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Altmetrics and Visualisation – The Complementary Tools for Analysing Scientific Collaboration and Behaviour on ResearchGate[4]

Abstract

Altmetrics, as a new scientometric measure, shows the scholarly impact of a scientist and her/his social activity on social networking platforms. We analysed communication on ResearchGate within the group formed by Nicolaus Copernicus University different domains researchers. They share interest in information visualisation and form local collaboration team. We considered two compositions of research sample: the original team and the nearest collaborators. The common attributes of RG users such as co-authorship, skills set, topics, and ascribed domains were analysed. Based on these units, we carry out the sociographs to reveal social structure dynamics. Domain analysis was performed by the use of the PCA – the method which is able to extract the most essential factors from the variables set. The results indicate a good coincidence for these two approaches: collaboration between researchers and their skills development can significantly change their major. We strived to show that RG is a space of interdisciplinary train-

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ing in building and identifying their own field research based on full text. Thus RG is a proper tool for cross-disciplinary qualitative analysis. Altmetrics and visualisation are mutually substituted and complemented devices, perceived as new tools for team science study. This requires, nevertheless, not only the use of appropriate tools, but also collecting a large dataset on global scientific activity within multidisciplinary groups.

Keywords:
altmetrics, sociometrics, social networks analysis, science visualisation, PCA

1. INTRODUCTION

Qualitative and quantitative evaluation of scientific research has always been the central interest of scientometricians. Formerly, when researchers published papers and participated in several conferences per year, science analysis concerned individual activity of people and relied on comparison between featured indicators.

Biblio- or scientometricians could look through single papers and make quick superficial evaluations. They could consult with one another in case the subject was highly hermetic. Scientific knowledge was not so mutable and dynamic like today, and researchers could stay up-to-date with developments in their own domain. But nowadays, academics 'product' incomparably more publications. Moreover, they join interdisciplinary groups based on their specialization, experience and interests. There are so many conferences in the scientific world that even a researcher's absence does not mean he or she cannot participated virtually in an event. One should also mention that strict scientific discussions are provided by thematic forums and blogs, as well as academic professional web services.

Thus, scientists create an enormous amount of information. For layman it resembles a kind of noise[5]. But this specified information stream has no random features, which are possible to prove by observing the distribution of suitable variables. The authors measured selected parameters which are no Gaussian shape, but undoubtedly a massive data stream between scientists presents exploratory and descriptive potential. Collaboration of scientific networks contain new ideas, inventions, and even discoveries. How can we filter the most relevant to research topic information from a varied data stream?

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[5] J. Gleick, *A History, A Theory, A Flood*, London: Vintage 2012, pp. 189–217.

Scientometricians, in this regard, meet the problem similar to that in which there is a hospital emergency physician investigating the patient just after accident: he need to rush. Like today, scientometric evaluation must be quite fast: every day thousands of new papers emerges (1 mln. publications per year[6]), thousands of items of academic writing. The difference is that the doctor must diagnose within a few minutes, scientometrician have a "little" more time. From a large dataset concerning clinical symptoms, interviews with the patient, his medical history, the doctor has to extract the most important features in order to make a quick diagnosis and propose specialized treatment. A mistake at this stage is usually tragic.

Scientometricians operate in a similar manner, although the effects of their activity are not so critical. They have to retrieve relevant information from a large collection, usually accessible in digital form. After that, researchers need to parametrize the given data and using an appropriate algorithm make a detailed analysis.

This situation is similar to the "cocktail party" effect described by the psychologist Colin Cherry in 1953, where the scientist wondered how our brain is capable to extract the voice of a friend from random noise generated in a closed room by the event's participants. The parents looking for their child in a crowded playground are able to distinguish his voice despite the huge noise caused by a group of children. Therefore we meet the problem of "isolation" and, next, identification and characterization in particular parametric. To solve this problem we can use the method defined as the *Principal Component Analysis*[7]. This technique allows us to identify the most important components in a compiled information stream. The social academic portal ResearchGate has been selected as the source of the aggregated scientific activity.

Before we apply this tool, we need to study the cooperation between distinct researchers, including their individual features, domains, fields of interests and finally, to draw the network of social ties (sociograph). By the use of visualisation methods it is possible to reveal collaboration groups of scientists, their mutual connections, and indicate the centres of special activity. For analysts, the places of activity with significant effects may be of particular interest. The theory of nonlinear systems determines such places in the structure of complex systems as the bifurcation points. There can be expected scientific discoveries and important publications, which may have an impact on the current research paradigm.

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[6] K. Boerner, *Atlas of Science*, Cambridge: MIT press 2010, pp. 7–18.

[7] Principal Component Analysis is a very useful method to analyse numerical data structured in many observations and variables. It is usually used to bring out strong patterns in a large dataset.

We strive to show that combination of altmetrics and visualisation can be useful tool for collaboration analysis within scientific communities. As research material we picked out local group of scientists – VISteam. They all use social networking platform – ResearchGate; so the next section particularly presents the features and advantages of this service, as well as specifies the measures of network communication. Methodology description includes characteristics of dataset, applied tools and also statistical test of normality as a preliminary step for further research. To emphasize the potential of current approach, we presented both possibilities: social and domain structure analysis of measured group.

2. ALTMETRICS

2.1. THE TOOLS

The scholars who lack the time to read all relevant papers received alternative tools – altmetrics, the term proposed in 2010 in a series of papers[8]. Altmetrics rises from webometrics and offers an alternative to traditional means of measuring scholarly impact like citations and impact factors. Alt indicators based on social media platforms and tools show how scholars populate online social environments, and interact with scholarly products[9]. It measure the frequency of browsing and downloading the texts, discussions topics and associated comments, messages and tweets. Besides scholars, this tool can be also used for non-experts passing judgements on researchers for appointment, promotion, funding or other purposes[10].

Although peer review is at the heart of many academic evaluations, the basic quantitative measures are based upon citations. Scholarly impact indicated by altmetrics is observed more quickly and more widely than scholarly citation. It supplies the usage statistics on the academic web service. Due to altmetrics, therefore we can study:

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[8] J. Priem, *Tweet by Jason Priem on September 28, 2010*, Blog, https://twitter.com/#!/jasonpriem/status/25844968813, [Access date: 01.02.2015]; J. Priem and K. Costello, *How and Why Scholars Cite on Twitter*. In Proceedings of the 73rd Annual Meeting of the American Society for Information Science and Technology 2010, Pittsburgh, PA, USA.

[9] S. Haustein et al., *Coverage and Adoption of Altmetrics Sources in the Bibliometric Community*, "Scientometrics" 2014, Vol.101(2), pp. 1145–1163.

[10] P. Sud and M.Thelwall, *Evaluating Altmetrics*, "Scientometrics" 2014, Vol. 98(2), pp. 1131–1143.

- scholarly interest in articles through readership statistics (view, download, citations),
- the popularity of research topics (view, downloads),
- the influence of researcher and familiarity with him or her (view profile),
- stability or variability of research interest (by dynamics of indexes),
- the scope of researchers community (co-authorship, co-citations, discussions),
- the spread of researcher's interests and skills (view profile, personal virtual library, discussion topics),
- teaching specialization and scope (educational resources such as presentations),
- subject profile of researcher (favourite/featured publications, personal library),
- hobbies of researcher and personal websites.

1.2. ALTMETRICS THROUGH SOCIAL NETWORKING

Digital libraries, repositories as well as academic web services are flexible in domain identification of a scientist's research because they are rather independent on subject classification, as in the case of most journals. The researchers can select more than one discipline in their profile. Moreover, some included mechanisms (ResearchGate) extend the specialization scope by analysing metadata and text in profile. Inter- and multidisciplinary researchers have much more possibilities to describe their full academic profile regardless of standardized structure of science. Professional web services such as Academia.edu, ResearchGate, and Mendeley address to scientists and academics of all disciplines. We will focus on the interface and functions of professional service which is commonly recognized by leading scientific centres in Poland – ResearchGate[11]. Another popular social networking platform – Academia.edu – is dedicated beyond scientists, to the teachers, trainers, educators, and persons working outside of high schools and national institutes' structures. The main research question concerns how accurately we can identify the research field and specialization of a person through scientific portals. Namely, how can we improve this identification and our own comprehension of cross-domain

[11] B. Stachowiak, *The Presence of Polish Academics on Social Networking Websites for Academics. Using the Example of Employees of Nicolaus Copernicus University*, "Universal Journal of Educational Research" 2014, Vol. 2(1), pp. 64–68.

research? And how can we capture quick changes of major, interests? How can we find scholars with a similar research area?

What specifies Mendeley – the web service allowing researchers to organize and collaborate – is a reference management tool combined with an online social network[12]. In addition to biographical information, Mendeley also provides readership statistics over time by showing number of page views, readers and downloads by websites users. Categorization of readers according to their domains (Mendeley includes 25 basic research fields and disciplines: from *Art* and *Humanity* through *Science* and *Social Sciences* to *Sport* and *Design*) can be very useful information for all who provide multidisciplinary research and want to expand their own collaboration network on distinct areas[13].

The main professional network for scientists and researchers – ResearchGate (RG) – combines social networking with data sharing, various collaborative applications and an easily searchable, comprehensive publications database[14]. Each researcher can control their own social by multivariable RG score – the index, which is based on altmetrics. It includes the number of citations, uploaded publications, view, questions and answers, and naturally acclaims from another users. According to the authors' observations, particularly the last week activity decides about the significant RG gain. Many academics criticize that the point that RG score is like researcher's "usefulness for identifying the value of new members to connect"[15]. Authors' experience, however, lets to confirm the principle of RG score increasing according to the interaction with social network.

ResearchGate's setup process involves identifying researchers' scientific skills and loading papers using automatic or manual functions. RG skills are the basic object of current analysis and therefore we need to pay more attention to this topic. Skills describe the knowledge, methods, and techniques the researchers use. This subjective organisation is used by the recommendation system which helps find collaborators – specialists in specific fields. It is worth to emphasize that the ranking

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12 E. Mohammadi and M. Thealwal, *Mendeley Readership Altmetrics for the Social Sciences and Humanities: Research Evaluation and Knowledge Flows*, "Journal of the Association for Information Science and Technology" 2014, Vol. 65(8).

13 E. Kulczycki, *Transformation of Science Communication in the Age of Social Media*, "Teorie vědy/Theory of Science" 2013,Vol. 35(1), pp. 3–28.

14 K. Rother, *10 Questions to ResearchGate*, 2014, Blog [on-line], http://www.academis.sites.djangoeurope.com/blog/posts/10-questions-researchgate/, [Access date: 01.02.2015].

15 E. Kintisch, *Is ResearchGate Facebook for Science?*, http://sciencecareers.sciencemag.org/career_magazine/previous_issues/articles/2014_08_25/caredit.a1400214, [Access date: 01.02.2015].

of skills strongly depends on the users' endorsements. Skills organisations create some kind of descriptive language in the scientists' community. RG system uses another user's categorisation mechanism: periodically suggests the skills, resulting from papers' text analysis as well as foreign skills set and ties with other users.

3. METHODOLOGY

In the last two decades visualisation became the basic mean in scientometrics study. Mapping (or network visualisation) applies the mutual relations between measured objects. For example, if two publications have the same items in the reference list, the more related they are. Co-citation analysis today is a dominant research field in bibliometrics. If the documents have common authors, the method is called co-author's analysis, in the case of common keywords – co-terms analysis[16]. Mapping principle is based on counting common features of analysis' objects that can be scholar articles and journals, patents, people of science. In the current study of local scientific community we used first of all common RG skills of team's members. According to our assumption, published on RG skills won't necessarily reflect "official" domain of specialization of researchers. Current work presents multi-perspective analysis of common skills of selected participants. It is largely based on visualisation patterns.

2.1. TEAM'S CHARACTERISTICS

In 2014, scientists from Toruń formed an interdisciplinary team – VISteam – aiming to disseminate the practical knowledge about visualisation. Information visualisation, its techniques, application in a broad range of scientific disciplines such us information science, computer science and social science, are the main research areas of VISteam members. They created a website www.wizualizacjainformacji.pl dedicated to the information visualisation technology and the world's community.

Such big differentiation gives the possibility of greater insight into research problems, the broader implementation of scientific tools derived from seemingly distant disciplines. VISteam website[17] introduces visually to the researcher's do-

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[16] V. Osińska, *Documents Visualisation and Retrieval*. Warszawa: SBP 2010, pp. 44–66 [in polish].

[17] http://wizualizacjainformacji.pl/onas.php.

main structure by using diagrams and infographics. Information scientists are the biggest subgroup and the most distributed across subdisciplines (Figure 1). Library and Information Science is the leading specialization of four LIS graduates at the Nicolaus Copernicus University (NCU). But only three people point out *Library* as the basic skill, wherein one specializes in the history of book and publishing, and one – in social sciences issues. Two information scientists have computer science qualifications and appropriate skills towards text and data mining, large data visualisation and artificial intelligence.

Cognitive scientists represent different specialties in psychology, neurophysiology, philosophy, and many others – as a base for interdisciplinary integration within brain sciences. The scope of the research field covers an area of neuroscience to social sciences cultivated in theoretical and experimental dimension in the Neurocognitive Laboratory in Interdisciplinary Centre for Modern Technologies (CMIT)[18]. Cognitive scientists represent even smaller research group pursuing their goals at the same time in different directions and research specializations. Therefore, they have natural predispositions to create large and diverse interfaces between different disciplines.

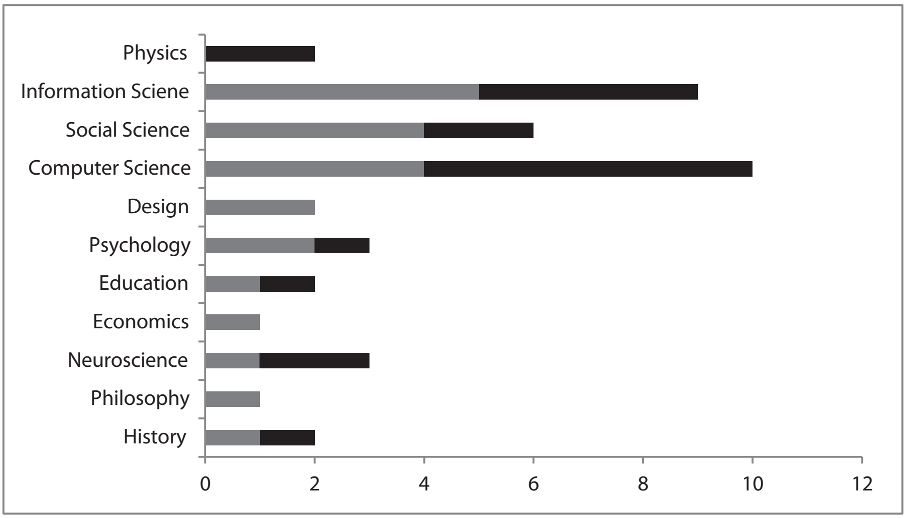


Figure 1. Domains occupation by VISteam members (lighter) and their nearest collaborators (darker)

[18] Centre website is available at: http://www.icnt.umk.pl/o_projekcie/?lang=EN.

Computer science currently plays larger role in research than just the use of ICT tools. Algorithms must be created from outline, based on the latest changes in the structure of scientific research. Therefore, it is necessary to develop both close cooperation and transfer of knowledge from the areas completely different than original foundations of Computer Science. We decided to extend the number of people to 23 persons to avoid unrepresentativity of a small sample. The records were selected from the nearest collaboration network of VISteam members. All data about co-authorship, collaboration and similar skills have been gathered manually from researchers' RG profiles. Thus each subgroup must reveal the distinct substructure. Moreover, they are different in terms of population and we need to consider ratio. There are three main fields the proportions of added persons have been kept: 31/31/38 for cognitive science, computer science and LIS, accordingly. Figure 1 presents the growth of the dataset across domains.

2.2. REPRESENTATIVITY OF A SAMPLE SET

Firstly we analysed RG users' behaviour. We strove for the comparisons of the frequency of viewers and download indicators. It is natural that not all view clicks result in a download. If the scientist finds an abstract or a title of his interest, he or she possibly starts downloading the paper. On the other hand, an author does not depose all publications as full texts, but only parts of them. What is the fraction of full texts to all articles on a researcher's profile? What is the fraction of downloads to view number and does it depend on full texts' fraction? These questions became the main ones in preliminary characterization of samples.

Normal distribution is the basic requirement in statistical analysis. This indicates the data describing the nature instead of some artificial entity. Shapiro-Wilk normality tests show the Gaussian distributions for both the full text fraction (p=0.087) and download fraction (p=0.197). Skewness close to 0 and kurtosis in the range [-1; 1] are also acceptable for normal distribution. We visually estimate the normality of these variables from the quality of normal distribution plots in Figure 2. Although the dataset is small (N=23), the distribution of variables is normal and our sample is representative. On the contrary, RG score is not normal (Shapiro-Wilk's test p<0.000), which can be explained by an intricate algorithm of computing. Therefore, further analysis will focus on careful examination of the bond between members of the group. If the browsing behaviour of users and the full text uploading strategy have normal distribution (that is proved by tests), the next question will concern their correlation. Spearman's test shows these two variables are not correlated (*p=0.133*).

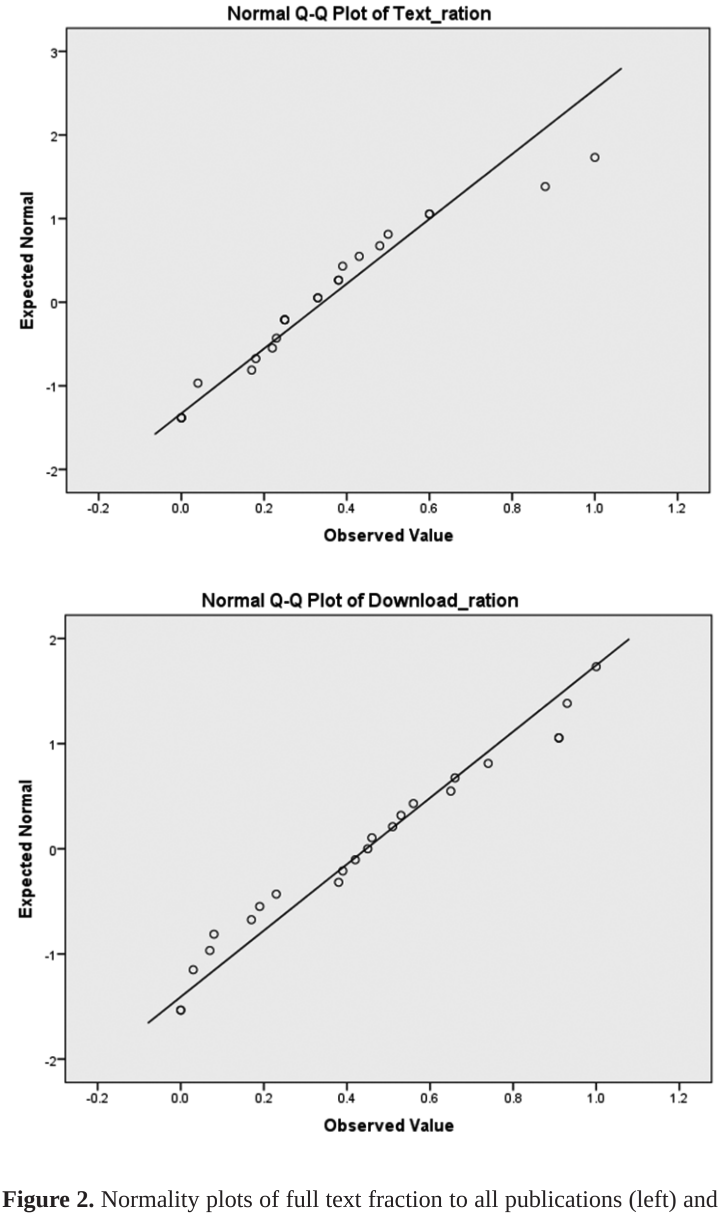


Figure 2. Normality plots of full text fraction to all publications (left) and downloads fraction to all view (right)

Therefore, authors share full text of their publication on the basis of random, particular motivations. On the other hand, there are users exploring and interacting with the RG website. There is no observed specific behaviour pattern in decision-making process of downloading publications. We did not find dependency between full texts fraction and download quantity.

2.3. METRICS AND TOOLS

As social analysis units we selected such indicators as common publications and common or semantically very close (like *EEG* and *Brain*, *Library* and *Digital Library*) skills. In domain analysis we registered the useful data about domain belongingness. The scientists at RG themselves define major and minor(s) as primary and secondary specializations in both research and teaching. The description mechanisms they used are: "domains" and "topics". For example, one of them (VOS) chose "Computer Science", "Social Science", and "Design". Finally, we defined the Collaboration Proximity (CP) as:

$$CP = \sum_i a_i * CA + \sum_j a_j * CS$$

where *ai*, *aj* are constants depending on the experimental coefficient of normal distribution, *CA* – is quantity of co-authorship, and *CS* is co-skills quantity.

This way we constructed a symmetric matrix, because the relation is reciprocal. The dimension of matrix is equal to 23 – the number of members. For network visualisation exploration platform – Gephi – has been used. Two graphs from the original and extended groups were compared and analysed. In both cases we have applied the same layout – *Force Atlas 2*, based on force directed algorithm[19]. Statistical tests were performed in SPSS application.

[19] Force directed algorithm – one of network algorithms giving the best understanding of structure. From Wikipedia: It is a class of algorithms "for drawing graphs in an aesthetically pleasing way. Their purpose is to position the nodes of a graph in two-dimensional or three-dimensional space so that all the edges are of more or less equal length and there are as few crossing edges as possible […]". Available at the Web: http://en.wikipedia.org/wiki/Force-directed_graph_drawing [Access date: 01.02.2015].

4. VISUAL ANALYSIS

4.1. SOCIOGRAPHS ANALYSIS

The major task of sociographics analysis is recognizing the groups and defining the relationship between them. In Figure 3 we present scientific collaboration within the VISteam and its extended version. The members are signed by three characters code, the rest – one letter. The clusters which have appeared through mapping are indicated by different colours. From the original group it is possible to identify the three main specializations: library science (blue), information science (green), and cognitive science (pink). Our familiarity of examined persons validates this conclusion. WAC and MKO nodes have a strong tie: they work together in editorial board. VOS is an initiator of the visualisation framework and

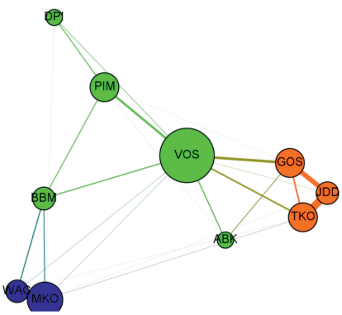
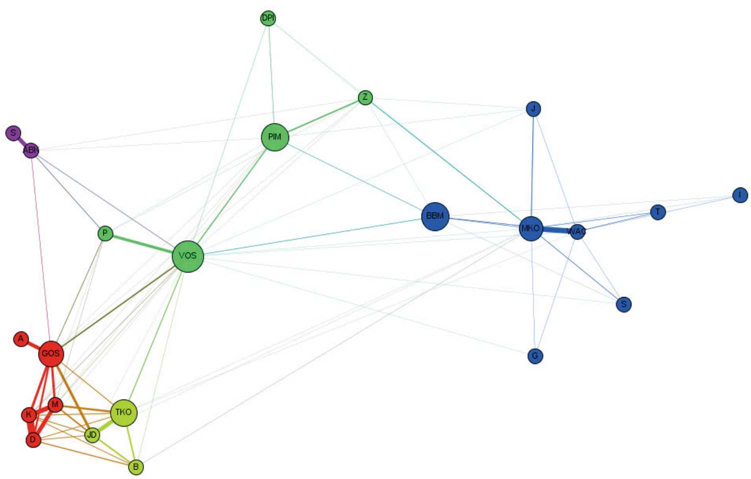


Figure 3. The sociagraphs of VISteam (left) and an extended group (right)



therefore an appropriate node is placed in the centre of the network and has the highest degree, i.e. the total number of in- and out- connections. This measure shows the importance of persons in group communication.

VISteam is a kernel of the next, extended group. The structure grows up from the edges. By comparing palettes we can see that two additional domains have appeared. Computer scientists are identified by their own cluster (red), which is visible in the common structure. Another speciality, education (violet), consists of two members. Three researchers change the previously defined RG discipline: GOS moved from cognitive to computer science, ABK left information science for education, BBM "became" LIS expert instead of informationology. Information science is currently assigned to both main domains: humanity and social sciences. Because LIS is a user-centred discipline, it shares with social science one blue cluster. Cognitive groups became more explicit, where TKO took control. Due to adding new collaborators, some researchers change the primary discipline. The structure is quite sensible for a change of skills set. The reason is a high weight of co-authorship that is exposed in an established metrics.

4.2. DOMAIN ANALYSIS

As presented in the introduction, the PCA is a useful statistical technique for the reduction dimension of data. Using PCA, we can see and analyse correlations between the variables (i.e. domains) as well as extract important factors influencing the dataset[20]. Figure 4 presents the so called correlation circles for two groups of people, which show the projection of the initial variables (domains) in the factors space.

This is defined by the coordinates F1 and F2 abstractive space of the most essential variables, which cannot be related explicitly to the original variables because they aim qualitative analysis instead of quantitative. It means the purpose of such transformation is to find correlations and associations between the groups. Relations between people working in different fields form spatial configurations of these domains according to principle: the closer they are placed to each other, the bigger significant correlation between them. Visualisation shows also how we can be explicit in interpretation. Most domains are those that have the greatest distance from the inside – the length of "tendrils". If the variables are far from the

[20] H. Abdi and L.J. Williams, *Principal component analysis*, "Wiley Interdisciplinary Reviews: Computational Statistics" 2010, Vol. 2(4), pp. 433–459.

center, it means they can be related to the projected ones (factors); if close – they are dispersed over factors and interpretation is ambiguous.

Thus we can observe how discipline correlation changes as the intellectual and social potential of the community increases. VISteam scientific structure is more certain (longer vectors), where 3 main groups can be distinguished. First (social science, design and history – left down quarter) is associated with blue cluster on sociograph (Figure 3, left), the second in the right down quarter (neuroscience, psychology, philosophy) is indicated by the pink cluster and the third consist of education, computer and information sciences. After joining of collaborators, the first two groups kept their structure, although the third had scattered. Education vector "jumped" to humanity group (left down quarter). Such computer science skills as machine learning, classification algorithms, programming, artificial intelligence of new members – red cluster (Figure 3, right) – caused a blur of the third cluster. It means computer science has the biggest influence on fields which widely apply computing tools and strongly depend on them: information systems, economics.

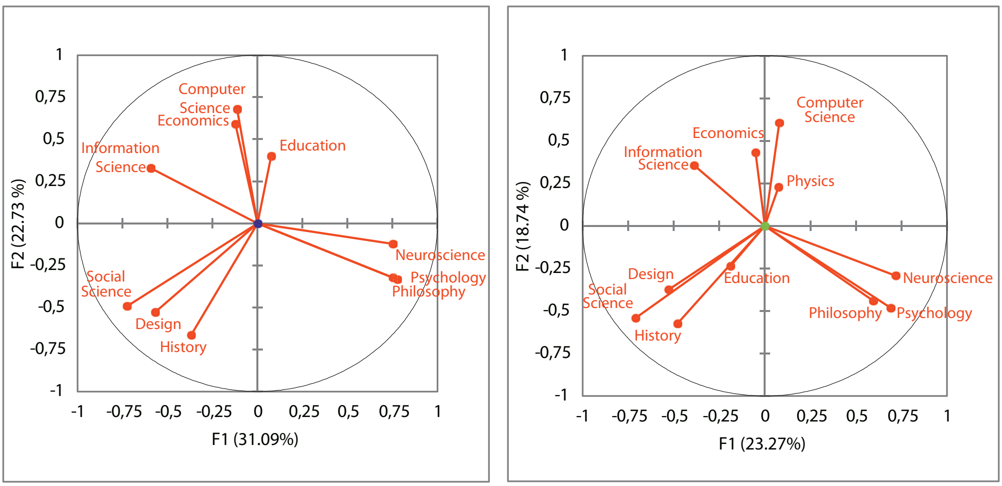


Figure 4. PCA plots of domains in VISteam (left) and extended group (right)

The next diagram on Figure 5 shows observation space, i.e. the adjacency of people, according to their specialities. Social structure is mapped to the space of domains, presented on right circle (Figure 4). VISteam members are signed by red circles. A large group of people is concentrated around computer science. Three scientists are placed in the quarter of the cluster of neurology, psychology, and philosophy. TKO, WAC, PMI are the ones for whom it is easy to define dominant speciality (far from the center). VOS specializes in the area between computer science, social science, and design.

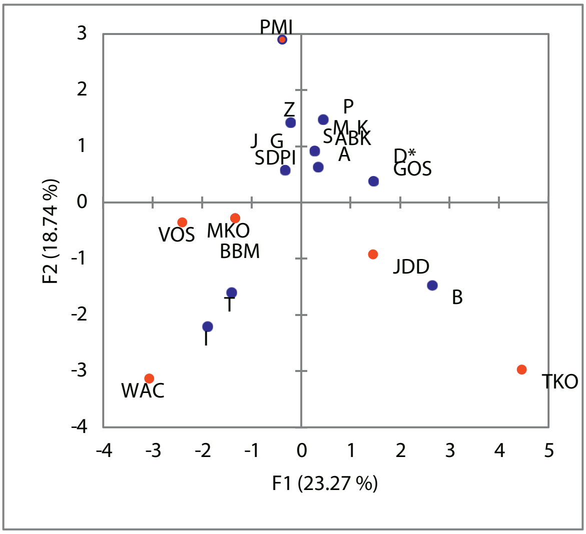


Figure 5. PCA plots of observations (i.e. members) in extended group

Such visual representation allows us to identify scientists who are characterized by dynamics and the highest influence of research development. At the same time, we can observe a detailed, exotic landscape of all disciplines represented by these group of researchers.

5. SUMMARY

The role of social networking platform such as ResearchGate in the planning and implementation of interdisciplinary research cannot be overestimated. Scientists find there the opportunity to exhibit their interests in the layout of specialization's framework and therefore attract colleagues with a similar profile. By participating in professional web services, academics can monitor co-authors' and collaborators' activity, organize research based on and improved by their own experience. Thus, RG allows for an interdisciplinary training. Social web services provide an alternative to scientometrics tools, which allow researchers to control their scholar impact as well as analyse the popularity of their articles. Beside the importance of altmetrics, the authors emphasise that visualisation can be a complementary tool in net data analysis. By implication, network visualisation, as the most frequent method for studying ties between people within the community, can be also a tool for analysing professional skills and topics correlation.

The results visually illustrate that collaboration between researchers and their skills' development can significantly change their leading specialities. Scientific communication and self-education will not only expand scientists' cross-disciplinary knowledge, but also give them an opportunity to become specialist in other fields. The authors present also the metrics based on new analysis units such as co-skills and co-classes instead of co-classes, co-authors. If we analyse interdisciplinarity by means of altmetrics, the PCA is a proper approach – the method which is able to extract the most essential factors form the variety ones. The classical organisation of scientific activity cannot complementary describe multi- and interdisciplinarity because of rigid disciplines sets narrowing down the qualifications of scholars. Under quickly changing scientists' interests, an analysis by this organisation is difficult if not impossible.

We need to attempt to create a new, global system of academic evaluation based on both large dataset analysis and visual insight on interconnections in new parametric spaces. Social networking portals like ResearchGate became an object of study within science and of team science. However, it should be remembered, results obtained by the new tools must remain coherent with classical indicators. To achieve this, the research must be carried out within interdisciplinary groups for statistically significant results. This requires nevertheless not only the use of appropriate tools, but also collecting large dataset about global scientific activity within multidisciplinary groups.

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