and computational. During the time, a rich source of ideas has arisen from the studies of random graphs in which the edges are distributed randomly. This kind of network describes a system composed by a fixed number of nodes which have an identical average number of links (the degree of the node). Consequently the nodes are indistinguishable each other, having the same degree. Since their introduction and for decades these models have been used to represent complex networks but they are not very suitable to describe real networks (Barabási and Albert, 2002).

Recently, a simple model that allows to describe some of principal characteristics of real networks has been proposed. This model is based on two principal assumptions: (1) *incremental growth*: networks grow by addition of new nodes, (2) *preferential attachment*: there is a higher probability to link to a node with a large number of connections (this principle is also known as "rich gets richer").

Thanks to these assumptions it is possible to build a network in which only few nodes have an high number of links. Network having this topology are named *scale-free*. In this kind of networks the probability $P(k)$ that a randomly selected node has exactly k edges follows a power-low distribution. This distribution remains the same increasing the number of network nodes, thus it is independent from the magnitude and scale of the network, whence the name *scale-free*. In the networks, a distance is measured by its path length, which tells us how many links we need to pass through to travel between two nodes. As there are many alternative paths between two nodes, the shortest path is the path with the smallest number of links between the selected nodes. The first studies on the social network property discovered that in most networks there is a relatively short path between any two nodes (*small worlds* effect). The distance between two nodes is defined as the number of edges along the shortest path connecting them. The most popular manifestation of small worlds is the "six degree of separation" concept, uncovered by the social psychologist Milgram (Milgram, 1967), who concluded that there was a path of acquaintances with a typical length of about six between most pairs of people in the United States.

It seems that a common property of social networks is just this tendency to cluster (Watts and Strogatz, 1998).

3. The university network

The movements of students between faculties (as homogeneous aggregates of university courses) or between different courses, active at the University of Bologna, can be seen as networks and can be represented by graphs.

After having identified "*attraction*" nodes, given by faculties (or courses) which tend to attract students from other faculties (or courses), and "*escape*" nodes given by faculties (or courses) which have a high *out*-transfer rate, we will search for the variables influencing the network structure.

As a first step, we analyze the network of the 23 faculties within the University of Bologna. In this network, the nodes are faculties, whereas the links are student inter-faculty transfers. In this context, the weight of each link is given by the number of student transfers. Such a network is called a valuated (or weighted) network.

The data come from the data-warehouse of the University of Bologna, which contains relevant information regarding the students' careers for four academic years (2004-2008). The softwares *Ucinet 6.158* and *Netdraw 2.055* are used for processing data. Specifically, *Ucinet* is a software used in social network analysis to store data and it incorporates a collection of network techniques (Borgatti *et al.*,1999), whereas *Netdraw* is a program designed for drawing social networks.

In order to identify "attraction" nodes in the network of faculties, we calculate global network centralization indices, which express the degrees of inequality or variance in the network.

For non-symmetric data the *in*-degree of a vertex v is the number of ties received from v and the *out*-degree is the number of ties starting from v. In addition, if the data are weighted we estimate the *in* and *out* degrees by the sums of the numbers of ties.

For a given binary network with vertices $v_1, ..., v_N$ and maximum degree centrality $c_{\max}$, the network centralization measure is:

$$C_N = \frac{\sum_{i=1}^{N} (c_{\max} - c_i)}{\max\left\{\sum_{i=1}^{N} (c_{\max} - c_i)\right\}}$$

where c_i is the degree centrality of vertex v_i.

Hence, we can estimate the variability between the degrees of actors (the nodes) as a percentage of the maximum corresponding to a star network of the same size. The star network is the most centralized or most unequal possible network in which all the actors but one have degree of one, and the "star" has degree of the number of actors less one (Freeman, 1979).

Table 1. Network centralization measures

	Out-degree	*In*-degree
2004-05	9.69%	12.54%
2005-06	13.66%	14.78%
2006-07	10.55%	8.37%
2007-08	6.99%	8.54%

In the considered academic years, the *out*-degree and *in*-degree network centralization measures range from 8.37% to 14.78% (Table 1). It means that there is only a little amount of concentration or centralization into the whole network, therefore the positional advantages (the faculties preferred by students) are rather equally distributed in the network. As we can see the centralization indices tend to decrease in the years further reducing the few positional advantages.

In order to identify and visualize some significant "classes", we apply multi-dimensional scaling (MDS) of geodesic distance, that is a display graph network method based on proximity among actors (nodes).

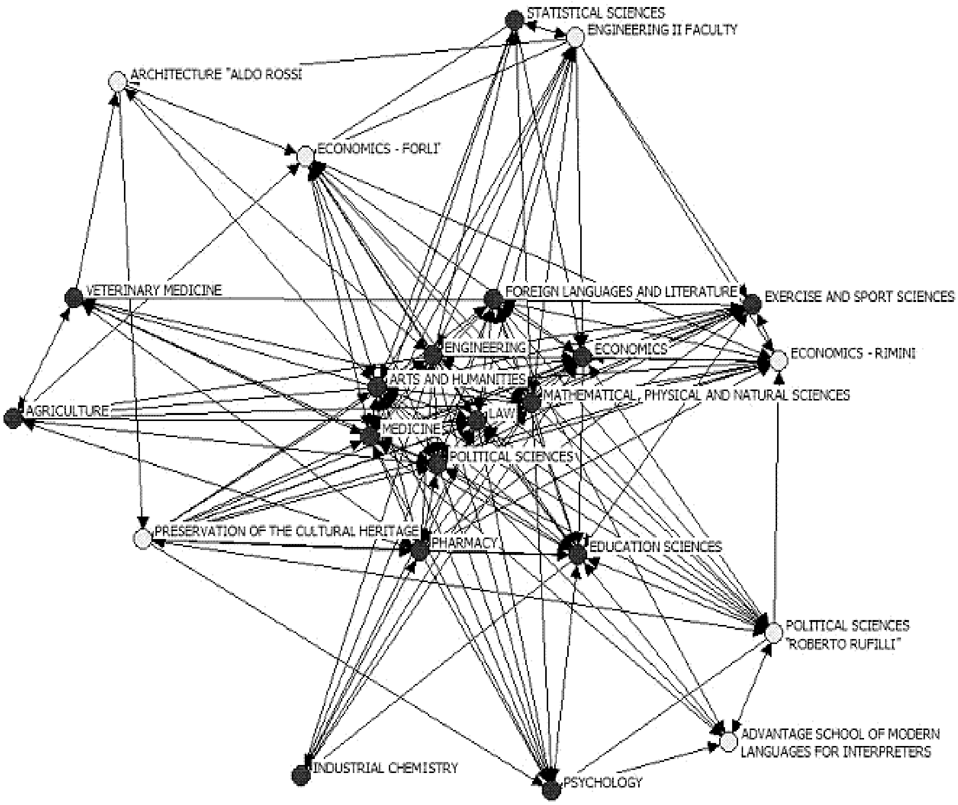


Figure 1. MDS of Geodesic Distance

MDS represents the patterns of similarity or dissimilarity in the tie profiles among actors as a "map" in the multi-dimensional space. This map allows to see how "close" the actors are, whether they "cluster" in multidimensional space, and how much variation there is along each dimension. Figure 1 displays the graph nodes in a two-dimensional space, where actors having large between-interaction are placed near, while actors having small interaction are placed in a more distant space (Kruskal and Wish, 1978). Black and white circles represent the different geographic locations of the faculties in the five campuses of the Bologna University (Bologna, Cesena, Forlì, Ravenna, Rimini). Faculties outside Bologna are represented by a white small circle, while faculties within Bologna by a black small circle. In Figure 1, we can see a group of "center" faculties having more between-interaction all located in Bologna. A possible reading is that students studying in Bologna prefer to move to other faculties within the same campus.

3.1. The identification of "attraction" and "escape" nodes

Empirical measurements which allow to discover "attraction" and "escape" nodes are *in* and *out*-degree. Bigger is the number enter links of the node (*in*-degree), bigger is the power of the node to recall students. On the other hand, bigger is the number of node out links (*out*-degree), smaller is the faculty attitude to keep students.

Since these quantities depend on different faculty dimensions, we have normalized degrees by using for each faculty the relative student number (frequency). After this normalization, the results change: new faculties, displayed in grey in Table 2, are now included as "escape" or "attraction" nodes. Besides potential "escape" and "attraction" nodes $\hat{i}$ there are faculties with high *out*-degree and *in*-degree that are displayed in bold.

The "escape" faculties in addition to "Engineering" and "Mathematical, Physical and Natural Sciences" are "Pharmacy", "Industrial Chemistry" and "Foreign Languages and Literature", because they have a high *out*-degree with respect to their number of enrolled students. At the same way, additional "attraction" faculties are "Veterinary Medicine" and "Psychology".

Figure 2 displays graphically the network for year 2007-08, where nodes with high *in*-degree are in white, while nodes with high *out*-degree are in grey.

In order to explain the large *in*-degree of "Medicine" we build its weighted egonet (Figure3). An "ego network" (egonet) consists of:

- a focal node (ego), in our case the "Medicine" faculty;
- the nodes to which ego is directly connected to (called "alters");

Table 2. In and out degree of the faculties

	Degree							
	2004-05		2005-06		2006-07		2007-08	
	Out	In	Out	In	Out	In	Out	In
Agricolture	15	15	26	13	24	17	25	23
Architecture	7	3	1	7	1	11	5	13
Industrial Chemestry	10	3	2	3	9	4	10	7
Preservation of Cultural Heritage	17	17	14	9	10	15	5	7
Economics	60	72	66	64	54	66	43	70
Economics - Fo	16	26	25	37	19	24	22	28
Economics -Rn	12	24	24	21	15	21	10	33
Pharmacy	73	26	92	21	80	23	122	33
Law	86	65	79	75	82	42	59	33
Engineering	**145**	29	**106**	28	**120**	31	**121**	24
Arts and Humanities	94	**175**	89	**190**	89	**134**	74	**138**
Foreign Languages ..	80	27	77	35	66	50	75	37
Medicine	18	**131**	22	**138**	14	**149**	17	**179**
Veterinary Medicine	9	21	17	27	13	13	18	19
Psychology	3	20	9	25	6	30	7	14
Education Sciences	39	72	29	82	40	80	26	65
Mathematical, Physical . . . Sciences	**145**	77	**179**	74	**177**	68	**154**	67
Exercise and Sport Sciences	7	25	14	22	10	22	18	21
Political Sciences	84	**100**	77	64	71	76	66	66
Political Sciences - Fo	34	20	30	27	17	27	18	18
Statistical Sciences	5	5	5	16	12	13	9	6
Advantage School of Modern...	2	11	3	5	2	8	3	3
Engineering II Faculty	30	27	23	26	26	33	28	31

- the ties, if any, among the alters.

When each tie has a weight this network is called *weight egonet*. Only two faculties, “Mathematical, Physical and Natural Sciences” and “Pharmacy”, affect significantly the high *in*-degree of “ego”. This because “Medicine” has a fixed number of students: students who do not pass the admittance test tend to enroll temporarily in similar faculties and then ask for transfer. The second step of the analysis will show that the specific courses used by students to pass the drawback of failure admittance test in “Medicine” are “Biological Sciences” and “Pharmacy”.

3.2. The course network

After having identified “attraction” and “escape” faculties, we analyze the network of the courses within the Bologna University.

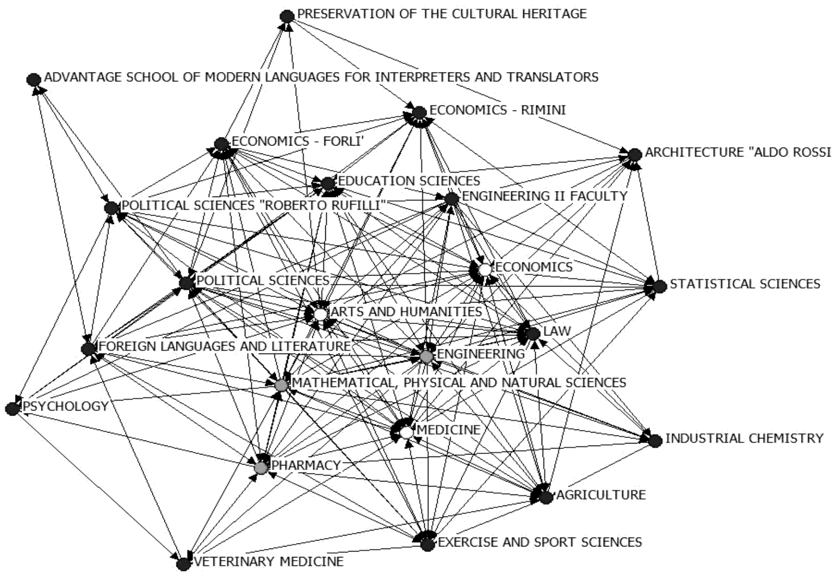


Figure 2. Faculties network of University of Bologna

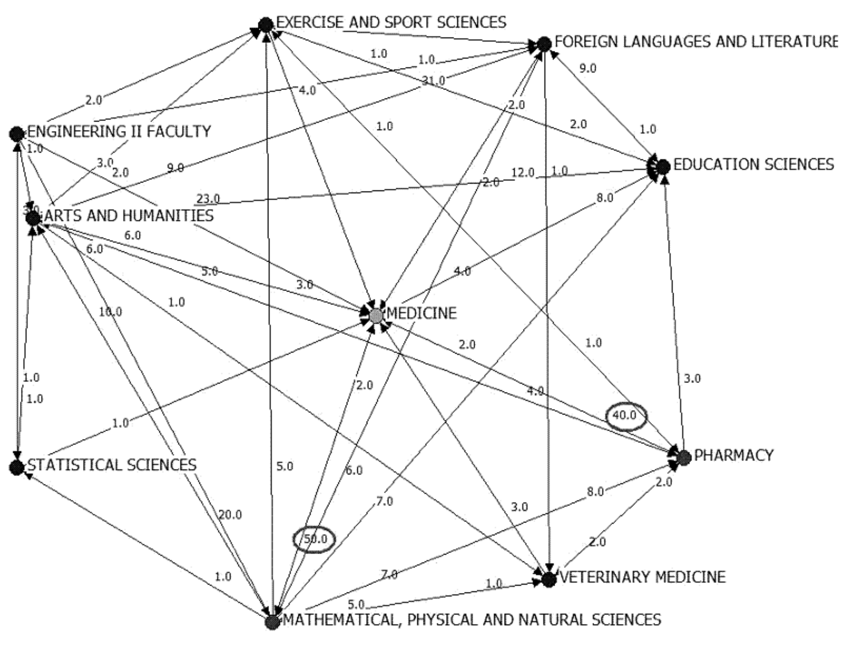


Figure 3. Egonet of Medicine

Table 3. In and out Normalized Degree for the faculties

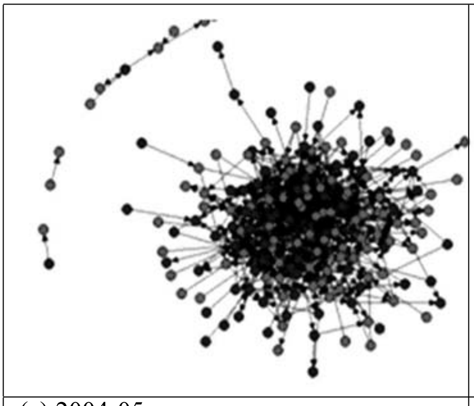
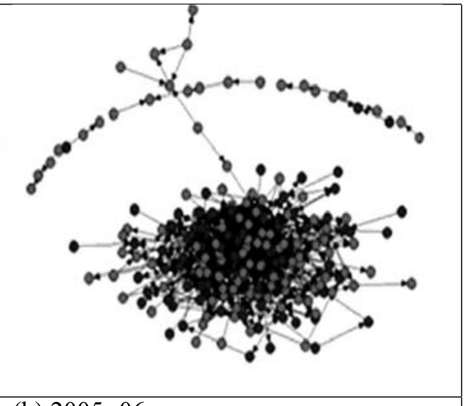
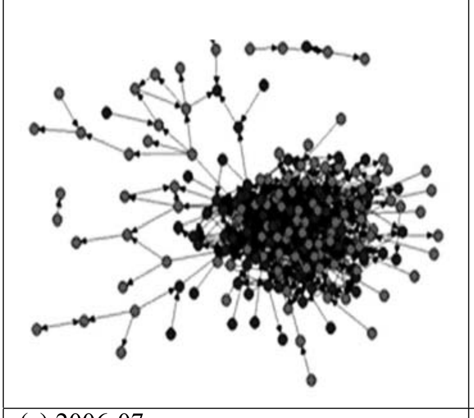
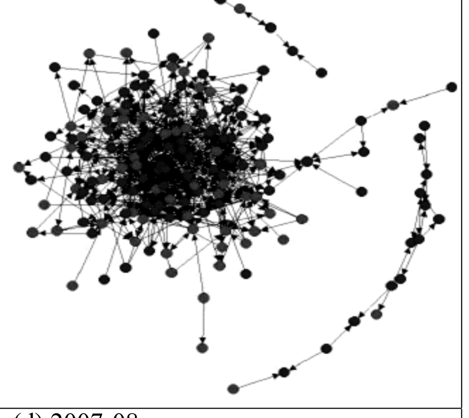
	Normalized Degree - *percentages values*							
	2004-05		2005-06		2006-07		2007-08	
	Out	In	Out	In	Out	In	Out	In
Agricolture	3.8	3.8	6.9	3.4	8.0	5.7	9.2	8.5
Architecture	5.1	2.2	0.7	5.1	0.9	9.6	4.0	10.4
Industrial Chemestry	12.5	3.8	2.0	3.0	9.3	4.1	8.8	6.1
Preservation of Cultural Heritage	6.5	6.5	5.7	3.7	5.5	8.2	4.1	5.7
Economics	4.6	5.6	5.4	5.2	5.7	7.0	4.5	7.3
Economics - Fo	3.1	5.1	6.9	10.2	4.4	5.5	5.3	6.7
Economics -Rn	2.2	4.3	5.6	4.9	3.9	5.4	2.5	8.3
Pharmacy	12.3	4.4	24.7	5.6	10.6	3.1	16.5	4.4
Law	5.4	4.1	5.2	5.0	6.0	3.1	4.8	2.7
Engineering	9.2	1.8	6.8	1.8	8.3	2.1	9.1	1.8
Arts and Humanities	2.9	5.5	3.1	6.6	3.5	5.3	3.4	6.3
Foreign Languages ..	10.5	3.5	9.8	4.5	8.6	6.5	11.0	5.4
Medicine	1.9	13.8	2.1	12.9	1.4	14.5	1.7	17.4
Veterinary Medicine	5.1	12.0	9.4	15.0	6.8	6.8	9.8	10.3
Psychology	1.2	8.2	3.6	10.0	2.5	12.5	2.8	5.7
Education Sciences	3.4	6.2	2.5	7.1	4.2	8.4	3.2	8.0
Mathematical. Physical . . . Sciences	9.9	5.2	12.0	5.0	14.0	5.4	13.5	5.9
Exercise and Sport Sciences	2.5	8.9	4.7	7.5	3.4	7.4	6.2	7.3
Political Sciences	6.3	7.5	6.3	5.2	6.9	7.4	9.1	9.1
Political Sciences - Fo	6.6	3.9	6.2	5.6	3.6	5.7	3.9	3.9
Statistical Sciences	4.0	4.0	2.4	7.6	8.3	9.0	8.8	5.9
Advantage School Of Modern...	1.3	6.9	1.9	3.1	1.3	5.2	1.8	1.8
Engineering II Faculty	7.7	6.9	5.9	6.7	7.7	9.8	7.8	8.6

In these new networks, the nodes are the courses, while the links are always the student inter-course transfers (Table 4). We analyze this network for four academic years (2004-2008).

Graphs in Figure 4 represent the different dimensions of the faculties related to the number of courses, each flower represents one faculty and the petals the relative courses.

The first remark is that the evolution of networks is not in terms of growth, but of change in linkage system. The graphs in Table 4 display the changing linkage structure in the last four academic years.

Table 4. Whole course networks

	
(a) 2004-05	(b) 2005 -06
	
(c) 2006-07	(d) 2007-08

The simplest and most common method to simplify a network is to dichotomize data using a specific cut-off.

To decide the cut-off to be used for creating images, after empirical simulations, we have chosen cut-off=3: it means that links between courses which have less than 3 student transfers are not considered.

The results for the academic year 2007-08 are shown in Figure 5. The

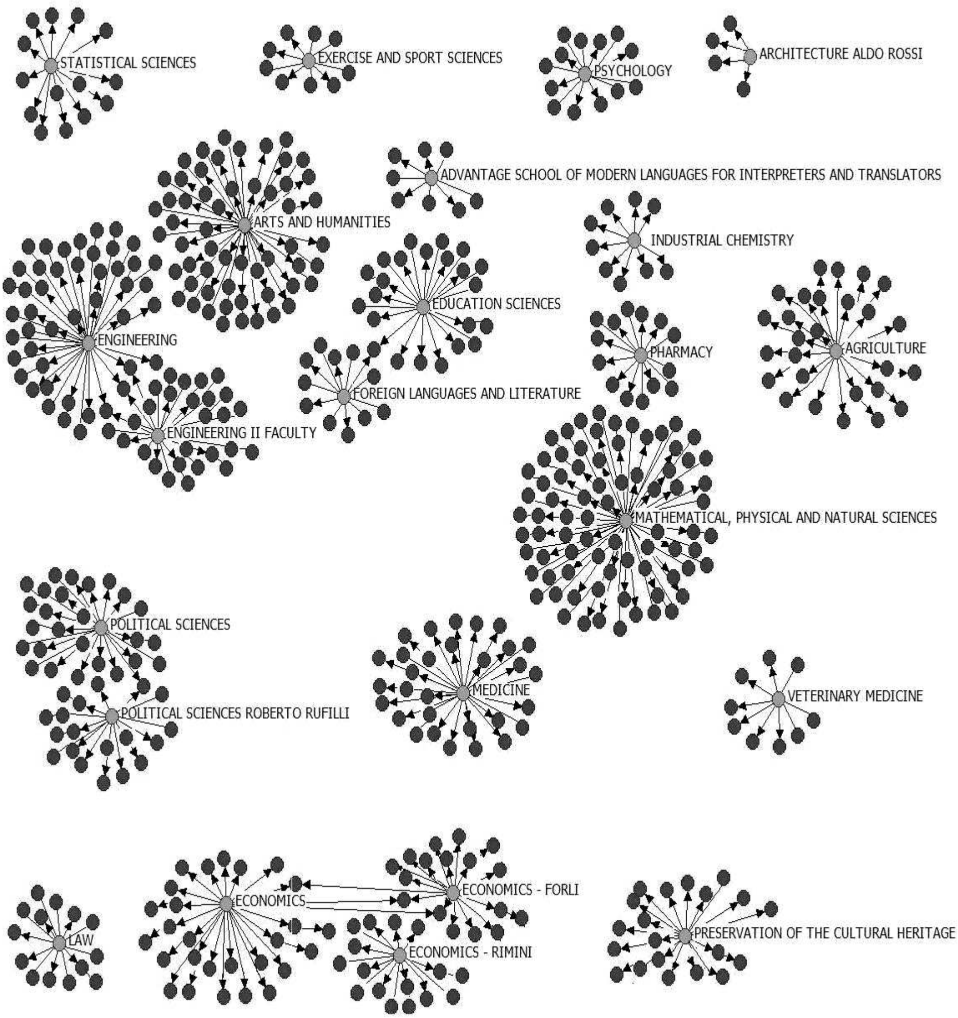


Figure 4. Faculties with relative courses

different grey scale circles indicate: black – courses located in Bologna Campus; grey – courses located outside Bologna Campus; white – courses with high *out*-degree; soft grey – courses with high *in*-degree.

Particularly, we can see 4 areas:

- "medical and paramedical" area,
- "economic" area,
- "humanistic and legal" area
- "engineering" area.

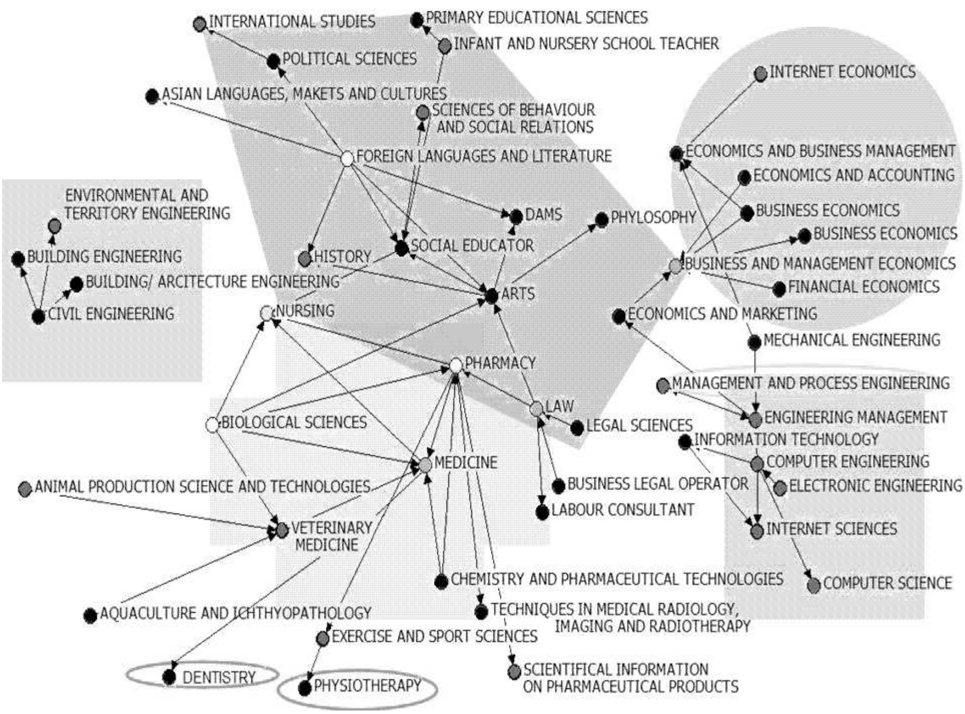


Figure 5. Simplified network with cut-off 3 (academic year 2007-08)

Two bridges link "economic" and "engineering" area: precisely, between "Engineering management" and "Economics and marketing" and between "Mechanical engineering" and "Economics and business management". It means that students felt those courses rather similar even if they belong to different areas.

The nodes with only *in*-degree (“leaf” nodes) represent the “final” courses, namely students choose those courses like target, and not as passage.

The “engineering” area is split up into “informatics” and “traditional” engineering, therefore students that choose “informatics” courses change only to come to another “informatics”. Finally, in the year 2007-08 we have the “Nursing” course that attracts students in the “medical area”.

Until now we have spoken only of “escape” and “attraction” courses, but it is necessary to rename some “escape” courses in “transit” courses. This is the case of “Biological Sciences” and “Pharmacy”, used by students to pass to “Medicine”.

Even if the linkage structure changes, the “leaf” nodes remain about the same: for example, in “medical” area, “Dentistry”, “Physiotherapy” and “Scientific information on pharmaceutical products” are courses in which students only arrive.

3.3. Some centrality measures in course network

To discover the “attraction” and “escape” nodes in our course network, we have used: *i) in* and *out*-degrees, *ii)* their normalized percentage values, *iii)* the enrolled student numbers, and *iv)* the “degree centrality” of each node . While in faculty network it is uncommon that students move from one node to arrive all to another one, in course network this event often occurs. Therefore, we define as “attraction” a course with an high normalized *in*-degree combined with centrality degree different from 1. The same is for “escape” courses on the bases of their *out*-degree.

The potential “escape” and “attraction” courses in the different years are shown in Tables 5 and 6, respectively.

Particularly, in Table 5 some courses have been deleted either because they have not been offered (like “Social safety and control operator” and “Economics and management of tourist services”) or because their degree centrality is equal to 1 (like “Computational informatics mathematics”). Moreover “Business Economics” was a course split up in two campuses: Forlì and Bologna. So the high *out*-degree is due to the closure of the course in Forlì. The same for “Legal Sciences”, which was split up in a course in Ravenna and another one in Bologna: the closure of course in Ravenna in 2006-07 created the high *out*-degree.

As we said, "Biological Sciences" and "Pharmacy" are "transit" nodes, used by students to go to "Medicine". All other actors in Table 5 that have a high normalize *out*-degree can be considered "escape" courses.

Table 5. Potential "Escape" courses

	Out-degree	*In*-degree	# enrol	Norm. *Out*-deg	Degree centr.
YEAR 2004-05					
~~Social Safety and Control Operator~~	**161**	0	0	-	2
~~Business Economics~~ (**)	**150**	6	198	**75.8%**	28
Biological Sciences (*)	**90**	19	432	20.8%	39
Foreign Languages and Literature	**80**	27	761	10.5%	41
Computer Engineering	48	24	154	**31.2%**	29
Telecommunications Engineering	25	3	49	**51.0%**	15
~~Computational-Informatics Mathematics~~	7	1	14	**50.0%**	1
YEAR 2005-06					
~~Economics and management of tourist Services~~	**250**	0	0	-	9
Biological Sciences (*)	**112**	30	527	21.25%	46
Foreign Languages and Literature	**95**	34	729	13.0%	41
Pharmacy (*)	56	18	141	**39.7%**	28
Chemistry and Pharmaceutical Technologies	44	13	121	**36.4%**	21
Telecommunications Engineering	12	1	33	**36.4%**	6
Cultural Operator	11	17	11	**33.3%**	17
Territory Technician	9	0	18	**81.8%**	2
Scientific Information on Pharmaceutical...	6	5		**33.3%**	7
YEAR 2006-07					
Biological Sciences (*)	**106**	20	334	**31.7%**	42
Foreign Languages and Literature	**75**	47	709	10.6%	41
~~Legal Sciences~~ (**)	**72**	6	25	**288.0%**	35
Management Process Engineering	22	21	40	**55.0%**	10
Telecommunications Engineering	17	4	30	**56.7%**	9
YEAR 2007-08					
Pharmacy (*)	**83**	33	288	28.8%	32
Biological Sciences (*)	**76**	25	278	27.3%	35
Foreign Languages and Literature	**70**	38	611	11.5%	45
Management Process Engineering	14	9	39	**35.9%**	5
Telecommunications Engineering	9	2	28	**32.1%**	9

(*) 'Transit' (not 'escape') nodes, use by students to go to 'Medicine'.
(**) Courses split in two cities: their high *out*-degree is due to closure of one of them.

Similar remarks can be drawn for "attraction" courses. In Table 6 two courses are deleted because their high *in*-degree is due to closure of similar courses. For example, the high *in*-degree of “Sociology and criminology science for safety” is due to its replacement with “Social safety and control operator” course: the high *in*-degree of “Economics and markets of tourist system” is due to its replacement with “Economics and management of tourist services” and the large enter link of “Economics and marketing” is due to the closure of “Business economics”.

Table 6. Potential “Attraction” degree courses

	Out-degree	*In*-degree	# enrol	Norm. *Out*-deg	Degree centr.
YEAR 2004-05					
~~Sociology and Criminology Science for Safety~~	6	**174**	200	**87.0%**	14
~~Economics and Marketing~~	12	**134**	219	**61.2%**	23
DAMS	45	**68**	1114	6.1%	37
Legal Sciences	68	**65**	1235	5.3%	53
Medicine	24	**65**	259	25.1%	28
Physiotherapy	1	18	36	**50.0%**	11
Dentistry	1	13	15	**86.7%**	6
YEAR 2005-06					
~~Economics and market of tourist System~~	2	**243**	145	**167.6%**	5
Legal Sciences	76	**76**	1181	6.4%	56
Medicine	20	**61**	266	22.9%	29
DAMS	42	**54**	993	5.44%	38
History	7	**48**	238	20.2%	28
Physiotherapy	1	20	41	**48.8%**	12
Cultural Operator	11	17	33	**51.5%**	17
YEAR 2006-07					
Medicine	13	**79**	251	**31.5%**	31
Foreign Languages and Literature	75	**47**	709	6.6%	41
Business Economics	4	**46**	130	**35.4%**	21
....					
Physiotherapy	1	22	31	**71.0%**	14
Techniques in medical radiology, imaging ...	1	9	17	**52.9%**	9
YEAR 2007-08					
Medicine	20	**82**	257	**31.9%**	27
Business Economics	11	**54**	152	**35.5%**	21
Nursing	8	**43**	187	23.0%	27
Law	52	39	899	4.3%	40
Foreign Languages and Literature	70	38	611	6.2%	45
Social Educator	19	38	259	14.7%	24
....					
Dentistry	0	14	16	**87.5%**	7

(–) Deleted because their high *in*-degree is due to the closure of a specific degree course.

All other actors in Table 6 that have a high normalized *in*-degree can be considered "attraction" courses, but in the time the trend of student preferences is towards "medicine" area, while other potential "attraction" courses tend to balance.

4. Architectural features and a micro modelling approach

The random graph theory introduced in the late 1950s and based on Erdäs-Rényi (ER) model, assumes that a fixed number of nodes are connected randomly to each others. This kind of network starts with N nodes and connects every pair of nodes with probability p, creating a graph with approximately $pN(N-1)/2$ edges. Therefore most nodes have roughly the same number of links, approximately equal to the network average degree $\bar{k}$, while nodes that have significantly more or less links than $\bar{k}$ are absent or very few. In probabilistic terms, in ER networks the nodes follow a Poisson distribution with a peak at $\bar{k}$ (Figure7).

Usually when we describe real phenomena the large events are rare, but small ones are quite common. Therefore, a random network model cannot explain the topological properties of real networks (Barabási *et al.*, 2003). Particularly, in contrast to Poisson degree distribution, for many real networks the number of nodes with a given degree follows a power law in which the probability that a node has exactly k links is

$$P(k) \sim k^{-\gamma}$$

where γ is the degree exponent (its value is between 2 and 3 in most networks).

This implies that nodes with only few links are numerous, but few nodes (called "hubs") have a very large number of links. Networks with a power-law degree distribution are called scale-free (Barabási and Albert, 1999).

Two traits characterize the scale-free model: (1) *incremental growth*, i.e. networks grow by addition of new nodes linked to other nodes already present in the system, (2) *preferential attachment,* i.e. there is a higher probability to link to a node with a large number of connections.

The Bologna University network approximates a scale free topology but, because of "institutional" constraints, it has not "incremental growth" and "preferential attachment". The first evidence comes from the analysis of networks (see section 3), in which the nodes are the courses, while the links are the student inter-degree course transfers. As the network is directed, we can assign "in" and "out" degree to each course on the basis of the number of students that "enter" or "leave" it, respectively.

The analysis of the degrees of the different courses shows that this network has a scale-free topology, in which most degree courses have few "enter" or "leave" of students and only few courses have most students that "enter" or "leave". The degree distribution of this network follows a power law with exponent $\gamma \simeq 1.7$(see Figure 6). The estimation of exponent γ is obtained by graphical criteria. The γ estimate is the value which preserves the slope of the real probability distribution of the number of links. The model fitting has been validated by a chi square test.

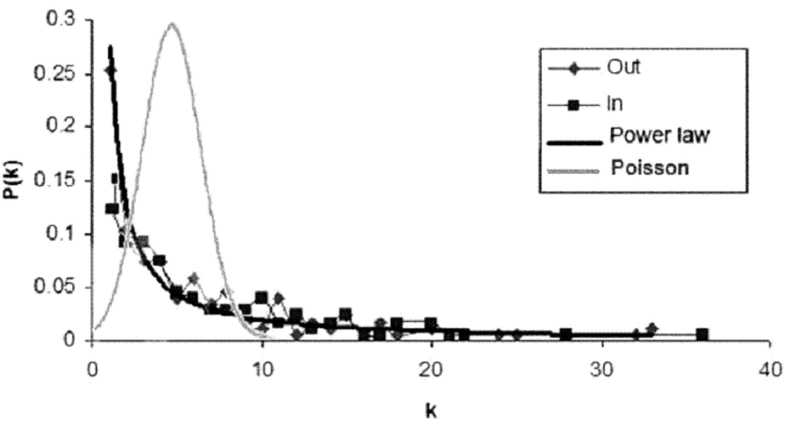


Figure 6. Degree distribution of University course network

The structural mechanism that governs the topology of Bologna University network is a scale-free constraint, where the institutional regulation inhibits the free growth and the preferential attachment. Even if there are "hubs", their rules are strongly influenced by different institutional decisions applied to university system: such as geographical location, admittance tests, closure of some courses and so on. Therefore, the evolution of the network is not in terms of growth, but in terms of linkage structure. In order to implement simulation studies, it is useful to assess a micro model of the network, where the principal features are described not in terms of nodes, but in terms of links between them. In other words, we must take into account the motivations which lead to student transfers.

The idea is to introduce an utility transfer function for each course, in order to preview the birth or the death of a link when usual constraints are perturbed. The model used is a binary logistic model, because the response variable is binary: a new link is created only when there are significant numbers of student transfers, while a link dies when on the contrary there aren't any.

The first problem to solve is to analyze when there is a significant transfer and which is the corresponding cut-off. A possible solution is to binarize the normalized degree of each node with cut-off= 0.10. As we have discovered in the preliminary analysis (section 2), different predictors can affect the response variable, such as geographical location, free restricted entry, presence of courses with similar examinations, etc.

In the following of our research, the most important variable to introduce is the satisfaction expressed by students about the different courses. For this purpose, we can use the questionnaire usually submitted to students in order to know the student satisfaction about their attending courses. From the collected data, as well as from the preliminary results of the analysis, we can build the covariates of the binary logistic model. After assessing this micro model of the network, simulation studies will be implemented by perturbing institutional decisions or student choices to forecast future possible changing of the university system (Stracqualursi and Monari, 2009).

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