# Understanding Researchers Collaboration in eParticipation using Social Network Analysis

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## ABSTRACT

*Over the past years electronic participation (eParticipation) became a political priority worldwide. Consequently, research on the field has dramatically grown. However, eParticipation is still an unconsolidated research area that lacks generally agreed upon definitions, research disciplines, methods and boundaries. The aim of this paper is to contribute to the establishment of the eParticipation identity by investigating the scientific collaborations in the domain. The study of the nature of academic collaboration reveals the structure and the intellectual roots of the research community and the most influential authors. The approach followed in this paper includes the construction of the co-authorship network and the calculation of the social network analysis (SNA) metrics that describe the nature of the collaboration. The results revealed that eParticipation is a rather active academic field in the last decade including a high degree of collaboration and a core network of very influential researchers.*

*Keywords:* *Co-Authorship Networks, eParticipation, Social Network Analysis*

## 1. INTRODUCTION

Electronic Participation (eParticipation) is a relatively new field that "*describes efforts to broaden and deepen political participation by enabling citizens to connect with one another and with their elected representatives*" (Macintosh, 2004). Over the past years eParticipation has become a political priority worldwide, as it is considered a powerful tool for enhancing democracy and citizen participation and assuring openness and transparency. In particular, the European Digital Agenda refers to citizen empowerment as one of its key pillars. Similarly other initiatives worldwide consider eParticipation as an essential ingredient of eGovernment policies (UN, 2012).

As a result, over the last few years, research on eParticipation has dramatically grown, from the sporadic appearances of the eParticipation term in various research papers to an established

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research field with a number of specialized conferences and journals (Erman & Todorovski 2009b, Medaglia, 2012).

However, eParticipation is still an unconsolidated research field that still lacks a generally agreed upon definition, a clear overview of the research disciplines or methods it draws upon and agreed research boundaries (Saebo et al. 2008).A variety of recent studies addresses this concern by attempting an in-depth investigation of the eParticipation field, e.g. Sanford and Rose (2007), Tambouris et al. (2007), Medaglia (2007), Saebo et al. (2008), Freschi et al. (2009), Macintosh et al. (2009), Ergazakis et al. (2011), Medaglia (2011), Susha and Grönlund (2012). All these approaches focused on surveying the field and identifying its main research areas, proposing frameworks, revealing research constrains and proposing trends.

This work aims to contribute to the process of establishing the eParticipation identity by investigating researchers' collaboration in the field; to the best of our knowledge there is currently no relevant study in the literature. Communication and collaboration between scientists is a significant aspect of each scientific community. Past studies have shown that research collaboration produces higher research impact than a single researcher in terms of number of publications and citations (Li et al. 2015). Therefore, the analysis of eParticipation's research collaboration will provide greater insight regarding the structure (Cerveny and Behara, 2011) and the intellectual roots and development of the field (Culnan, 1987). Furthermore, it will serve as an empirical basis for socializing the newest members in the field by transmitting professional norms for scholarships (Culnan, 1987).

The analysis of research communities is usually conducted using citation or co-authorship networks. The nodes of such a network represent authors while the edges represent co-authorships between authors. In order to construct the eParticipation network we identified and refined relevant literature, resolved authors' names disambiguation, and recorded the authors and the co-authorships pairs. Next, we analysed the network using Social Network Analysis (SNA). In particular, we calculated SNA metrics that describe the nature of the eParticipation network. Following this approach, we identified the various research groups in the field, the most influential authors, the development of the field over time as well as the geographic areas where the most intense authoring activity took place.

The rest of this paper is organized as follows. Section 2 presents some background information on eParticipation, researchers' collaboration, SNA and co-authorship analysis while Section 3 outlines the methodology used. Section 4 presents the analysis results. Finally, Section 5 presents the main conclusions and future work.

## 2. RESEARCH COLLABORATION AND SOCIAL NETWORK ANALYSIS

### 2.1. eParticipation

eParticipation is described as "ICT-supported participation in processes involved in government and governance. Processes may concern administration, service delivery, decision-making, and policy making" (Macintosh, 2006). It aims to support active citizenship with the latest technology developments, increasing access to and availability of participation in order to promote fair and efficient society and government (Saebo et al., 2008).

Saebo et al. (2006) identified the different forms of e-participation that include: e-voting, i.e. the opportunity to vote with the use of ICT from different locations, online political discourse, describing the changes in public discourse linked to the emergence of ICT, online decision making referring to citizens' participation to the decision making process, eActivism, that describes the efforts of voluntary organizations and interest groups to use ICT to promote their special interests or viewpoints, eConsultation, i.e. a two-way relationship between citizens and government providing a feedback mechanism from public authorities to citizens, eCampaigning that describes the efforts of various stakeholders to raise money, organize volunteers, and gather intelligence on voters and ePetitioning which refers to the sign of an online petition

ePartication reduces the impact of constraints on participation, broadening public opinion and the public sphere, and increases citizens' interest in politics (Medaglia, 2012). Additionally, it empowers citizens and communities as it leverages the voices and expertise of huge numbers of individuals and groups, setting their own agendas and developing their own policies (European Commission, 2009) and transforms them in co-producers of political decisions (Medaglia, 2012). Furthermore, it enhances public transparency and openness as reveal the purposes, processes and outcomes of government (European Commission, 2009).

Nevertheless, eParticipation might extend the marginalization of already marginalized groups in society, and further empower those that are already powerful in society (Goldfinch et al., 2009).

## 2.2. Social Network Analysis

A social network is a finite set or sets of nodes and the edge or edges among them. A node (also called vertex, actor, agent or entity) mainly represents people or organizations, but it can also be states and countries, web pages, keyword tags, videos or locations. An edge (also called relationship, tie, link or connection) connects a pair of nodes. Social Network Analysis (SNA) is the method that maps and measures the relationship between units in a network. Units could be nodes, subgroups or groups with similar attributes.

A number of metrics has been proposed in the literature for SNA. We briefly outline those we will employ in our analysis.

- *Density* is the ratio of the number of relationships that exist in a specific network divided by the total number of relationships it could be if all edges where connected among them. Its value varies between 0 and 1. If density is close to 1, the network is called dense. Otherwise, it is called sparse.
- *Centralization* is a metric which determines to what extend the network is centred on one or more nodes.
- *Degree centrality* counts the total amount of edges connected to a node. It could be argued that degree centrality measures the "popularity" of a node. For undirected networks, degree centrality measures the number of edges which connect each node with the rest.
- *Betweenness centrality* measures the frequency a node appears on the shortest path between two other nodes in the network.
- *Closeness centrality* measures the average distance between a node and any other node of the network. A low closeness centrality means that a node is "directly" connected to most of the other nodes.
- *Eigenvector Centrality* is a subset of closeness centrality. This metric focuses on the importance of the node's neighbourhood. It is more significant to have popular neighbours than loners. Eigenvector centrality metric is based not only on the amount of connections a node has (degree), but also the degree of the nodes it is connected to. A node with few connections could have a very high eigenvector centrality if those few connections were themselves very well connected.
- *Information centrality* (Stephenson and Zelen 1989) measures the harmonic mean length of paths ending at a node which is smaller if the node has many short paths connecting it to other nodes.

## 2.3. Researchers Collaboration

Interaction between researchers has for long been the essence of scientific practice (Melin and Persson, 1996). Researches not only communicate research results and information to each other, they also co-produce and co-report research results (Melin and Persson, 1996). In the last decades, an increase of collaboration has been observed as illustrated for the first time by Smith (1958). Examining 4,189 papers published between 1946 and 1957 in "American Psychologist" he found that the mean number of authors per paper increased to 1.7. According to Abramo et al. (2009) various factors are responsible for this, such as the growing specialisation of science, the complexity of investigated problems, and the increasing costs of scientific equipment needed to perform experiments.

Collaboration can be measured using different research methods including bibliometrics, interviews, observations, controlled experiments, surveys, simulations, self-reflection, social network analysis and document analysis (Sonnenwald, 2007). However, the most formal ways to analyse collaboration are via co-authorship networks or via citation networks.

## 2.4. Co-Authorship Networks

A co-authorship network, according to Cheong and Corbitt (2009), is a social network consisting of a collection of researchers which are connected if they have co-authored one or more papers, whilst citation networks, Ding (2010), illustrate the citing behavior in publications. In both networks, nodes represent the authors of studied papers. Edges among nodes denote respectively the co-authorship of one or more papers and the citing of one author by another. Co-authorship networks are undirected networks and citation networks are directed networks. It is important to mention that in both cases, the analysis of interaction between authors must be based on accurate bibliometric databases and software. Nevertheless, Melin and Persson (1996) point out that despite the use of automated systems, analysis requires considerable manual effort.

Lie et al. (2005) argue that co-authorship implies a much stronger social bond than citation. This opinion is based on the assumption that co-authorship is based on a collegial relationship among the authors, while citation can occur without authors knowing each other. Moreover, Patel (1973) claims that there is a positive correlation between scientific collaboration and co-authorship. However, Katz and Martin (1995) express their doubts about the circumstances under which someone could be indicated as "co-author". As an example, La Follete (1992) indicates the issue of "honorary co-authors", i.e. persons that are mentioned as co-authors without having actually collaborating, e.g. due to their position.

In this paper, we use co-authorship networks to study researchers' collaboration. However, we acknowledge that co-authorship data should be used as a rough indicator of collaboration while other kinds of data should be also used (Melin and Persson, 1996).

Co-authorship Network Analysis has been used extensively in the literature. For example, Newman (2001a, 2001b) analyses the scientific collaboration in physics, biomedical research and computer science. In his first study (2001a), he determines the differences between disciplines, pointing out that the collaboration in experimental disciplines is more common and in larger extent, due to the number of collaborators, than in theoretical fields. In his second study, he focused on the distances between scientists. Using only the most central scientists he points out that typical distances between authors are small. Additionally, Newman (2004b) found that scientists who work as a team tend to have shorter average distances to other scientists in the graph.

Liu et al. (2005) focus their investigation on digital libraries, trying to illustrate a co-authorship network. Examining binary directed and undirected networks, they try to present the impact of an individual author in the network. They also show how beneficial some metrics, such as PageRank and AuthorRank, are.

Based on the papers published during the period from 1978 to 2004 in international Journal "Scientometrics", Hou et al. (2008) analyze scientific collaboration networks using social network analysis, co-occurrence analysis, cluster analysis, and frequency analysis in words. Guns et al. (2011), studying the scientific collaboration in the fields of informetrics, bibliometrics, webometrics and scientometrics between 1990 and 2009, indicate the existence of low degree in international collaboration.

Several other intersecting papers have been published such as Wagner and Leydesdorff (2005) who claim that international collaboration increased, Leydesdorff and Wagner (2008) presenting that the level of collaboration is not the same in all countries, Lee and Bozeman (2005) who show that collaborations drive to scientific productivity.

To the best of our knowledge, co-authorship networks and citation analysis has not been used in the field of eParticipation. The only relevant research refers to the field of eGovernment which is often considered as a wider area including also eParticipation. In particular, Erman (2009) proposed a methodology for scientific research in terms of citation analysis and defined the citation network for the papers published in seven proceedings of the International Conference of eGovernment (EGOV conference) during the period from 2002 to 2008. Furthermore, based on the same papers, Erman and Todorovski (2009a, 2009b) create a co-authorship network, analysing the centrality measures and the most central and active authors.

## 3. METHODOLOGY

The main objective of this work is to identify and analyse the eParticipation research network. In order to construct the network, we had to identify the authors of the field and the collaborations among them. For analysing the network, we had to calculate metrics that indicate the nature of the collaboration within the field. Following similar approaches found in the literature (Erman & Todorovski, 2009a, Yan & Ding, 2009, Glänzel & Schubert, 2005, Newman, 2004), we followed a five step approach including: literature identification, literature refinement, disambiguation resolution, data set recording, and data analysis. The overall process is elaborated in the next paragraphs.

### 3.1. Step 1: Literature Identification

We started by identifying eParticipation literature. For this purpose we searched in two of the most popular scientific databases, i.e. ISI– Web of knowledge[1] and Scopus[2], for relevant references. The used as search terms the terms proposed by Sæbø et al. (2008) for characterizing the eParticipation field. These terns are:

- e-Democracy, eDemocracy, electronic democracy, digital democracy, democracy internet, democracy and information system;
- e-Participation, eParticipation, electronic participation, e-Government and participation, eGovernment and participation, e-Governance and participation, eGovernance and Participation;
- e-Voting and participation, e-Inclusion and participation, digital divide and participation.

Moreover, according to Sanford and Rose (2007) analysis, we also used terms related to research areas of eParticipation such as:

- e-Consultation, eConsultation electronic consultation, internet consultation, digital consultation and participation, democracy, government and governance;
- e-Deliberation, eDeliberation, electronic deliberation, internet deliberation, digital deliberation and participation, democracy, government and governance;
- e-Voting, eVoting, electronic voting, internet voting, digital voting and participation, democracy, government and governance;
- e-Community, eCommunity, electronic community, internet community, digital community and participation, democracy, government and governance.

This activity resulted in *3234 articles.*

## 3.2. Step 2: Literature Refinement

Then, we excluded all the non-English ones as well as the ones belonging to the following categories: Biochemistry, Genetics and Molecular Biology, Medicine, Physics and Astronomy, Chemistry, Nursing, Chemical Engineering, Pharmacology, Toxicology and Pharmaceutics, Dentistry and Materials Science. This process provided us with a collection of approximately *1539 publications*. These were imported to EndNote[3] for further analysis.

The next step was to investigate which are really related to eParticipation field. We therefore read all publications' titles, keywords and abstracts and selected only relevant publications. After this, we ended up with *1340 publications*.

## 3.3. Step 3: Disambiguation Resolution

We thereafter resolved problems relevant to the spelling of authors' names, as author name disambiguation is a major problem in citation analysis (Kang et al., 2009). Following Kang et al.'s (2009) guidelines, we studied the authors carefully and identified resolved any duplications and inconsistencies, e.g. the authors J. Abbott and J. P. Abbott are the same person. In particular, we decided to keep authors in the form "surname" and "initials of the other names", e.g. the aforementioned author was referred as Abbott J.P.

Then, we identified the geographic affiliation of each author. To this extend, we study the authors' records in ISI– Web of knowledge and Scopus and retrieve the affiliation recorded there. In cases of multiple affiliations, we used the one presented in the most recent publication.

## 3.4. Step 4: Data Set Recording

Next, we recorded the collaborations among the authors. For doing so, we study the authors of each publication and assume that all co-authors collaborate with each other. In this way we created co-authors pairs for the papers we examined. It is noted here that we also recorded all the single-authors, those who authored articles by themselves only.

Additionally, we recorded the geographic information of each collaboration, meaning that we transform the co-authors pairs created before in countries pairs (each country is the country in which the affiliation of each author is based).In this way, we can identify the type of each collaboration (e.g. national, international) and also determine the more collaborative countries.

## 3.5. Step 5: Data Analysis

Next, we constructed the eParticipation network by importing the data in Cytoscape[4] version 3.0.2, an open source platform for complex network analysis and visualization. It is noted here that the nodes of the network correspond to the authors, while the edges indicate the collaborations between authors.

We choose to analyse the eParticipation network using SNA because the SNA metrics highly contribute to the understanding of the nature of the collaboration within the field. SNA metrics indicate the collaboration degree within the network (density), the most influential authors (centrality). Using specific Cytoscape's plugins, i.e. NetworkAnalyzer[5] and CytoNCA[6] we calculated the SNA metrics and created a number of charts and graphs.

The main limitations of the employed approach follow. First, only publications written in English were considered. Secondly, only publications included in ISI– Web of knowledge and Scopus were considered. Moreover, these databases include only scientific publications and not reports or white papers from governments and other organizations. Finally, we accepted the assumption that co-authors are also collaborators.

# 4. RESULTS

## 4.1. Short Analysis of the eParticipation Field

The network of eParticipation researchers consists of *2210 authors* and 1340 publications. Each publication has a mean of 2.23 authors. Figure 1 shows the number of publications and the number of authors in the field of eParticipation. The number of publications as well as the number of authors is steadily increased. There is a significant increase in 2005 as well as in 2008. *After 2011 the total number of eParticipation publications started to decrease*.

At this point it is worth mentioning that the numbers of year 2013 (Figure 1) represent the publications of 2013 presented in ISI–– Web of knowledge and Scopus during the time of this research, i.e. October – December 2013. It is possible that ISI and Scopus did not record, at this time, all eParticipation publications of 2013.

Figure 2 indicates the type of publications while Figure 3 presents the different publication types from 1980 to 2013. It is noted here that the types of publications are proposed include: journal articles, books, book sections and conference articles.

It is clear that *during the early years of eParticipation,* i.e. until 2004, *journal articles prevail*. From then on, there is a turn in book sections and conference articles. It is noted here that the great majority of book sections are articles presented in conferences and then published in books.

In Figure 4, we compare percentages of singe-author, two-author, three-author and ≥4-author papers in eParticipation for each year. It is clear that the percentage of single-author publications is decreasing whereas the percentage of multi-author publications is increasing over the years. In particular, one-author publication is steadily decrease after 1998, while two-author publication is increased since 1998, three-author since 2001 and more-than-four author publications since 2003. In total, as shown in Figure 5, the average number of authors per publication is increasing over time (from 1 in 1980 to 2.66 in 2013). Thus, *there is a tendency for collaboration among eParticipation researchers*.

The 2210 authors included in the eParticipation network come from 76 different countries. We did not identify the country of 22 authors as no such information was provided. The geographic distribution of the researchers per county and per continent is presented in Figure 6 and Figure 7 respectively. It is clear that the majority of researchers come from USA, United Kingdom, Italy, Spain and Greece. Despite the fact that *most researchers come from USA*, *European countries accumulate almost half the researchers (49%) of the eParticipation field*.

The eParticipation network contains 3222 different collaborations. The geographic distribution of the collaborations per country is presented in Figure 8. The countries with the highest

*Figure 1. Number of publications and number of authors per year*

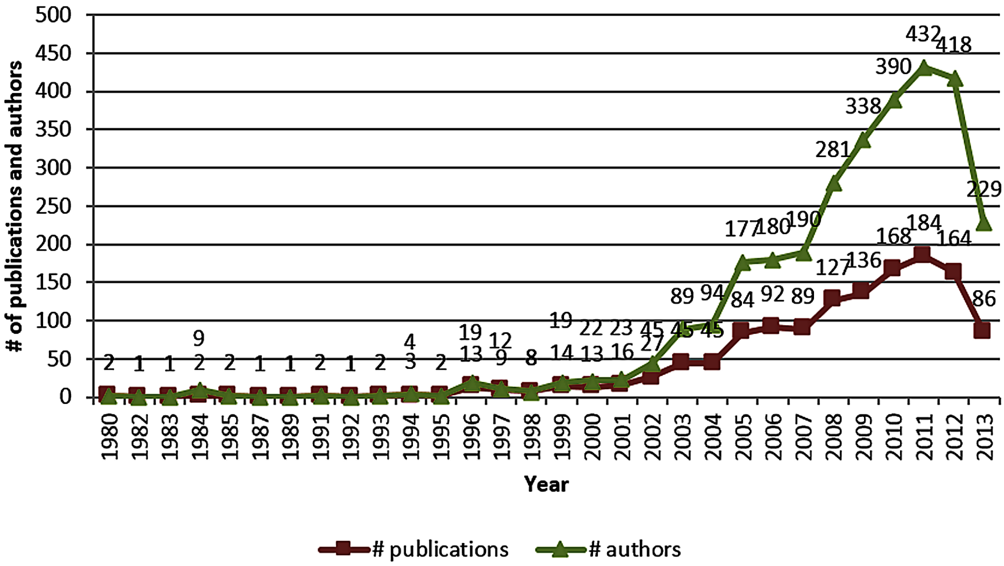
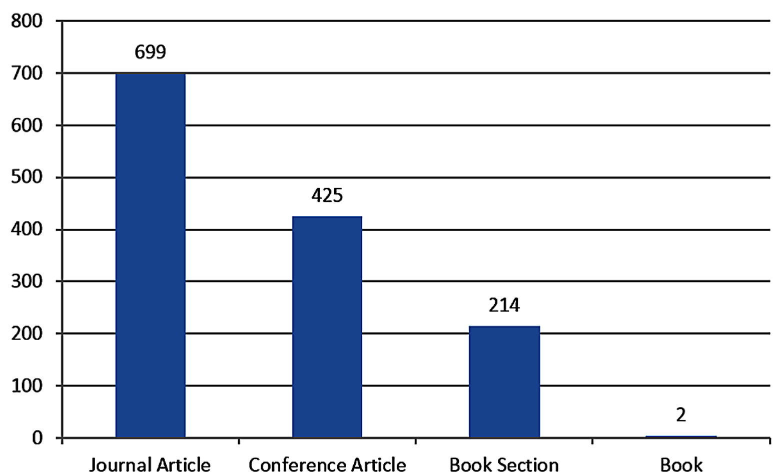


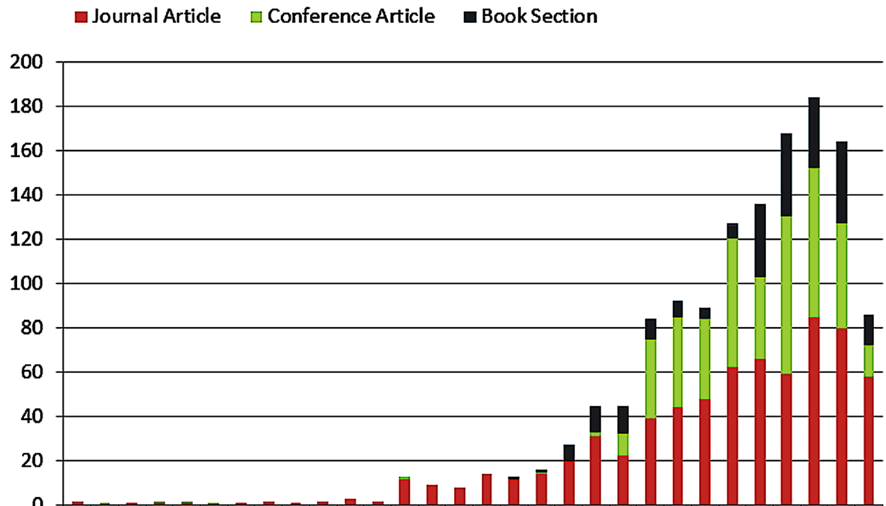

*Figure 2. Number of publications per reference type*




number of collaborations are USA, UK, Greece, Spain and Italy. By comparing Figure 6 and Figure 8 we can conclude that *in general countries with large number of researchers have also large number of collaborations*.

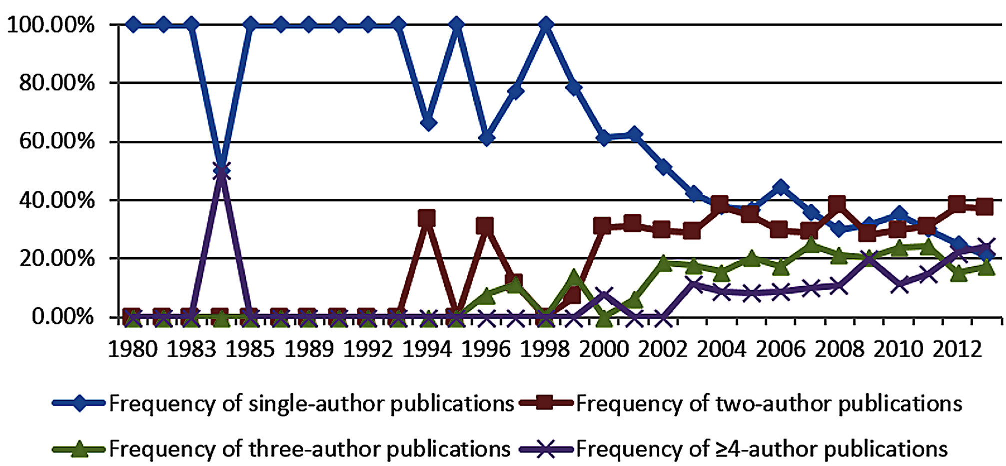
From the 3222 collaborations among the researchers of the eParticipation network, only the 819 (25.42%) are international and the rest 2396 (74.36%) are national collaborations. It is noted here that we did not identify the type of 7 collaborations, as they included authors with no geographic information. Therefore, *eParticipation is a field that presents high degree of national collaboration.*

*Figure 3. Cumulative graph of reference types per year*




| | 1980 | 1982 | 1983 | 1984 | 1985 | 1987 | 1989 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Book | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 |
| Book Section | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 7 | 12 | 13 | 9 | 7 | 5 | 6 | 33 | 37 | 32 | 37 | 14 |
| Conference Article | 0 | 1 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 2 | 10 | 36 | 41 | 36 | 58 | 37 | 71 | 67 | 47 | 14 |
| Journal Article | 2 | 0 | 1 | 1 | 1 | 0 | 1 | 2 | 1 | 2 | 3 | 2 | 12 | 9 | 8 | 14 | 12 | 14 | 20 | 31 | 22 | 39 | 44 | 48 | 62 | 66 | 59 | 85 | 80 | 58 |

*Figure 4. Frequency of single-author, two-author, three-author and ≥4-author publications*




## 4.2. Network Analysis of the eParticipation Field

Figure 9 presents the eParticipation authorship network and Table 1 the results obtained from its analysis in Cytoscape; in particular, we used NetworkAnalyzer plugin[7]. The network consists of

*Figure 5. Average number of authors per publication*

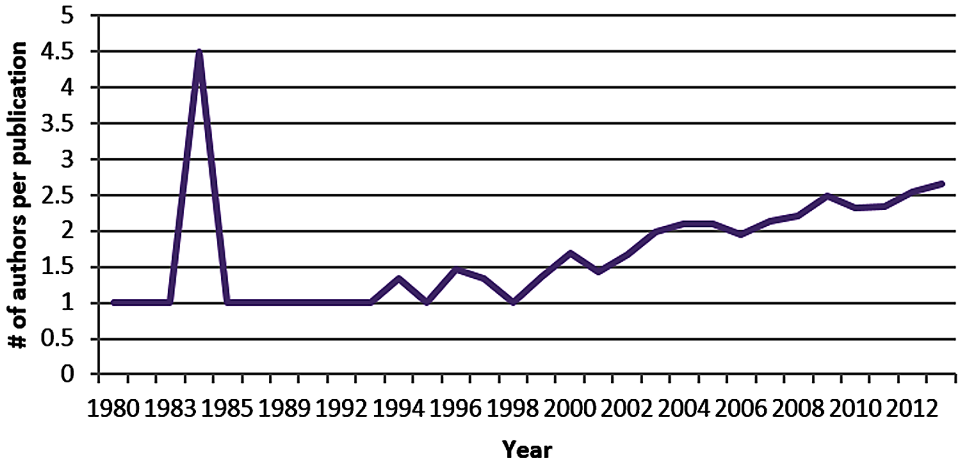
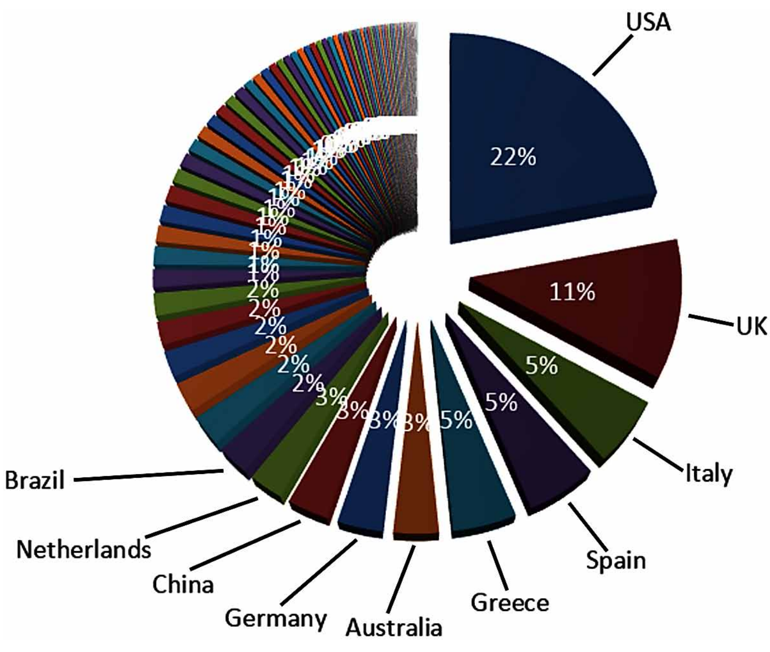



*Figure 6. Geographic distribution of authors per country*




2210 nodes (authors) and 3222 edges (co-authorship links). The average number of neighbours is 2.566 indicating that in average an author has collaborated with 2.566 other authors (see Figure 10). Moreover, the number of multi-edge node pairs equals to 279 implying that 279 author pairs have been collaborated more than once. In addition, there are 330 isolated nodes, representing 330 authors (14.93%) that have published an article but they did not collaborated with any other author in the network.

*Figure 7. Geographic distribution of authors per continent*

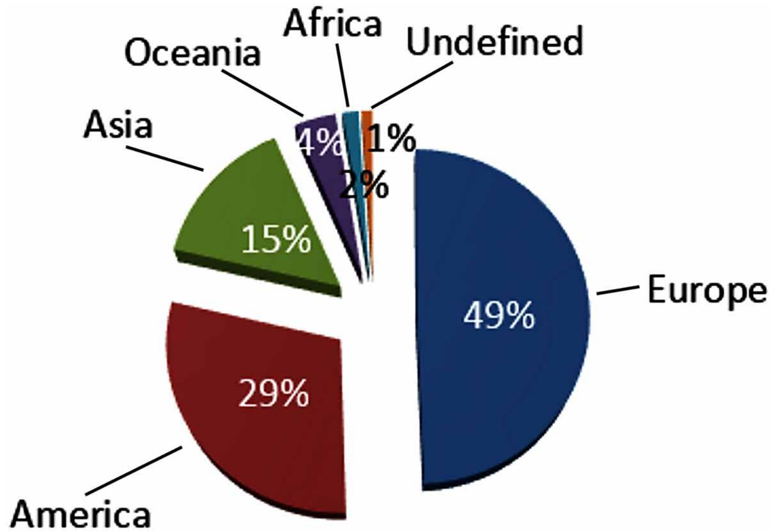
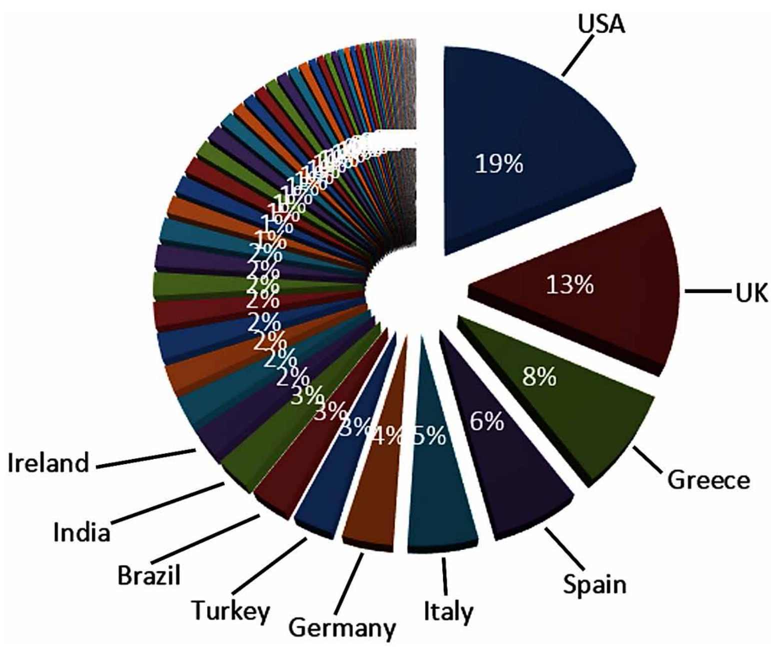



*Figure 8. Geographic distribution of collaborations*




Similar to any other large-scale network, the eParticipation network consists of 853 different components (all nodes that are pairwise connected form a connected component). Depicts the distribution of the number of authors per the number of components of the eParticiption network. It is clear that only few components contain large number of authors. The vast majority of components, i.e. 796 components (or 93.32% of all components) include one to five authors; 48 components (5.63% of all components) contain six to ten authors, while only 9 components (1,05% of all components) contain more than ten authors.

The largest of them contains 133 authors (6.02% of total authors) who are highly productive as it includes 613 co-authorships (19.03% of total co-authorships). This component is illustrated with yellow in Figure 11.

The density of the network is 0.001. In general, network density is a normalized parameter of the average connectivity of the nodes in the network and shows how densely the network is populated with edges. Consequently, the eParticipation network is considered a low-density network whose relationships tend to be large, open, diverse and externally focused (Baker, 2000).

Network clustering coefficient is a normalized parameter of the average clustering coefficient of a node in the network, i.e. the ratio of the number of edges between the neighbours of the node divided by the maximum number of edges that could possibly exist. It measures the degree to which nodes in a network tend to cluster together. The eParticipation network has a network clustering coefficient equal to 0.556, indicating that is a rather clustered network.

The network diameter is 9. This means that the shortest path connecting two nodes in the network equals to 9. In cases of disconnected networks, like eParticipation, its diameter is the maximum of all diameters of its connected components. The network radius, i.e. the minimum non-zero distance among nodes of the network, equals to 1. The characteristic path length, is 3.290, indicating that the average distance between two connected nodes is 3.290.

Network centralization (Dong, 2007) provides insight how the network density is distributed. In other words it measures how central its most central node is in relation to how central all the other nodes are (Freeman, 1979). Networks whose topologies resemble a star have centralization close to 1, whereas decentralized networks are characterized by having centralization close to 0. eParticipation network's centralization is 0.012 meaning that it is a rather decentralized network. Network heterogeneity (Dong, 2007) reflects the tendency of a network to contain hub nodes. Here, heterogeneity is 1.196 implying that the eParticipation network contains a significant number of hub nodes.

Summarizing, the network analysis reveals that *eParticipation is a rather decentralized network* containing a significant number of different components and isolated nodes. In particular, *eParticipation contains a large number of isolated components most of which contain a small number of authors*. Additionally, *the field contains a significant number of isolated researchers*.

## 4.3. Measures of Centrality of eParticipation Network

Measures of centrality are generally used in undirected networks. In co-authorship networks, an author is assumed to be more central if s/he is connected to many other authors. As mentioned earlier, the most common centrality metrics are degree, closeness centrality, betweenness, eigenvector and information centrality. It is noted here that centrality measures have been calculated using the CytoNCA, a Cytoscape's plugin for network analysis.

## 4.4. Degree Centrality

Degree centrality counts the number of edges connecting each node with the rest. It can be interpreted as the immediate risk of a node for catching whatever is flowing through the network e.g. information. In co-authorship networks, it measures the collaboration between authors; authors with high degree centrality the most active in sense of collaboration (Erman & Todorvski, 2009a). However, in some cases some authors may present high degree centrality because they

*Figure 9. The whole network of eParticipation field*

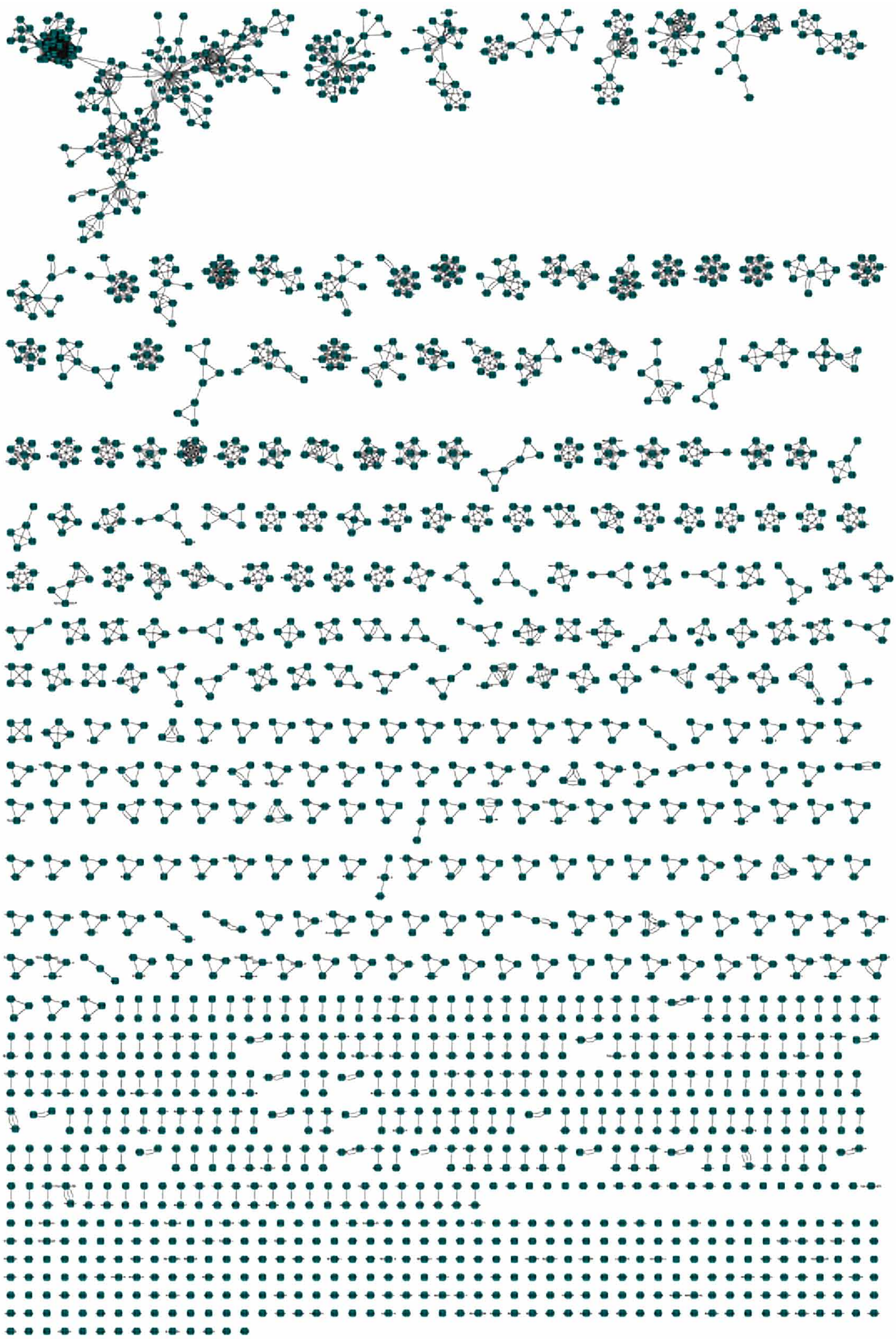


*Table 1. Network metrics for the whole eParticipation network*

| Network Metric | Value |
|---|---|
| Nodes | 2210 |
| Edges | 3222 |
| Connected Components | 853 |
| Isolated Nodes | 330 |
| Self-Loops | 0 |
| Average number of neighbors | 2.566 |
| Multi-Edge Node Pairs | 279 |
| Network Density | 0.001 |
| Network Clustering Coefficient | 0.556 |
| Network Diameter | 9 |
| Network Radius | 1 |
| Characteristic Path Length | 3.290 |
| Network Centralization | 0.012 |
| Network Heterogeneity | 1.196 |

*Figure 10. Distribution of number of authors per number of components in the eParticipation network*

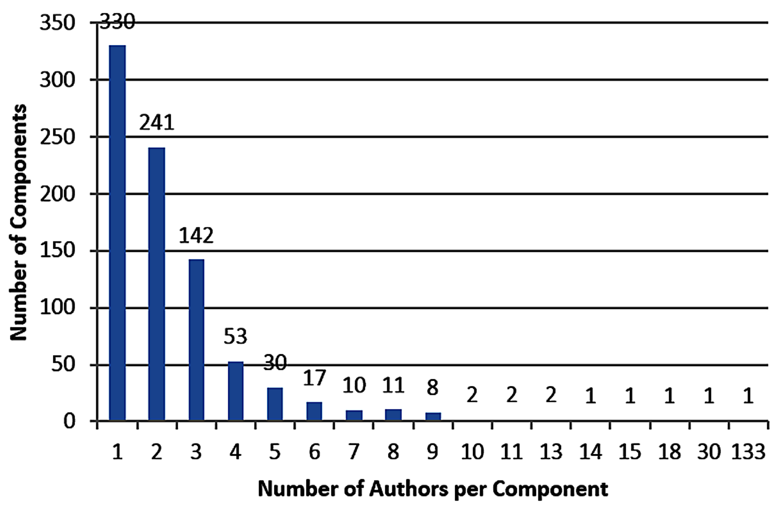
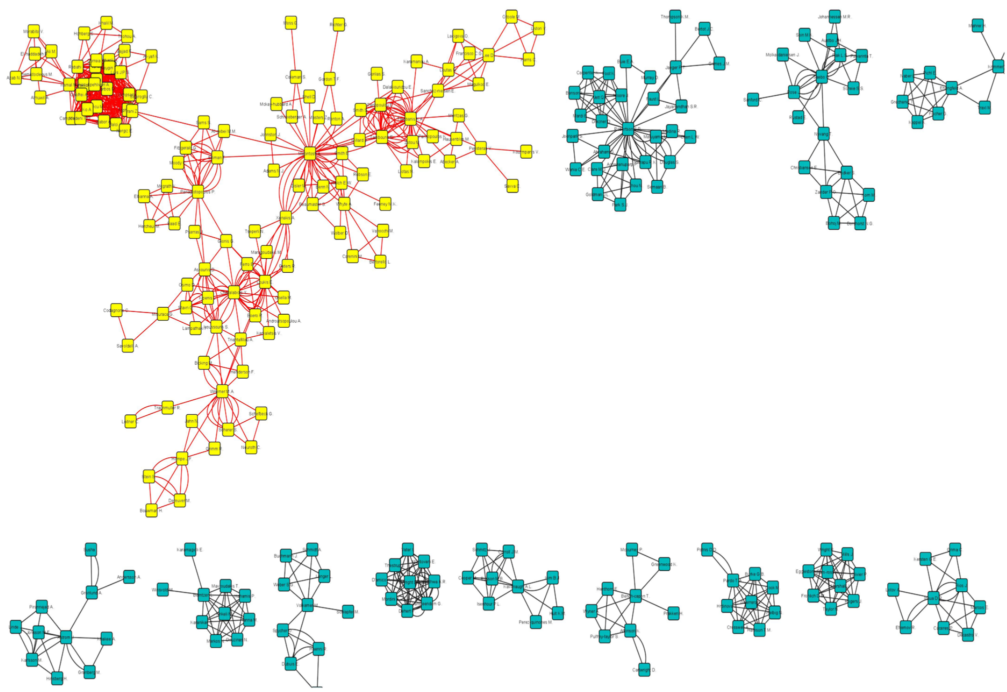


*Figure 11. The largest component in the eParticipation network*



co-authored with many authors in a single paper, rather than co-authored in many papers (Yan & Ding 2009).

Table 2 presents the ten most central authors according to degree centrality. We observe that Macintosh A. has by far the highest degree centrality in the network. This implies that Macintosh A. is the most collaborative author in the eParticipation network.

*Table 2. Top authors with the highest degree centrality*

| | Author | Degree Centrality |
|---|---|---|
| 1 | Macintosh A. | 40 |
| 2 | Tarabanis K.A. | 35 |
| 3 | Lee H. | 33 |
| 4 | Charalabidis Y. | 32 |
| | Robertson S.P. | 32 |
| 6 | Irani Z. | 31 |
| 7 | Tambouris E. | 30 |
| 8 | Kamal M. | 30 |
| 9 | Rebahi Y. | 27 |
| 10 | Weerakkody V. | 25 |

The positions of the most central authors are depicted in Figure 12. It is obvious that the most central authors belong to the largest component of the eParticipation network. Only Robertson S.P. does not belong to this component; he belongs to the second largest component of the eParticipation network (Figure 8).

The average degree centrality of the eParticipation network equals to 2.91, implying that an author has in average to 2.91 collaborations. In Figure 13 we can see the degree centrality distribution for the whole network. It is clear that only few authors have a high degree centrality. The vast majority of authors have degree centrality between 1 and 4. From the 2210 authors of this network, only 385 (17.25%) have degree centrality of 5 or more. 330 authors that have not collaborated with no one in the network have degree centrality equals to zero.

## 4.5. Betweenness Centrality

Betweenness centrality is a measure of the number of shortest paths passing through a node (Yan & Ding, 2009). Nodes with a high betweenness play the role of connecting different groups; therefore it reflects the amount of control that this node exerts over the interactions of other nodes in the network (Yoon et al. 2006). Betweenness centrality favors nodes that join communities (dense subnetworks), rather than nodes that lie inside a community.

Betweenness centrality is computed only for networks that do not contain multiple edges. CytoNCA ignores multiple connections among authors in order to compute betweenness centrality. Table 3 shows the list of the most central authors according to betweenness centrality.

In co-authorship networks, an author is central if he lies between many other authors. A betweeness centrality equals to zero indicates that the node do not appear in a path between two nodes, i.e. either is an isolated node in the network, or a node that has only a single connection. The positions of the most central authors are depicted in Figure 14. It is obvious that the central authors belong to the largest component of the eParticipation network.

Table 3 represents the ten most central authors according to betweenness centrality. Macintosh A. has by far the highest betweennes centrality in the network, indicating that Macintosh A. is the author who appears more frequent in the paths connecting other authors. She acts as a connecting point between authors and controls the flow of information in the network.

Comparing Table 2 and Table 3 there are major differences in authors who compose each list. Five authors are present in both lists, i.e. Macintosh A., Charalabidis Y., Tarabanis K.A., Irani Z. and Tambouris E., while the four others vary.

The average betweenness centrality of the network equals to 22.42, implying that an author act as a link among 22.42 other authors. In Figure 15 we can see the betweenness centrality distribution for the whole network. It is clear that only few authors have a high betweenness cen-

*Figure 12. Authors with the highest degree centrality*

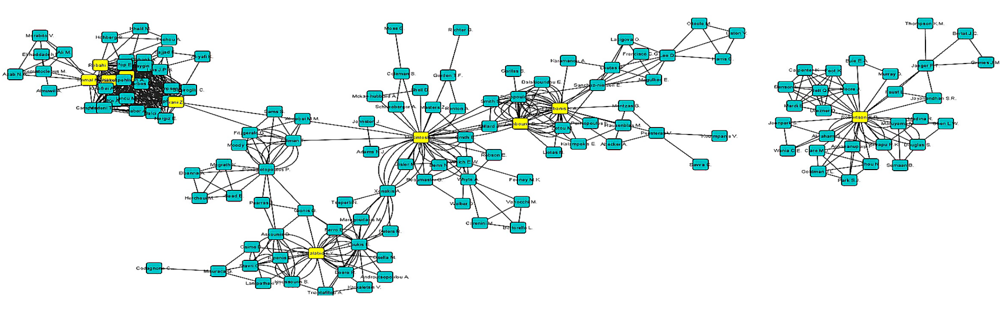


*Figure 13. Degree centrality distribution in the eParticipation network*

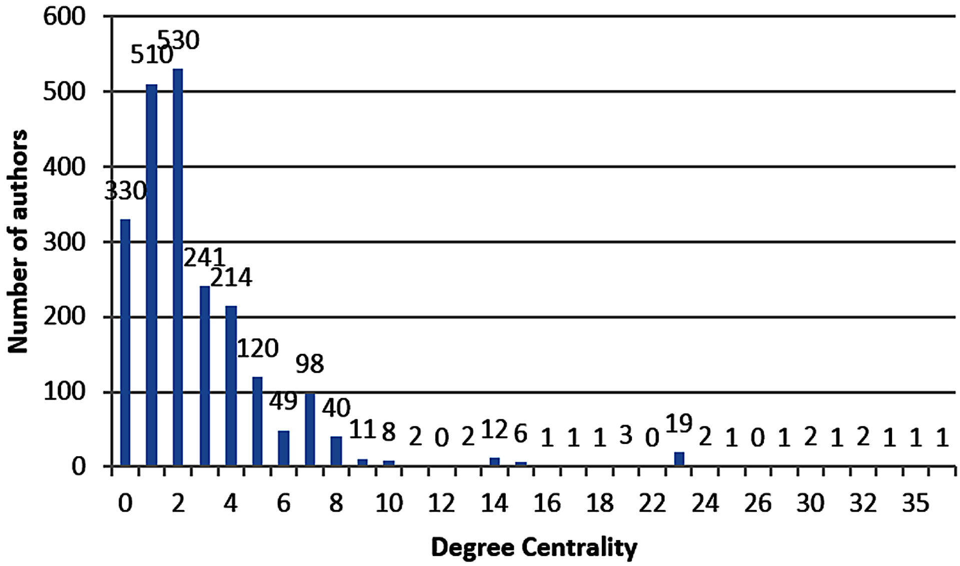



*Table 3. Top authors with the highest betweenness centrality*

| | Author | Betweenness Centrality |
|---|---|---|
| 1 | Macintosh A. | 12193,875 |
| 2 | Irani Z. | 6708,838 |
| 3 | Xenakis A. | 5764,634 |
| 4 | Loukis E. | 3872,106 |
| 5 | Tarabanis K.A. | 2972,520 |
| 6 | Wimmer M.A. | 2900,124 |
| 7 | Charalabidis Y. | 2353,263 |
| 8 | Elliman T. | 2048,213 |
| 9 | Panagiotopoulos P. | 1818,232 |
| 10 | Tambouris E. | 1672,394 |

trality. The vast majority of authors have zero betweenness centrality; 2036 authors have zero and only 174 authors (7.87% of total authors) in the network have non-zero betweenness centrality.

## 4.6. Closeness Centrality

Closeness centrality measures the average distance between a node and any other node of the network. Closeness centrality is a measure of how fast information spreads from a given node to other reachable nodes in the network (Newman 2003). So, the most central author is the one who can quickly interact with all the others which means that a central author is characterized by many short connections to other authors in the network (Erman & Todorvski, 2009a).

*Figure 14. Authors with the highest betweeness centrality*

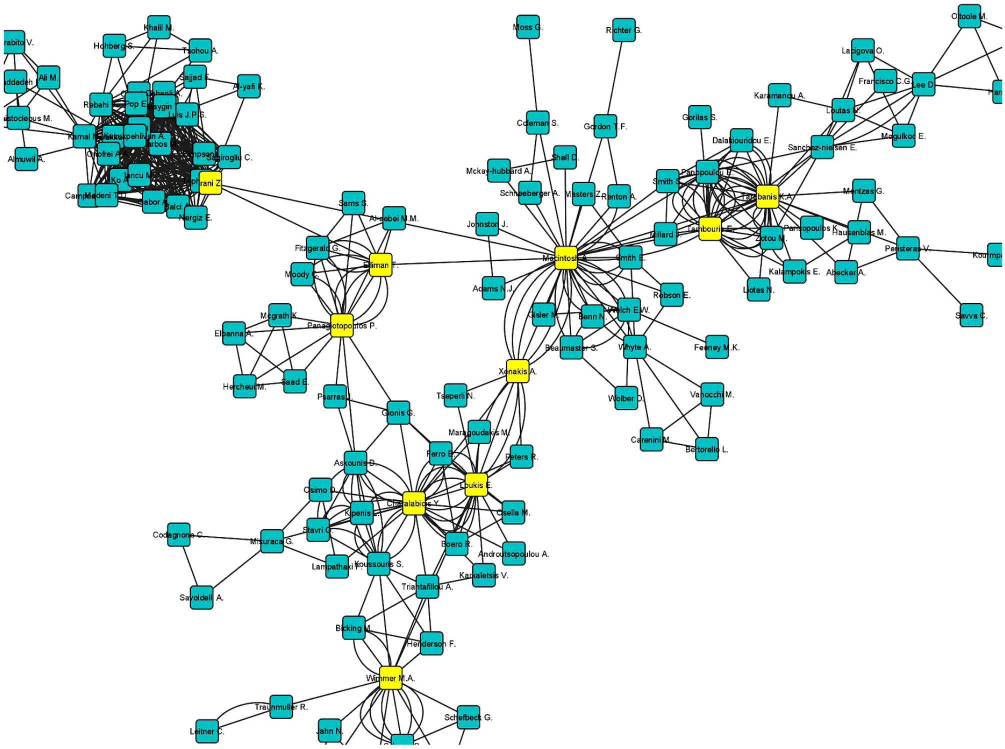
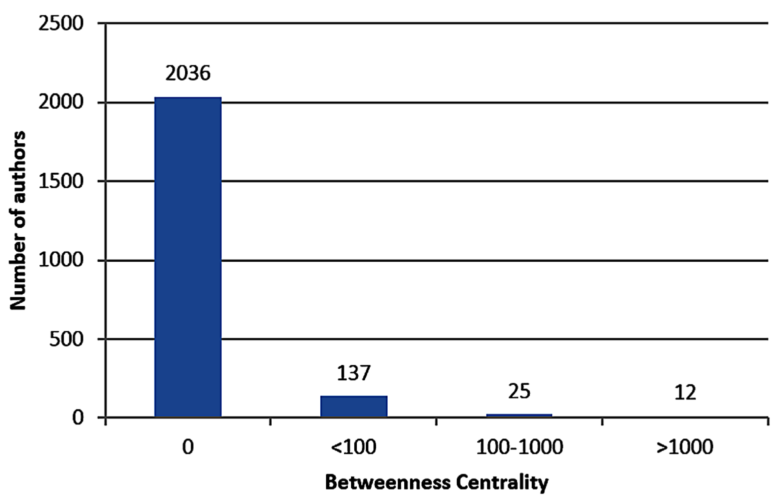


*Figure 15. Betweeness centrality distribution in the eParticipation network*



In the e Participation network closeness centrality cannot be calculated. This is due to the existence of the 853 separate components of the network (Table 1). In cases that separate components, i.e. sub-networks disconnected from each other, exist in a network closeness centrality can't be used in order to determine the most central authors, Dekker (2008). In such cases, measuring closeness centrality for the whole network is impossible as the distance between two nodes from different components is equal to infinite. Therefore closeness centrality for the Participation network cannot be calculated.

## 4.7. Eigenvector Centrality

Eigenvector centrality is calculated using factor analysis (Bonacich 1987). In particular, this metric calculate the distance of each node to some "distance patterns" of the overall network. Higher scores indicate that actors are more central to the main pattern of distances among all nodes, while lower values indicate that actors are more peripheral. Eigenvector centrality measures the influence of a node in the whole network. In particular, a node has a high eigenvector score if it is influential and connected to other influential nodes (Wei et al. 2011).

However, in order this measure to be useful the network has to be connected. In cases of unconnected networks, like the eParticipation network, the Bonacich algorithm does not guarantee that the eigenvector centrality equation has a positive and unique solution. Unconnected networks often have nodes with centrality scores at 0, without the guarantee that nodes in the largest component actually get non-zero scores. Another oddity is that the highest score is given to a dyad (2-node component), whereas one is usually interested in finding nodes embedded in larger components. These nodes are most likely to have scores lower than those of the dyadic component (Wei et al. 2011).

Therefore, we excluded this metric from our analysis.

## 4.8. Information Centrality

Information centrality (Stephenson and Zelen 1989) measures the harmonic mean length of paths ending at a node which is smaller if the node has many short paths connecting it to other nodes. This metric ranks nodes according to their ability to spread information more quickly.

For disconnected networks this measure equals to zero, as some nodes have no path connecting them.

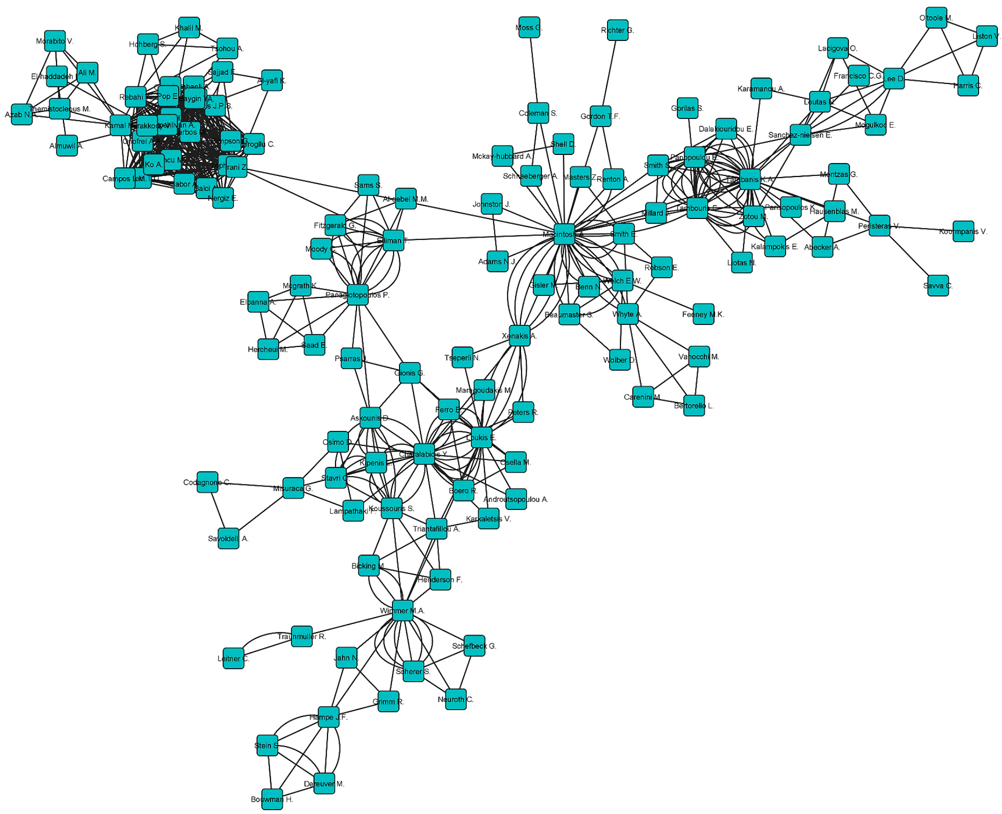
## 4.9. Analysing the Core

After having analysed the characteristics of the whole eParticipation field's network as an entity, it could also be interesting the analysis of the core of the field (Figure 16), consisting of the largest component of the whole network.

It is worth mentioning here that the core component is mainly consisting of European researchers (87.97% of the whole researchers of the core network). Amongst them the 28.57% come from UK, 23.31% from Greece, 10.53% from Germany, 6.77% from Italy, 4.51% from Ireland and the rest from other European countries. Moreover, the 6.02% of the researchers come from Turkey and the 3.01% from USA.

The network metrics are presented in Table 4, are related to the network of the core of eParticipation field. These suggest the core network consists of 133 authors collaborating with each other 633 times. An author has collaborated with 7.729 other others, a significant larger collaboration than in the whole eParticipation network. Moreover, 52 author pairs have been collaborated more than once.

*Figure 16. The core of eParticipation field*




The density of the network is 0.059 suggesting that the core eParticipation network is a sparse-density network. The clustering coefficient equals to 0.787 indicating that the core is a rather clustered network.

Network's diameter is 9 alike the whole eParticipation network's diameter. This indicates that the core network has the maximum of all diameters of eParticipation's connected components. The network radius, i.e. the minimum non-zero distance among nodes of the network, equals to 5, while the average distance between two connected nodes is 4.022. Network's centralization is 0.156 meaning that the core is a decentralized network, while heterogeneity is 1.063 implying that the core contains a significant number of hub nodes.

Table 5 shows the top authors ranked on the centrality measures (Degree, Betweenness, Closeness, Eigenvector and Information).

As far as degree centrality concerns the metrics of the whole eParticipation network are the same with those of the core network, with the exception of Robertson S.P. who does not belong in this network. This is due to the formula used for calculating degree centrality; as stated above, degree centrality measures the connections of a node with the other nodes in the network; thus, this metric stays unchangeable in the core network.

Similarly, the rank of the authors of the core network according to betweeness centrality is the same with this of the whole eParticipation network. This is also stems from the formula used for calculating betweeness centrality; as stated above, betweeness centrality is the frequency of

*Table 4. Network metrics for the core eParticipation network*

| Network Metric | Value |
|---|---|
| Nodes | 133 |
| Edges | 613 |
| Connected Components | 1 |
| Isolated Nodes | 0 |
| Self-Loops | 0 |
| Average number of neighbors | 7.729 |
| Multi-Edge Node Pairs | 50 |
| Network Density | 0.059 |
| Network Clustering Coefficient | 0.787 |
| Network Diameter | 9 |
| Network Radius | 5 |
| Characteristic Path Length | 4.022 |
| Network Centralization | 0.156 |
| Network Heterogeneity | 1.063 |

*Table 5. Top authors of the core network according to various Centrality measures*

| Degree Centrality | | Betweenness Centrality | | Closeness Centrality | | Eigenvector Centrality | | Information Centrality | |
|---|---|---|---|---|---|---|---|---|---|
| Author | Value | Author | Value | Author | Value | Author | Value | Author | Value |
| Macintosh A. | 40 | Macintosh A. | 12193,875 | Macintosh A. | 0,418 | Lee H. | 0,208 | Macintosh A. | 2,353 |
| Tarabanis K.A. | 35 | Irani Z. | 6708,838 | Irani Z. | 0,361 | Kamal M. | 0,206 | Tarabanis K.A. | 2,338 |
| Lee H. | 33 | Xenakis A. | 5764,905 | Xenakis A. | 0,351 | Irani Z. | 0,206 | Tambouris E. | 2,328 |
| Irani Z. | 31 | Loukis E. | 3867,471 | Elliman T. | 0,346 | Rebahi Y. | 0,206 | Charalabidis Y. | 2,302 |
| Charalabidis Y. | 31 | Tarabanis K.A. | 2972,520 | Tarabanis K.A. | 0,330 | Weerakkody V. | 0,204 | Loukis E. | 2,239 |
| Tambouris E. | 30 | Wimmer M.A. | 2900,142 | Tambouris E. | 0,324 | Saygin Y., Hintoglu A., Gabor A., Iancu M., Campos L.M., Barbos M., Dabanli A., Correia P., Onofrei A.A., Nergiz E., Pop E., Kucukpehlivan A., Ko A., Medeni T.D., Luis J.P.S., Balci A., Simpson G., Topham S. | 0,203 | Panopoulou E. | 2,233 |
| Kamal M. | 30 | Charalabidis Y. | 2353,208 | Panopoulou E. | 0,321 | | | Irani Z. | 2,210 |
| Rebahi Y. | 27 | Elliman T. | 2048,213 | Smith S. | 0,314 | | | Lee H. | 2,204 |
| Weerakkody V. | 25 | Panagiotopoulos P. | 1818,232 | Millard J. | 0,314 | | | Wimmer M.A. | 2,166 |
| Loukis E. | 23 | Tambouris E. | 1672,394 | Panagiotopoulos P. | 0,306 | | | Kamal M. | 2,152 |

the appearance of a node in the shortest path of two other nodes. Therefore this metric depends only of the component in which the nodes belong and thus is unchangeable in the core network.

Degree centrality indicates that the most central authors in the core network are Macintosh A., Tarabanis K.A., Lee H., Irani Z. and Charalabidis Y. These are the most collaborative authors in the network as they have the highest number of collaborations among the other authors in the network.

Macintosh A., Irani Z., Xenakis A., Loukis E., and Tarabanis K.A. are as leaders of the network according to betweenness centrality. This means that they appear more frequently in the shortest paths between other authors, they have the ability to control the flow of information in the network. Without these authors, the network would be highly fragmented having separate unconnected components.

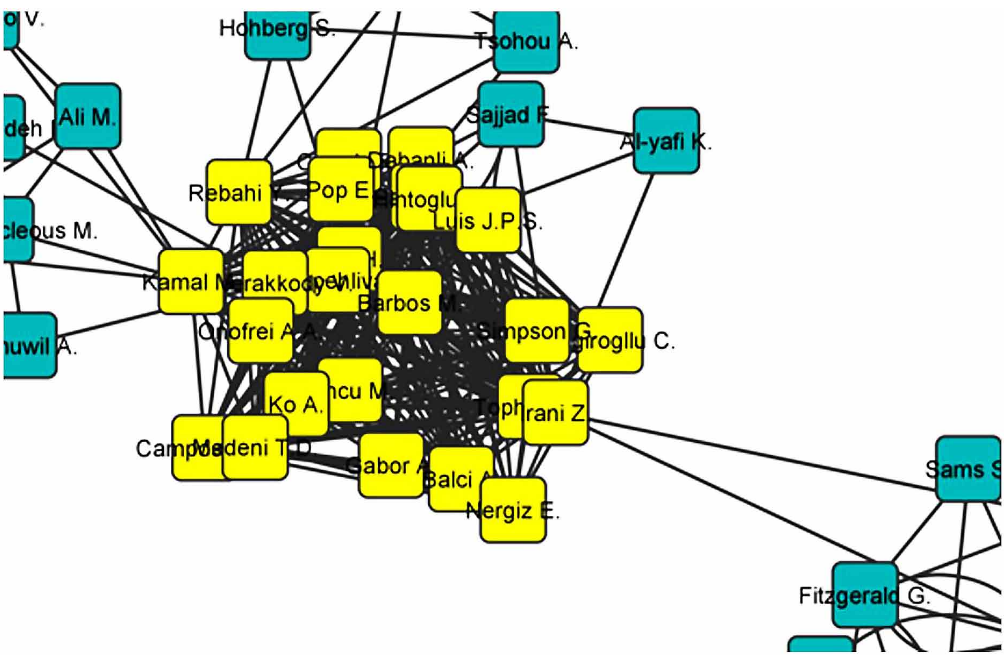
The leading authors in terms of closeness centrality are Macintosh A., Irani Z., Xenakis A., Elliman T., and Tarabanis K.A.. In other words, these are the most "favored" authors of the network as they are closer to the rest authors than no one else.

Lee H, Kamal M., Irani Z., Rebahi Y. and Weerakkody V. are by far the leading author observing the eigenvector centrality. This means that they are connected with the most well-connected authors in the network. It worth noticing here that the most leading authors according to this metric belongs to a specific sub-group depicted in Figure 17. This means that this subgroup is the most well-connected group in the whole e-participation network.

Macintosh A., Tarabanis K.A., Tambouris E., Charalabidis Y., Loukis E. are the most central authors according to information centrality. This means that these authors have the ability to spread information more quickly than any other author in the network.

According to the above, *Macintosh A., Irani Z., Tarabanis K.A. and Tambouris E. are the most central authors of the eParticipation network* as they have high scores in all centrality measures,

*Figure 17. The most central authors according to eigenvector centrality*



with the exception of eigenvector centrality. The positions of these authors in the network are depicted in Figure 18. *Macintosh A. is the most important author in the network* as she has the highest scores in all centrality measures. Additionally, the subgroup of Figure 17 is the most well connected subgroup in the network as its members have the highest eigenvalue centrality scores.

## 4.10. Network Analysis of the International Collaborations of the eParticipation Field

Finally, we analyzed the international collaborations among the researchers of the eParticipation network. To this extend, we imported international collaborations data in Cytoscape and performed a network analysis. The network of the international collaborations in eParticipation is depicted in Figure 19.

The network metrics are presented in Table 6. These suggest the network consists of 56 countries collaborating with each other 819 times. A country has collaborated with 4.237 other countries, a rather high collaboration indicator. Moreover, 114 country pairs have been collaborated more than once.

The density of the network is 0.056 and the clustering coefficient equals to 0.417 suggesting a slightly sparse but a rather clustered network.

Network's diameter, i.e. the shortest path connecting two nodes in the network, is 6. The network radius, i.e. the minimum non-zero distance among nodes of the network, equals to 1, while the average distance between two connected nodes is 2.371. Network's centralization is 0.353 while heterogeneity is 1.377 implying a rather centralized network containing a significant number of hub nodes.

The network consists of 22 different components; 2 multi- node and 20 isolated components. The 20 isolated countries are countries with no international collaborations at all. In particular 5 of them have only isolated researchers who did not collaborated with anyone else in the network, and the rest 15 countries have only national collaborations.

From the two multi- node components of the network, the core (Figure 20) consists of 54 countries (71.05% of all countries) and 818 collaborations (99.88% of all collaborations) and

*Figure 18. The most central authors of the core network*

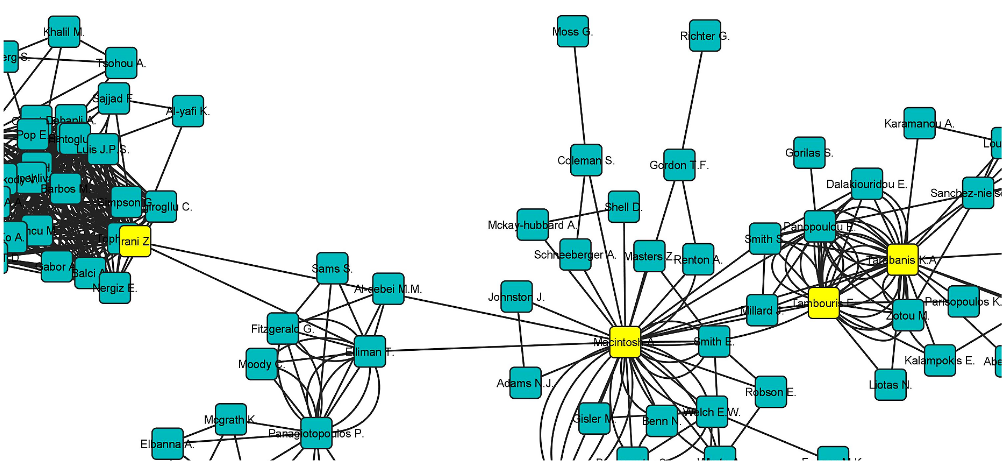


*Figure 19. The network of the international collaborations of eParticipation*

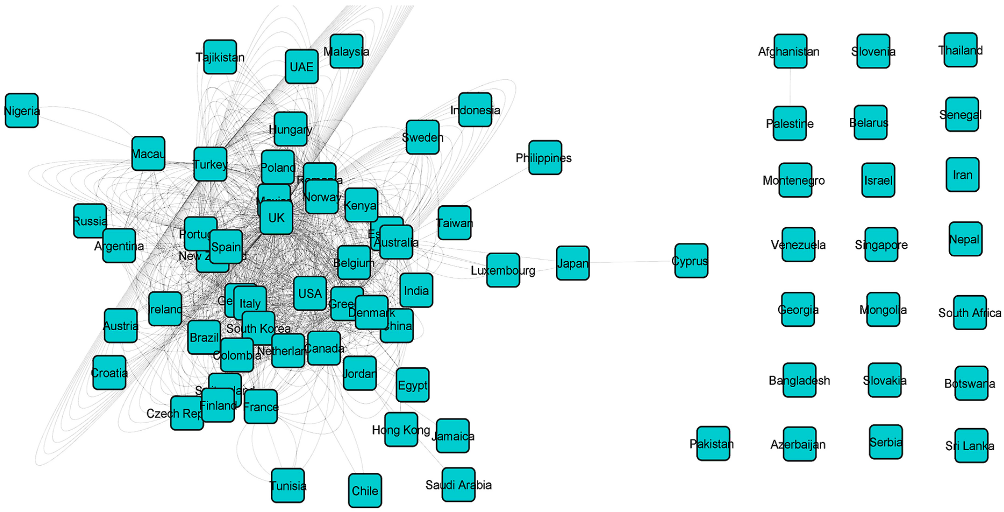
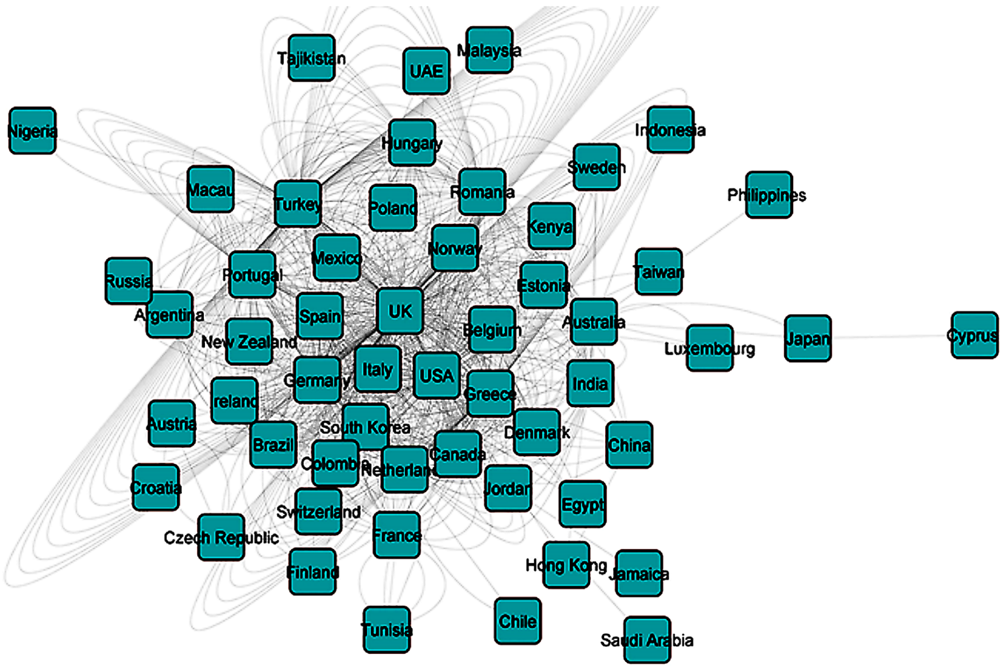



*Table 6. Network metrics for the international collaborations network*

| Network Metric | Value |
|---|---|
| Nodes | 76 |
| Edges | 819 |
| Connected Components | 22 |
| Isolated Nodes | 0 |
| Self-Loops | 0 |
| Average number of neighbours | 4.237 |
| Multi-Edge Node Pairs | 114 |
| Network Density | 0.056 |
| Network Clustering Coefficient | 0.417 |
| Network Diameter | 6 |
| Network Radius | 1 |
| Characteristic Path Length | 2.371 |
| Network Centralization | 0.353 |
| Network Heterogeneity | 1.065 |

*Figure 20. The core network of the international collaborations of eParticipation*




the other consists only of 2 countries (i.e. Afghanistan and Palestine) and only one collaboration among them.

Summarizing, the network analysis reveals that *international cooperation in eParticipation is a slightly decentralized network containing a small number of different components and a respectable number of isolated nodes*. Furthermore, *the majority of countries (71.05%) engaged in eParticipation research are inter-connected forming a large network.*

Next, we indented to identify the most central countries in eParticipation research. In order to calculate all centrality measures for the countries and taking into account that some of them can't be computed for unconnected networks, we use only the core network of Figure 20.

Table 7 shows the top countries ranked on the centrality measures (Degree, Betweenness, Closeness, Eigenvector and Information).

Rank of degree centrality values indicates that the most collaborative countries in eParticipation research are UK, USA, Turkey, Germany and Greece. Betwenness centrality suggests that UK, USA, Australia, Spain and Germany appear more frequently in the shortest paths among other countries and therefore control the flow of information in the network. Without these authors, the network would be highly fragmented having separate unconnected components. Closeness centrality shows that UK, USA, Spain, Germany and Italy are closer to the other countries and thus are the most "favoured" countries of the network. Rank of eigenvector centrality implies that UK, USA, Germany, Spain and Netherlands are connected with the most well-connected authors in the network. Finally, information centrality indicates that UK, USA, Turkey, Germany and Greece have the ability to spread information more quickly than any other country in the network.

Based on Table 7 we may conclude that *UK, USA, Germany, Spain and Italy are the most central authors of the network* as they have high scores in all centrality measures. The positions of these countries in the network are depicted in Figure 21. *UK and USA are the most important countries in the network* as they have the highest scores in all centrality measures.

*Table 7. Top countries of the international collaboration network according to various centrality measures*

| Degree Centrality | | Betweenness Centrality | | Closeness Centrality | | Eigenvector Centrality | | Information Centrality | |
|---|---|---|---|---|---|---|---|---|---|
| Country | Value | Country | Value | Country | Value | Country | Value | Country | Value |
| UK | 266 | UK | 1030,466 | UK | 0,679 | UK | 0,387 | UK | 3,834 |
| USA | 152 | USA | 793,882 | USA | 0,631 | USA | 0,331 | USA | 3,793 |
| Turkey | 128 | Australia | 465,624 | Spain | 0,552 | Germany | 0,299 | Turkey | 3,776 |
| Germany | 106 | Spain | 288,503 | Germany | 0,552 | Spain | 0,270 | Germany | 3,752 |
| Greece | 87 | Germany | 250,797 | Italy | 0,552 | Netherlands | 0,246 | Greece | 3,724 |
| Spain | 80 | Italy | 189,470 | Netherlands | 0,546 | Italy | 0,244 | Spain | 3,709 |
| Italy | 76 | Canada | 152,469 | Australia | 0,535 | Greece | 0,216 | Italy | 3,700 |
| Portugal | 73 | Netherlands | 142,521 | France | 0,515 | Brazil | 0,210 | Portugal | 3,694 |
| Romania | 72 | Macau | 104,563 | Brazil | 0,505 | Ireland | 0,198 | Romania | 3,691 |
| Netherlands | 54 | Jordan Japan | 104,000 | Greece | 0,505 | France | 0,175 | Netherlands | 3,627 |

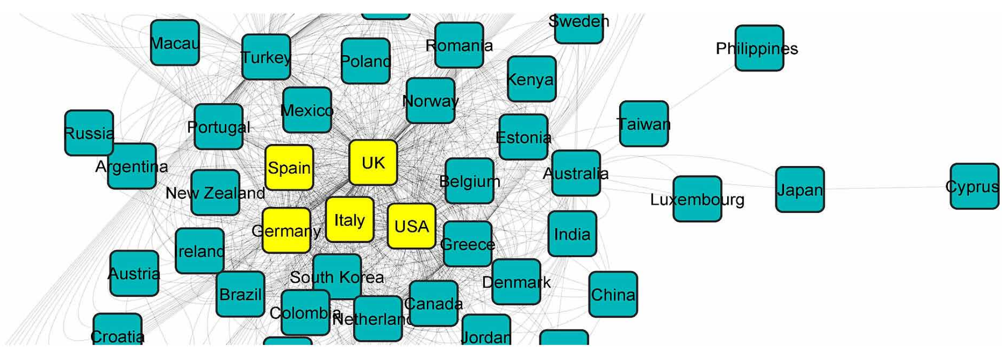
## 5. CONCLUSION

eParticipation is an emerging research field that still lacks consolidated definitions and boundaries. This paper contributes to the establishment of the eParticipation identity, by investigating researchers' collaboration in the field. For this purpose, we employed social network analysis and most specifically co-authorship networks, where nodes correspond to authors and edges correspond to co-authorships. The data used for the construction of the network, were publication records collected from ISI – Web of Knowledge and Scopus.

This work helped us gaining an insightful view and a deeper understanding of the field as it revealed:

- *The development of the research activity on eParticipation over time*. eParticipation is a rather active academic field. We identified and analysed 1340 publications, the vast majority of which are journal articles. eParticipation research flourished after 2005. However, after 2011, the number of published articles slightly decreased.

*Figure 21. The most central countries of the international collaboration network*



- *The structure of the eParticipation research community*. The eParticipation network has 2210 authors and there are 3222 co-authorship links between them. In particular, eParticipation is a rather decentralized network containing a large number of unconnected multi-author components (523) most of which contain a small number of authors as well as a significant number of isolated authors (330) who did not collaborate with anyone else in the network.
- *The degree of collaboration in eParticipation*. eParticipation is characterized by a high degree of collaboration. In average an author in the field has collaborated with 2.566 other authors. Only the 14.93% of the researchers did not collaborated with any other author in the network. Furthermore, the total number of co-authors of eParticipation articles tends to increase; thus there is a tendency for collaboration in eParticipation.
- *The most influential authors*. The core component of the eParticipation network consists of authors with the highest centrality metrics in the whole network. In particular, the core network contains 133 authors and 613 co-authorships, representing the 6.02% of the authors and 19.02% of the collaborations of the whole network. The most influential authors are Macintosh A., Irani Z., Tarabanis K.A. and Tambouris E. as they have the best centrality metrics.
- *The geographic locations where the research took place*. Most researchers in eParticipation come from USA; however, European countries accumulate almost half the researchers (49%) of the eParticipation field. The geographic analysis of eParticipation collaborations revealed that eParticipation is a field that presents high degree of national collaboration.
- *The nature of international collaboration in eParticipation*. We also analysed the network of the international collaborations in eParticipation. The analysis indicate that the majority of countries (71.05%) engaged in eParticipation research have international collaborations and are inter-connected forming a large connected network. Furthermore, UK, USA, Germany, Spain and Italy are the most central countries in eParticipation research.

The major limitation of the study is that the eParticipation literature used in the analysis doesn't include non-English papers, reports or white papers from governments and other organizations. Furthermore, the study assumed that co-authors are also collaborators.

Future work includes the analysis of citation networks of authors, where edges correspond to citations. Furthermore, the inclusion of non-English papers is another route for further research.

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## ENDNOTES

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