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# The dynamics of triads in aggregated journal–journal citation relations: Specialty developments at the above-journal level

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ABSTRACT

Dyads of journals—related by citations—can agglomerate into specialties through the mechanism of triadic closure. Using the Journal Citation Reports 2011, 2012, and 2013, we analyze triad formation as indicators of integration (specialty growth) and disintegration (restructuring). The strongest integration is found among the large journals that report on studies in different scientific specialties, such as *PLoS ONE*, *Nature Communications*, *Nature*, and *Science*. This tendency toward large-scale integration has not yet stabilized. Using the Islands algorithm, we also distinguish 51 local maxima of integration. We zoom into the cited articles that carry the integration for: (i) a new development within high-energy physics and (ii) an emerging interface between the journals *Applied Mathematical Modeling* and the *International Journal of Advanced Manufacturing Technology*. In the first case, integration is brought about by a specific communication reaching across specialty boundaries, whereas in the second, the dyad of journals indicates an emerging interface between specialties. These results suggest that integration picks up substantive developments at the specialty level. An advantage of the bottom-up method is that no *ex ante* classification of journals is assumed in the dynamic analysis.



## 1. Introduction

Scientific disciplines and specialties are difficult to delineate because their borders are diffuse and changing. Nevertheless, they are important to the study and evaluation of the sciences. For example, the citation impact of publications can be compared across subsets only after normalization, so evaluative bibliometrics requires the delineation of disciplines and specialties as reference sets for the normalization (Bornmann, Leydesdorff, & Mutz, 2013). Furthermore, the study of changing boundaries between disciplines and specialties can be expected to indicate scientific developments (Whitley, 1984). Assuming that a scientific specialty represents organization of the literature above the level of individual journals, in this study we address the question how journal–journal citation relations can be used to reveal the development of specialties within the sciences.

Clustering techniques, also known as community detection techniques, have usually been applied to networks of citations (e.g., White, Wellman, & Nazer, 2004) or to collaboration relations (e.g., Lambiotte & Panzarasa, 2009) in order to delineate scientific disciplines and specialties. Many clustering techniques have been developed both within and outside social network analysis (for an overview see, e.g., Fortunato, 2010; Newman, 2010; Wasserman & Faust, 1994). However, the different

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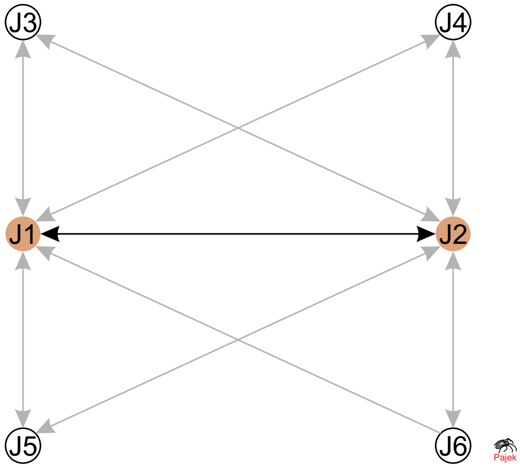


**Fig. 1.** Example: shared network neighbors of the journal pair {J1, J2}.

clustering algorithms and similarity criteria generate a parameter space (Ruiz-Castillo & Waltman, 2015). Different clustering solutions can thus be generated for the same network. Furthermore, clustering techniques often require parameter choices or a random seed *ex ante* that can be consequential for the results.

In the case of "big data," for example, one can search for local and global optima in this parameter space, but the results will predictably remain uncertain at the margins. The choice of one set of parameter values or another may lead to a fit (and perhaps potential validation) in some areas, but perhaps not in others (Leydesdorff & Rafols, 2011). Interdisciplinary developments can be expected to generate novelty at margins where the boundaries may then become unreliable (Rafols, Leydesdorff, O'Hare, Nightingale, & Stirling, 2012; Wagner et al., 2011). In sum, the data contain uncertainty and multivariate methods require choices of parameters.

Whereas the choice among different clustering solutions for the same network may already be difficult, the comparison of clustering solutions across years is truly a hard nut to crack (Leydesdorff & Schank, 2008; Studer & Chubin, 1980, pp. 269 ff; for a recent attempt to crack the nut, see Glänzel & Thijs, 2012). As we shall see below, for example, only a minority of citation links among journals in the Journal Citation Reports (JCR) appear in three consecutive years. As a consequence, the structure of the citation network can be expected to change considerably between subsequent years, which introduces a lot of variation in clustering outcomes even if the same clustering technique is used with the same parameter settings. Does the measurable change in comparisons between similar representations for different years indicate substantive change and development over time, or a difference in the error and uncertainty? Furthermore, clusters and journals are co-constitutive (Breiger, 1974): a cluster is identified by the journals it contains, so a change in the set of journals constituting a cluster also changes the nature of the cluster. What does it mean if a journal moves over to a different cluster (Rosvall & Bergstrom, 2010)?

Using a time-series of JCR data, we propose to abandon the focus on clustering the overall citation network and start analyzing local network structures, that is, journals in the context of the other journals with which they are directly linked. This approach resembles Cho et al.'s operationalization of research facilitation as increasing local network closure (Cho, Huy Hoang Nhat Do, Chandrasekaran, & Kan, 2013). Furthermore, we abandon the focus on clustering journals as nodes, and shall argue for studying the dynamics of citation links instead. The basic element of a network is a link, which is identified as a relation between a *pair* of nodes. In this study, we focus on pairs of journals (cf. Klavans, Persson, & Boyack, 2009) that are citing each other. We call this a mutual (citation) link and we restrict our analyses to this type of link.

For each pair, one can determine the density of its local network context. This can be done in several ways, but in this exploration we simply count the number of shared network neighbors of each pair. A pair of journals has a shared neighbor in the citation network if there is a third journal that they both cite and by which they are both cited. Fig. 1, for example, shows the shared neighbors of the journal pair {J1, J2}: J3, J4, and J5 are mutually related to both J1 and J2. Journal J6, however, does not have a reciprocal citation link with journal J1, so it is not counted in this study as a common neighbor to journals J1 and J2. The journal pair {J1, J2} has three shared network neighbors. Each shared neighbor creates a complete or closed triad with this journal pair.

Already in the 1960s, social network analysts realized that two people tend to establish a direct relation more frequently if they share a network neighbor (Foster, Rapoport, & Orwant, 1963). This effect became known as the transitivity of social relations and as triadic closure, which generates a clustering of cohesive subgroups or communities at the level of the overall network (e.g., Bianconi, Darst, Iacovacci, & Fortunato, 2014; Frank & Harary, 1982). If we follow the argument that clusters at the overall network level result from local network closure, we may use triadic closure as a measure of cohesion and thus avoid the potentially problematic delineation of communities at the level of the overall network.