COLLECTING SENSOR-GENERATED DATA FOR ASSESSING TEAMWORK AND INDIVIDUAL CONTRIBUTIONS IN COMPUTING STUDENT TEAMS

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Abstract

The aim of this paper is twofold. First, the authors describe a series of experiments that have been conducted in a dedicated smart-spaces laboratory, aiming to combine the use of several sensors in collecting student data. Second, the paper shares key findings from the use of sensor-generated data as an instrument for assessing individual contributions as well as team performance. The early sections of the paper describe the setting of a smart-space laboratory and how it was used for two scenarios; on one hand student teams were monitored during a coordination meeting involving decision making, while on the other hand students were observed during a team presentation. The discussion explains how sensors were used to monitor emotions (using facial image processing), stress (using galvanic skin response) and participation (based on the use of Kinnect). The key contribution is in the form of the experiment setting that can be replicated with students from different educational backgrounds but also in scenarios involving practitioners from different disciplines. The authors discuss the drivers for organizing this type of experiment and explain the reasoning behind the use of certain sensors and the value of collecting specific data sets. The later part of the paper describes how the analysis of collected data has produced visualizations of patterns that can be used in education for assessing student contribution, emotions and stress levels. Similar approaches could be used for project management where student teams are replaced by software engineering teams in agile development scenarios (e.g. scrum stand-up meetings).

Keywords: Student teamwork, smart labs, sensor data, smart classroom, intelligent learning environments.

1 INTRODUCTION

In this paper we provide a set of guidelines for collecting sensor-generated data as part of formative and summative assessment of students in computing programmes. The authors share their experiences with setting up scenarios for teamwork but also individual tasks that are monitored in a smart spaces laboratory that is part of their institution's intelligent environments infrastructure.

The driver behind this work was the need to provide instructors with a 'smart' assessment mechanism using sensor data as the means for assessing student contribution. The output is a series of dashboards providing visualizations of learning analytics that are necessary for decision-making in educational contexts. The paper contributes in two ways to the relevant fields. First the paper describes how to select suitable sensors for generating data that can offer measurable criteria for both team and individual student work. The paper also explains how various sensors can be used together, the reasoning behind each sensor and the benefit from collecting such data. This discussion can help instructors of computer science programmes to reflect whether part of the experiments conducted could be replicated and consider how to apply the proposed data collection and analysis techniques. The second contribution is in the form of findings showing correlation between certain key characteristics of student behaviour and assessment patterns and the data collected from certain sensors. Our aim is to establish whether certain patterns can provide a strong indication for a number of assessment criteria such as contribution, confidence, understanding for a range of tasks.

2 LITERATURE REVIEW

The authors share findings from a two-year study that has been part of the delivery of a module on Strategic Management in Information Systems. This is a very popular module amongst students studying Business Information Systems, as well as Information technology. As part of this module students must engage in role playing, involving regular project management meetings, online collaboration, the use of Social Networking Sites and the use of progress reporting tools. Students are

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encouraged to communicate and interact as if they were part of virtual, geographically dispersed teams throughout the week. The module lasts for 24 weeks over a term that begins in October, and ends in April. The experiments discussed in this paper take place during the mid-term period and focus on assessing team coordination and management as well as contribution and participation in presentation activities.

2.1 Investigating collaboration in student teams

The authors have almost a decade of experience in setting up Global Software Development (GSD) projects with the participation of students residing in different time zones. Prior work has involved student groups from different institutions, and investigation spanned across the elements of time zone, distance and cultural differences. Emphasis was given on the interactions between team members, the exchange of information between teams collaborating on specific tasks and the interactions taking place with the support of synchronous and asynchronous communication. These experiences have driven the study discussed in this paper, as the main objective was to investigate (i) team collaboration in GSE, (ii) team building and teamwork in software engineering scenarios and (iii) social and human aspects in GSD. This paper presents the latest research considerations involving the use of sensors for gathering data essential for project management decisions. More specifically the authors investigated how teams coordinated a project management meeting in preparation for a team presentation. The contribution of this paper should not be considered only within the narrow boundaries of computer science education and the facilitation of student teams. The findings of this work advocate that the use of sensors can become a useful tool for educators who wish to obtain 'smart' data about student performance. Such data can be used for the provision of formative feedback and might also influence summative assessment. A future direction of this work can be towards the development of GSD project management practices where the use of 'smart' performance toolkits are based on the collection of sensor-generated data. For example data showing stress levels, contribution levels, enthusiasm, active participation and emotion could help project managers to assess team members Therefore project managers' decision-making could be facilitated and supported with the provision of GSD coordination and communication data collected from sensors monitoring human behavior.

Computer science education should be based on providing students with realistic scenarios so they can obtain the necessary skillset. This is why this study is based on role-playing of certain project management and GSD roles. There are several examples in the relevant literature on how certain software development skills are practiced in educational settings. As the software engineering skillset can vary significantly it is necessary to adopt a variety of methods when designing learning activities. Paasivaara et al [13] who worked on assessing global software engineering students, they employed a mixed-method approach including "post-course interviews, pre-, post-course and iteration questionnaires, observations, recordings of daily scrums as well as collection of project asynchronous communication data". This achieved the assessment of a range of different competencies. There is evidence in the literature that several works also focus on investigating additional factors that may affect group performance. Such factors may include "gender, age, cultural diversity, previous work experience, and the degree to which work is equitably shared among team members as possible factors affecting success" [11]. There are several examples of work sharing experiences in setting up software engineering courses and sharing good practices. When reviewing the relevant literature the authors were aware that focus spanned across a number of areas. Some of the most common areas in computer science education and in particular software engineering included project management, requirements engineering & quality assurance, architecture, and implementation [6].

A significant part of this work relates to team building and teamwork. It was therefore important to ensure that the appropriate aspects of software engineering were investigated in the learning scenarios developed. The work of Schneider et al [14] concluded that 74% of publications in the relevant fields focused on aspects associated with distributed team and project management. The authors decided to stay in line with the majority of existing work and design scenarios associated with project management tasks in software engineering teams. The vast majority of work in the area is concerned with the main challenges associated with software engineering and in particular GSD [8] such as (i) creating overlap in time between different sites, (ii) geographical distance challenge team spirit, i.e.'teamness' and (iii) the inherent challenge of creating mutual understanding between people with different backgrounds. The study was designed to include a synchronous meeting, establish team spirit and help members during a decision-making task. According to Khan et al there are several factors affecting software engineering teams during the requirements understanding stage [10]. Such factors may include cultural differences, loss of communication richness, loss of teamness, time zone differences, coordination breakdown and geographic dispersion.

The study focused on collaboration and communication, in relation to social and human aspects in software engineering teams. In line with relevant literature this study focused on human issues affecting software engineering team performance including (i) lack of common understanding of goals and requirements assigned, (ii) difficulties in communication, (iii) bottlenecks and problems in project execution and (iv) ineffective management of knowledge sharing [7]. These areas are also identified by Misra et al [12] who determine challenges relating to personnel as (i) communication, (ii) knowledge management, (iii) coordination, (iv) collaboration, (v) socio-cultural distance (lack of group awareness), and (vi) lack of trust.

2.2 Sensor-based data collection

We argue that sensor-based project management provides an excellent opportunity for increasing the effectiveness of dealing with social aspects in software engineering. We also argue that sensor-based data collection could enhance student learning in computer science for a number of reasons. Students can become familiar with such observation and data collection techniques, while appreciating the use of data visualization, learning analytics and the impact of intelligent environments in educational contexts, as well as project management practices. Our views are advocated in the relevant literature, as Ara et al [1] propose a sensor-based project management process, which uses "continuous sensing data of face-to-face communication, was developed for integration into current project management processes".

Our previous work involved several years of investigation in the field of GSD and especially in the way virtual teams are formed, and their patterns of collaboration and communication [5]. Previous work involved more than thirty pilots involving GSD teams from six institutions involving four countries (UK, USA, Panama and Turkey). Our studies emphasized on understanding the way students would interact during software development activities ranging from design and analysis tasks to coding and interface testing. Focus was also on assessing communication patterns during synchronous and asynchronous discussions using text coding. Amongst the research objectives was the investigation of how culture as well as time zone differences affected the way teams collaborated in short projects. Our experience with such data collection practices helped us to establish a robust mechanism for monitoring how software engineering teams collaborated while using sensors to collect performance data. Furthermore previous work focused on analyzing the collaborative interaction patterns of global software development learning teams composed of students from different countries. In particular, qualitative and quantitative analysis methods were used to determine the differences between a group's communication patterns in asynchronous versus synchronous communication mode. K-means clustering with the Ward method was used to investigate the patterns of behaviors in distributed teams [5]. Another key consideration of previous work was assessing e-learning, virtual team and GSD platform infrastructures available for supporting such work in a feasible and sustainable way [3]. Our work was also driven towards considering stress assessment at the workplace [18].

3 EXPERIMENTING WITH THE USE OF SENSORS FOR COLLECTING STUDENT BEHAVIOURAL DATA ASSOCIATED WITH PERFORMANCE

This section describes the set-up of investigating project management activities with the use of sensors. Emphasis is given on the collection of behavioural data associated with performance of students as part of their contribution towards team tasks. The scenario was designed in order to investigate team coordination and communication with the aid of a multi-sensor setting. The scenario was based on the observation of teams consisting of 4-6 members working towards a portfolio of work for strategic management in information systems. The objective of the experiment was for students to each consensus by deciding the topics to be covered in a brief presentation following their project meeting. The scope of the presentation was for each student to demonstrate an understanding of topics covered in the module, provide evidence of individual contribution, participate in the team's effort to present an executive summary of project work and reflect on individuals' contribution of teamwork. As mentioned earlier participants in this study were students of a module that is offered to two programmes (i) Business Information Systems and (ii) Information Technology. All students were in their final year of their undergraduate programme. The smart spaces laboratory used has the form of a smart-home including various rooms with sensors installed. The experiment used two rooms, the first room for the team's project management meeting and the second room for the team presentation.

The experiment was based on a number of steps. The first step involved induction activities, during which prior to the experiment students were given a tour of the smart-spaces lab and were acquainted with the research study, while one hour before the monitoring students were provided with the research briefing documentation, consent forms and detailed explanation of what information was collected and the sensors used during the study. The second step involved student reflection. During this period, students were given a few minutes to consider their contribution to the teamwork over the past ten weeks and assess their ability to present certain topics. This stage was critical to enable students to prepare for the negotiation phase of the experiment. Students had to agree with the rest of the team the content of the team presentation, their own contribution and the order of the member contributions. The third step involved the teams' coordination, during which teams appointed a team leader for the project meeting who was responsible to ensure that each member would provide sufficient input in the discussion and that the team would reach consensus. The fourth step focused on team communication, as all members had to exchange their views on which topics each member should present, working towards team consensus. This step offered the main volume of data as student emotions, contributions and behaviour were monitored. The fifth step involved the team presentation, during which the team had to present a selection of topics following the agreed plan during the project management meeting. The sixth and final step involved a feedback phase, during which the team was provided with immediate feedback on their presentation, the process they followed to reach consensus and indicative measurements from the different sensors.

Due to the space limitations of this paper we cannot go into too much depth in describing the experiment setting which has been published in previous work. The duration of the project management meeting was 10 minutes and the time provided for the team presentation was 60-90 seconds. The concepts associated with the coordination meeting of the software engineering team were as follows:

1 Duration – the time it took the team to reach consensus.
2 Participation – evidence of involvement in team communication.
3 Presentation – the proportion of each member's presentation part.
4 Concern – evidence of anxiety or stress during discussions.
5 Disagreement- frequency of discussion debates and disagreement.
6 Emotion – range of emotions during specific meeting milestones.
7 Contribution – evidence of individual effort towards teamwork.
8 Misalignment – difference between individual and team decisions.

In total 53 participants from 13 student groups participated in the experiment. Our aim was to investigate social and human aspects of software engineering tasks based on previous experience on setting up student projects. The study also aimed to investigate the validity of the data collection approaches used with a number of sensors in order to understand the way software engineering teams were coordinated and their members communicated. Our hypothesis was that sensor data could be used to understand team cohesion, team dynamics, individual contribution to team decisions, states of emotional arousal and possible associations between the concepts identified in in the above list. The experiment is now in its second year and another fifteen groups participated with more than fifty students. Currently the second set of data is being analysed in an effort to build up numbers to back the findings but also to further strengthen the findings from the first experiment run.

Figure 1. Multi-sensor laboratory set-up

Fig. 1 shows the set-up followed for the data collection. Several sensors and data collection techniques were considered in preparation for the pilot study. Galvanic Skin Response sensors were used for monitoring perspiration, in an effort to associate readings with stress. The use of heart rate monitors was also considered but was not implemented as there was minimum movement during the meetings and the readings might not be conclusive due to the short duration of the meeting. In previous experiments heart rate monitors were used for full-day periods in order to be able to assess lengthy patterns. The use of a portable polygraph to record physiological measures was considered as intrusive to such an extent that it would most definitely affect the focus of the students and the meeting progress. Heat sensor cameras were considered but for follow up experiments. The use of eye tracking software for measuring blink rate and direction of gaze was considered for future scenarios involving face-to-face communication. The use of a sociometer was regarded as unsuitable for the setting as students would be seating around a table. The experiment would further support similar work based on statistical pattern recognition techniques for "automatically learn the underlying structure of the network and also analyze the dynamics of individual and group interactions" [2].

Audio data was collected using the Kinect for Xbox One, motion-sensing device. The device was programmed to collect the sound source angle (in degrees), and the direction that sound is arriving from a sound source. The scope of using this sensors was to monitor individual participation in team discussions. Hung et al automatically estimating high and low levels of group cohesion [9]. The aim of collecting audio feeds from each meeting and presentation was to investigate team cohesion and also the level of participation from different team members.

Electrical conductance of the skin was measured using galvanic skin response sensors. Each member was using such a sensor, holding it for the entire meeting. The accuracy of this sensor has been under criticism, as well as its suitability to denote stressful situations [16]. We used the sensor in an effort to see any patterns emerging when debates took place during the decision-making process.

Figure 2. Production of good practice guide.

The experiment also involved video recording,, as participants' facial expressions were collected in real-time during the decision making process. Team members' facial expressions were collected as input and returned set of emotions for each face as well as the bounding box for the face using Microsoft Face API. The possible emotions to be detected were (i) anger, (ii) contempt, (iii) disgust, (iv) fear, (v) happiness, (vi) neutral, (vii) sadness and (viii) surprise, which are universally communicated using facial expressions. The objective was to associate expressions to particular emotions of team members during certain points during the decision making process and throughout the consensus meeting. In the past robust recognition of facial expressions from images and videos was still a challenging task due to the difficulty in accurately extracting emotional features [17]. Fig 2. Shows the video production of a good-practice guide for setting up such experiments. This would allow the application of the approach to other subject areas in computing, and even across several disciplines.

4 FINDINGS – MAPPING SENSOR DATA TO STUDENT PERFORMANCE FROM LEARNING ANALYTICS

As shown in Fig 3., a dashboard was created to summarise the collected data. The project's timeline was recorded so further analysis could be conducted to identify patterns from different data sets. The analysis conducted was based on assessing how the data patterns emerging for each individual or team could be attributed to certain characteristics of the different teams and their members. Separate dashboards were created for each sensor to ensure that more meaningful findings could emerge.

Figure 3. Dashboard showing experiment data.

Fig. 4 shows the association between level and timing of contribution. This is only one of the many findings identified, and shows there is a correlation between the total participation in the meeting (i.e. how long they each member talked) and the timing of their participation (i.e. during which third of the meeting members talked). Similar patterns emerge in relation to the number of tasks members completed and their participation levels. These patterns can help to forecast student participation but also to assess who has contributed in team decision-making tasks.

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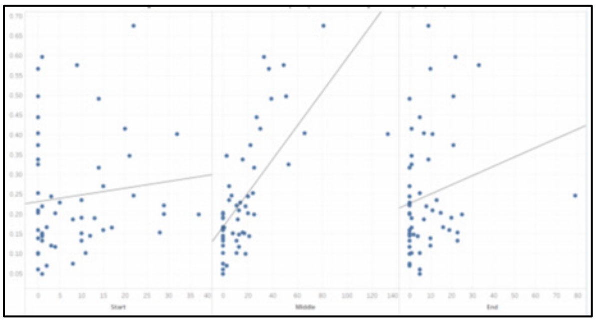

Figure 4. Association between timing & level of contribution.

5 CONCLUSIONS

This paper discussed the use of multiple sensors for generating data that can be used to help assessing individual and team performance in software engineering student teams. The paper also discussed the use of learning analytics for assessment purposes and the interpretation of emerging patterns for investigating student performance.

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