Computer Supported Team Formation

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Abstract. Composing teams may be a time consuming and complex task. In any type of teams, the adequate selection of individuals to a team may increase the intellectual growth of the team in order to cooperate and reach the established goals. However, success of the composed team is not always guaranteed. To fill this gap, researchers develop different tools aiming to help team makers to assign team members to teams, in order to satisfy their expectations. The main goal of this paper is to present a literature review on team formation methodologies, tools, and applications that have been implemented. In this paper we present an analysis of what are teams, and its social structure. Next, a literature review and the efforts of computer supported team formation are presented and finally, the efforts of the researchers to achieve the optimal result are discussed.

Keywords: Team · Team composition · Computer supported team formation
Team formation methodologies/tools

1 Introduction

Team formation is crucial because team success depends largely on the appropriate assignment of team members to teams. Thus, it is important for an effective technique to be applied, so that optimal team composition can be ensured. The fact is that all teams are neither identical nor working by following the same procedures like size, purpose, and common characteristics. Distinctions between species, size, types, styles of the teams, etc. are found. Moreover, some variables such as communication skills, experience in teamwork, personality traits, are criteria that affect team effectiveness as well [1–3].

Researchers from different disciplines, using multiple data, attempt to develop tools, techniques and methodologies in order to facilitate the process of a successful team composition. Different goals, various teaming criteria and technologies make the task hard and complicated. Computer supported team formation offers an increasing range of tools and practices that increase the probability of generating an ideal team.

2 Team Formation

Team is the primary component of the social structure, which refers to a set of people, who are very close together, for a short or long time, in order to meet basic common

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goals. Occasionally, investigators defined team, depending on the goal of their research and science. Many definitions have been developed, some of which are:

Lewin defines group as “a dynamic whole based on interdependence rather than similarity” [2]. Bales define team as “any number of persons engaged in interaction with one another in a single face-to-face meeting or series of such meetings” [3]. Sherif incorporates in his definition the concept of structure “a social unit which consists of a number of individuals who stand in “more or less” definite status and role relationships to one another and which possesses a set of values or norms of its own regulating the behavior of individual members, at least in matters of consequence to the group” [4].

Francis and Young define team as “an energetic team of people dedicated to achieving common goal/s, collaborating successfully by producing high-quality results, and by drawing pleasure from it” [5]. MacGrath emphasizes interrelations and defines team as “an aggregation of two or more people who are to some degree in dynamic interrelation with one another” [6]. Adair adds the responsibility of the team members [7], and Larson and LaFasto point to the coordination of its members’ activities as a necessary feature of the team, to achieve the goal [8]. Katzenbach and Smith refer to team as a small number of people with complementary skills - skills that are dedicated to a common purpose, a set of performance objectives and an approach for which are mutually responsible [9]. Mankin et al. add to team definition the element of interdependence of people’s activities, while the work of each member is dependent on the work of other members [10].

Keyton focuses on shared tasks and goals defining team as “three or more people who work together interdependently on an agreement upon an activity or goal”, while Gould defines team as “individuals who stand in certain relations to each other, for example, as sharing a common purpose or having a common intentionality, or acting together, or at least having a common interest” [11].

Goal is the central component around which a team is formed. Consequently, the formation of each team differs from another in size, type, specific features, etc.

Definitions are numerous, according to each researcher’s study, and the general characteristics of the team that is related to his work.

3 Social Structure Formation

Teams, according to the specific characteristics such as the purpose, composition, duration, etc. are classified into categories and described by different social structure. Basically, the social structure types are:

Teams: Teams are a set of individuals planned to collaborate together on a well-defined task. A team is task-oriented and limited by the scope of its goal. It expands from a pair to as large as needed. Its structure depends on the purpose of the task.

Specific-Task Team (or **Knot**), is a short period of time limited team convened to accomplish a critical goal (i.e. chat groups, online with video to collaborate for a specific topic, etc.). For Engeström [12]: ‘The notion of knot refers to rapidly pulsating, distributed, and partially improvised orchestration of collaborative performance between otherwise loosely connected actors and activity systems. Knot working is characterized by a movement of tying, untying and retying together seemingly separate threads of activity".

Networks: There are two common sorts of networks. **Intentional Networks** (IN): informal, with low degree of cohesion, no need to be aware of each other. Network coordinator manages all communication needed. Members are task focused and collaborate to carry out a specific task [13]. **Social Networks** (SN): A social network is "a set of people (or organizations or other social entities) connected by a set of social relationships, such as friendship, co-working or information exchange." [14].

Communities: Which are divided into: **Communities of Practice:** "CoP are groups of people who share a concern, a set of problems, or a passion about a topic, and who deepen their knowledge and expertise in this area by interacting on an ongoing basis" [15]. Members of the CoP have meetings because they want to, whenever they want to, discussing, sharing aspirations, helping each other to solve problems, developing practices, personal relationships, etc. **Virtual Communities:** Virtual communities are: "an aggregation of individuals or business partners who interact around a shared interest, where the interaction is at least partially supported and/or mediated by technology and guided by some protocols or norms [16], "community of people sharing common interests, ideas, and feelings over the Internet or other collaborative networks". Rheingold [17] defines virtual communities as "social aggregations that emerge from the Internet when enough people carry on public discussions long enough and with sufficient human feeling to form webs of personal relationships in cyberspace. A virtual community is a group of people who may or may not meet one another face to face, and who exchange words and ideas through the mediation of computer bulletin boards and networks'.

4 Team Member Characteristics

Team work is a necessary prerequisite for constructive completion of many projects. Successful team composition has become the point of focus of many studies that attempt to identify all the factors that are needed in order to compose the optimal functional team. However, it is generally accepted that it is not always possible to compose a successful team. The existence of many criteria and the complexity of their combination is a time consuming procedure, and frequently the creation of functional teams is not guaranteed.

Generally, to compose a successful team, it's crucial to consider many characteristics of team members, since every team has its special characteristics (goal, subject-matters, member's motivation, etc.). It is acknowledged that regardless of knowledge and expertise, many fundamental criteria of team members are necessary to be taken into consideration for team assignment, such as collaboration, communication skills, teamwork capability, experience [18], and flexibility.

Also, while interaction between team members is occurring, personal characteristics have to be considered as well. For a high functional teamwork, in the process of recruiting appropriate (suitable) members for a certain project, a combination of the following characteristics must be considered: interdependence, open communication, positive feedback, and commitment to team success, shared goals, interpersonal skills, functional expertise, interests, and personality traits [18, 19]. Researchers, usually, do not study all the characteristics at the same time, but a combination of them. In literature, communication is most often referred to, as the key component for building a successful team. Two aspects of communication barriers are highlighted: communication networks established in teams and difficulties encountered by team members in communicating with each other.

According to Blackwell [19], the main characteristics of a team, are communication skills, motivation through job assignment, expertise in individual specialty areas, personal attributes, and performance. He also argues that communication error is a central problem for team designing. Campion et al. [20], Taylor [21] refers also to communication, expertise, and flexibility in job assignments. Allen [22] cites that many studies indicate the positive impact of communication to project performance. For team designing MacDonald [23] included communication among the characteristics of leadership, coordination, cohesiveness, conflict, team age, and size.

For an effective team, mature communication was referred by Sundstrom et al. [24] among factors such as personality traits, organizational structure, culture, experience, and group stability over time. Prince et al. [25] identified communication as one of the skills of team process behaviours. The other is leadership, situation awareness, assertiveness, decision-making, mission analysis, and adaptability/flexibility.

Prasad [26] points out that an ineffective communication environment reduces the project team performance constraining the communication channels for idea exchanges across organizational lines. Smart and Barnum [27] stated that poor or inadequate communication often lead teams to failure. From the same point of view, Safoutin and Thurston [28] emphasized to the importance of communication in team designing, while communication errors, at key decision points, cause a great number of failures. Pawar and Sharifi [29] argue that team performance is improved when team members with adequate communication skills impel agreement between team members. For Lappas et al. [18] expert knowledge is considered in relation with communication, collaboration and team working skills.

Other characteristics such as team size, demographic, abilities (i.e. cognitive ability) have been also investigated by researchers with conflicting (positive, negative or none) correlation results to team effectiveness. In summary and to most researchers five important characteristics of team members, contribute to a successful team formation which are: Functional expertise, teamwork experience, communication skill, Flexibility and personality traits.

5 Computer Supported Team Formation Existing Applications

Adequate team composition meets difficulties during the design of a team, while forming successful teams is a complex task. Using many variables may create constraints that require complex correlations. Methods for team formation implement formal and human-oriented tasks. In formal tasks, efforts have been made to help team makers using computer science.

Computer supported tools are of great value for decision makers for team composition. Researchers focus on investigating techniques for automating team formation with computer supported techniques. These techniques vary according to team characteristics that are taken into consideration.

Mainly, most applications developed, concern the field of learning. Cruz and Isotani [30] overviewed team formation in collaborative Learning with computer support. Based on their algorithm or methodologies they used we classify them into three categories.

5.1 Multi-agent, Agent Based Algorithms

Opportunistic Group Formation was an idea of Ikeda et al. [31]. Opportunistic Group Formation is the procedure of forming, dynamically, a collaborative learning group. When the system detects that it's the right time for a learner to change to collaborative learning mode from individual mode, it forms a learning group. Each member of this learning group "is assigned a reasonable learning goal and a social role which are consistent with the goal for the whole group". The OGF system concentrates to form a learning group by negotiating with all learners' agents, taking into account individual goals, as well. When the system comes to an agreement, a learning group is formed.

I-MINDS: Soh et al. [32] worked on a computer-supported cooperative learning system in education. They developed an infrastructure called the Intelligent Multi-agent Infrastructure for Distributed Systems in Education. I-MINDS consist of three different intelligent agents: teacher, group, and student agent/s. A teacher agent, interacting with a teacher, is responsible for disseminating information streams to student agents, maintaining profiles for all students, assessing the progress and participation of different students, ranking and filtering of the questions asked by the students, and managing the progress of a classroom session. A student agent, on the other hand, mainly works as a personal helper to a specific student. The student agent, also, presents the learning material to the student and forms coalitions with other students for collaborative learning. A group agent forms and conducts structured cooperative learning such as the Jigsaw model [33]. The model monitors and facilitates group activities. These three agents cooperate to support student-student and student-instructor interaction in a typical classroom, in the distance education setting. Results in I-MINDS evaluation have shown that "the system can be used in a real time environment to support student cooperative activities.

Maghami and Sukthankar [34] introduced an agent-based simulation for examining the effects of stereotypes on task-oriented group formation and network evolution. They demonstrate that stereotype value judgments can have a negative impact on task performance, even in the mild case when the agents' willingness and ability to cooperate is not impaired. By modifying the social network from which groups are formed in a systematically suboptimal way, the stereotype-driven agents eliminate the skill diversity required for successful groups by driving the network toward specific topological configurations that are ill-suited for the task. Their results showed that making connections with agents solely based on group membership yields a sparser network with many isolated nodes.

5.2 Heuristic Algorithms

CATME is a peer evaluation system. It's an online free tool that helps instructors to form student teams and to evaluate individual performance within those teams (through peer evaluation) distribution, the particular system analyzes given data by students through a web interface, in order to facilitate grade adjustments for an equal among team members. Layton et al. [35] estimate that Team-Maker Comprehensive Assessment of Team-Member Effectiveness is a strong support system for team-based and cooperative learning and for a variety of research purposes and they suggest a combined use of them.

Graf and Bekele [36] suggested a mathematical approach for heterogeneous groups taking into account the students' personality traits, and their performance on the domain. They used an Ant Colony Optimization algorithm aiming to assign each student to the appropriate team, maximizing the diversity of the team, while at the same minimizing the deviation between the groups to minimum, in order to maximize the heterogeneity of teams formed.

DIANA: Suggested by Wang et al. [37] is a computer-supported heterogeneous grouping system that uses genetic algorithms to achieve fairness, equity, flexibility, and easy implementation. The system uses student's characteristics, to form heterogeneous groups, from 3 to 7 members, trying also to avoid the creation of exceptionally weak teams. Overall, DIANA results indicate that teams: (a) performed better than the randomly assigned groups and (b) showed less inter-group performance variance.

FROG: Craig et al. [38] using an evolutionary algorithm, suggested a mathematical model for homogeneous and heterogeneous groups in education aiming to optimize group forming. Group formation criteria, fitness measures and a set of attribute types were defined according to teachers' criteria. These refer to attributes of the students, such as GPA, sex, or timetable.

OmadoGenesis by Gogoulou et al. [39] addresses to homogeneous, heterogeneous, and mixed group formation. It relies on student's characteristics. The system implements three types of algorithms: Genetic algorithms for mixed group formation, Homo-A, and Hete-A for homogeneous and heterogeneous group formation accordingly. Groups may be also formed either manually by the teachers or randomly. The genetic algorithm and Homo-A have similar performance for homogeneous teams, while Hete-A yields better solutions than the genetic algorithm for heterogeneous groups. For mixed groups, the genetic algorithm gives better solution.

Wi et al. [40] used a genetic algorithm and social network measures in order to select a team manager and team members to form a new team in enterprising institutions. They presented a framework for analysing the knowledge and collaboration of the candidates for managers and team members. They tested the feasibility of the model. Their results ensured their suggestion as a quantitative and systematic method that can help enterprising institutions to assign the personnel for appropriate teams.

Spoelstra et al. [41] aiming to determine a fit-value for a team of learners for a specific project, suggested an automated team formation process model for use in Social Learning Networks contexts. Self-directed learners using the model (that contains the variables: knowledge, preferences and personality) form teams for project-based learning.

5.3 Fuzzy Algorithm

Strnad and Guid [42] proposed a fuzzy-genetic algorithm for the problem of project team formation by using previous quantitative data with several modelling enhancements like derivation of personal attributes, complex attributes models and handling unnecessary over competency. Their result makes up shortages of previous models, while providing the benefit of using intelligent team management system.

Christodoulopoulos et al. [43] proposed a web-based group formation tool, which, helps the instructor to automatically structure homogeneous groups using Fuzzy C-means and heterogeneous groups which are structured by Random Selection algorithm. The tool is based on up to three criteria. In grouping process, clustering algorithm informs the student about the probability of belonging to any group. Same information is also provided to the instructor. That facilitates him/her to adjust the formation manually. The tool was evaluated with only one criterion in a number of 18 groups. Evaluation results gave efficient satisfaction.

Torres et al. [44] proposed a fuzzy-based Multi-Agent Model for team formation based on nine roles defined by Belbin typology using the strengths and ideal responsibilities for each team member role. To better balance different working teams based on existing roles by applying a fuzzy logic approach that allows classifying the role performance of each individual into the team. The team algorithm performed by team-formation agent allowed them having teams of similar performance where each student can offer their best abilities and skills according to the role-played and demonstrate the effectiveness of integrating fuzzy-based approach with MAS to team formation.

5.4 Other Computational Techniques

Expert Finder: Vivacqua and Lieberman [45] presented, a user-interface agent, often used in recommender systems. Expert Finder offers matchmaking services generating automatically user models. The system, uses Java programming, helps a novice to find an answer to a difficult question. Expert Finder classifies novice and expert knowledge, and analyses documents developed in the course of routine work. The agent automatically match-make the novice and the expert.

MATEO (Making Adapted Teams Oriented to collaboration): is a generic system that supports adaption team forming. Adapted is the term for a team that is formed by selected individuals, according to their collaboration skills, their personal profiles and team needs [46]. The system takes into account physical context information, such as team member location, infrastructure, etc. and other resources. MATEO can adequately assign team members, based on their competencies and behaviors. Moreover, MATEO assists the person in charge of forming teams, by automating part of the team-formation process.

De Faria et al. [47] in an “Introductory Computer Programming” describes and evaluates an approach for constructing groups for collaborative learning of computer programming. Groups are formed based on students’ programming styles. The style of a program is characterized by simple well known metrics, including length of identifiers, size and number of modules and numbers of indented, commented and blank lines. The experiments showed that collaborative learning was very effective for improving the programming style, particularly for students that worked in heterogeneous groups.

Tobar and Freitas [48] suggested a rule-based assignment tool, in order to reduce the time consuming procedure for teachers in group formation for learning. It is based on students' IMS learner information package (IMS LIP) specification [49]. It relies on students' characteristics. The instructor defines the rule according to his/her preferences for a team. Information is manually adjusted by the instructor, if needed.

Isotani et al. [50] suggested an ontology to be used as a framework, in order to facilitate group formation and collaborative learning design. The authors used the ontology, combining theory driven group formation with collaborative activities. An interface offers to the users the possibility to identify intended goals, roles, etc. The system recommends, automatically, team members and activities need to be performed, in order to fulfil team's goals. In order to validate system's usefulness, four instructors and twenty participants carried out the ontology. By using the ontological framework, the design of team activities was better, and had a positive effect on the performance of individuals during group learning.

Project Group Assignment System by Doyle et al. [51] describes a Web-based interactive system for creating teams for project work in industry or academia. The system allows project team members and managers to use a Web interface to enter projects and preference information into a database, and then allows the project manager to execute an algorithm that composes the teams. Teams are formed based on student preferences of projects (i.e. experience, location, time, etc.).

Pollalis and Mavrommatis [52] adopted methods from Group Technology derived from Group Technology (users and learning objects) and proposed a model for distance learning environments. Their system is based on an algorithmic approach that simultaneously selects appropriate learning objects to form a corresponding educational package for each group, by assuring optimal value of user's learning.

Ounnas et al. [53] proposed a semantic web technology system companying logic programming to form learner groups, using ontologies based on Friend of a Friend (FOAF) ontology. Specifically, they extended FOAF aiming to give semantic data about the learner's profile. In this case, every learner completes his own data at any time. The proposed framework handles the group formation process based on modelling the student's features, negotiating the group formation by the student's allocation problem as a Constraint Satisfaction Problem.

Babkin et al. [54] developed an evolvable web-based semantic platform called Info Port for research team formation, using four types of ontologies: organizational, ontology of scientific areas, historical and personal. In personal ontology they included professional knowledge of the researchers, articles, competencies and skills. They classified information about researchers considering three parameters: researcher as a person, researcher as a skillful agent and researcher as a team member.

Balmaceda et al. [55] suggested an intelligent assistant agent to form collaborative groups based on psychological styles, team roles and social relationships that may affect the team's performance. The psychological styles are those proposed by Myers-Briggs (extroversion/introversion, sensing/intuitive, thinker/sentimental, judgment/perception). The proposed WCSP approach was able to combine constraints and preferences both for individuals and groups.

Table 1. Listing CSTF tools/algorithms.

Ref. num.	Primary goal	Solution approach	Grouping criteria
[38]	Define an expressive, general model that provides more control over the criteria and attributes on that are used	Evolutionary algorithm	Numeric, one-of-bin, many-of-bin, both bin types, timetable
[40]	Selection of project managers and team members	Fuzzy/genetic algorithm	Knowledge, social network measurement
[41]	Provide team formation services to individual, self-directed learners in a social learning network	Fitness algorithm	Knowledge, personality, preferences
[42]	A new fuzzy-genetic analytical model for the problem of team formation	Fuzzy-genetic algorithm	(Fuzzy modeling of) skills
[44]	A fuzzy-based multi-agent model for team formation based on 9 roles defined by Belbin	Fuzzy, multi-agent model	9 roles defined by Belbin typology
[46]	Creation of an adaptive team. Based on personal characteristics and collaboration capabilities	Grouping algorithm	Personal characteristics, collaboration capabilities
[50]	Present an ontology that works as a framework that facilitate team formation and collaboration learning	Ontology framework based on learning theories	Individual/team goals, learning strategies/ behavior, knowledge/skill etc.
[54]	Information modeling and software design in the domain of research team formation	Semantic modeling	Research work, skills

6 Discussion and Conclusions

Even though successful team formation does not always guarantee successful research outcome, it's the cornerstone on which a successful team effort can be built. The advantages of collaborative teams are many and benefit both the research area and the individuals as well. Computer supported team formation is developed by researchers aiming to succeed the best. In this paper we presented a literature review of many approaches in the field of Computer Supported Team Formation. One of our major conclusions indicates that, few applications evaluate communication impact as a factor during the formation of the team/s, and in almost none of the existing applications communication is considered as a variable.

Furthermore, few applications indicate the importance of the factors knowledge/skills and personality in the team formation process. This may be due to the difficulty to establish one's personality and outline the knowledge or skill that is possessed. Nevertheless, in recent years, emphasis has been placed on features such as personality, knowledge, skill, trust, motivation and others, which play a major role in team performance.

In addition, most systems model a few and a fixed set of parameters, mostly 3-7, which limits the types and the diversity of teams, knowledge domain, learning goals, performance in previous teamwork, specific expertise, preferred time slots, preferred projects, performance and personality traits which are often used as team formation variables. This may be due to the fact that, by increasing the set of parameters it would hinder the selection of the most suitable person to the team and it would require a more complex algorithm/framework.

Although many systems ensure satisfaction to users through negotiation, none of them discuss the efficiency of the negotiation when all members are teamed simultaneously over and above these systems which are based on self-selecting team formation models, thus limiting the efficiency approach in forming teams.

Additionally most systems fail to assign a person/user to a team when handling limited or incomplete data and in some tools not all persons/users are assigned to team/s at the end of the formation, instead these persons/users are assigned manually to some teams by swapping other persons/users which decreases the efficiency in automated formation.

However, few solutions or work are useable, and most of them are used in traditional learning settings (classroom). Also many of the proposed approaches have been tested, but especially to validate the effectiveness of algorithm rather than evaluating the effects on the performance of the team that was formed. In addition and to the best of our knowledge, only few papers conducted peer evaluation after assigning individuals to teams, but almost none of them noted any problem/s that may have arisen from the beginning of the project till the completion.

Finally, almost none of the applications revealed a success rate on completing individuals/team tasks in time and none explain what team/s did, what knowledge resources were produced and how they were applied to obtain results. Nevertheless in the last years, the current perspectives for computer supported team formation and its relationship to intelligent systems augur the emergence of new approaches to the formation of groups which will take into account other parameters such as motivation, emotion, intuition etc.

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