Academic Research Policy-making and Evaluation using Graph Visualisation

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***Abstract*—Higher education institutions need to have a social responsibility and attainable objectives regarding their education and research activities. In our approach we use multi-indicator analysis in order to evaluate the research activities of an institution as well the degree of achievement for a specified research policy. Our work is a part of prototype system that supports academic evaluation and decision-making processes concerning research policies, using visual analytics. The presented case study emphasises on the analysis of the research collaborations indicated in published research work. Our main data sources are the Scopus library, Google Scholar and the Quality Assurance Unit Service of a Greek higher education institution. Data are retrieved and enriched by additional analysis and graph metrics. The developed system provides enables user to evaluate aspects of the quality of academic research activities in the context of specific policies and criteria and make informed decisions on the establishment of new strategies.**

Keywords-decision support systems; research policy; research indicators; visualization; co-authoring; knowledge discovery

I. INTRODUCTION

Higher Education Institutions (HEI) worldwide are facing an increased demand to strengthen their capacities for research and innovation. Reinforcing research activities is essential for universities that aim to perform a catalytic role in modern, knowledge-based societies. This process undoubtedly involves identification and establishment of working relationships among universities, their stakeholders in society and external systems of knowledge production (e.g. industry) [4].

Establishing and sustaining informed relationships with stakeholder communities and other research-related entities calls for well-designed policies providing a clear vision and setting the research landscape for the institutions.

Institutional research policy development is based upon decisions on key issues of the research function and its environment, namely quality, relevance, resource provision and international networking. Moreover, it is greatly influenced by overarching national and international policy contexts.

On this basis, universities within the European Higher Education and Research areas need to have a clear research mission and objectives reflected in their institutional policies taking into consideration and incorporating quality aspects set by the national and European quality agencies; responding to key research areas that address society and economy requirements and priorities at national and European levels; striving for financial autonomy through the optimized exploitation of available funds for contribution to important fields; promoting inter-institutional collaboration with diverse knowledge production communities and entities.

In this paper we seek to address some of the key issues of the interconnection between academic research policy development and institutional research activity management. Firstly, we discuss the fundamental policy constituents and associated indicators that enable performance evaluation for each constituent. In continuation, we present a multi-indicator analysis approach that enables the measurement of the degree of a specific policy achievement based on actual research activity evidence. For implementing this approach, we have developed and introduce a software system architecture that supports research policy evaluation processes and decision-making strategies, using visual analytics. Finally, concrete results obtained through a prototype of our system for a Greek higher technological educational institution are shared and commented.

II. DEVELOPING AND ASSESSING RESERCH POLICIES

Higher education institutions need to have a definable mission and attainable objectives [9][9]. As far as research is concerned, universities are expected to intensify their efforts towards quality activities, supported through solid funding

frameworks, responsive to society needs and open to international collaborations.

Supporting each of the facets of this ambitious goal encompasses a wide variety of initiatives, frameworks and entities, established at European and national levels. Regarding quality, the European Association for Quality Assurance in Higher Education (ENQA) and national quality agencies are responsible for developing standards and guidelines to assist institutions in defining policies and associated procedures for the assurance and of the quality of their activities and services. European research priorities and funding opportunities are promoted through programmes like the Seventh Framework Programme for Research and Technological Development (FP7) [12] and EUREKA [13]. National initiatives express a country's perspective with regard to research prioritization and targets. The Greek General Secretariat for Research &Technology (GSRT) has set the following priorities for national research: 1) Increasing the demand for new knowledge and research results in Greece, 2) Reorganization of the research system and provision of knowledge in Greece, "Freeing-up" the Greek research system and opening it further to the international field, 3) Development and Technological infrastructure in the context of a policy for Science and Technology , 4) Thematic / Sector priorities for a policy on Science and Technology and 5) Qualification of goals [11][11].

Within this context, higher education institutions need to have formal policies and procedures as a framework within which they can develop and monitor the effectiveness of their activities. Obviously, informed institutional policies need to be designed in relevance to the key aspects of overarching trends and strategies, e.g. promoting target research topics to attract funds; raising awareness on funding opportunities among academic and research staff; monitoring of active research topics; correlation between activity and availability of resources (researchers, infrastructure and equipment); degree of collaboration between universities – industry [5].

Research must be consistent with policy objectives. Research activities need to be assessed in order for an educational institution to measure the degree of achievement of past performance or future capability regarding specific policy constituents. Towards this direction, the Hellenic Quality Assurance Agency (HQAA) has set a list of criteria regarding the academic research quality[10]. These criteria function in combination with high-level policy constituents and provide metrics for their quantification. HQAA research-related criteria relate to the research programmes the academic staff took part in, the effectiveness of research activities, the degree of acceptance and recognition of research by society, the degree of collaboration with the industry, the inter-departmental and inter-institutional collaboration (with specific emphasis to international networking), the number of scientific publications and the involvement of students in research.

III. Research Indicators for Academic Policy-Making and Evaluation

In this section we outline a method that takes into consideration a specified research policy and associated performance criteria and, by applying a multi-indicator analysis, produces valuable results related to the evaluation of institutional research activities. Our case study is based on information and data from a Greek higher technological educational institution, obtained through our prototype software system which supports the overall process using graph visualization. The benefit of multi-indicator analysis [4] is that it provides us with the ability to measure the degree of achievement for a specified research policy through a composite measure. This particular method enables us to evaluate the research activities using different indicators that could be combined in order to provide strong statistical associations.

Based on the institution's research policy and the criteria set by HQAA, we have elicited and use four core indicators related to:

- Scientific publications
- Collaboration with other HEIs
- Collaboration with Industry
- Research sectors

In the following paragraphs we discuss each indicator, present concrete results produced by our prototype system and briefly comment on their potential contribution in the evaluation and decision-making processes.

A. Research indicator-Scientific pubications

In [16] we have discussed the problem of activity in research communities focusing mainly on the number of papers that an author has published. In this paper we use the h-index [3] science-metric in order to measure the "quality" of each of the authors. Our experiment was based on the research publications of the Department of Informatics academic staff for the period 2000-2008. The relevant data were retrieved from the Quality Assurance Service of the institution and enriched by our system with appropriate metrics for graph representation. Figure 1 illustrates the corresponding co-authoring network where nodes represent the authors and edges the collaboration among them. Each of the edges was assigned by a value denoting its weight. In this network we use the degree centrality [14] measure in order to represent the nodes. This measure is defined as the number of links incident upon a node, so for a graph $G: = (V,E)$ with n vertices, the degree centrality $C_D(v)$ for vertex v is:

$$C_D(v) = \frac{\deg(v)}{n-1}$$

Using this formula we measure the degree of each of the nodes and we represent the nodes in a way that their size depends on the number of the publications that authors have made. On this basis, the node with the biggest size represents the most active researcher, i.e. the one with most publications. The number of publications is one of the

criteria set by HQAA for the evaluation of academic researchers.

In Figure 2 the network was constructed by using the h-index metric as the represented value and we can observe that the size of the nodes has changed. From this representation we can understand that there is a difference between the most active (Figure 1) and the most distinguished (Figure 2) researcher. So, as regards to research development, the most important author is author 88, while, according to the HQAA criteria, the most important researcher is author 12.

Consequently, in order to be able to evaluate a researcher, we should use some of the known science-metrics in combination with the number of publications. Thus, we add the h-index metric in our methodology, as the most well-known and accepted science metric.

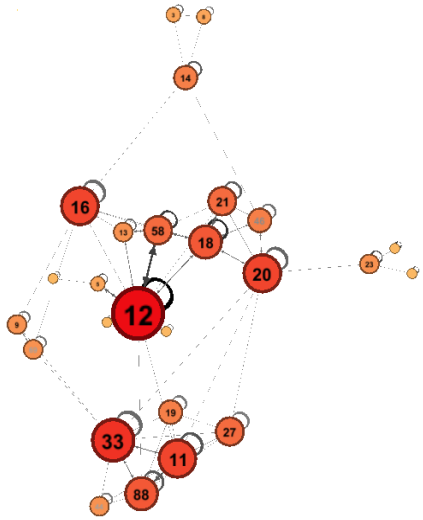

Figure 1. Co-athoring network using degree centrality

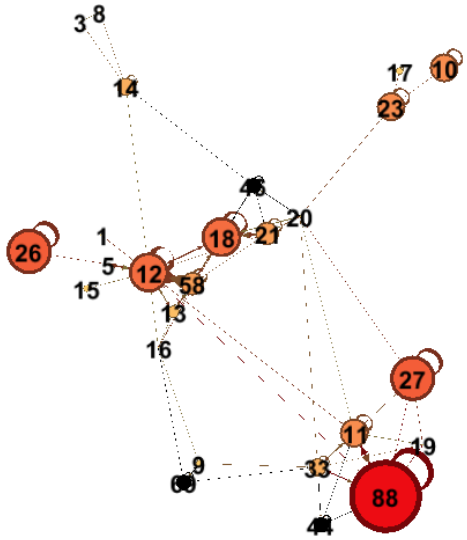

Figure 2. Co-authoring network using h-index represenation

B. *Research indicator-Collaboration with other HEIs*

One of the main indicators set by GSRT is the degree of research collaboration, with particular emphasis on the inter-institutional and international networking. In the context of our case study, we retrieved data on the research activities for the academic staff of the Technological Educational Institute (TEI) of Athens for the period 2000-2010. The data were retrieved-parsed from the Scopus library, Google Scholar and the Quality Assurance Service of the institution. 756 authors have published 1.214 research documents within this period (Table I). As illustrated in Table II, there is a limited number of established collaborations between TEI of Athens and other institutions. This number is particularly low in the case of international collaborations: out of the 1.214 documents, only 59 were published in collaboration with researchers affiliated to 3 international universities. Hence, with regard to the policy set by GSRT, the institution should focus on and improve its international co-operations.

Apart from the range of collaborations at institutional level, we also try to study academics' collaboration with other researchers. In the corresponding co-authoring network, we use the betweenness centrality measure [15], which takes into account the connectivity of the node's neighbors, giving a higher value for nodes which have more cooperation than the others. For a graph *G: = (V,E)* with n vertices, the between-ness *CB(v)* for vertex v is:

$$C_B(v) = \sum_{s \neq v \neq t \in V} \frac{\sigma_{st}(v)}{\sigma_{st}}$$

where σ_{st} defines the number of shortest paths from s to t, and $\sigma_{st}(v)$ the number of shortest paths from s to t that pass through a vertex v.

Using this measure, we can see in Figure 3 that academics 12 and 20 have more collaborations than the others and the value of the weight that the edge (connection) assigned provides information about the most common cooperating authors.

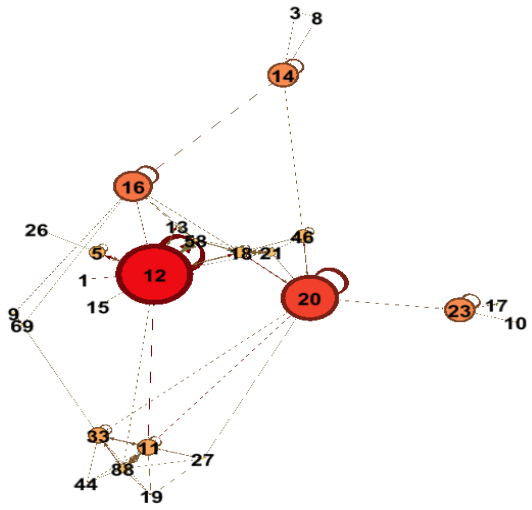

Figure 3. Co-authoring network using betweenness centrality

TABLE I. TEI OF ATHENS RESEARCH ACTIVITY
(SOURCE: SCOPUS, QUALITY ASSURANCE SERVICE)

Type	*Number*
Documents	1.214
Authors	756
Patent	0
Research Programmes	40

TABLE II. TEI OF ATHENS RESEARCH COLLABORATIONS

id	*Aff. Name(Doc.)*	*id*	*Aff. Name(Doc.)*
1	Panepistimion Patron(158)	10	Technologiko Ekpaideutiko Idrima, Kritis (28)
2	University of Athens(156)	11	Demokritos National Centre for Scientific Research (23)
3	Ethniko Metsovio Polytechnico(114)	12	Panepistimion Pireos (23)
4	Panepistimion Aegaeou(54)	13	Institute of Microelectronics, Athens (22)
5	Uni.of Athens Medical School(53)	14	Aghia Sophia Children's Hospital (22)
6	University of Patras, School of Medicine(52)	15	Universite de Limoges (21)
7	Panepistimion Ioanninon (40)	16	Brunel University (20)
8	Computer Technology Institute(15)	17	Harvard School of Public Health (18)
9	Euromedica Medical Center(15)	18	University Hospital of Ioannina (14)

C. *Research indicator- Collaboration with Industry*

An important policy constituent in many national and regional research agendas is the degree of collaboration between universities and the industry [5]. However, the establishment of such a form of collaboration is not always acceptable by researchers. There are those that consider interaction with the industry as having positive effects for the university [6][7] (e.g. by providing extra funds for research activities and supporting equipment). On the other hand, some academics hesitate to engage with industry since such collaboration could distract researchers from academic relevance [8] and alter the institution's independent mission.

In our case, measuring the co-operation between researchers and industry has been very difficult because of the lack of available information. Based on the Scopus, Google Scholar and the institution's Quality Assurance Unit Services, we made an attempt to measure the patent counts involving institution's academics. Patent counts is a widely accepted [1][2] as one of the most appropriate indicators, as patents enable researchers to contribute to the inventive or innovative performance of companies, in terms of new technologies, new processes and new products. As illustrated in Table I, there is not any apparent interaction of the institution and the industry in terms of patent production.

On the other hand, research programmes prove to be of great interest to the institution since they attract funding resources on targeted research. In most occasions, research programmes implement strategic priorities related to the establishment of working relationships among academic institutions, the industry and other knowledge-production entities. Our intention is to retrieve and process data regarding the project consortia participants thus revealing and representing institution-industry collaborations.

D. *Research indicator- Research Sectors*

In accordance with regional and national needs and strategies, policy makers identify specific sectors in order to provide guidance for and prioritize research activities. The Agriculture sector is, for example, of common interest in the FP7 and GSRT agendas. Using our methodology we investigate on the institution's activity in this field, we categorize publications of the academic staff in thematic areas as shown in Figure 3 and compare the institution's active thematic areas to the FP7 and GSRT identified sectors. Figure 4 illustrates the institution's activity per sector. As we can see, the research interest in the agriculture sector is very low due to the fact that the institution does not provide relevant programmes of study and, consequently, lacks academic staff with such expertise. Our methodology enables us to investigate on the reason(s) why specific sectors have greater development than others (e.g. link degree of development to funds, etc.).

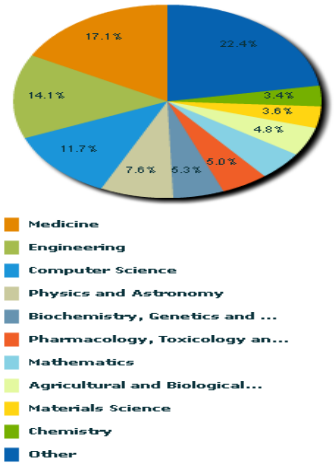

Figure 4. TEI of Athens thematic research activity

Raising awareness on such issues among the institution's academic community could significantly encourage inter-institutional collaboration, thus broadening the range of research activity and boosting inter-disciplinary research and application of the institution's expertise in other sectors.

IV. SYSTEM ARCHITECTURE

In our system, data are represented by means of a Java-based interactive prototype using the Gephi visualization tool [17]. Gephi was selected because of its ability to represent high quality graphs in networks up to 50K nodes and 500K edges.

The overall architecture of our system is depicted in Figure 5. The Graph Visualization Unit integrates the discussed techniques, related algorithms and visualization tools. Compared to other research activity visualization tools [18], our system supports ontology modelling (existing or desired) institutional research aspects (i.e. areas, rules, objectives).

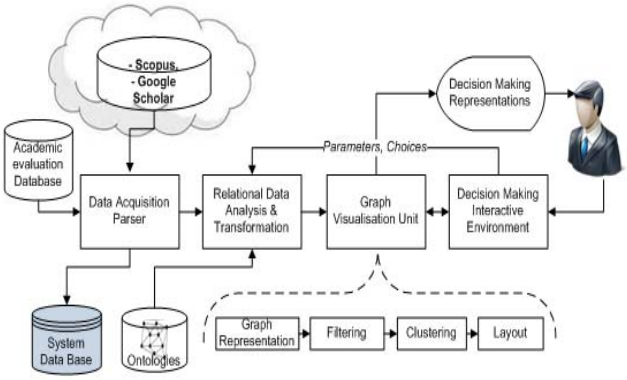

Figure 5. Decision-support system architecture for academic research policy-making and evaluation

The system's features enables policy makers to set target policies and monitor current and future performance towards the specified directions. Moreover, the user could be provided with additional kinds of representations in order to be further supported towards more accurate decisions.

V. CONCLUSION-FUTURE WORK

Universities are complex social actors that should support educational activities and act as drivers of research and innovation. In order to be able to assess academic research activity and consistency with national and regional objectives we provide a software tool based on multi-indicator analysis methods and visualization techniques. Well-established policies and criteria are taken into account in this approach. In the presented case, we have traced an institution's performance in following a specified research policy. In addition we have examined the inter-institutional collaborations and identified the most active academics in terms of co-operations. Also we observe that authors with more publications are not always the most distinguished.

Future work falls under the perspective to evaluate how research activity of academics is influenced by their additional factors (e.g teaching hours, administrative duties, existence of Masters or PhD programmes in the institution, etc.). This evaluation will be carried out using a combination of classic science metrics, the research indicators set by policy-makers like the HQAA and special features academics have as members of the educational staff of a department. Finally, we will focus on enhancing the system's functionality to adequately support the process of institutional policy design.

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