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This is a copy of the author's accepted version of a paper subsequently published in the proceedings of the IEEE Technology and Engineering Management Conference, Chicago, USA, 28 Jun - 01 Jul 2018.

The final published version will be available online at:

https://dx.doi.org/10.1109/TEMSCON.2018.8488386

Towards Team Formation Using Belbin Role Types and a Social Networks Analysis Approach

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***Abstract*—Problems relating to team formation is common across many industrial sectors, including education, sport and general business. For Team Leaders, team member selection can be a critical challenge due to the complexity in creating a well-balanced productive unit. It is beyond manual implementation to build near optimal teams as pools of employees grow. An essential requirement is teamwork skill, especially in engineering workgroups where the project member is expected to know how to collaborate with peers. In this paper, we use a social network analysis approach to represent social links between prospective team members and use the Belbin Team Roles as the main characteristic of prospective members. In our case study, based on an undergraduate computer engineering course, students expressed their preferences for working with three peers at the beginning of the course for an assessment. This information was used to distinguish groups within the social network using network analysis algorithms. We compared the network analysis results versus groups formed by a Teacher. Finally, we discuss the advantages and disadvantages of project teams, from a social network analysis approach, to making team formation recommendations into a socio-technical system.**

Keywords— Engineering Education; Group Formation; Social Network Analysis; Belbin Team Role Theory.

I. Introduction

Over time, industrial workplaces, such as manufacturing shop floors, have shifted from individual-oriented working environments to team-oriented workplaces. Despite often difficult decision-making tasks involving groups of individuals [1], teams have proven to have an inherent ability to solve complex problems that are confronted in workplace scenarios. In project management, it is essential that teams are formed coherently [2, 3]. Research shows that team formation is an ever-present problem and has been explored in a variety of business sectors [4, 5].

There are many methods that can be used to configure a professional groups to set up teams, but we would like each team to be qualified to develop proposed tasks successfully. One method is to create random groups but, by using this approach, some could become unproductive and fail. Another way is through voluntarily assignment of groups but the success of all cannot be assured. Other strategies exist, including those based on profiling, such as personality traits, learning styles, education background, reputation or information that we can match through clustering [5, 6, 7, 8].

One of the most critical theories regarding successful team dynamics is the Belbin Team Role taxonomy. These nine individual behavioral patterns (or roles) should be played by different team members to facilitate a successful, well-balanced team. In this research, we use Belbin role types and a social networks approach to analyze relationships between team members.

The social network describes the individual preferences used to find cultural traits, similarity or identify specific people in social systems. There are multiple studies that use metrics from social networks, such as network diameter, density, and centrality to form teams [4, 5, 9]. Network theory metrics can help us to establish a core to qualify the viability of teams. Different social and psychological theories have been explored using social network analysis approaches. The identified groups can express the local structures in the social system and could be used to propose teams that are socially convenient. In our case study of an undergraduate computer engineering course, students expressed their preferences for working with two peers at the beginning of their course. This information is used to distinguish groups within the social network using network analysis algorithms, combined with the empirical experience of the Teacher with the Belbin role types. Although at first, we were focused on community structures to describe the naturally formed groups, we tried to find triad structures as we are interested in exploring three members' team behavior. We compared the network analysis results versus groups formed by a teacher. The teacher combined network analysis and Belbin roles for determining the set teams. Finally, we discussed the advantages and disadvantages of project teams, from a social network analysis approach to make team formation recommendations into a socio-technical system.

II. Related Work

A. Belbin Team Role Types

Dr. Mertith Belbin proposed a model for classifying members of a team into nine role types, regarding their specialty and attitude towards team working. He presented a self-perception test to classify people or employees, in organizational settings [10]. Belbin's research recorded mental and personal abilities of group members and developed group role preferences with this information. He identified nine team role types: (1) Co-Ordinator (CO-coordinates and controls the activities of the team), (2) Resource Investigator (RI -

extrovert, makes outside contacts and develops ideas), (3) Teamworker (TW - person oriented, communicates well with others), (4) Plant (PL - creative and imaginative), (5) Monitor-Evaluator (ME - prudent and analytical), (6) Implementer (IM - practical and task oriented), (7) Completer–Finisher (CF - attentive to details, finishes tasks), (8) Shaper (SH - dynamic and challenging). A ninth team role type was added to this taxonomy at a later stage: (9) the Specialist (SP - with high technical skills and in-depth knowledge for the task); see [11, 12] for more information on Belbin team role types.

B. Team Formation

In [13], Katzenbach and Smith define a team as “a small number of people with complementary skills who are committed to a common purpose, performance goals and approach for which they hold themselves mutually accountable”. Haberyan [14] and others report that team-based learning has been recently utilized in science, education, business and medical education disciplines with positive results. For a Teacher, forming groups manually can be both challenging and time consuming. For this, researchers have investigated several techniques for automating this process through the use of Computer-Supported Group Formation (CSGF). However, existing tools often fail in allocating all students to groups, leaving some students unassigned to any group after the formation [7, 15]. In recent research, researchers have tried to form groups from different perspectives: the incorporation of social structures, through a mathematical framework [4], the use of self-organization mechanisms [16] and the use of artificial intelligence techniques [17, 18], among others.

C. Sociograms

Sociograms represent the social relationships within a group; nodes represent actors and edges represent relationships between them [19]. Sociograms were developed by Jacob L. Moreno to analyze choices or preferences within a group [20]. They can analyze several kinds of relationships, which can be obtained by asking questions, such as “Who would you choose as a workmate?” or “Who would you avoid working with?”. Specifically in education, [21] performed a study in a large city in China and showed how the low academic-level of students increased their performance when they were included in heterogeneous academic-level groups. In [22], they applied a Genetic Algorithm (GA) to group partners, based on the analysis of a social network, considering sociometrics for assessing the social statuses of students.

D. Social Network Analysis

Social Network Analysis (SNA) is a method for studying relationships between individuals or groups of individuals, while simultaneously studying the social context [23]. The value of SNA, as a research approach, is the ability to examine individuals who are embedded in a social structure and how social structures emerge from the relationships between individuals [24]. SNA, therefore, has the advantage of allowing researchers to measure both individual and socio-cultural influences on educational, psychological, economic and health outcomes [25].

Normally, relationships and friendships are established when there is a common interest, community or geographical location. To build a successful team for a certain project, many factors should be taken into consideration. In our work, we consider a social network that consists of people (nodes) and relationships (edges). An edge between two nodes means that two nodes are friends. Every node has a set of skills and the network is assumed to be composed of experts in their fields.

1. **Social Network Analysis using Communities**: Social creatures interact in diverse ways: forming groups, sending emails, sharing ideas and mating. In order to understand social interactions, it is crucial to identify these social structures or communities which are loosely defined as collections of individuals who interact frequently [26]. Communities often refer to groups or clusters and people or things in the same community, who often have more similarities. Community structure often reveals interesting properties shared by members, such as common hobbies, occupations, social functions or rank/status [27, 28]. A large quantity of approaches for detecting communities has been proposed over the years [29].

2. **Social Network Analysis using Triads**: A triad is a subgraph of three nodes and links between them. Triads can be composed of sixteen different triad types. The different Triads can be labeled according to the M-A-N scheme, where each type has a description of three to four digits that respectively represents the number of Mutual (M), Asymmetric (A) and Null (N) dyads [30] and the direction of ties among them. A mutual dyad refers to a two-way interaction where one user initiates the connection and the other reciprocates. An asymmetric dyad constitutes one-way interaction where a user initiates a connection to another user, which reciprocates. A Null dyad entails no interaction between the two users. When two triad types contain an equivalent number of dyads, the fourth digit is used to distinguish the direction of the ties: D for downward, U for upward, T for transitive and C for cyclic [31]. Fig. 1 classifies the 16 triad types according to the transitivity of their underlying relationships. We next describe the social theories linked to each of these triads.

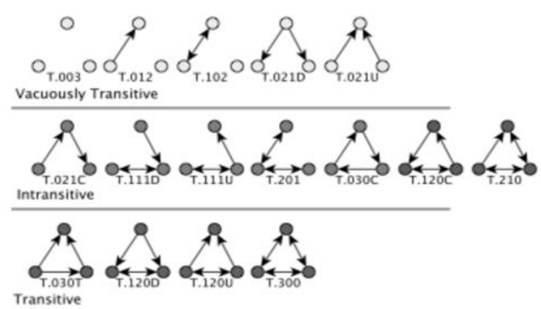

Fig. 1. The Vacuos, Intransitive and Transitive Triads.

- **Vacuously Transitive Triads - Egocentricity**

In these triads, the two asymmetric connections either point towards or away from the egocentric users. T.021D features an egocentric user who interacts with many others but does not receive reciprocal responses. T.021U, on the other hand, represents an egocentric user who receives attention from many others but, never reciprocates.

- **Intransitive Triads - Social Stature**

Intransitive triads typically emerge due to social effects that encourage users to interact with an intermediary, rather than establish a direct relationship. Such triads are uncomfortable and can be a source of distress to at least one other user [32] because they open opportunities for intermediary users to hide secret information and relationships. Consequently, intransitive structures represent three users who intentionally choose to withhold interactions.

- **Transitive Triads - Relationship Strength**

While the effect of social stature diminishes in transitive triads, the strength of relationship sculptures such interactions. Thus, transitive triads dominate networks in which users exhibit homophily, whether it occurs naturally and by choice. Accordingly, transitive triads are abundant in a network of close personal friends due to the existence of strong underlying relationships between them [33].

III. METHODOLOGY

Fig. 2 show the process adopted to form into teams. Project member preferences are represented by sociogram (the social network) and each team member has a corresponding Belbin role type. This information is then analyzed and used to infer a recommendation.

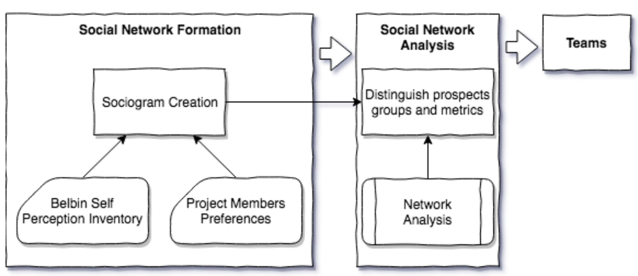

Fig. 2. Methodology for Work-Group Formation.

A. *Social Network Formation*

During this step, the aim is to create a social network. The social network has a set of nodes with links. The nodes can have different characteristics, while links represent different types of interactions (e.g. between friends, colleagues, advisors, collaborations, etc.).

- Belbin Self Perception Inventory

This study used the Belbin Self Perception Inventory to select the eight team roles. The role of 'specialist', in the nine-item questionnaire [34], is generally consistent with the education and professional profile of the respondents. The eight team roles used in the questionnaire were: Co-ordinator (CO), Resource-Investigator (RI), Teamworker (TW), Plant (PL), Monitor-Evaluator (ME), Implementer (IM) and Completer–Finisher (CF).

- Project Member Preferences

Project member preferences were captured by a questionnaire. The questionnaire poses questions about different kinds of relationships. For example, "Who would you choose as your workmate?" or "Who would you choose to avoid working with?"

- Sociogram Creation

The previous project member preference data was used to help a build a social network (Sociogram) where each node represented the participant of the study and each node had a respective Belbin role as an attribute of the node. The edges show the preferences found in the questionnaire. The weight of the edges is the preference level selected by the participant.

B. *Social Network Analysis*

In this step, information is processed using network analysis algorithms to identify prospective groups and obtain metric values.

- Network Analysis

Communities and triads algorithms are used to analyze the social network created in the previous step.

- Distinguish Prospective Groups and Metrics

Prospective groups and parameter values are identified.

IV. CASE STUDY

The case study consisted of a small group of students enrolled in an Advanced Object-Oriented Programming (AOOP) course at The Autonomous University of Baja California, Mexico. Data collection consisted of two questionnaires: (1) Belbin self-perception inventory and (2) preference test. The first questionnaire was divided into seven parts, each of which had eight sub-points. Respondents had unlimited time to split ten points into each of the seven parts. The sum of ten points were then assigned to either a single sub-point or distributed at the respondent's discretion. The second questionnaire consisted of one question: "Who would you choose as a workmate?"; the students chose two partners from the most important to the least.

Following this, the Teacher / Professor made a sociogram that represented the data collected. The sociogram was then analyzed with the help of the NetworkX and Community packages; both are Python language software packages. The main aim is to find communities within sociograms using the Louvain method. The purpose of the Louvain method is to extract the community structure of the networks, which is a heuristic method based on the optimization of modularity. This method is considered one of the best for detecting communities regarding computing time [35]. Once completed, the Professor takes each community found and searches the triads through the algorithm proposed in [36]. They then give more importance to the triads that show greater transitivity among its members. Each triad will be a team. Finally, the professor takes into account these triads and communities to make the final decision of which teams to form.

V. RESULTS

The results of the questionnaire are presented in Fig 3. In this sociogram, the size of each actor corresponds to the number of students the participant choses as possible members of their team. The colors of the ties represent the importance that each student gave to their choice (High=Black, Low=Gray). Each node has a label with the strongest Belbin role type that corresponds to it.

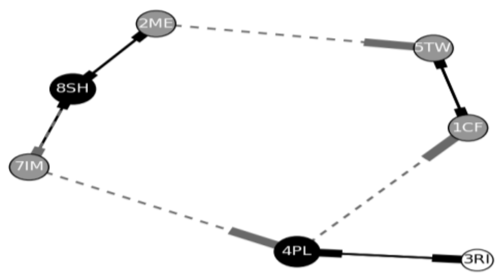

Fig. 3. Sociogram of advanced Object-Oriented Programming (AOOP) course that describes student preferences to work and Belbin Self Perception.

Fig 4 and Fig 5 show the teams found by social network analysis and the group formed by the Teacher. Each team is represented by different shapes. The results of the network analysis, with the groups formed by the Teacher, present little differences.

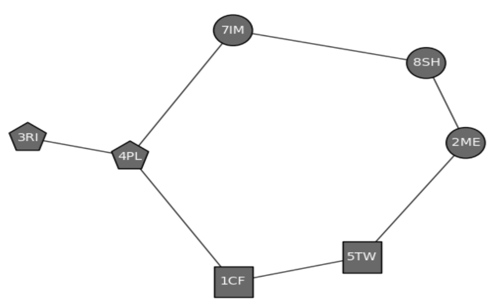

Fig. 4. Teams found using Social Network Analysis in the Sociogram of the Advanced Object-Oriented Programming (AOOP) course.

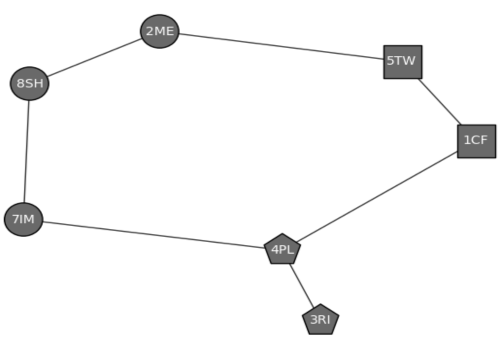

Fig. 5. Teams found using Social Network Analysis and Belbin Self Perception in the sociogram of the Advanced Object-Oriented Programming (AOOP) Course.

The algorithm used to search for communities focused on the structures of the network, looking for totally transitive triads (T-300). However, this does not take into account the characteristics of the node; in this case, the Belbin role types. The Teacher, based on the communities identified, can empirically adjust the teams, taking into account the Belbin role types. Table 1 shows a summary of the results obtained by the analysis of social networks and the adjustment of the Teacher taking into account his experience in Belbin theory. In this case study, a minimal difference was found, but this can mean a small number of people were surveyed.

TABLE I. TEAMS FORMED BY THE TEACHER AND SNS

Teams	SNA	Professor
A	1, 5	1, 5
B	2, 8	2, 7, 8
C	3, 4, 7	3, 4

Taking into account only the preference factor can cause closed and excluded groups that limit the union and creation of learning problems for this case study. The results of the Belbin questionnaire are presented in Table 2. As shown, the results are different among the teams. The underlined value represents the strength of the corresponding member team role.

TABLE II. RESULTS OF SURVEYS CONDUCTED ON STUDENT TEAMS

Teams	Mem	IM	CO	SH	PL	RI	ME	TW	CF	Grade
A	1	13	9	6	16	0	5	0	<u>**21**</u>	85
	5	11	7	9	5	5	8	<u>**13**</u>	10	
B	2	9	5	5	15	4	<u>**16**</u>	12	4	100
	7	<u>**18**</u>	6	10	7	0	9	13	7	
	8	10	6	<u>**31**</u>	3	6	2	1	11	
C	3	6	11	12	12	<u>**16**</u>	3	9	1	85
	4	10	15	9	<u>**20**</u>	1	5	9	3	

VI. DISCUSSION

The case study reported on in this paper of the Teacher and class Workgroups served to exemplify the need to form teams with different perspectives, taking into account the preferences of prospective members (structure of the network), and its characteristics (Belbin role types, psychological roles, etc.). Whether using the communities (SNA) or a hybrid between the search for communities and the empirical knowledge of the teacher taking into account Belbin theory. The advantage of the Teacher using SNA as a tool for the selection of equipment is that the Professor is provided with more information to make better informed decisions. He knew the priorities in the preferences and the member characteristics (Belbin's role). He used this information to create teams starting from the most influential relationships (cohesion) and most affinity (similarity characteristics). With this experience, we can assume that SNA may help form better teams. We can also presume that by using several methods, we could improve the formation of groups and provide a better recommendation, closer to our experience with the Teacher's decision.

The creation of teams is required in many business situations. We want to make the best recommendations for each particular case. Many socio-technical systems require the creation of working groups [37]. For example, a support system for courses, such as Blackboard, where the teacher can create teamwork using built-in tools.

It could also improve the training of programmer teams in support systems for software development e.g., SCRUM teams [38, 39]. An advantage in automating this process is that the stakeholders can form groups in a standardized way. However, one disadvantage is that it will be difficult to guarantee the success of the project because human behavior is complex and will remain a challenge to predict. Even so, recommending how to form groups can be of great help, as it can eliminate the inclination of the planner towards one individual or group of people and try to benefit them at a disadvantage from others. Furthermore, algorithms could be included in simulators, which try to predict the best equipment and its behavior, taking into account the previous relationships between team members' (positive and negative relationships).

VII. Conclusion

In this paper, we used sociograms to represent social links between students on a Advanced Object-Oriented Programming Course at The Autonomous University of Baja California, Mexico. In our case study, each student expressed their preferences for working with one other and this information was used to detect communities and triads within the social network, using network analysis algorithms. The Professor, taking into account these triads and communities, was able to make the final decision of which teams to form. The teacher, according to his experience, could adjust the equipment according to the Belbin theory. We then compared the network analysis results versus groups formed by a teacher in a real course. This comparison showed that we need to improve the creation of teams so that they perform better in future. Future work should include the exploration of other techniques of community discovery. It is also necessary to explore other metrics, not only the preferences of the students, to create realistic models of how students are grouped and behave. Furthermore, we will conduct new studies in companies where the formation of work teams is essential, such as in software development, manufacturing, etc.

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