Analysis of Roll-Calls in the European Parliament by Multiple Partitioning of Multiplex Signed Networks

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In a *signed graph*, each link is associated to a sign, which can be either positive (+) or negative (−). This type of graph can be used to model any system containing two types of antithetical relationships (like/dislike, for/against, similar/different...). A signed graph is considered *structurally balanced* if it can be partitioned into two [1] or more [2] clusters, such that positive links are located inside the clusters, and negatives ones are in-between them.

However, it is very rare for a real-world network to have a perfectly balanced structure: the question is how to quantify its imbalance. Various measures have been defined for this purpose, the simplest consisting in counting the numbers of misplaced links, i.e. positive ones located inside the groups, and negative ones located between them [1]. Such measures are expressed relatively to a graph partition, so processing the graph balance amounts to identifying the partition corresponding to the lowest imbalance measure. In other words, calculating the graph balance can be formulated as an optimization problem.

Our goal is to use this paradigm to study the roll-call voting activity of the Members of the European Parliament (MEPs). We want not only to detect groups of MEPs which would be cohesive in terms of votes, but also to identify the different characteristic polarizations of the European Parliament (EP), i.e. the characteristic ways in which the MEP set is partitioned by these votes. The standard approach to study this type of system is to extract a vote similarity network, in which nodes represent MEPs and weighted (possibly signed) links represent the similarity between two MEPs, averaged over the series of roll-calls (e.g. [3, 4]). However, this averaging leads to some information loss due to the temporal integration performed on the raw data [5].

In this work, we propose to adopt an approach based on a multiplex signed vote similarity network, in which each layer models a single roll-call as a signed unweighted graph. The literature contains 3 main approaches to partition multiplex graphs in general: 1) merge the

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layers and apply a traditional partitioning method to the resulting aggregated graph; 2) apply a traditional method separately to each layer and merge the resulting partitions; and 3) use a method specifically designed for multilayer graphs, which partitions the set of all nodes (over all layers). All 3 approaches are based on the assumption that one is looking for a *single* partition.

However, this single-partition assumption is not compatible with all our objectives. Indeed, we look for the *different* characteristic polarizations of the EP, so we want our method to be able to identify *several* partitions. To this aim, we propose a new partitioning process for multiplex signed graphs, which is three-stepped. First, we separately partition each layer, through a standard signed graph partitioning method. Second, we compute the similarity between all pairs of the resulting partitions, and perform a standard cluster analysis in order to identify clusters of similar partitions. Third, we process a characteristic partition for each cluster by solving a signed graph optimization problem.

We show the interest of our approach by applying it to a subset of the 7$^{\text{th}}$ term European Parliament dataset presented in our previous work [5] for France and Italy. It allows identifying groups of cohesive voters, but also their different characteristic voting polarizations, as well as the legislative propositions to which they apply. There is a limited number of voting polarizations for a given roll-call: either *unanimity* (all MEPs vote similarly) or *antagonism* (two opposed groups), with the possibility of an additional *abstention* group. Based on our results, we show that antagonistic situations are not stable and depend on the topic at hand. We also uncovered some points overlooked by [5]. For instance, it is noticeable that the presence of a relatively significant French G-EFA group (environmentalists) causes a strong polarization when voting agriculture-related documents including environmental aspects, whereas this is not the case for Italy, due to the complete absence of any G-EFA MEPs. However, we find that the apparent unanimity observed in the previous case is not always true, and that a strong polarization appears for a certain small subset of roll-calls. We also identify roll-calls or subtopics treated differently by the French and Italian MEPs. For instance, general questions related to the *Agricultural Structural Fund* generally lead to unanimous votes for both countries, whereas all texts related to the *Processing and Marketing of Agricultural Products* are treated unanimously by Italian MEPs, but not by French MEPs.

By comparison to existing approaches, our method has the following advantages. First, it undergoes much less of the information loss appearing when integrating the raw voting data to extract the voting similarity networks, since it treats separately each roll-call vote in the partitioning process. Second, in addition to antagonistic groups of voters, it allows identifying sets of legislative propositions causing the same polarization among these groups. This additional information can be leveraged by the end-user to better explain the observed outcomes. Third, unlike other methods, it does not require to filter out (quasi-)unanimous propositions, or to discard week links appearing in the model for interpretation or computational purposes. Fourth, it explicitly represents abstention in each roll-call vote layer, which allows detecting relevant groups of abstentionists.

Our method is generic and can be applied to any system with similar properties. For example, in the context of document/artwork classification, the opinion expressed by a selection of specialists can produce a set of polarizations, each one representing a variety of opinions regarding an item [6]. Our method could allow identifying clusters of items leading to similar expert polarization. It can also be used to group specialists sharing the same point of view on certain issues. In the near future, we will apply our method more systematically to the whole EP dataset. Also, we will perform a textual content analysis of the voted documents, in order to provide the information required to properly interpret the identified characteristic polarizations.

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