International Journal of Computing and Digital Systems
2024, VOL. 17, NO. 1, 1–10

http://dx.doi.org/10.12785/ijcds/XXXXXX

Exploring the Role of Software Team Leader in Socio-Technical Networks

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Received 12 March 2024, Revised 15 June 2024, Accepted 10 July 2024

Abstract: Effective teamwork is a critical factor in the success of software development projects, where technical expertise must be complemented by collaborative skills. This study explores the role of software team leads within socio-technical networks, investigating how their social network and interactions shape software project teams. Drawing from the growing recognition of social structure's pivotal role in teamwork, the study incorporates concepts from social network analysis, such as centrality, centralization, and network density, to understand their impact on work satisfaction, performance, and power within teams. The research methodology employs an experimental approach within a university setting, involving 60 participants from software engineering courses. Participants are asked to list preferred team members and desired roles (i.e., team leader or programmer), with complex network techniques used to analyze these preferences. The study's findings are expected to contribute to both academia and industry. In academia, the insights gained can inform curriculum development to better prepare students for real-world software development teamwork. In industry, a deeper understanding of effective team leadership dynamics can potentially enhance the outcomes of software development projects. By shedding light on the intricate interplay between technical skills, social interactions, and leadership qualities, this research aims to advance effective teamwork in software engineering contexts.

Keywords: Software teams, team leader, Socio-networks, software engineering

1. INTRODUCTION

In software development, the success of a project hinges not only on the technical skills of the team but also on the social dynamics that influence collaboration, communication, and decision-making. Socio-technical networks provide a framework for understanding how both technical expertise and social interactions come together to impact project outcomes [1], [2]. In these networks, team members rely on their technical abilities to solve complex problems while leveraging interpersonal relationships to facilitate teamwork, knowledge sharing, and conflict resolution. The interplay between these two dimensions—social and technical—forms the backbone of successful software development. Effective leaders in socio-technical networks foster environments where both collaboration and technical proficiency thrive. By understanding and optimizing these networks, project managers can enhance productivity, improve team cohesion, and ultimately drive better project outcomes. This emphasis on socio-technical factors becomes especially crucial as teams grow in size, complexity, and diversity, highlighting the need for leadership that balances technical competence with social influence. Recent studies have highlighted a concerning reality: the success rate of software development projects is as low as 6 [1]. Previous research has attributed this low success rate to various factors, with software development team composition being a significant contributor. To address this issue, past studies have recommended that the soft (non-technical) skills of team members should be given equal consideration alongside their hard (technical) skills [2]. Collaborative teamwork is not only an educational imperative but a reflection of real-world industry practices [3], [4]. The success of software projects often hinges not only on technical expertise but also on effective collaboration, communication, and leadership within teams [5]. As such, understanding the dynamics of team roles, particularly that of the software team lead, is essential for achieving successful project outcomes [6]. The software development process is inherently complex,

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requiring the integration of technical components and the coordination of diverse talents [7], [8]. However, the effectiveness of software teams is not solely determined by technical skills but also by the ability of team members to work together towards a common goal [1], [9]. This socio-technical aspect of software development emphasizes the importance of considering both technical and social parameters for project success [10]. In this context, the role of the software team lead emerges as a critical factor. Team leads are not only responsible for technical guidance but also for fostering a collaborative and productive team environment. Their ability to effectively communicate, lead, and resolve conflicts can significantly impact the success of a software project [11]. This research study aims to explore deeper into the role of the software team lead within socio-technical networks. By exploring the interactions between technical and social parameters within software development teams, this study seeks to identify the qualities and characteristics that define effective team leadership [12]. The findings of this study are expected to contribute to both academia and industry. Educators can use the insights gained to refine their curricula and better prepare students for the realities of software development teamwork. Likewise, industry professionals can benefit from a deeper understanding of the dynamics of effective team leadership, potentially improving the outcomes of their software development projects [13], [14], [15] . The next section has reviewed related studies in the field before presenting the methods employed in this study. Subsequently, the results are presented, followed by a detailed discussion of their implications. Finally, the study concludes by summarizing the findings and discussing avenues for future research.

2. RELATED WORK

Social structure plays a crucial role in teamwork, as recognized by scholars in recent years [16]. Concepts from social network analysis, such as centrality, centralization, and network density, have been expanded to encompass elements like work satisfaction, performance, and power [17]. According to Yang and Tang [18], network factors influence various aspects such as job-related perceptions and performance, academic performance and learning attitudes, intergroup conflict, and individual performance. Consequently, social structural properties play a significant role in both individual and group performance, potentially impacting the outcomes of a software development team.

Analyzing the social network of a software development team can provide valuable insights into its dynamics and the underlying relationships among team members. Previous studies have sought to identify the success factors for team performance in software development. Researchers have explored the impact of team members' personalities, team structure characteristics, communication modes, as well as the relationship between developers and users, including concepts like users' participation and involvement in the software development process [19]. Moreno [20] developed a method known as sociometry to assess interpersonal relationships within a group. This method, commonly used in social psychology, psychodrama, and education, delves into the deeper, often invisible, social interactions within a group. It offers a framework to explore the "deep structure" of human relationships, contributing to the understanding of social networks. In the context of sociometry, the concept of centrality emerges, describing individuals who hold a central position within their group. Early sociometry literature referred to centrality as social status [21], with the sociometric concept of a "star" embodying a similar idea. Centrality is often measured by the degree of connectivity in a graph, reflecting how well-connected a node is within its local environment, termed "local centrality." While group characteristics like cohesion and conflicts are important in social network analysis, their definitions in this context differ from common usage, focusing on structural properties rather than qualitative aspects.

Sociograms, originally used in the Hawthorne studies [22], visually represent the informal relations within a workgroup. These diagrams illustrate various aspects of group behavior, including involvement in games, job trading, helping, friendship, and antagonisms, often depicted through lines and arrows to represent positive and negative relationships between individuals. Arrowheads indicate the direction of these relationships, differentiating between the orientations of individuals within the group. Through sociometric analysis and social network exploration, this study aims to uncover the underlying dynamics of interpersonal relationships within software development teams, shedding light on the intricate social structures that influence team performance and outcomes. The Role Assignment Methodology for Software Engineering Teams (RAMSET) [23]is a structured approach designed to facilitate the formation of software development teams by taking into account both individual preferences and team dynamics. RAMSET emphasizes the assignment of specific roles, such as team leader or programmer, based on each participant's strengths, aspirations, and social network analysis. The methodology encourages team members to list their preferred teammates and roles, ensuring that not only technical expertise but also interpersonal relationships are considered in team formation. This approach is particularly valuable in educational settings, where students are learning to navigate both the technical and social aspects of software engineering projects. RAMSET helps in creating balanced teams that can leverage individual preferences for roles while maintaining a cohesive and productive working environment. By analyzing these preferences through metrics such as degree centrality and betweenness centrality, RAMSET allows for an evidence-based approach to team composition, fostering collaboration and leadership in socio-technical environments. The method also considers factors like communication patterns, conflict resolution potential, and role suitability, providing a comprehensive framework for ensuring that team leaders can effectively manage both the technical aspects of the project and the social dynamics of their teams. This makes RAMSET an essential tool for educators and industry professionals alike, helping them to build teams that are not only technically proficient but also socially cohesive, thus enhancing overall project outcomes. In a research titled *"Methodological framework for the allocation of work packages in global software development"*[24], the authors discussed how role assignment methodologies, including RAMSET, were vital in distributed teams. They used a framework that adapted RAMSET principles to allocate work packages effectively, ensuring the right people were assigned leadership and technical roles. This study underscored the importance of assigning roles based on team members' strengths and the potential for optimizing productivity, particularly in global and virtual software teams. In another study *"Experiences in software engineering courses using psychometrics with RAMSET"*[23], the authors explored the use of psychometrics combined with the RAMSET methodology to assign roles in software engineering teams. The study took place in an academic setting where students were assigned roles based on their technical abilities, personality traits, and preferences. RAMSET played a crucial role in helping to determine effective team compositions, which in turn improved teamwork and project outcomes. The study highlighted how structured role assignment, with an emphasis on personal attributes, enhances both student performance and collaboration.

Based on the definition from Team Software Process (TSP), a team leader can be defined: a team leader is responsible to bring the management in software development projects and he is responsible for outcomes of the development projects [24] . In the same vein, Ruano-Mayoral et al. [24] further maintained that team leader is also responsible for guiding, motivating team members, handling teams and customers issues, and dealing management. They also mentioned that team leader is also required to follow the deadlines to produce the projects from assigned resources. The position of a team leader can be defined like the role of the orchestra leader who guides the team members of a music band and similarly a team leader supervises and monitors the whole process of the development of the software at all the phases. A team leader does not only strive to bring success to the software but he/she is also responsible to keep higher authorities updated by providing them reports on software. Moreover, a leader also supervises different projects to ensure their quality [25].

3. METHODOLOGY

According to González [26], a complex system consists of many interacting units whose collective behavior cannot be explained solely from the behavior of the individual units. Similarly, a software development team functions as a collective entity composed of multiple members, each contributing to its overall behavior. Therefore, generalizing individual behavior to the entire team presents a complex challenge within the realm of human psychology.

During the data collection phase, participants in the experimental group were instructed to list four preferred team members with whom they wished to work, along with their desired role within the team, following the Role Assignment Methodology for Software Engineering Teams (RAMSET) methodology [23]. These preferences were meticulously recorded for further analysis. To form teams, complex network techniques were employed to explore participants' choices (i.e., team leader or programmer), ultimately identifying suitable team leader or programmer. However, this study focuses exclusively on the results pertaining to team leaders.

In the network analysis, two broad categories of measures were utilized: local and global. Degree centrality and betweenness centrality metrics were employed to identify highly favored individuals, effective communicators, and those who could effectively collaborate with other team members. Opsahl's et al., [27] weighted degree centrality metric was used to measure the degree, strength, and degree centrality, with a tuning parameter () controlling the equation's outcomes. When =0, the metric returned the number of nodes connected to each node (node degree), while =1 returned the weight of the links (strength). For values between 0 and 1, the metric combined both degree and weight to measure the links (weighted degree centrality). Additionally, the Betweenness global measure was applied to determine the shortest paths within the nodes. Formalized based on Opsahl's et al., [27] equations, the betweenness centralities calculated binary short distances if =0, employed Dijkstra's algorithm if =1, and used a combination of both for =0.5. These equations were implemented using R-project, with the i-graph and TNET packages within R-project providing a comprehensive visualization of the network connections.

Weighted degree centrality:

$$C_D^W(i) = deg_i(strength/deg_i)^{(1)}$$

Betweenness centrality:

$$C_B^W(i) =_J^N {}_K^N(g_j k^W(i))/(g_j k^W) jk \qquad (2)$$

Graph theory serves as a vital analytical tool in this research, offering a framework for problem-solving within the network. R-project, a widely used tool for data analysis and computation, was utilized for its accessibility and versatility in simulation. Additionally, various network analysis tools such as Gephi, NetDraw, NetMiner, Pajek, and UCINET were employed in the study, leveraging their capabilities in network science.

To achieve the research objectives, an experimental approach was adopted, focusing on a study population from a university setting. The study involved a total of 60 participants who were enrolled in software engineering courses, selected for their technical expertise in software development within team environments. Data collection utilized a methodology inspired by Jacob L. Moreno [8], where participants were asked to list four preferred team members (1st, 2nd, 3rd, and 4th choices) with whom they wished to work, along with their desired role within the team. For this study, we have asked them to choose between being a team leader or a programmer. These preferences were meticulously recorded for subsequent analysis.

The process of assigning team roles involved an exploration of participants' choices using complex network techniques, specifically degree centrality and betweenness centrality. These analyses were instrumental in identifying suitable team leader and programmer roles, shedding light on the dynamics of team composition within the context of software development. By leveraging these tools and methodologies, this research study aims to provide valuable insights into the complex interplay of technical skills, social dynamics, and leadership qualities within software development teams. Through an empirical investigation of participant preferences and roles, this study seeks to contribute to the understanding of effective team composition and leadership in the context of software engineering education and practice.

4. RESULTS AND DISCUSSION

During the survey, 18 out of 50 participants expressed an interest in assuming a team lead role. However, for this study, only 10 team leaders were needed, as each team consisted of 5 members and there were 50 participants in total. To assign the team lead roles, we first measured the frequency of the nodes using the weighted degree centrality metric proposed by Opsahl et al., [27], as discussed earlier. as discussed above. Figure 1 visualizes the overall behavior of the network of participants' choices.

Firstly, the in-degree of each node was measured to identify the most sought-after node. In this context, nodes with higher ”in-degree” or ”in-nodes” were considered to be the most central. Acuña et al. also emphasized that a team leader should possess sociability or openness to effectively lead the team. To achieve the in-degree frequency, the alpha value was set to 0 (i.e., = 0). Additionally, in addition to measuring in-degree, the relationships between participants were evaluated based on the weight of their choices. This implies that the alpha variable in the weighted degree centrality measure was assigned a value of 1 (i.e., = 1). Lastly, using Opsahl's et al. measures, centrality was calculated based on both node degree and weight combined. This was calculated using Opsahl's metric with = 0.5. Table 1 below summarizes the weighted degree centrality results for all participants, where ”P” denotes ”Programmer” and ”TL” denotes ”Team Lead.

The initial findings of the experiment were relatively straightforward to interpret. For example, when = 0 (indicating degree centrality), participants p43, p3, p47, p36, p4, p50, p23, and p7 were frequently selected as team members. This suggests that these individuals exhibited sociability or openness, qualities associated with effective team leadership. Additionally, these participants had higher weights compared to others who aspired to lead, likely due to their high appearance in degree. For instance, a total of 106 links appeared within their network, with 91 directed towards them, each with different weights. Consequently, these 8 participants could be considered suitable for team leadership. However, their ability to communicate effectively with team members remained a question. Furthermore, although five participants aimed for a programmer role, their in-degree and weight were higher than several others aspiring to lead. Table 1 provides details about these five participants (p22, p19, p6, p8, and p31) interested in the programmer role. Despite this, their higher degree centrality suggests their suitability for team leadership. Therefore, betweenness centrality was also assessed to identify participants capable of effectively bridging the gap between team members and clients. This is essential as team leaders are responsible for conveying requirements to their team members. Opsahl's betweenness centrality was used to identify effective nodes for information exchange. Table 2 summarizes the top 15 participants based on weighted degree centrality and betweenness centrality.

The results revealed that a node may not necessarily establish an effective communication bridge even with a higher degree frequency. For example, p25 and p39 had 3 in-degree centrality but higher betweenness centrality than p7, which had 8 in-degree centrality. Therefore, the selection of team lead roles was based on the results of both measures. Gender and academic balancing were also considered, with priority given to those aspiring to lead in case of ties. Additionally, p43, p19, p23, p22, p36, p8, p3, p7, p47, and p50 were selected based on their higher in-degree frequency and betweenness centrality, as well as gender and academic balance. Conversely, p25, p39, p31, and p49 were not selected for team lead roles due to their lower in-degree appearance in the network and their preference for the programmer role. Lastly, in a tie between p7 and p4, p7 was chosen to balance gender representation, as there were already 5 female participants assigned to team lead roles (p19, p23, p36, p8, and p3). All remaining participants were assigned the programmer role, except those designated as team leads. The following section details the team formulation process based on the assigned roles.

5. CONCLUSION AND FUTURE WORK

The findings of this research are expected to contribute significantly to both academia and industry. In the academic sphere, the insights gained can be utilized to refine curricula, ensuring that students are better prepared for the challenges of real-world software development teamwork. On the industry front, a deeper understanding of the dynamics of effective team leadership can potentially enhance the outcomes of software development projects. The review of related studies emphasized the growing recognition of social structure's critical role in teamwork, as highlighted by scholars in recent years. Concepts from social network analysis have been expanded to include elements like work satisfaction, performance, and power,

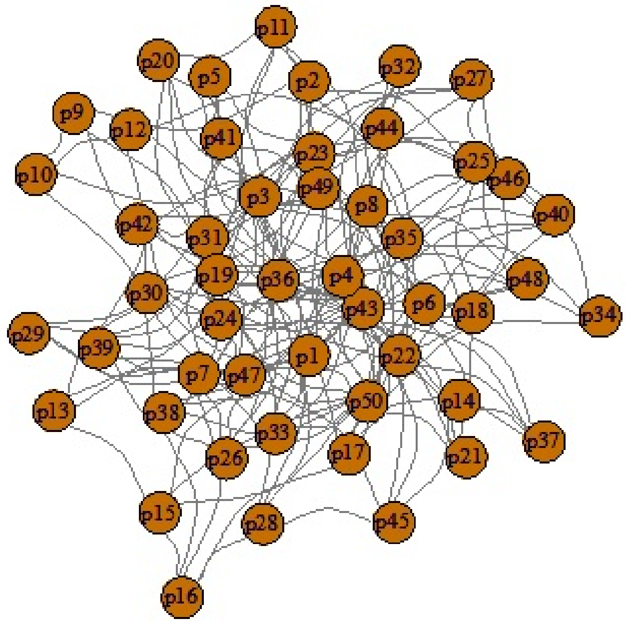

Figure 1. Participants' Connections

TABLE I. Participants in appearance in Weighted Degree Centrality (WDC)

Node	Role Want	Gender	WDC			Node	Role Want	Gender	WDC		
			$\alpha = 0$	$\alpha = 0.5$	$\alpha = 1$				$\alpha = 0$	$\alpha = 0.5$	$\alpha = 1$
p1	P	Male	5	6.71	9	p26	P	Female	2	3.16	5
p2	P	Male	2	2.83	4	p27	P	Female	1	1.73	3
p3	TL	Female	13	22.52	39	p28	TL	Female	1	1.00	1
p4	TL	Female	10	14.49	21	p29	P	Male	0	0.00	0
p5	P	Female	1	1.41	2	p30	P	Female	1	1.73	3
p6	P	Female	9	13.08	19	p31	P	Female	7	11.22	18
p7	TL	Male	8	13.56	23	p32	P	Female	1	1.41	2
p8	P	Female	9	12.73	18	p33	TL	Female	1	2.00	4
p9	P	Female	1	1.41	2	p34	P	Female	0	0.00	0
p10	TL	Male	2	3.74	7	p35	P	Female	6	8.12	11
p11	TL	Male	2	2.83	4	p36	TL	Female	12	19.29	31
p12	TL	Female	1	1.00	1	p37	P	Female	1	1.00	1
p13	P	Male	0	0.00	0	p38	TL	Male	2	3.46	6
p14	P	Female	1	2.00	4	p39	P	Female	3	4.90	8
p15	P	Male	1	1.41	2	p40	P	Female	2	2.45	3
p16	P	Female	1	1.00	1	p41	TL	Male	2	3.16	5
p17	TL	Male	2	3.74	7	p42	P	Male	2	2.83	4
p18	P	Male	2	2.83	4	p43	TL	Male	16	26.53	44
p19	P	Female	9	15.87	28	p44	TL	Male	1	1.41	2
p20	TL	Female	1	1.00	1	p45	P	Male	1	1.41	2
p21	P	Male	1	1.73	3	p46	P	Male	3	4.90	8
p22	P	Male	11	17.86	29	p47	TL	Male	13	19.75	30
p23	TL	Female	9	15.30	26	p48	P	Female	2	3.46	6
p24	P	Male	4	6.93	12	p49	P	Male	2	2.83	4
p25	P	Male	3	3.87	5	p50	TL	Male	10	16.73	28

TABLE II. Shortlisted team leaders

Weighted Degree Centrality (WDC)				Weighted PageRank (WPR)			
Node	Role	Gender	$\alpha = 0.5$	Node	Role	Gender	$\alpha = 0.5$
p43	Team Lead	Male	26.53	p43	Team Lead	Male	269.00
p3	Team Lead	Female	22.52	p19	Programmer	Female	222.00
p47	Team Lead	Male	19.75	p23	Team Lead	Female	211.83
p36	Team Lead	Female	19.29	p22	Programmer	Male	174.50
p22	Programmer	Male	17.86	p36	Team Lead	Female	173.00
p50	Team Lead	Male	16.73	p8	Programmer	Female	168.50
p19	Programmer	Female	15.87	p3	Team Lead	Female	166.92
p23	Team Lead	Female	15.30	p4	Team Lead	Female	114.50
p4	Team Lead	Female	14.49	p25	Programmer	Male	109.00
p7	Team Lead	Male	13.56	p39	Programmer	Female	109.00
p6	Programmer	Female	13.08	p31	Programmer	Female	96.42
p8	Programmer	Female	12.73	p49	Programmer	Male	93.00
p31	Programmer	Female	11.22	p7	Team Lead	Male	74.50
p35	Programmer	Female	8.12	p50	Team Lead	Male	72.00
p24	Programmer	Male	6.93	p47	Team Lead	Male	70.42

indicating the evolving complexity of team dynamics in modern software development environments. The results and discussion section provided detailed insights into the analysis of participant preferences and role assignments. The use of weighted degree centrality and betweenness centrality metrics facilitated the identification of individuals suited for team leadership roles based on their network interactions and communication potential. This process resulted in the selection of ten team leaders from the participant pool, with considerations given to gender balance and academic representation. In conclusion, this study has shed light on the complex interplay of technical skills, social dynamics, and leadership qualities within software development teams. Building on this research, future studies could focus on the following areas: Long-Term Impact and cultural influence. Conduct longitudinal studies to observe the long-term impact of different leadership styles and personality types on team performance and project outcomes. This could provide valuable insights into the sustained effectiveness of team leaders over time. Cultural Influence will explore how cultural differences impact the dynamics of software development teams. Comparative studies across different cultural contexts could reveal unique challenges and opportunities for effective team leadership. By addressing these areas, future research can further enhance our understanding of effective team leadership in software development, ultimately contributing to improved project outcomes and team performance.

An interesting area for future research could involve exploring the role of artificial intelligence (AI) in shaping leadership dynamics within software development teams. As AI technologies advance, their potential to support decision-making, communication, and even conflict resolution in team settings grows. Future studies could investigate how AI tools might assist software team leaders in optimizing task assignments, enhancing communication flows, and monitoring team performance in real-time. This could lead to the development of AI-driven leadership assistance systems that augment human leaders' abilities to make data-driven decisions, particularly in complex, globally distributed software teams. Such research could also examine how AI's presence influences team dynamics, including whether it alters the traditional socio-technical relationships or enhances collaborative efforts. Additionally, the ethical implications of AI-driven leadership within software teams, such as biases in decision-making and privacy concerns, would be critical areas to explore.

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