Exploratory Analysis of Individuals' Mobility Patterns and Experienced Conflicts in Workgroups

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ABSTRACT

Much research argues the importance of supporting social interactions in teams and communities. The field of mobile sensing alone offers significant advances in recording and understanding human and group behaviours. However, little is known about behavioural changes as a consequence of in-group phenomena. One prominent example is intra-group conflict, which naturally arises between diverse groups of people. We demonstrate the feasibility of our approach to extract mobility patterns of individual's group behaviours sensed from a WiFi indoor localisation system and explore how these patterns relate to their team processes. 62 students enrolled in a project-intensive module, Software Engineering, were tracked over 81 days. Preliminary analysis of mobility patterns and interview data revealed differences in the mobility patterns of individuals based on their experience of conflict.

CCS CONCEPTS

• **Human-centered computing** → **User studies**; **Social engineering (social sciences)**; • **Information systems** → Location based services; Sensor networks.

KEYWORDS

conflict, small-group, mobility patterns, Wi-Fi indoor localisation

ACM Reference Format:
Camellia Zakaria, Kenneth Goh, Youngki Lee, and Rajesh Balan. 2019. Exploratory Analysis of Individuals' Mobility Patterns and Experienced Conflicts in Workgroups. In *The 5th ACM Workshop on Mobile Systems for Computational Social Science (MCSS'19), June 21, 2019, Seoul, Republic of Korea.* https://doi.org/10.1145/3325426.3329946

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MCSS'19, June 21, 2019, Seoul, Republic of Korea

ACM ISBN 978-1-4503-6777-6/19/06…$15.00
https://doi.org/10.1145/3325426.3329946

1 INTRODUCTION

Conflicts are inevitable in and around groups of people who share differences in goals, opinions and attitudes, and as a consequence, influence within-group behaviour [14]. With organisations and institutions increasingly structured via work teams, it is essential to understand and engage with conflict so that teams can fully capitalise on each member's variety of expertise and perspectives to address more complex problems. To better understand the conditions under which team processes gain and lose [16], considerable research on the conceptualisation and effects of conflict in teams [3–5, 8, 18] have been a central focus in management and groups research. However, techniques for measuring these phenomena have not changed much and are still dominated by survey methods.

We aim to contribute to research on teams by exploring how team processes and states might manifest in individual mobility patterns. As a first step, we examine how individual differences in experienced conflict relates to the time individuals spent on project-related activities and with their project groups over 81 days. These patterns were detected using Wi-Fi-based indoor localisation system [1] and group-detection system [15] deployed in our university infrastructure. This technique is an unobtrusive method for detecting location in 5-minute intervals, which we hypothesised could be used as a real-time proxy of team processes, such as conflict states. Given the emotionality of conflict [9, 17] it is likely that this emotion will spill over into the time that people spend physically with other team members.

Our findings revealed differences in the mobility patterns of individuals who reported experiencing conflict in the teams, compared to those who did not. While our interviews helped to reveal some of the differences in these patterns, other questions persist. These differences in mobility patterns provide preliminary support for the potential of using mobility patterns as real-time indicators of team processes and states.

2 INDOOR LOCATION-BASED SENSING SOLUTION

Inspired by prior work that leverages location information to measure group behaviours, we utilised similar large-scale sensing systems as in [7]. They are (1) a WiFi indoor location system to track coarse location between 6 to 8 meters accuracies that is sufficient

to localise a device to a specific room when connected to the environment (campus) network [1], and (2) a group detector system previously evaluated to detect groups of devices that congregate between locations with 97% precision within 10 minutes of identifying a group [15]. To maintain the anonymity of users while being tracked, the indoor location system anonymises MAC addresses of all connected devices using a 1-way hash function [6]. Note that in our study, users provided their device MAC address so that location traces could be identified and validated against their interview findings.

2.1 Location and Group Data Description

Location data informs us the amount of time a user is detected to be at a room-level location between 97-99% accuracy. Specifically, an entry corresponds to a connection between the mobile phone and a WiFi access point (AP) every 5 minutes. Each tuple consists of [di, ui, li, ai], where d=datetime stamp, u=hashed MAC address of (user's) mobile device, l=location code where device is localised (in the format of <building name>_<level>_<room name>), a=localisation accuracy and i=number of location entries.

Group data informs us of users in a group and their location histories. Each entry extends a location entry with [di, gi, cti, lli, tti, lhi, si], where d=datetime stamp, g=concate-nation of hashed MAC addresses connected to the same AP over a period of time, ct=last datetime the devices were detected as a group, ll=last location code the devices were detected as a group, tt=total time detected as a group, lh=concate-nation of location histories and the datetime, and s=size of group.

Note that the development and evaluation of these sensing systems are not within the scope of our work. Instead, they were used as a critical sensing component to collect individual and group-based location data, directly from the environment and thus bypassing connections made to the users' mobile phone. In what follows, we describe our user study procedure which includes collecting location and group data.

3 LONGITUDINAL USER STUDY

We conducted an IRB-approved study over 81 days during the Fall semester of 2017 (August to December) with participation from 62 undergraduate students (34 male, 28 female) from our university. All participants were between the ages of 19 to 25 (median = 22), majored in Information Systems (IS), and were in their Sophomore years. As part of the study requirement, all participants attended a mandatory IS course, Software Engineering (SE). Studying this population was uniquely suited for our goal for the following reasons. First, SE is anecdotally reported as a highly stressful course among our students because students have to juggle between the technical development of a cloud-based web application and strict project management requirements. Second, students must meet frequent deadlines spaced approximately two weeks apart. Thirdly, the course places heavy emphasis on students (physically) working together on the project such as alternating pair programming partners. Finally, students are put in pre-assigned teams unbiased across gender and grades, and therefore must work with people they do not know.

This user study was part of a broader study on understanding different mental health aspects through the mobility patterns of students working in teams. As part of this broader study, participants provided information about their academic and personality profiles (using Big-5 [10]), general work practices on campus and completed surveys measuring their stress levels (using PSS-4 [2] every three days and team process (using social identification measure [13] approximately every two weeks. We conducted two semi-structured interview sessions to understand students' primary sources of stress, experiences of working in their groups and ways of managing stressful workgroup situations. Sessions were guided by three questions:

(1) What is your main source of stress and experiences of critical (positive or negative) team events? Elaborate.
(2) Did any of these events change the dynamics of the team, and if so, how?
(3) If applicable, were problems in the team solved and how did the group communicate?

The first session was conducted at the term break (mid-study) and the second interview was conducted at the end of the term after project completion at the end of the study. All students provided us with their mobile phone MAC address so we could identify their location traces from our sensing component. Finally, students provided access to their SE project schedule, a standardised and graded course document used for project management, where each entry logs the date, duration, location, task, attendees for the group tasks everyone in a team fulfilled. Note that all surveys and qualitative resources served as ground truth for our analysis.

3.1 Interview Coding of Conflict

We followed a standard procedure in qualitative analysis to ensure stability, accuracy and reproducibility. First, we maintained the same two coders for all interview responses in both sessions. As we developed a standard coding scheme, findings from the first session led us to a particularly useful insight in defining *negative* critical events as intra-group conflict. We coded conflict as referring to any response that hinted incompatibilities or differences between and among group members [8]. The intercoder reliability, calculated using Cohen's Kappa is 0.923. The value closer to 1 is interpreted as "agreement", and both coders distinctly differentiated students experiencing relationship conflict. Note, there was no mention of *positive* events (e.g., a team celebration by team members after completing a milestone).

3.2 Processing Location and Group Data

We used the information of our students' general work routines on campus to assign activity-time thresholds to various locations on campus such as 'study', 'seminar', 'eat', 'transition' and 'cca'. As an example, the campus concourse is typically an area of transition but is utilised for co-curricular activities (cca) like dance and kickboxing practices. A student detected to be at the concourse in the evening over long periods will be recognised as having 'cca' instead of making 'transition' by the system. We processed approximately five-million location records and eight-million group records of all our participants over the semester. Based on this data, the following variables were measured:

(1) **Time Spent with Groups, *time_group***: Average total time spent (with 15 minutes unit time per activity) per 3 days students were detected in the same location with other connected mobile devices, indicating they were in a group. Number of connected devices is not more than 5, as in [7].
(2) **Time Spent Alone, *time_solo***: Average total time spent (with 15 minutes unit time per activity) per 3 days students were detected in the same location without other accompanying mobile devices, indicating they were on their own.
(3) **Group Meeting Attendance, *time_meetings***: Average total time spent on Software Engineering group meetings (with 15 minutes unit time per activity) per 3 days. We were able to verify that students were at the same locations as those logged in their team schedules for these events.

4 EXPLORATORY DATA ANALYSIS

Our goal in this study is to examine how individuals' differences in experienced conflict relates to their mobility patterns such as the number of times engaged in SE meetings, the total amount of time spent with groups and on their own. To identify these patterns, participants were grouped into "***conflict***", combining all three distinct types (n = 43) and "***no conflict***" (n = 19) based on their two interview reports. We conducted a Kolmogorov-Smirnov (KS) non-parametric test to compare the cumulative distributions of time series data from both groups; both the D-statistics and p-values are provided. Figures 1 - 3 show the CDF of students with conflict (represented in red line) and no conflict (represented in blue line) for their group behaviours on campus.

4.1 Results

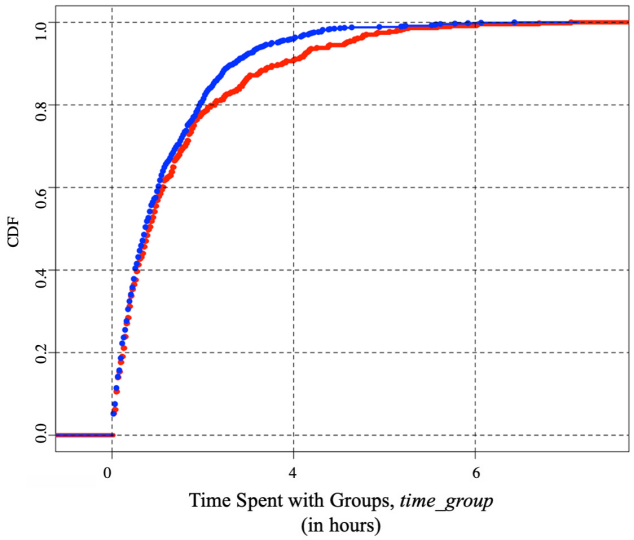

Figure 1: Empirical cumulative distribution of time spent in group between two groups; Blue dashed lines represent students who reported "*no conflict*", red represents "*conflict*".

We conjecture that students who experienced no conflict tend to be more involved in group matters than students who perceived

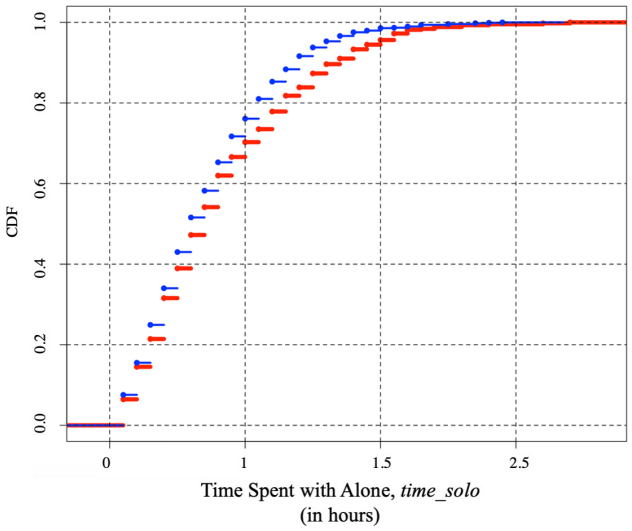

Figure 2: Empirical cumulative distribution of time spent alone between two groups; Blue dashed lines represent students who reported "*no conflict*", red represents "*conflict*".

themselves as being in conflict with a team member. For example, "group meetings" is one of the significant group events we would expect every person to show up. Hence, we hypothesised that: ***students who experienced no conflict with the team are more participative in group events***.

We observed the amount of time students spent in small groups. As presented in Figure 1, the differences between both groups are

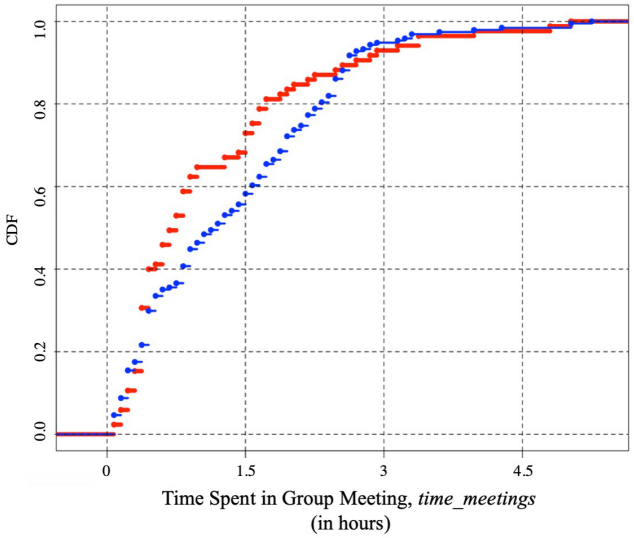

Figure 3: Empirical cumulative distribution of group meeting attendance between two groups; Blue dashed lines represent students who reported "*no conflict*", red represents "*conflict*".

not significant (D-statistics = 0.07, p-value = 0.09). That is, 95% of students with no conflict spent four hours with their SE groups every 3 days, 5% more than students with conflict. In contrast, an inverted pattern can be observed on the time spent alone (see Figure 2) – about 80% of students with no conflict spent slightly less time alone than those with conflict (D = 0.07, p-value = 0.05). Unfortunately, the differences in these mobility patterns did not provide significant evidences that conflict can be distinguished.

Our next step was to particularly observe students' group meeting attendances as we believe group meetings are often the time each member converges on decision-making processes for their project. This mobility pattern, however, required the students' team schedules as an additional resource to verify the type of activity students were engaged in. Students who experienced conflict showed compelling signs of little participation in group meetings. Specifically, 60% of students spent at least one and a half hours on group meetings, 30 minutes more than students with conflict. Moreover, 80% of students with no conflict spent over two hours on meetings on the whole. This pattern is significantly different between both groups (D-statistics = 0.18, p-value = 0.03).

4.2 Qualitative Findings

Our qualitative research continues with analysing the interviews responses to find plausible links between differences in SE involvement, measured by mobility patterns, and reports of conflict.

4 (out of 43) students who faced conflict expressed their willingness to work with the same team. 4 students expressed strong reluctance, while others (n=35) doubted about working together again. Among the 43 students who experienced conflict, 12 students felt that they did not receive the team support and 9 believed it was due to their technical incompetence. For example, one student reported, "I am not strong technically for SE and [always] feel pressured by the A coders. I was blamed for some of my decision tasks," which led her to be less participative both in meetings and Telegram group chats. Note: A-coder is a term students described as the technically-inclined members on standards and commitment to complete development work. In contrast, an A-coder believed she held more responsibilities than everyone else in her group. As she felt that her team always had the assurance that she would "fix their problems", she eventually stepped away from meetings and began communicating more through team Telegram workgroup chat for updates.

Types of Conflict – Most participants reported myriad experiences of conflicts, which started as early as the first week of SE group project. We categorised these conflicts into three distinct types, 1) *process conflict* is differences in logistics of achieving a task, 2) *task conflict* pertains to content and outcome of the task, and 3) *relationship conflict* involves personality differences [12]. 31 students described facing process conflict; for example, students reported feeling frustrated over scheduling for meetings and pair-programming sessions required for their project (11 students reported task conflict). 16 students dealt with relationship conflict, where some (n=5) even struggled to adapt with different personalities from the start. For most students, relationship conflict began at critical project milestones where teams were graded; for example, during *user acceptance testing* and *final presentation*. Unfortunately, such reports altered our students' personal motivation to work. A few students reported leaving their Telegram workgroup channel. They did not reach reconciliation by the end of the study and wished not to be teamed again. These accounts are the most salient and emotionally-charged outcomes that our students displayed from being affected by conflict.

The interviews thus reveal that the conflict experienced by students led to lesser participation for different reasons. For many, their withdrawal from group events stemmed from a perception that their efforts were not valued. We were able to distinguish significant differences in their group meeting participation through mobility patterns, nevertheless required team schedules as additional verification.

5 DISCUSSION

These results provided evidence on how team conflicts could influence an individual's in-group behaviour. Common reasons explained by our students who experienced conflict were a) feeling devalued for their efforts or b) believing others did not make a concerted effort to meet their high standards. What were initially described as process and task conflict, snowballed into relationship conflict.

Team Support. Our findings revealed that most events of conflict were typically shared between two team members, while others (in the same team) remained passive. Often, the lack of team support discouraged students from communicating to resolve differences. In contrast, most students who did not experience team conflict (12 out of 19 students) reportedly worked with a supportive team. It may be that the active and positive involvement of other members provided emotional sustenance for the team to persevere through difficult times and achieve a conflict resolution. Interestingly, the support among team members also helped create a more productive and less stressful work environment for 13 students without conflict. In this preliminary analysis, we did not examine how mobility patterns could be used to measure team support. However, it would appear to be of value to include team support as part of understanding the severity of team conflict.

Team-based Intervention. The function of conflict is evident in establishing not just user behaviour towards their group, but how systems are used between and among members; for example, one student reported creating a new chat group among some members after his colleague left the (original) Telegram workgroup from a conflict they both had. Our findings support Lampinen, who argues that users divide their communication platform into separate spaces to manage conflictive situations and perform self-censorship [11]. Unfortunately, cutting off the team's most convenient form of communication only led to more tenuous relationships between students. Instead, one possible use of our behavioural analysis is to integrate results into an online communication platform to encourage and assist other members to take a more proactive approach towards demonstrating team support.

6 CONCLUSION AND FUTURE WORK

We conducted an 81-day longitudinal study among 62 students, enrolled in Software Engineering group project, to investigate how

accounts of different team processes influenced their mobility patterns. Our preliminary analysis revealed how mobility patterns in group meetings corresponded to experienced conflict. Specifically, we demonstrated that compared to students who did not face conflict, those who experienced conflict were less engaged in group meetings. Our findings, while preliminary, support the possibility that mobility patterns could be unobtrusive indicators of team states and processes. One possible application of such analysis is as real-time indicators of team processes and states which leaders and team members can be proactive and positive on conflict situations within and among members. It is also likely that academic profiles (students with strong technical abilities versus students who are less technically inclined), personality profiles, reporting of perceived stress and social identification towards the workgroup played a part in the experience of conflict. This investigation makes up a more substantial part of our research to accurately identify distressing individuals in team situations.

ACKNOWLEDGEMENT

This research is supported by the National Research Foundation, Prime Minister's Office, Singapore under its IDM Futures Funding Initiative.

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