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Is the expertise of evaluation panels congruent with the research interests of the research groups: A quantitative approach based on barycenters

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ABSTRACT

Discipline-specific research evaluation exercises are typically carried out by panels of peers, known as expert panels. To the best of our knowledge, no methods are available to measure overlap in expertise between an expert panel and the units under evaluation. This paper explores bibliometric approaches to determine this overlap, using two research evaluations of the departments of Chemistry (2009) and Physics (2010) of the University of Antwerp as a test case. We explore the usefulness of overlay mapping on a global map of science (with Web of Science subject categories) to gauge overlap of expertise and introduce a set of methods to determine an entity's barycenter according to its publication output. Barycenters can be calculated starting from a similarity matrix of subject categories (N dimensions) or from a visualization thereof (2 dimensions). We compare the results of the N-dimensional method with those of two 2-dimensional ones (Kamada–Kawai maps and VOS maps) and find that they yield very similar results. The distance between barycenters is used as an indicator of expertise overlap. The results reveal that there is some discrepancy between the panel's and the groups' publications in both the Chemistry and the Physics departments. The panels were not as diverse as the groups that were assessed. The match between the Chemistry panel and the Department was better than that between the Physics panel and the Department.

1. Introduction

Discipline-specific research evaluations carried out by panels of peers are a common practice at many universities. The focus of these evaluations is research, in particular research quality. Expert panel review is considered the standard for determining research quality of individuals and groups (Nedeva, Georghiou, Loveridge, & Cameron, 1996; Rons, De Bruyn, & Cornelis, 2008; Butler & McAllister, 2011; Lawrenz, Thao, & Johnson, 2012), but also, for instance, for research proposals submitted to research funding organizations (Li & Agha, 2015). In 2007, the University of Antwerp, Belgium, decided to

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introduce evaluative site visits by expert panels, during which the panel meets the spokesperson of each research group and other relevant stakeholders, and panel members are given the opportunity to ask additional questions or request clarification of specific points described in the self-evaluation report they received in advance. The site visits thus guarantee interaction and involvement between experts and research groups.

Using data collected in the framework of two completed research evaluations, this paper studies the expertise overlap between expert panels and the research groups involved in the evaluation. To the best of our knowledge, no methods are available to measure and quantify overlap in expertise between panels and units under assessment. Yet, a sufficiently high degree of congruence between the expertise of the panel members charged with research assessment and the research of the units is a prerequisite for a sound, reliable assessment (Engels, Goos, Dexters, & Spruyt, 2013). Only panel members who are credible experts in the field will be able to provide valuable, relevant recommendations and suggestions that should lead to improved research quality. In this respect, Langfeldt (2004) explored expert panel evaluation and decision-making processes, and concluded that overlap of expertise between experts is highly desirable in order to foster cooperation among panel members. Moreover, each group expects its research interests to be well covered by the expertise of at least one panel member.

Research groups at the University of Antwerp (Belgium) consist of professors (of all ranks), research and teaching assistants, and researchers (PhD students and postdocs). A research group consists either of one professor assisted by junior and/or senior researchers, or of a group of professors and a number of researchers linked to them. The overall annual research output of the University of Antwerp comprises over 2000 peer-reviewed publications, the large majority of which are included in the Web of Science (Engels et al., 2013).

Research evaluations carried out at the University of Antwerp are organized by its Department of Research Affairs. At the start of a research evaluation, a department – typically encompassing several research groups – is invited to suggest potential panel chairs in addition to those suggested by the Department of Research Affairs. Preferably, chairs are appointed as full professor, have an excellent publication record, have experience in research evaluations, are editors or board members of important journals, and possess academic management experience. The Department of Research Affairs verifies whether proposed panel chairs and members have no prior involvement (i.e. no prior joint affiliations, no co-publications, no common projects) with the assessed research groups, and further checks if they are scholars with a prominent publication record in recent years, a proven track record of training young researchers, and sufficient experience in research policy, preferably in academic leadership positions. Furthermore, proposed panel chairs and members are preferably not affiliated with any Flemish institution of higher education and have no formal links to the University of Antwerp. The department that is being evaluated is also allowed to suggest potential panel members, but it should be noted that it is eventually the chair's prerogative to decide on the final composition of the panel.

The combined expertise of all panel members is to cover all subdomains in the discipline that is being evaluated and the panel is preferably balanced in terms of gender and nationality. When a sufficient number of professors have agreed to be on the panel, the university's research council ratifies the panel composition. Furthermore, all research groups belonging to a specific department (e.g., Physics) are to be evaluated by the same panel and the language of communication is English. Following the Dutch Standard Evaluation Protocol (SEP: VSNU, 2003, 2009), the peer panels assess the quality, the productivity, the relevance and the viability of each research group.

An expert panel, typically consists of independent specialists, and is multidisciplinary and/or interdisciplinary in its composition; each of the members are recognized experts in at least one of the fields addressed by the department under evaluation. Surprisingly, the degree to which the expertise of the panel (members) overlaps with the expertise of the research groups has not been quantified to date. The goal of this paper is therefore to present a bibliometric methodology to assess the congruence of panel expertise and research interests in the units under assessment. As such, we present a bibliometric analysis of the overlap of expertise between research groups in the Departments of Chemistry and Physics and the respective expert panels based on two research evaluations carried out at the University of Antwerp. We focus on the following research questions:

(i) How can we visualize the expertise of two entities (e.g., a research group and a panel) using publication data?
(ii) How can we quantify the overlap of expertise between two entities (e.g., a research group and a panel) using publication data?

We address these questions in the context of expert panel reviews. Specifically, we focus on comparing:

- panel and individual research group;
- panel member and individual research group (even if the panel does not cover a group's expertise well, it may suffice that one panel member does); and
- panel and all reviewed research groups (e.g., all physics research groups).

This article is an improved and extended version of (Rahman, Guns, Rousseau, & Engels, 2014) presented at the 2014 STI-ENID conference in Leiden, the Netherlands.

Table 1
Publication profile of the Chemistry and Physics research groups.

Group code	Number of publications	Number of journals	Number of WoS categories
Chemistry research groups (2001–2008)			
CHEM-A	129	47	27
CHEM-B	65	24	17
CHEM-C	156	52	26
CHEM-D	32	17	13
CHEM-E	70	39	23
CHEM-F	21	17	8
CHEM-G	161	47	42
CHEM-H	62	33	28
CHEM-I	51	24	19
CHEM-J	27	11	15
CHEM-K	97	66	48
CHEM-L	92	42	24
Total	920	300	94
Physics research groups (2002–2009)			
PHYS-A	125	53	44
PHYS-B	486	66	25
PHYS-C	525	147	46
PHYS-D	269	17	7
PHYS-E	159	55	28
PHYS-F	42	23	13
PHYS-G	43	26	12
PHYS-H	132	31	12
PHYS-I	115	63	49
Total	1732	353	108

2. Data

The data in this paper stem from the 2009 assessment of the twelve research groups (referred to as CHEM-A, CHEM-B and so on) belonging to the Department of Chemistry, and the 2010 assessment of the nine research groups (referred to as PHYS-A, PHYS-B and so on) belonging to the Department of Physics, University of Antwerp. The reference period encompasses eight years preceding the evaluation. In principle all articles, letters, notes, proceedings papers, and reviews by the research groups published during the reference period and included in the Science Citation Index Expanded (SCIE), the Social Sciences Citation Index (SSCI) and the Arts and Humanities Citation Index (AHCI) of the Web of Science (WoS) were considered in the evaluation. In practice only SCIE indexed papers occurred for these particular groups.

The Chemistry and Physics panels were composed of seven and six members (both including the chair), respectively. All the publications of the individual panel members up to the year of assessment were taken into account. The combined publication output of the Physics panel members is 1104 publications, none of which are co-authored publications between panel members. The number of publications per panel member ranges from 117 to 282. In total, these publications appeared in 204 different journals. The Chemistry panel members' publication output amounts to 2150 publications in 248 different journals. The number of publications per panel member ranges from 113 to 694. Panel members one and seven have two joint publications.

Table 1 lists the number of publications of the research groups during the eight years preceding their evaluation. The Chemistry research groups published 920 publications in 300 journals, including 43 joint publications between Chemistry groups, while the Physics research groups generated 1732 publications in 353 journals, with 164 publications co-authored by members of two or more Physics research groups.

3. Methods

3.1. Subject category similarity matrix and maps

Each journal in Thomson Reuters' Web of Science (WoS) is assigned to one or more WoS subject categories (SCs). Our method is based on the assumption that entities with more publications in the same or similar SCs have greater expertise overlap. While WoS categories have been criticized for being crude (Leydesdorff & Rafols, 2009; Leydesdorff & Bornmann, 2015) they are considered sufficient for evaluation of a given discipline (van Leeuwen & Calero-Medina, 2012), and are widely accepted and used by bibliometric practitioners. Moreover, the categories cover all disciplines (Rehn, Kronman, Gornitzki, Larsson, & Wadskog, 2014; Leydesdorff & Bornmann, 2015).

We determine the correlation between the publication output of two entities using Spearman's rank correlation coefficient for the numbers of publications per SC. To calculate Spearman's rank correlation, the value zero was kept on the corresponding categories in which either the panel or the groups had no publications (but not both). We argue that such correlations provide a first impression yet are insufficient, since they do not take into account the relatedness of SCs. One

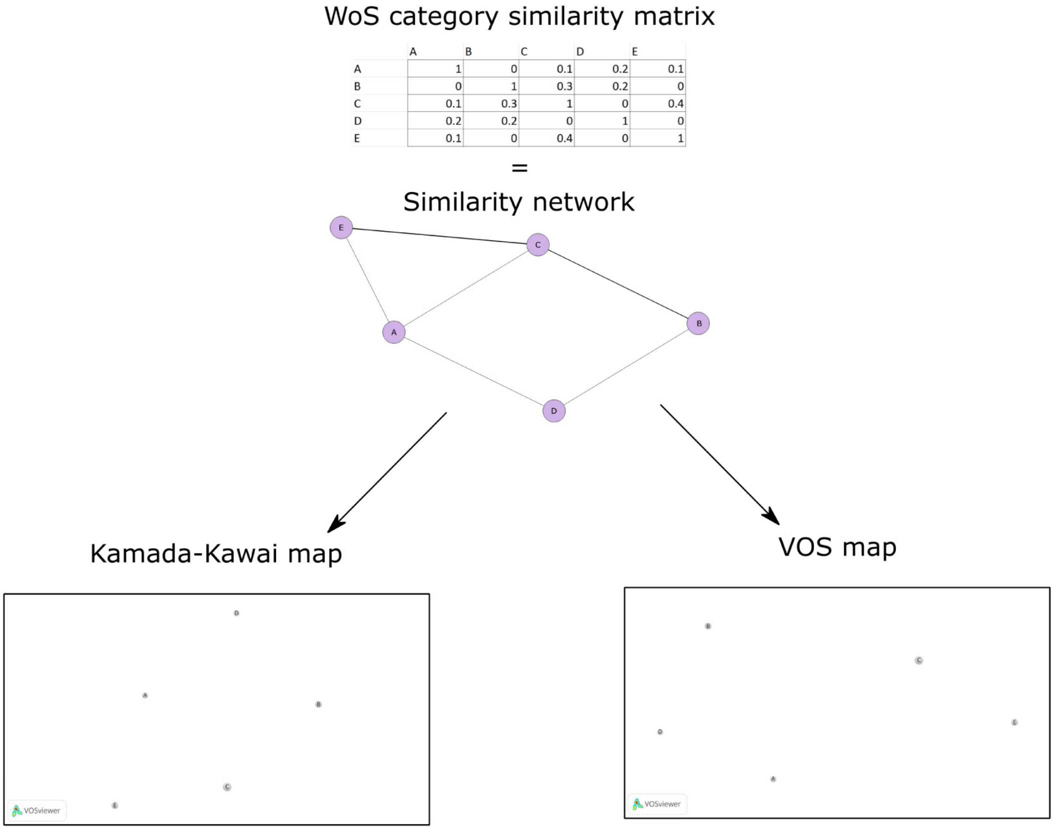

Fig. 1. Overview of similarity matrix and maps.

can intuitively understand that some categories are much more closely related than others. If a panel member has many publications in a closely related SC, she may still have relevant expertise, even if she has no publications in the exact same category as the group to be evaluated.

To operationalize the relatedness or similarity of SCs, we draw upon data made available by Rafols, Porter, and Leydesdorff (2010) at http://www.leydesdorff.net/overlaytoolkit/map10.paj. These authors created a matrix of citing to cited SCs based on the Science Citation Index (SCI) and Social Sciences Citation Index (SSCI), which was subsequently normalized in the citing direction. Only cosine values >0.15 were retained. The result is a symmetric $N \times N$ similarity matrix (here, $N = 224$). If we interpret it as an adjacency matrix, we see that it is equivalent to a weighted network, in which similar categories are linked (the higher the link weight, the stronger the similarity). The two most similar SCs are *Nanoscience & Nanotechnology* and *Materials Science*, *Multidisciplinary*, which have a cosine similarity of 0.978.

The information in the similarity matrix can be visualized. The subfield of bibliometric mapping is dedicated to the visualization, clustering and interpretation of similarity matrices or networks like the one we use. Many different algorithms or layout techniques have been developed for this purpose. In this paper, we use two:

- Kamada and Kawai (1989) introduced a spring-based layout algorithm for networks, which is implemented in, among others, Pajek (De Nooy, Mrvar, & Batagelj, 2012). Kamada–Kawai is the algorithm used by (Rafols et al., 2010).
- VOS (van Eck & Waltman, 2007) stands for ‘visualization of similarities’ and is a variant of multidimensional scaling (Borg & Groenen, 2005; Van Eck, Waltman, Dekker, & van den Berg, 2010). It is implemented in VOSviewer and in recent versions of Pajek.

Fig. 1 provides an overview of the relations between similarity matrix, network and the two maps. Since the source data include all research fields included in the SCI and SSCI, the resulting maps are global maps of science (as opposed to local maps of science, which focus on one or a few disciplines).

3.2. Overlay maps

Combining the maps described in the previous section with publication data (how many publications in which SCs?), one can create overlay maps as the visual representation of the expertise of a research unit (Leydesdorff & Rafols, 2009; Rafols et al., 2010; Leydesdorff, Carley, & Rafols, 2013). In an overlay map, the original map – referred to as the *base map* – provides the location (and sometimes cluster) of each SC, whereas publication data is used to visualize the unit's publication intensity for each SC. Typically, this is done by scaling the size of each node according to the number of publications. Hence, overlay maps can also be used for visual comparison and estimation of the degree of overlap of two or more entities in exploratory analysis.

In Section 4, we present several overlay maps. Some of these are zoomed in to better highlight places of interest. All distances presented are taken from the barycenter calculations (see further) and hence independent of whether the figures are enlarged.

For our purposes, however, overlay maps have an important limitation. Despite their value in an exploratory analysis, overlay maps are hard to compare. It is not always obvious, for instance, which of several candidate panel members has better overlap of expertise with a given group or department. This is especially the case if the entities publish in many different categories or in categories that are quite close to one another. We therefore propose using the barycenter method to estimate an entity's 'average' or 'overall' position. Consequently, one can determine and compare the cognitive distance between entities, thus adding a measure to the qualitative visual comparison facilitated by overlay maps.

3.3. Barycenter and distance calculation

An entity's barycenter is the center of weight (Rousseau, 1989, 2008) of the SCs in which it has published, where a SC's weight is the entity's number of publications therein. Barycenters can be determined in any arbitrary number of dimensions. For our purposes, there are two different ways of calculating a barycenter: either we calculate the barycenter in N dimensions (starting from the original similarity matrix) or we calculate it in two dimensions (starting from a map).

First, we explain calculation of the barycenter in N dimensions. In this case, each row of the similarity matrix is interpreted as a set of N coordinates for the corresponding SC. In the five-dimensional example in Fig. 1, for instance, A has $N=5$ coordinates (1, 0, 0.1, 0.2, 0.1). The barycenter in N dimensions is determined as the point $C=(C_1, C_2, \ldots, C_N)$, where:

$$C_k = \frac{\sum_{j=1}^{N} m_j L_{j,k}}{M} \tag{1}$$

Here $L_{j,k}$ denotes the kth coordinate of WoS subject category j (that is, $L_{j,k}$ is element $\mathbf{A}_{j,k}$ in the similarity matrix $\mathbf{A}$), m_j is the number of publications in subject category j, and $M = \sum_{j=1}^{N} m_j$. Note that M is larger than the total number of publications as we use full counting of WoS subject categories: if a publication appears in a journal belonging to two categories, it will be counted twice. For further elaboration on the barycenter method, we refer to (Rousseau, 1989; Jin & Rousseau, 2001; Verleysen & Engels, 2013, 2014).

Having obtained barycenters for each entity in the similarity matrix, we can determine the distance between (the barycenters of) the expert panel as a whole, individual panel members, the combined group, and individual groups. The Euclidean distance between two barycenters a and b is

$$d(a, b) = \sqrt{(a_1 - b_1)^2 + \cdots + (a_N - b_N)^2} \tag{2}$$

Let us now turn to the barycenter calculation in two dimensions, using the Kamada–Kawai or VOS map. Reusing formula (1), the barycenter on a two-dimensional base map is defined as the point $C=(C_1, C_2)$ where

$$C_1 = \frac{\sum_{j=1}^{N} m_j L_{j,1}}{M}; \qquad C_2 = \frac{\sum_{j=1}^{N} m_j L_{j,2}}{M} \tag{3}$$

The Euclidean distance between points $C = (C_1, C_2)$ and $D = (D_1, D_2)$ is calculated with the formula:

$$d = \sqrt{(C_1 - D_1)^2 + (C_2 - D_2)^2} \tag{4}$$

The distances thus obtained should be interpreted as having arbitrary units on a ratio scale (Egghe & Rousseau, 1990). This means there is a fixed meaningful zero (distance zero in the map), and distances can be compared in terms of percentage or fraction (e.g. the distance between A and B is 1.5 times larger than the distance between C and D).

The latter, two-dimensional approach allows for easy visualization of barycenters: C_1 and C_2 are, respectively, horizontal and vertical coordinates. A barycenter that is obtained using the former, N-dimensional approach cannot be visualized as easily, since it has N coordinates itself. However, visualization is possible if one expands the similarity matrix with one extra row and column, containing the barycenter's coordinates. The expanded $(N+1) \times (N+1)$ matrix can then be visualized using, for instance, VOSviewer. Note that this approach works well for visualizing the location of one barycenter but cannot be used for multiple barycenters at the same time, for two reasons:

- Adding extra rows/columns affects the layout algorithm and may distort the original base map. The effect of one extra point turns out to be quite limited.
- It is unclear what similarity score should be assigned to a pair of barycenters.

Table 2
Barycenter distances between Chemistry groups, panel and panel members in the Kamada–Kawai map.

	Group	CHEM-A	CHEM-B	CHEM-C	CHEM-D	CHEM-E	CHEM-F	CHEM-G	CHEM-H	CHEM-I	CHEM-J	CHEM-K	CHEM-L
Panel	0.113	0.151	0.118	0.186	0.106	0.274	0.347	0.114	0.173	0.061	0.265	0.357	0.141
PM 1	0.178	0.175	0.130	0.210	0.148	0.329	0.397	0.185	0.244	0.131	0.335	0.428	0.126
PM 2	0.189	0.305	0.299	0.330	0.136	**0.082**	**0.158**	0.137	0.111	0.172	0.194	**0.226**	0.337
PM 3	0.060	0.144	0.131	0.175	0.112	0.244	0.320	**0.052**	0.112	**0.003**	0.203	0.295	0.169
PM 4	0.115	0.229	0.225	0.255	0.110	0.156	0.232	0.063	**0.059**	0.099	**0.164**	0.231	0.265
PM 5	0.104	**0.047**	**0.022**	**0.083**	0.208	0.355	0.431	0.146	0.201	0.106	0.258	0.363	**0.069**
PM 6	0.208	0.289	0.261	0.323	**0.040**	0.171	0.229	0.170	0.196	0.156	0.302	0.361	0.282
PM 7	0.201	0.148	0.100	0.177	0.220	0.398	0.468	0.225	0.286	0.172	0.362	0.463	0.070

Shortest distances between a group and a panel member are underlined and printed in bold.

In the following section, we determine the barycenters of all entities and the distances between them using both the *N*-dimensional and the two-dimensional approach. For the latter, we employ both the Kamada–Kawai map and the VOS-map. We also calculate the average of the shortest barycenter distances as a comparative measure between two case studies.

4. Results

We start by calculating barycenters and distances to gauge the differences between the techniques. As we will see, the comparison leads us to conclude that we can use the Kamada–Kawai map as a basis for visual exploration and barycenter calculation and comparison. This map is implemented in Pajek and forms the basis for the map of science as introduced by Leydesdorff and Rafols (2009) and also available as base map in Leydesdorff's overlay toolkit (http://www.leydesdorff.net/overlaytoolkit). Hence, the Kamada–Kawai map is used for the overlay maps in the second part of this section.

4.1. Barycenter distances

All the coordinates of the barycenters are provided in the Supplementary online material, part 1. The distances between groups and individual panel members are calculated for both case studies using the three approaches described before (similarity matrix, VOS-map, Kamada–Kawai map). Tables 2 and 3 provide the distances in the Kamada–Kawai maps, while the distances in the similarity matrix and in the VOS-map are provided in the Supplementary online material, part 2.

Comparing the results for the three approaches, we find that 6 out of 12 Chemistry groups are most closely located to the same PM in the similarity matrix and VOS-map approach and 9 out of 12 groups are most closely located to the same PM in the VOS-map and Kamada–Kawai map approach. Likewise, 5 out of 9 Physics groups are most closely located to the same PM in the matrix and VOS-map approach and 8 out of 9 groups are most closely located to the same PM in the VOS-map and Kamada–Kawai map approach.

Spearman's rank-order correlation coefficient was calculated between the barycenter distances of the three approaches, considering the barycenter distances between groups and individual panel members only. Although there are co-publications between groups, the barycenter distances between panel and combined group and separate groups, and combined groups and individual panel member can be (or at least are) considered independent, and have been included in the correlation calculation.

Correlations for the Chemistry case study (see Fig. 2) are moderate between the similarity matrix and the VOS-map ($\rho = 0.620$) and strong between the similarity matrix and the Kamada–Kawai map ($\rho = 0.803$) and between the VOS-map and the Kamada–Kawai map in the Chemistry department ($\rho = 0.853$).

Correlations for the Physics case study (see Fig. 3) are moderate between the similarity matrix and the VOS-map ($\rho = 0.781$) and between the similarity matrix and the Kamada–Kawai map ($\rho = 0.776$), and strong between the VOS-map and the Kamada–Kawai map ($\rho = 0.927$).

Table 3
Barycenter distances between Physics groups, panel and panel members in the Kamada–Kawai map.

	Groups	PHYS-A	PHYS-B	PHYS-C	PHYS-D	PHYS-E	PHYS-F	PHYS-G	PHYS-H	PHYS-I
Panel	0.134	1.115	0.030	0.066	0.123	0.038	0.249	0.377	0.043	0.608
PM 1	0.206	1.151	0.106	0.195	**0.013**	0.123	0.195	0.471	0.105	0.643
PM 2	0.217	1.196	0.069	0.111	0.154	0.120	0.318	0.445	0.058	0.690
PM 3	0.131	1.047	0.137	0.187	0.090	0.105	**0.112**	0.389	0.147	0.539
PM 4	0.119	**0.982**	0.213	0.131	0.286	0.174	0.316	**0.204**	0.225	**0.491**
PM 5	0.157	1.136	0.033	**0.065**	0.135	**0.063**	0.273	0.391	0.037	0.630
PM 6	0.176	1.156	**0.031**	0.084	0.130	0.078	0.280	0.412	**0.026**	0.649

Shortest distances between a group and a panel member are underlined and printed in bold.

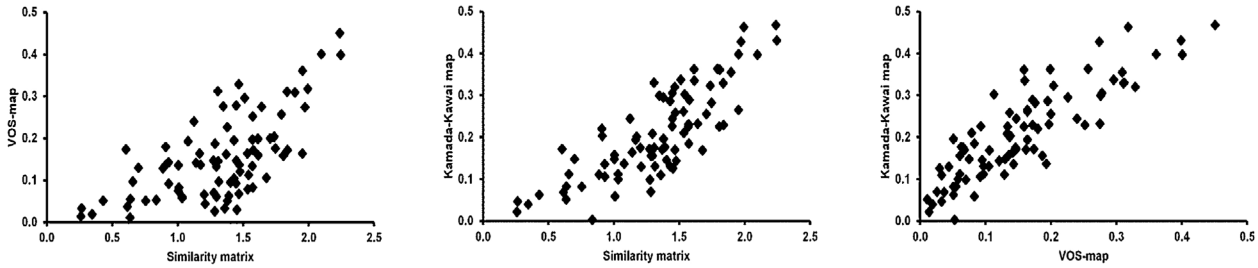

Fig. 2. Scatter plots of the barycenter distances between groups and individual panel members between similarity matrix, VOS-map and Kamada–Kawai map in the Chemistry department.

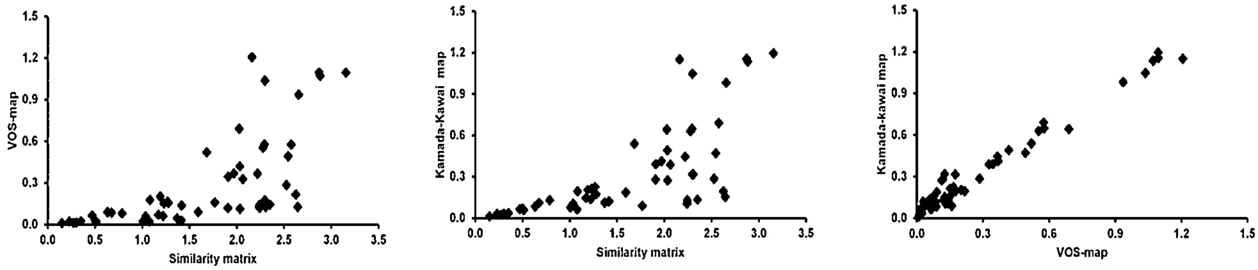

Fig. 3. Scatter plots of the barycenter distances between groups and individual panel members between similarity matrix, VOS-map, and Kamada–Kawai map in the Physics department.

As explained in Section 3, the most fundamental distinction is the question whether one determines a barycenter in N dimensions (starting from the similarity matrix) or in two dimensions (starting from a map). Fig. 4 provides a visual comparison, using the barycenter of CHEM-A as an example. The similarity matrix map was obtained from the expanded $(N+1) \times (N+1)$ matrix (see above for details). While not exactly identical, the two locations are very close nonetheless. The Supplementary online material, part 3, provides a total of 114 maps that allow for visual comparison of the similarity matrix map, the VOS map and the Kamada–Kawai map for each of the units (panel, panel members, groups) included in the case studies in this paper.

The above findings show that barycenters and the Euclidean distance between barycenters can be calculated both in two and more dimensions, and the results are quite similar. Especially the barycenter distances between the VOS-map and the Kamada–Kawai map are strongly correlated. Since the Kamada–Kawai map is readily available for creating overlay maps, in the remainder of this paper, calculations of barycenters, Euclidean distances, comparisons, and visual explorations are based on the Kamada–Kawai maps.

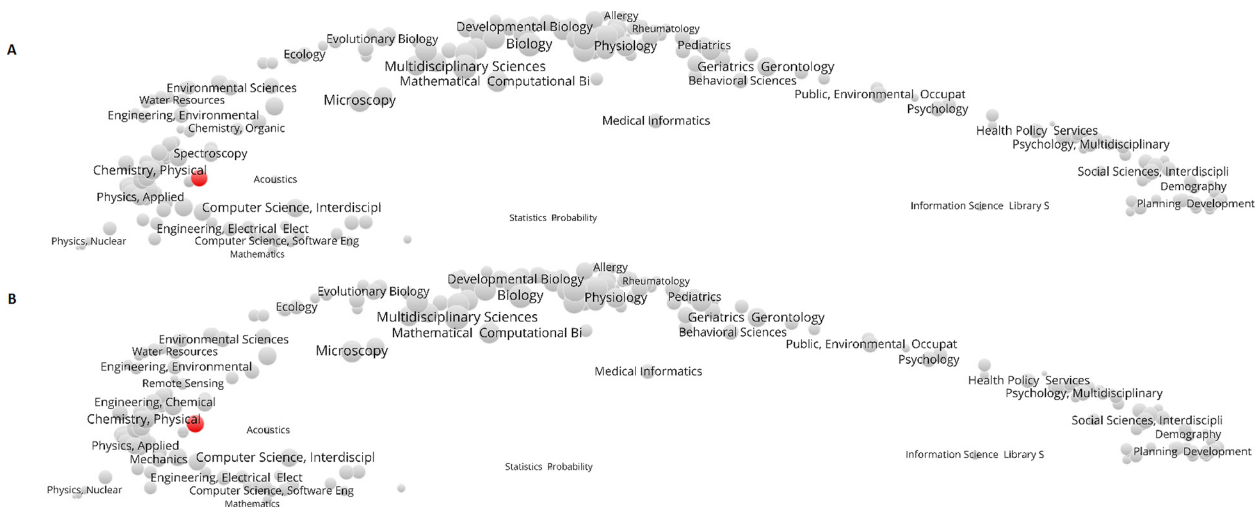

Fig. 4. Barycenter visualization of CHEM-A. (A) Barycenter calculated using similarity matrix approach, (B) barycenter calculated using VOS-map approach.

Table 4
Top ten WoS subject categories for the Chemistry panels and the groups.

Panel publications			Group publications		
Web of Science categories	Records	% of 2150	Web of Science categories	Records	% of 920
Chemistry inorganic & nuclear	798	37.11	Chemistry physical	198	21.52
Chemistry organic	458	21.30	Chemistry analytical	194	21.08
Chemistry analytical	350	16.27	Spectroscopy	164	17.82
Chemistry multidisciplinary	324	15.0	Physics atomic molecular & chemical	100	10.87
Chemistry physical	177	8.23	Physics applied	77	8.37
Physics atomic molecular & chemical	115	5.34	Materials science multidisciplinary	75	8.15
Environmental sciences	93	4.32	Environmental sciences	59	6.41
Spectroscopy	63	2.93	Biochemical research methods	43	4.67
Biochemical research methods	57	2.65	Physics condensed matter	43	4.67
Engineering chemical	41	1.90	Chemistry multidisciplinary	39	4.23

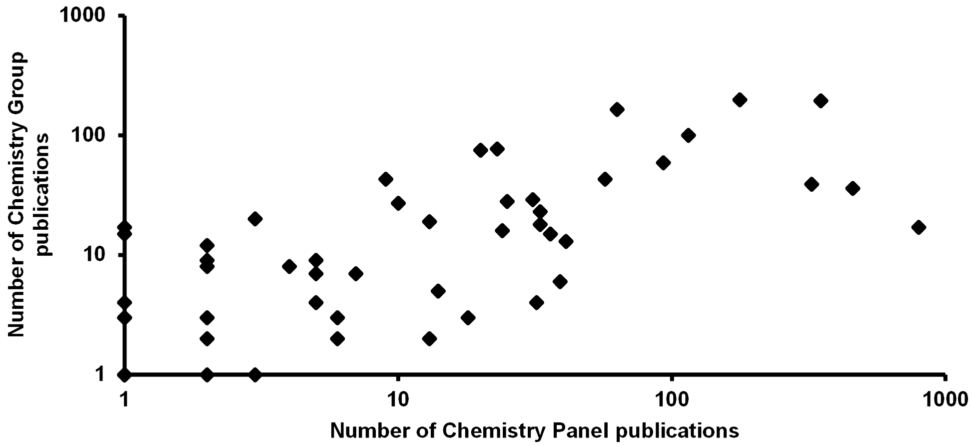

Fig. 5. Scatter plot of the number of publications (log–log scale) per WoS subject category for the members of the Chemistry panel (horizontal axis) and all scientists of the Chemistry department (vertical axis), excluding those for which at least one of the two has no publications (51 common subject categories).

4.2. Case studies of University of Antwerp research assessments

4.2.1. Chemistry assessment

4.2.1.1. Panel profile versus group profile. Together, the Chemistry panel and groups have published in 108 WoS subject categories; when considered separately, panel publications appear in 66 categories, and group publications in 94 categories. Furthermore, the Chemistry panel and groups have 51 WoS subject categories in common and 14 categories have panel publications only, but no group publications, while 43 WoS subject categories contain group publications but no panel publications.

Table 4 shows seven common categories in the top ten of WoS subject categories between the Chemistry panel and groups. More than half of the Chemistry panel publications belong to the *Chemistry inorganic nuclear* (37.11%) and *Chemistry organic* (21.30%) categories, whereas surprisingly, these two categories do not appear in the top ten of WoS subject categories for publications by the research groups.

A scatter plot of the number of publications per common WoS subject category ($n = 51$) for the members of the Chemistry panel and all scientists of the Chemistry department is shown in Fig. 5. For the 108 WoS subject categories in which the Chemistry panel and/or the department have publications (51 common categories, plus 57 categories in which either the department or the panel has publications) the Spearman rank correlation coefficient is positive but low ($\rho = 0.36$).

The overlay maps for the Chemistry panel (Fig. 6) and the combined groups (Fig. 7) clearly show that the publication scope of the combined chemistry groups is wider than that of the panel. The panel publications are strongly (74.67%) represented in the WoS subject categories of *Chemistry inorganic & nuclear*, *Chemistry organic*, and *Chemistry analytical*, whereas the research group publications are predominantly clustered (60.43%) in *Chemistry physical*, *Chemistry analytical*, and *Spectroscopy*.

4.2.1.2. Panel profile versus Individual group profile. Overlay maps of the publications of the individual groups were created, and subsequently compared with the panel overlay map (see Fig. 6).

We present the data for CHEM-A as an example. Fig. 8 shows the corresponding overlay map. The majority of the publications of the CHEM-A group fall in *Chemistry physical* (48.06%) and *Physics atomic molecular & chemical* (34.88%) WoS subject categories. We have found that the research output of six (CHEM-A, CHEM-B, CHEM-D, CHEM-G, CHEM-I, and CHEM-L) of the

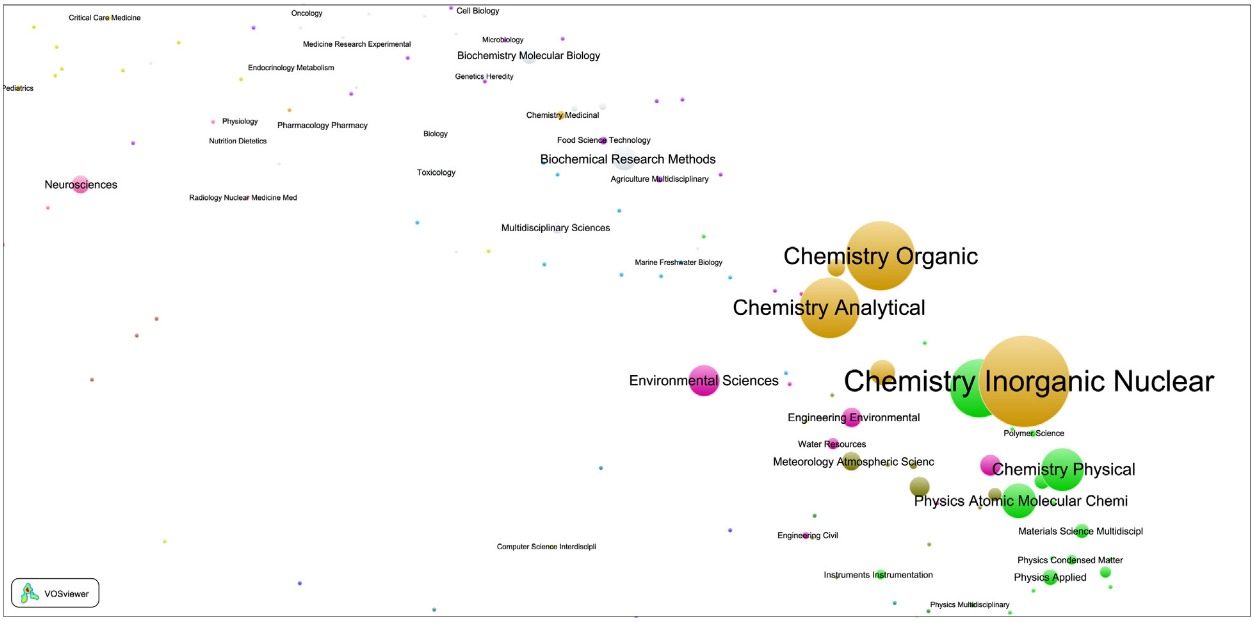

Fig. 6. Chemistry panel members' publication overlay map.

twelve research groups, are thematically well covered by the panel's expertise, i.e., the majority of the panel's publications can be classified in WoS subject categories, where also the majority of the corresponding group publications is found.

Furthermore, the majority of the CHEM-C group publications falls in *Physics applied* (35.25%) and *Spectroscopy* (23.71%); CHEM-H group: *Spectroscopy* (40.32%) and *Chemistry analytical* (27.41%; Fig. 9) WoS subject categories. These two research groups have a large number of publications in WoS subject categories where the publications output of the panel tends to be limited. Therefore, the research output of these two research groups only partially covered by the panel's expertise.

Likewise, the majority of the publications of CHEM-E group (Fig. 10) fall in *Chemistry Analytical* (38.57%) and *Spectroscopy* (34.28%); CHEM-F group: *Chemistry analytical* (66.66%) and *Biochemical research methods* (23.81%); CHEM-J group: *Chemistry analytical* (48.14%) and *Instruments Instrumentation* (33.33%); CHEM-K group: *Microscopy* (81.48%) and *Computer science*

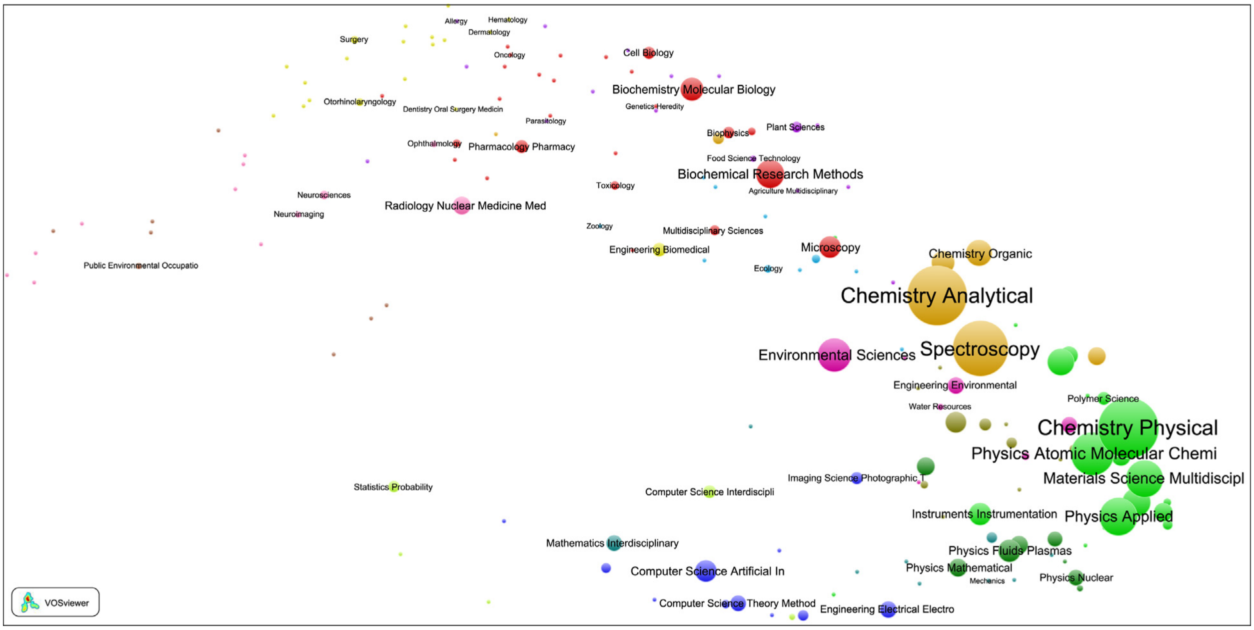

Fig. 7. Chemistry groups' publication overlay map.

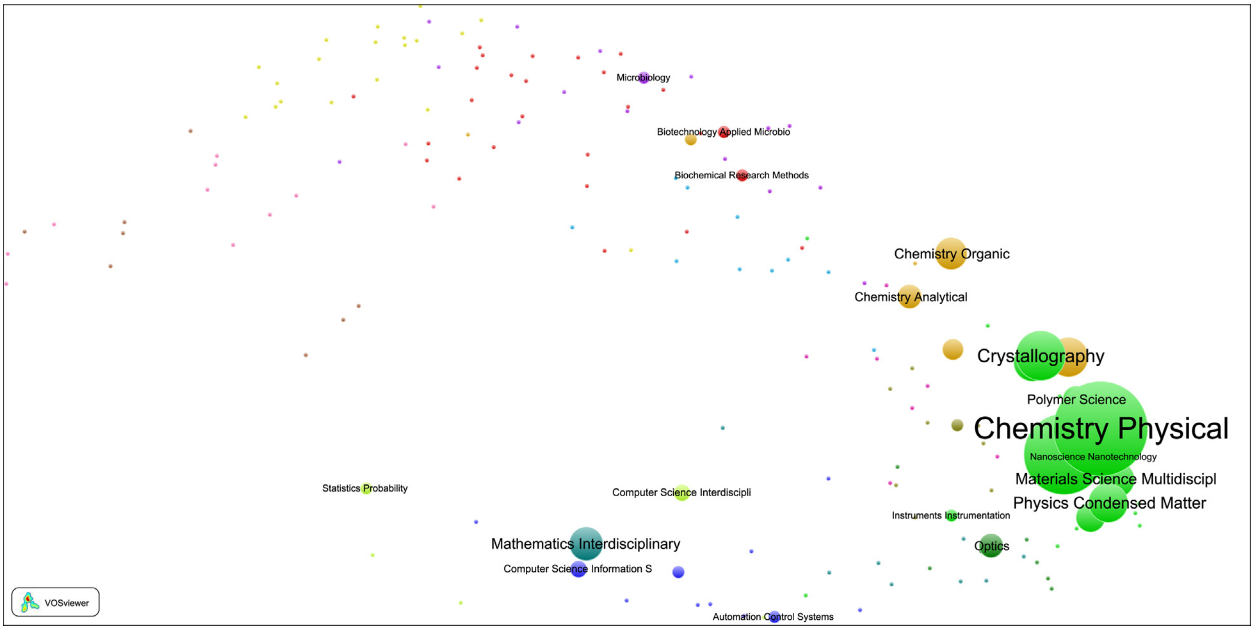

Fig. 8. Overlay map of CHEM-A research group's publications.

artificial intelligence (70.37%) WoS subject categories. Therefore, these four research groups hardly have any overlap in terms of the share of their publications in WoS categories where the evaluation panel has publications.

In summary, of the twelve Chemistry groups, six groups are well covered, two groups are partially covered, and the remaining four groups seem poorly covered by the Chemistry panel's expertise as far as publication output is described via WoS subject categories.

4.2.1.3. Barycenter distances. Fig. 11 and Table 2 provide data on the distances between the Chemistry panel's barycenter/coordinates and those of the individual Chemistry groups (panel members are indicated by the symbol PM).

The CHEM-I group is very close to the panel while CHEM-F group is almost 2.2 times farther away than CHEM-A group, and CHEM-K group is 3.1 times further away than CHEM-G group. CHEM-A (0.151), CHEM-B (0.118), CHEM-D (0.106), CHEM-G

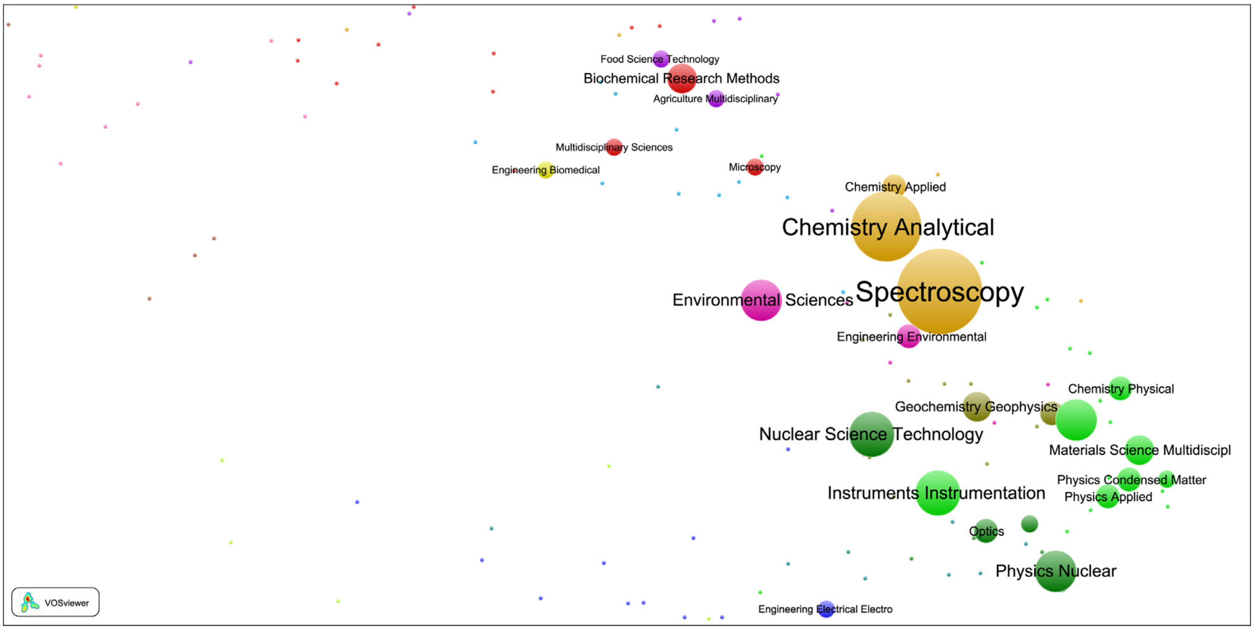

Fig. 9. Overlay map of CHEM-H research group's publications.

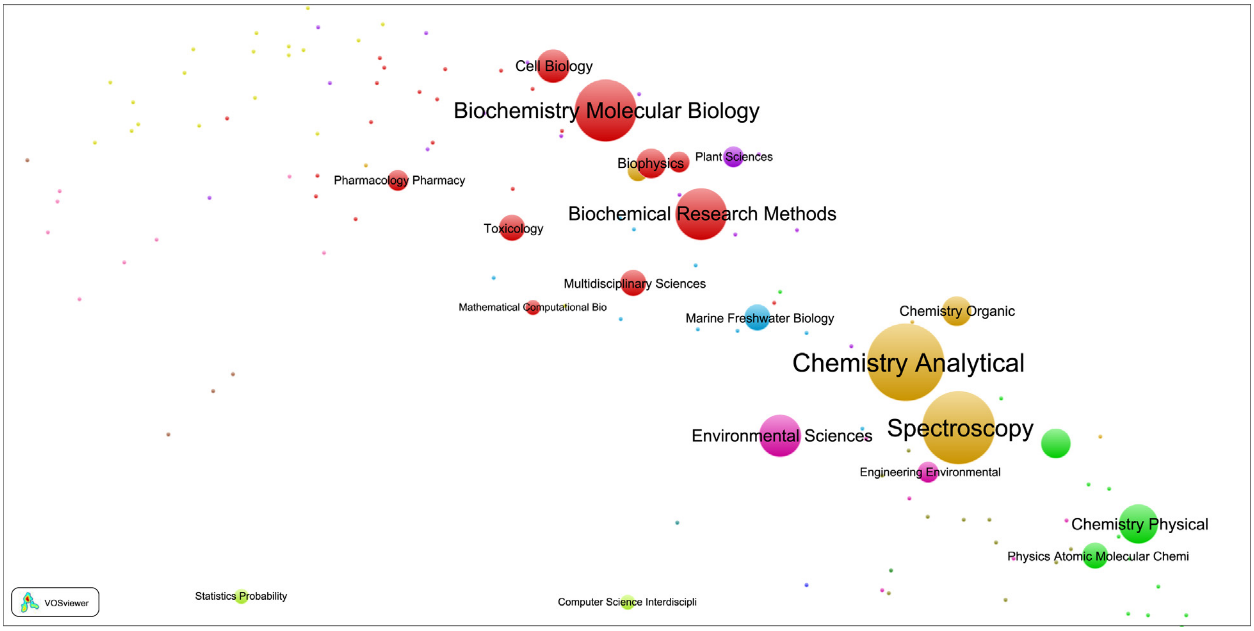

Fig. 10. Overlay map of CHEM-E research group's publications.

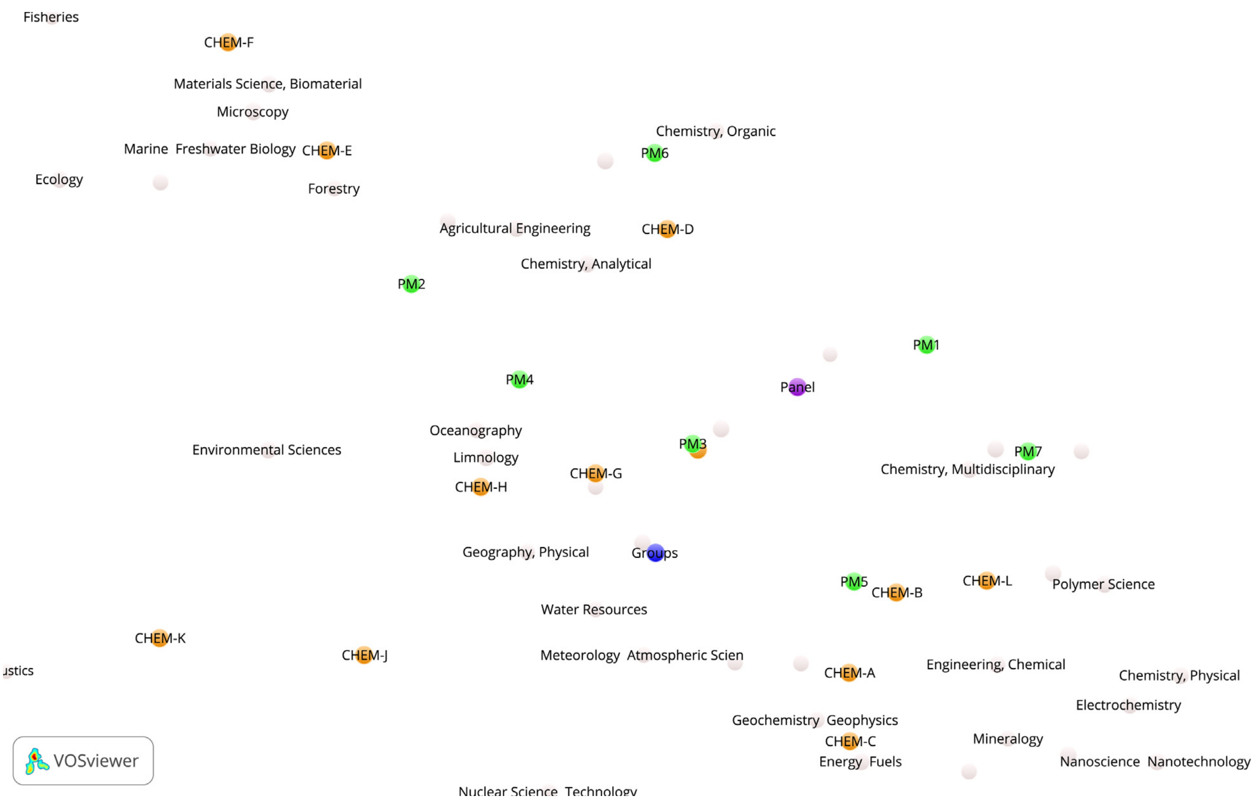

Fig. 11. Barycenter overlay map of Chemistry panel, panel members (PM) and research groups.

Table 5
Top ten WoS subject categories for the Physics panels and the groups.

Panel publications			Group publications		
Web of Science categories	Records	% of 1104	Web of Science categories	Records	% of 1732
Physics condensed matter	410	37.13	Physics condensed matter	515	29.73
Physics multidisciplinary	188	17.02	Physics applied	252	14.55
Chemistry physical	182	16.48	Physics multidisciplinary	231	13.33
Physics applied	159	14.40	Materials science multidisciplinary	226	13.04
Optics	124	11.23	Chemistry physical	193	11.14
Physics atomic molecular chemical	113	10.23	Physics particles fields	154	8.89
Materials science multidisciplinary	99	8.96	Nanoscience nanotechnology	111	6.40
Physics particles fields	65	5.88	Microscopy	72	4.15
Instruments instrumentation	50	4.52	Physics atomic molecular & chemical	66	3.81
Spectroscopy	38	3.44	Otorhinolaryngology	65	3.75

(0.114), CHEM-I (0.061) and CHEM-L (0.141) are situated comparatively close to the panel's coordinates, while CHEM-C (0.186) and CHEM-H (0.173) are located farther away, and CHEM-E (0.274), CHEM-F (0.347), CHEM-J (0.265) and CHEM-K (0.357) are found at a considerable distance from the panel's barycenter (Table 2).

A further comparison of the distances between the Chemistry groups and individual Chemistry panel members as presented in Table 2 reveals that the partially covered CHEM-C and CHEM-H groups, while located moderately far away from the panel, are relatively close to PM5 (0.083) and PM4 (0.059), respectively. Similarly, the less covered groups CHEM-E and CHEM-F are found relatively close to PM2, CHEM-J close to PM4, and CHEM-K situated at a remote distance from the panel's coordinates. In Table 2, the shortest distance between the Chemistry groups and a panel member is printed in bold and underlined. The average of these distances is 0.084 and can be used as a measure of the fit between the expertise of the Chemistry panel and the research interests of the Chemistry research groups.

4.2.2. Physics assessment

4.2.2.1. Panel profile versus group profile. Physics panel and group publications are found in 112 WoS subject categories, with Physics panel publications appearing in 46 categories, and group publications in 108 categories. Furthermore, 42 WoS subject categories were common, 4 categories contained panel publications, but no group publications, and 66 categories have group publications but no panel publications.

Table 5 shows seven common categories in the top ten of WoS subject categories between the Physics panel and groups. The majority of the publications by the Physics panel and the groups are found in *Physics condensed matter* (panel: 37.13%; groups: 29.73%), followed by *Physics multidisciplinary* (panel: 17.02%; groups: 13.33%), *Chemistry physical* (panel: 16.48%; groups: 11.14%) and *Physics applied* (panel: 14.40%; groups 14.55%). The top ten lists of the Physics panel and of the Physics groups have seven WoS subject categories in common.

A scatter plot of the number of publications per common WoS subject category ($n = 42$) for the members of the Physics panel and all scientists of the Physics department is shown in Fig. 12. For the 112 WoS subject categories in which the Physics panel and/or the department have publications (42 common categories, plus, 70 categories in which either the department or the panel has publications) the Spearman rank correlation coefficient is positive but low ($\rho = 0.524$).

The overlay maps for physics similarly revealed a wider publication scope for the combined research groups (Fig. 14) compared to the Physics panel (Fig. 13). The panel's publications are strong (68.75%) in *Physics condensed matter*,

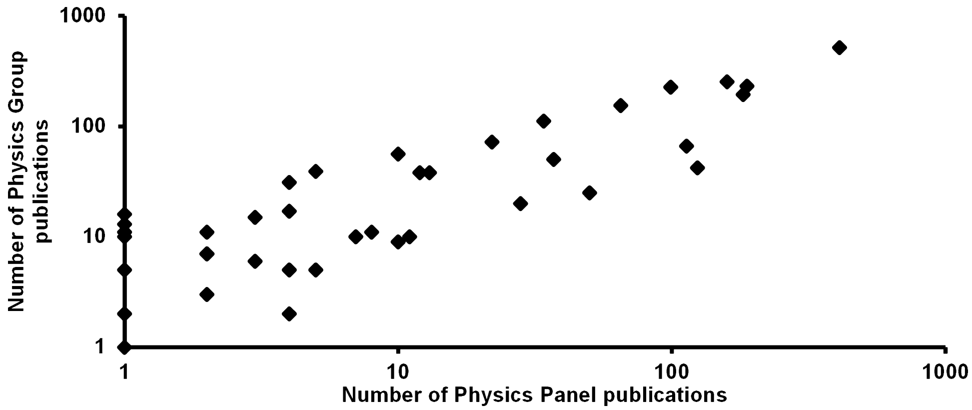

Fig. 12. Scatter plot of the number of publications (log–log scale) per WoS subject category for the members of the Physics panel (horizontal axis) and all scientists of the Physics department (vertical axis), excluding those for which at least one of the two has no publications (42 common subject categories).

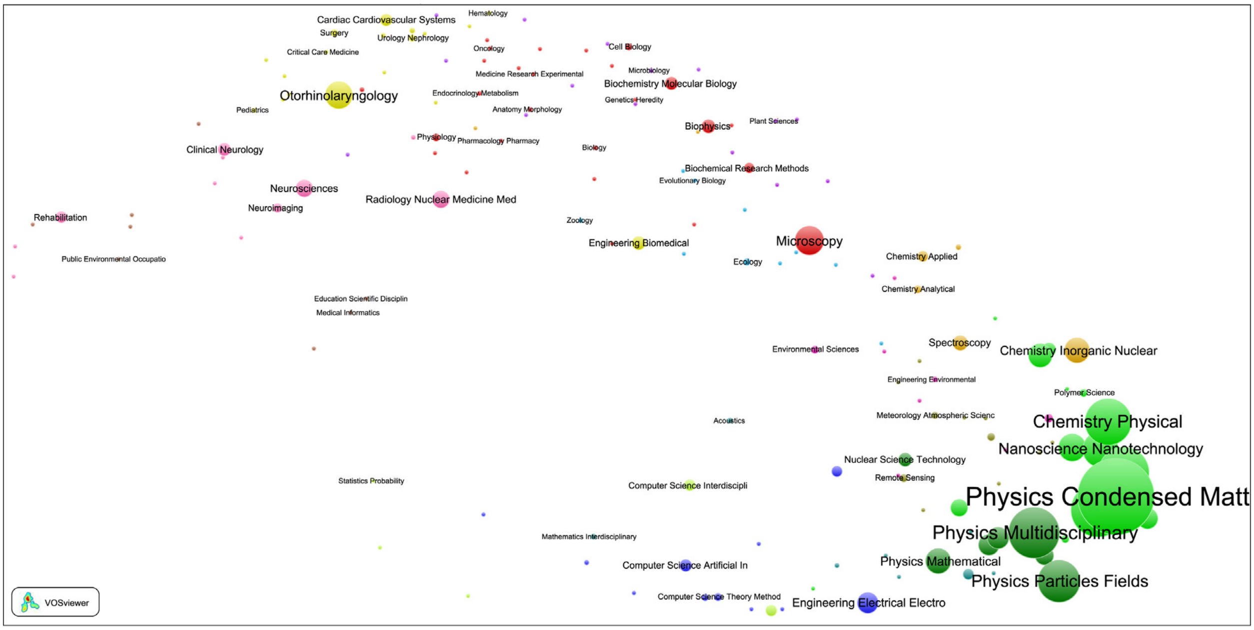

Fig. 13. Physics groups' publication overlay map.

Physics multidisciplinary, *Chemistry physical*, and *Physics applied*, whereas the groups' publications tend to be mainly clustered (57.62%) in *Physics condensed matter*, *Physics multidisciplinary*, *Physics applied*, and *Materials science multidisciplinary*.

4.2.2.2. Panel profile versus individual group profile. Overlay maps of the publications of the individual groups were created, and subsequently compared with the panel overlay maps (Fig. 14).

PHYS-B group: Physics condensed matter (59.67%) and Physics applied (19.34% Fig. 15); PHYS-C: Materials science multidisciplinary (35.61%) and Chemistry physical (29.9%); PHYS-D: Physics particles fields (56.87%) and Physics multidisciplinary (40.89%); PHYS-E: Physics multidisciplinary (25.15%), Physics particles fields (24.52%), and Physics condensed matter (20.75%); PHYS-H: Physics condensed matter (61.06%) and Physics applied (19.08%).

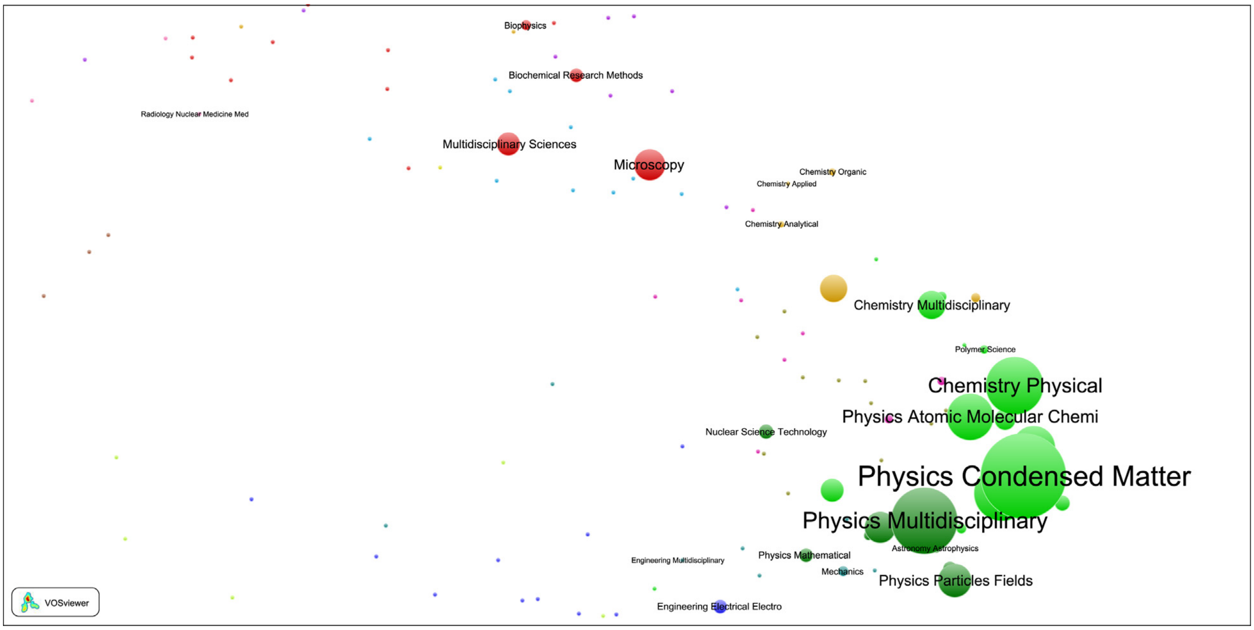

Fig. 14. Physics panel members' publication overlay map.

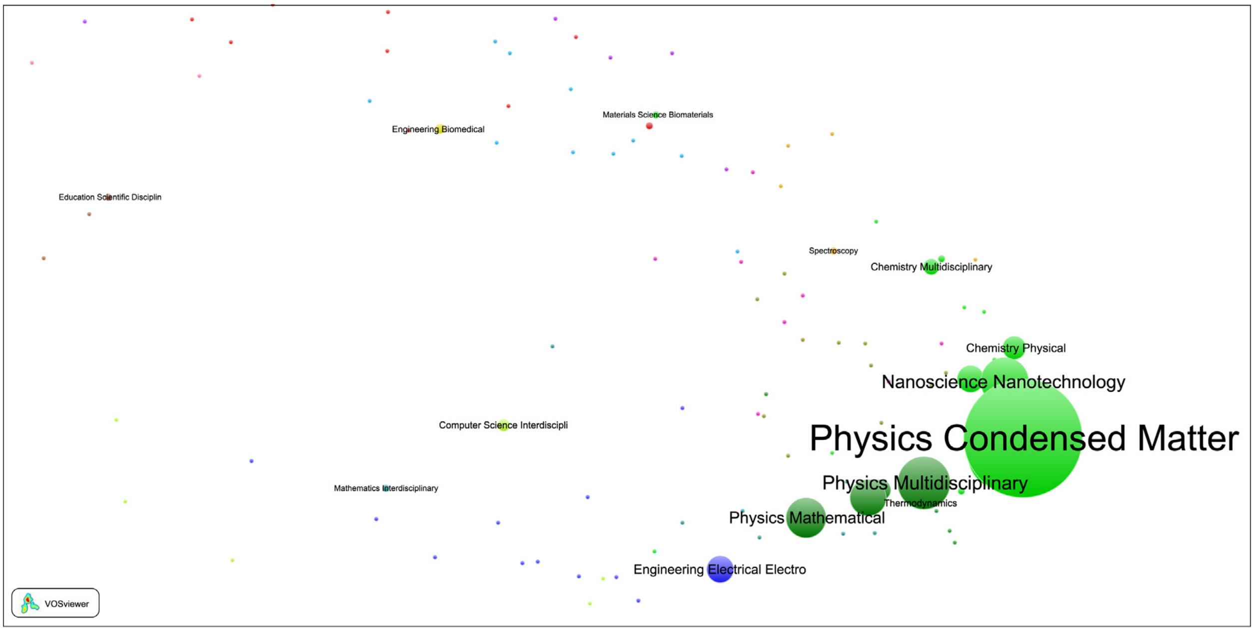

Fig. 15. Overlay map of PHYS-B group's publications.

These data show that five of the nine Physics groups (PHYS-B, PHYS-C, PHYS-E, PHYS-F, and PHYS-H) are thematically well covered by the panels' expertise as the majority of the groups publications are found in WoS subject categories where the majority of the panels' publications have been classified.

PHYS-F: *Physics multidisciplinary* (59.52%) and *Physics mathematical* (42.85%); PHYS-G: *Physics atomic molecular chemical* (34.88%) and *Chemistry physical* (32.55%; Fig. 16). Two physics groups (PHYS-F and PHYS-G) have a large number of publications in WoS subject categories where the publication output of their respective panels tends to be limited. The research output of these four groups is therefore only partially covered by the respective panels' expertise.

PHYS-A: *Otorhinolaryngology* (51.2%) and *Audiology speech language pathology* (14.4%) (Fig. 17); PHYS-I: *Microscopy* (26.08%) and *Radiology nuclear medicine medical imaging* (20.87%) WoS subject categories. There was hardly any overlap in terms of the share of their publications in WoS subject categories between these groups and the evaluation panel.

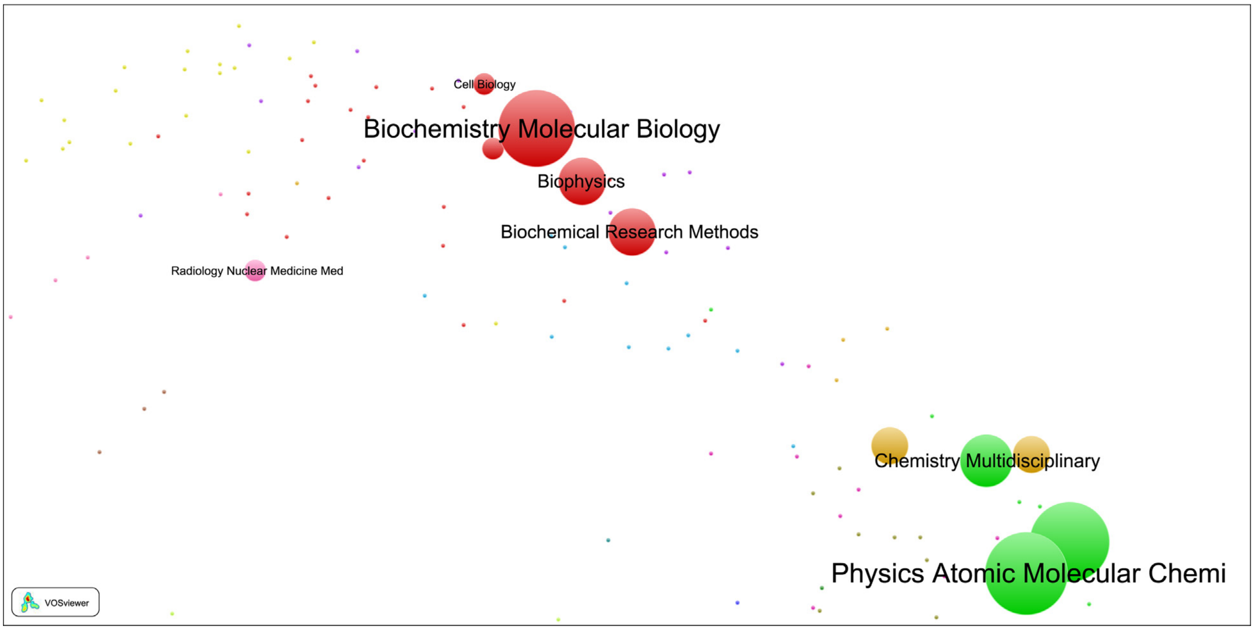

Fig. 16. Overlay map of PHYS-G research group's publications.

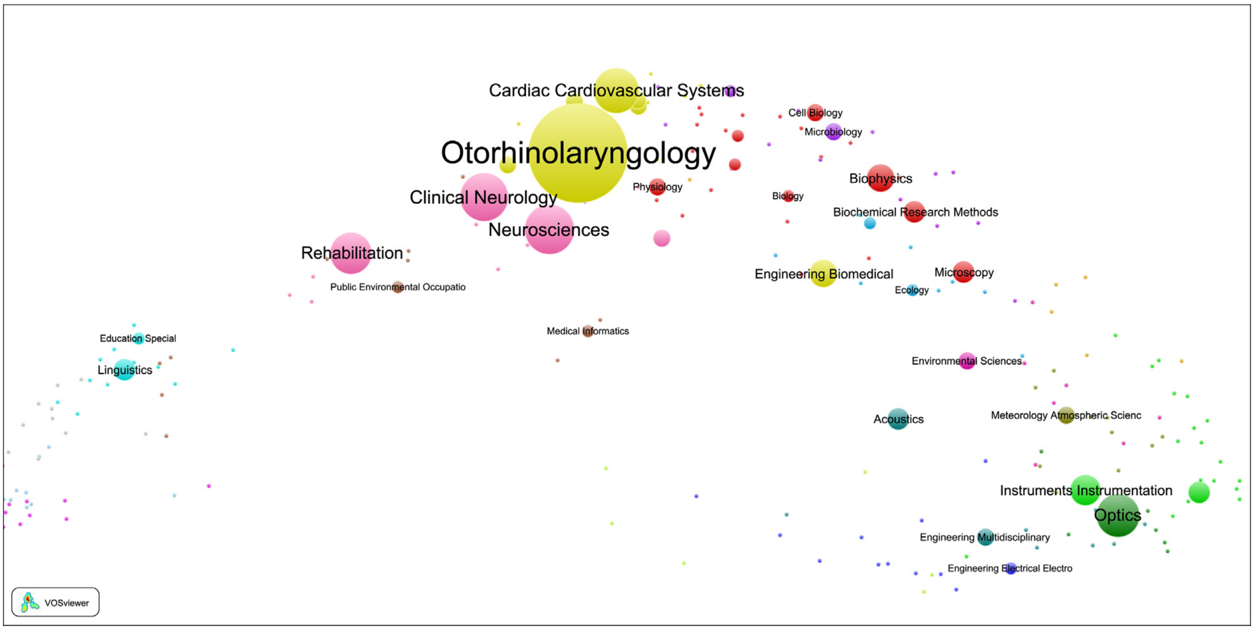

Fig. 17. Overlay map of PHYS-A research group's publications.

In summary, of the nine Physics groups, five groups are well covered, two groups are partially covered, and the remaining two groups seem to have been poorly covered by the Physics panel's expertise.

4.2.2.3. Barycenter distances. Fig. 18 and Table 3 show the distances between the Physics panel's coordinates and the different Physics groups.

The Physics panel is very near to the PHYS-B group, while the PHYS-F group is 12.5 times and PHYS-I is 20.2 times further away from the panel than PHYS-B. PHYS-B group (0.030), PHYS-C (0.066), PHYS-E (0.038), and PHYS-H (0.043) are found closest to the panel's coordinates, while PHYS-D (0.123), PHYS-F (0.249) and PHYS-G (0.377) are still moderately close. It

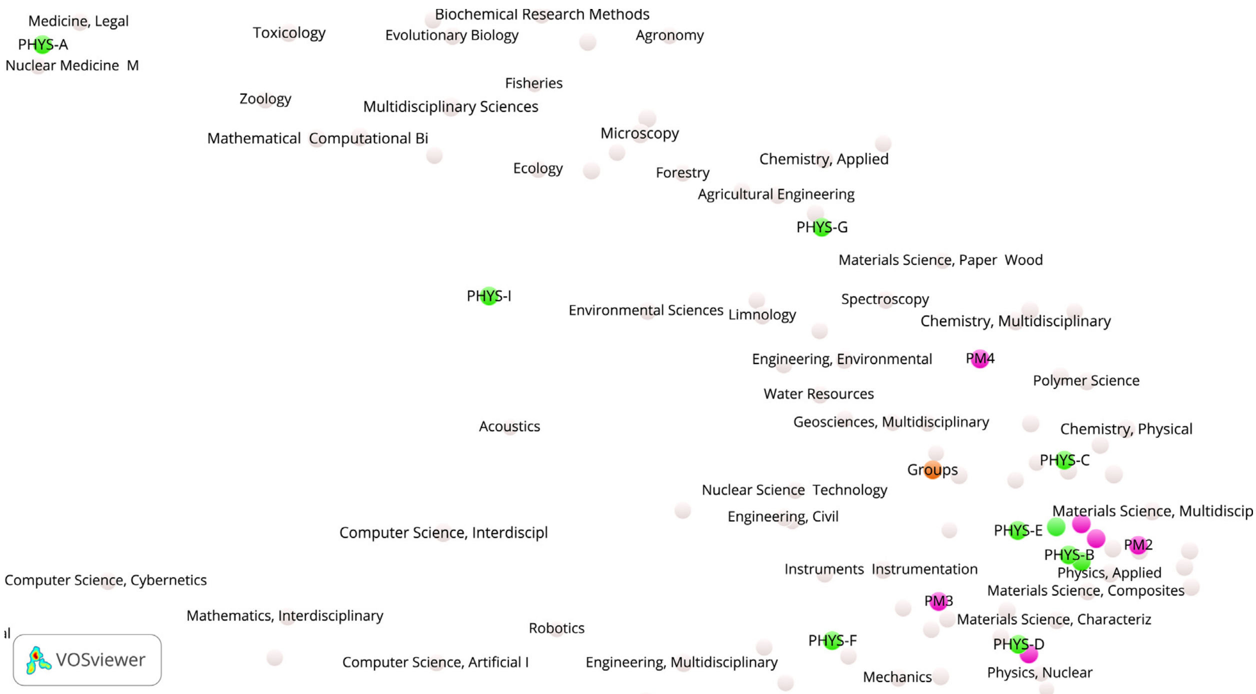

Fig. 18. Barycenter overlay map of Physics panel, panel members (PM) and research groups.

should be noted that PHYS-D emerged as well covered and PHYS-F and PHYS-G as partially covered by the panel's expertise from the comparative individual group vs. panel profile. Furthermore, although PHYS-D is situated moderately far away from the panel's coordinates, PM1 is located in the immediate (0.013) neighborhood of PHYS-D, with the majority of the publications of PHYS-D D and PM1 belonging to the same subject categories.

Similar observations can be made for the other moderately close groups, PHYS-G and PHYS-F, which also have individual panel members in their immediate neighborhood, i.e., PM4 (0.204) and PM3 (0.112), respectively, and also have the majority of their publications in the same WoS subject categories as these two panel members. Further, PHYS-A (1.115), and PHYS-I (0.608) are located at a considerable distance from the panel's coordinates, have no individual panel members in their neighborhoods, and are poorly covered by the panel's expertise. Table 3 shows that the distances between PHYS-A and PM3 (1.047) and PM4 (0.982), and between PHYS-I and PM3 (0.539) and PM4 (0.491) are smaller compared to other panel members. However, the expertise of PM3 and PM4 is even less aligned with the publication output of PHYS-A and PHYS-I. The average of the shortest distances of the barycenters of the Physics panel members to the barycenters of the Physics research group is 0.221.

5. Conclusion

We have explored not only overlap of expertise between research groups and an expert panel but also applied the barycenter method to calculate the distances between groups and panel (members). The barycenter method is well compatible with the WoS subject category-based overlay mapping, since it offers a simple way of representing the location of the panel and groups in a global science map based on WoS subject categories. Our results indicate that barycenters – and Euclidean distances between barycenters – can be calculated both in two and more dimensions and the results are very similar. Each map of science "contains a projection from a specific perspective" (Leydesdorff & Rafols, 2009). Therefore, different layout techniques may produce different outputs. An exploration of two different layout techniques from the similarity matrix exposes that the Kamada–Kawai map is strongly correlated with the VOS-map.

Overlay maps constitute an interesting tool to visualize the position of panel and group publications in a fixed map based on WoS subject categories. The results reveal a number of discrepancies in WoS subject categories between panel and group publications in both the Chemistry and Physics departments. This could be expected, since panel members are selected primarily because of their expertise and not necessarily because of the match thereof with the research in the groups. Overall, group publications are found in a wider range of SCs than panel publications, which might be due to the interdisciplinary orientation of some of the groups. The Spearman's rank correlation coefficients point to a positive but low overlap of expertise between the Chemistry panel and groups, and to a moderate correlation between the Physics panel and groups. The barycenter analysis showed that six Chemistry groups and five Physics groups are well covered by the respective panels' expertise and are located close to the panel's coordinates while the remaining groups are not, although this gap is sometimes filled by the expertise of individual panel members. Furthermore, in some cases, neither the individual panel members nor the panels (as a whole) are situated close to the groups, in which case the panel seems to possess only partial expertise to evaluate these research groups. These barycenter findings are hence well in line with the results of the comparative analysis of individual group versus panel profile. Overall, the Chemistry panel, with an average barycenter distance of the nearest panel member to the research groups of 0.084 seemed to be better aligned with the research interest of the units under assessment studied in this paper. Note that the conclusion from Spearman's rank correlation is the opposite. This confirms the necessity of a method that moves beyond correlation coefficients, since they do not capture relatedness between SCs. The application of the barycenter method in the similarity matrix, VOS-map and Kamada–Kawai allows to identify the Euclidean distances between the panel, combined research groups, individual panel members and individual research groups. It also allows calculation of average distances, comparison of distance and visual exploration of the barycenters on the map. Thus, the barycenter method provides information about the relevance of the expertise of an individual panel member to the assessment of both individual and combined research groups in a coherent way.

A similar, though less pronounced difference emerges from the comparison of the distance between the combined Chemistry groups and the Chemistry panel (0.113, see Table 2), and that between the combined Physics groups and the panel (0.134, see Table 3). These findings clearly demonstrate that in both cases, the majority of the panel publications appears in the categories in which group publications are found, while the groups have publications in a substantial number of WoS subject categories that have no panel publications. There is a visible discrepancy between panel and group publications as far as WoS subject categories are concerned. Overall, group publications are found in a wider range of subject categories than panel publications, which might be due to the interdisciplinary orientation of some of the groups.

In this investigation, we used distances between barycenters as a determinant for the correspondence between the publications by the group of panel members and the publications of a research group. Within this framework a distance of zero would mean a perfect correspondence. As pointed out by a reviewer one could envision other frameworks. One such framework would measure the correspondence between these two sets of publications by the similarity-weighted cosine measure as introduced in (Zhou, Rousseau, Yang, Yue, & Yang, 2012). In this framework perfect correspondence would be obtained when the similarity is one. We believe that this too is a valid approach in particular because the barycenter and the weighted-similarity approach, as illustrated in (Zhou et al., 2012), use the same input. Further investigations will have to show which of these two leads in practice to the best results.

A limitation of this paper arises from the question whether it is really relevant to have panel and groups publishing in the same subject categories, since one category may comprise a wide array of different subfields and topics. At present, this question cannot be answered with the methods outlined in this article, but instead would require a journal level analysis, as journals cover more closely related subfields and topics. A subsequent analysis will hence focus on fractional counting in WoS subject categories (Bornmann, 2014), and overlay maps at the journal level (Leydesdorff, Rafols, & Chen, 2013), with special attention to the quantification of similarity between groups and panel at this level for different disciplines. In addition, we will investigate how panel composition could be improved in terms of cohesion and expertise of panel members (Langfeldt, 2004). This comprehensive approach should allow us to define which overlap leads to the best standards for evaluation and hence permit us to propose the most appropriate expert panel composition for a collection of units of assessment. More generally, the matching of research expertise in several contexts might benefit from a comprehensive bibliometric approach.

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Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.joi.2015.07.009.

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