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WORK SAMPLING OF PRODUCT DEVELOPMENT ACTIVITIES

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Original scientific paper
For effective management of development projects, it is necessary to take into consideration its socio-technical perspective – working processes, teamwork and features of the working environment. Data gathering about socio-technical aspects of the product development activities is often hampered by constraints of the actual working environment in R&D organizations. For that reason, to support practical data collection, the work sampling application for mobile phones has been introduced. The work sampling application consists of sequence of input screens with predefined input menus enabling data gathering about different aspects of the product development activity (such as work type, activity type, context, participants, execution manner, information transaction and motivation). For validation of the proposed application, the empirical study was carried out in the company whose research and development activities are focused on the systems for the generation, distribution and transformation of electrical energy.

Keywords: *empirical study; mobile application; product development; teamwork; work sampling*

Primjena uzorkovanja rada na aktivnosti razvoja proizvoda

Izvorni znanstveni članak
Za učinkovito upravljanje razvojnim projektima, potrebno je uzeti u obzir socio-tehničku perspektivu projekta – radne procese, timski rad te značajke radnog okruženja. Prikupljanje podataka o socio-tehničkim aspektima razvojnih aktivnosti je često otežano zbog ograničenja prikupljanja podataka u organizacijama koje se bave razvojem. Implementacijom metode za uzorkovanje rada za mobilne uređaje, omogućava se prikupljanje podataka o stvarnim aktivnostima u realnom vremenu, te na praktičan i jednostavan način. Razvijena aplikacija za uzorkovanje rada se sastoji od niza ekrana s preddefiniranim izbornicima koji omogućuju prikupljanje podataka o različitim aspektima razvojnih aktivnosti: tip rada, tip aktivnosti, kontekst, sudionici, način izvođenja aktivnosti, kvaliteta informacije i motivacija. Za potrebe vrednovanja pristupa, provedena je studija u tvrtki čije su istraživačke i razvojne aktivnosti orijentirane na sustave za generiranja, distribucije i transformaciju električne energije.

Ključne riječi: *empirijska studija; mobilna aplikacija, razvoj proizvoda; timski rada; uzorkovanje rada*

1 Introduction

Traditional project management approaches used within the product development context often focus only on the technical aspects of project management [1]. With the progress of information technology, the technical side of project management has become more efficient and, in a relatively simple manner, allows an analytical approach to project and project's risk management. However, to effectively manage development projects, it is necessary to take into consideration socio-technical perspective – working processes, teamwork and features of the working environment [2]. In addition, there is a practical need for continuous project performance measurement and monitoring, and for providing the timely feedback necessary for successful management of development projects.

For monitoring and tracking performance at individual and team level within development projects, data gathering is often hampered by constraints of the actual working environment in R&D organizations. Analysis of product development project activities is often conducted by using activity logbooks and retrospective interviews/questionnaires that cannot provide information in the real-time and on the required level of activity granularity. Usage of the work sampling method can correct these deficiencies and provide insight into the actual patterns of working activities [3]. In this paper, the work sampling application is presented as a tool for gathering real-time data about individual and team level performance in development projects.

2 Work sampling method

Work sampling is a methodical approach for measuring the share of time that individual spent performing certain activities. Several expressions for work sampling can be found in the literature such as activity sampling or occurrence sampling, but the one that prevails is work sampling [4]. The method is based on collecting data about ongoing activities at specific time intervals, and it is known in different research areas (e.g. healthcare sector). The most known application in the context of the development of technical systems is Robinson's study conducted in automotive sector [5, 6]. Robinson studied the behaviour of engineers in terms of the use of information and analysed how much engineers spent time on certain information usage type throughout the development process [5, 6].

Mathematical base [3] of the work sampling is:

$$PT_A = \frac{T_A}{OT} \times 100, \quad (1)$$

where: PT_A – time percentage that participant spends on the particular activity A, expressed using values from 0 % to 100 %; T_A – time spent on activity A – number of sample points in which activity A was recorded; OT – overall time spent on all activities – overall number of sample points.

To formulate valid work sampling study, it is necessary to follow these steps: 1. identification of activities whose tracking is the main purpose of the study; 2. assessment of the time percentage relevant for the type of study; 3. selection of required precision level for the study; 4. definition of time intervals for carrying out study; and 5. re-calculation of the number of sampling points in order to meet the required level of precision [7].

In order to achieve a desired study precision in terms of the activities granularity, the required number of sampling points needs to be determined. The sample size can vary from a few hundred to several thousand sampling points. The obtained results are more relevant and precise if number of sampling points increases. The exact number of required sampling points per day depends on the number of participants and the duration of the study. Sampling points should be evenly distributed over different working days of the study.

Although Dickson et al. [8] in their research (pharmaceutical sector) found no significant difference between the results of observations performed in fixed and random intervals, it is recommended that the sampling points should be randomly distributed within the working hours. Random sampling intervals allow collecting more valid and unbiased results from a statistical viewpoint. Randomness can be achieved in several ways –by using tables of random numbers or random number generator applied on working time interval of participants.

According to the Pape [9] and Robinson [3], number of sampling points that is needed may be calculated as:

$$N = \frac{(1-p)Z_{\lambda/2}^2}{pR^2}, \tag{2}$$

where: p – time percentage that participant spends on the particular activity, expressed using values from 0 to 1; R – level of precision (accuracy) - value shows how close is estimated value p to the real value p; $Z_{\lambda/2}$ – number of standard deviations required to achieve specific confidence level (e.g. 1,96 for the confidence of 95 %).

Work sampling offers several benefits in comparison with other work measurement techniques. The work sampling is a practical method that requires minimal preparation by participants for the implementation of the study. The cost of the study is much lower in comparison with continuous observation. The method enables a direct data collection from participants who are not required to estimate how much time they spend performing a given activity. The work sampling method allows data collection from a larger number of participants over thelonger period of the time, but with a lower level of detail. For this reason, Finkler et al. [10] argue that it is necessary to achieve a balance between the number of participants and level of detail.

There are several shortcomings of the work sampling method. Work sampling method is primarily applicable to workplaces with a higher percentage of routine activities (smaller number of activities with a longer duration). If a process, which is under scrutiny, is going through changes, work sampling results will not be representative. Also, in case process consists of many activities with a shorter duration, it is demanding to apply and adapt this method to satisfy study requirements.

Data collection for the work sampling can be carried out by conducting observations (e.g. [11]) or by self-reporting (e.g. [5, 6, 12]). Observations require plenty of resources since the continuous presence of researchers and observers is needed during the study. Observation is an appropriate technique when work sampling research has to be conducted in limited working area (e.g. nurses at the hospital, workers in the production plant) [10]. However, for carrying out research in engineering context, observation is rarely used in organisational environments.

Self-reporting can be done by using work diaries [13] and questionnaires [14]. It should be noted that these methods are retrospective, as participants are asked to fulfil them at the end of the day, week or month. In this way, accuracy and precision of the collected data are affected. That is the reason, why there is a need for the data collection in real time and capturing a more accurate activity records. There are several drawbacks of the self-reporting approach. When self-reporting is done in the organizational environment, participants are prone to entry biased data for reasons such as the desire to appear better than other employees [15]. The emotional state of the participants and their level of motivation also significantly affect the quality of the collected data.

One of the possibilities for work sampling based on self-reporting approach is by using paper templates. Such approach is time-consuming for the participants since it limits amount and detail of the collected data. With the advancement of technology, personal telecommunications devices (PDA) [5] were used in the past to inform participants about the time when they are required to enter self-reporting information. Besides emitting alarms, PDAs were used for digital data acquisition of work sampling data.

Data collection using PDAs showed several advantages [5]:

- Presence of researchers was not required for conducting studies, and significantly fewer resources were needed to carry out studies
- It allowed monitoring of a vast number of participants
- It allowed frequent and unpredictable monitoring of participants
- It enabled data gathering that depends on the perception of each participant and not as perceived by observer

Simplification of data entry process by PDA enabled a faster collection of much larger quantities of data on the sampled activities over longer time period.

Since PDAs are obsolete technology, as a part of this research study work sampling application was developed for smartphone platform. Smartphones are easily available, and the majority of people are accustomed to their everyday use via intuitive and practical interfaces. By reviewing existing applications, few solutions for work sampling were found, but the main problem was lack of flexibility in terms of their adjustment to the particular needs of the research in domain of the engineering teams and projects. The work sampling mobile application was designed and developed with a goal to enable real-time data gathering about individual and teamwork activities during the development of technical systems.

2.1 Mobile application for work sampling

The mobile application for sampling (Fig. 1) has been designed as a sequence of input screens with predefined menus, inspired by Robinson's research [5, 6] and by using the analogy with the concept of an electronic diary (for self-reporting). On each input screen, there is a menu on which one or more predefined options can be selected. This way of collecting simplifies and speeds up data entry and allows the data collection on several aspects of development activities that can be combined and thereby jointly analysed, giving a more detailed and complete picture for each sample point.

Since work sampling is a general method for data collection, the menu (list of items) on each input screen of mobile application needs to be defined for the particular study. The menus for the study presented here were created based on a literature review of the various perspectives of engineering activities. Menus had been created in a way that input items have the following characteristics [16]:

- They are easily differentiated;
- They are clear (it is possible to determine easily what each menu item means);
- List of menu items is exhaustive (covering all the options that single participant would like to select); and
- They are not overlapping (current activity can be described with only one menu item).

Taking into consideration previously stated rules, ten input menus were developed (examples of input items are given in brackets) [7]:

1. Project selection (Project 1, Project 2 etc.)
2. Work type (Individual technical work, Individual administrative work, Teamwork, Break)
3. Work subtype (Discussion, Meeting, Reporting etc.)
4. Activity type from the product development perspective (Planning, Analysis, Decision making, Conceptualization/Design, Innovation/Improvement etc.)
5. Activity context (Technical-product, Technical-process, etc.)
6. Party within teamwork activities (Team members – prior to the sampling session project structure with involved people is imported into the application, Customer, Supplier etc.)
7. Activity execution manner (Face-to-face, E-mail, Videoconference, Engineering software etc.)
8. Information transaction type within activity (information seeking, receiving, giving, etc.)
9. Relevance of the information for the current phase of the project (rating 1-5)
10. Personal motivation for the activity (rating 1-5)

The first two menus *Project selection* and *Work type* are located on the initial input screen of the application (Fig. 1). For each specified work type (individual technical work, individual administrative work, teamwork, break), different menu scenario is executed during the sampling.

The input items used in the menus *Work subtype* and *Activity context* were devised on the basis of the previous work of Robinson [5], although some modifications were made. Compared to Robinson's menu [5], *Activity context* menu includes detailed classification of the technical context of activities. It allows participants to specify the particular aspect of the product (e.g. electronic, mechanical or software part) and process (e.g. manufacturing, installation, maintenance, disposal), following the ontology for engineering design proposed by Ahmed and Štorga [17].

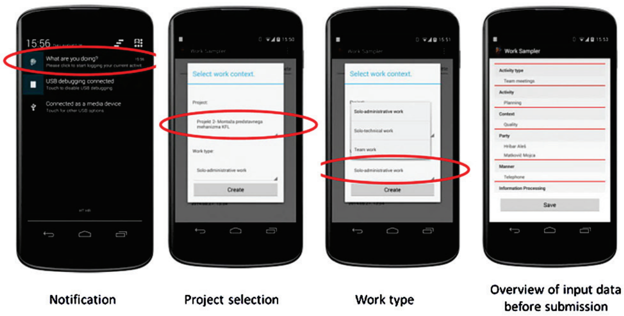

Figure 1 Screenshots of work sampling application [7]

For creating input items for the menu *Activity type from the product development perspective*, the ontology of product development activities proposed by Sim and Duffy [18] was used. Given the abstraction and level of detail within the ontology, individual items were aggregated into entities on higher level to facilitate proper activity identification. In order to ensure completeness of menu *Activity type from the product development perspective*, the analysis of the work activities was requested from HR department of the company that was participating in the case study. Work analysis received from the HR experts enabled the normalization of input items and confirmed the completeness of the menu items. Using the terminology suggested by the HR experts, names of items were adapted and customised, to improve understanding of participants.

Before the work sampling study started, it was necessary to adjust the menu *Party* to contain the names of the participants who were allocated to sampled projects. Data about ongoing projects and project members were imported using the administration interface of the application. Only project members allocated to the ongoing project are listed on the menu *Party* (apart from the generic menu items such as Customer, Supplier etc.). For creating the items for menu *Manner*, the work done by Allard et al. [19] and McAlpine et al. [20] was adopted in order to define communication means and computer tools. Items for the menu *Information transaction* were defined based on work done by Cash [21].The last two menus *Relevance of information for the current phase of the project* and *Motivation* are designed to use Likert scale (1-5) for describing the corresponding levels during activities.

3 Case study

3.1 Set up of the test work sampling session

A case study was carried out in the SME whose research and development activities are focused on the systems for the generation, distribution and transformation of electrical energy. For the purpose of conducting the case studies, the team members whose activities are related to the development of control embedded systems for the railway transportation sector were selected.

In the work sampling study, 15 selected team members (13 technical team members, project manager and department manager) were working on more projects simultaneously (for more details please check [7]). Projects that were included in the sampling study were at different stages and consequently had different workload distributions.

To become familiar with the work sampling methodology and application, prior to the start of the sampling session, team members were asked to use the application for one day. In addition, a workshop was organised where they have been introduced with the study objectives and how the sampling is going to be carried out. Team members received tutorial with instructions how to use application and a description of all menu items. As a result of the case study session, data was collected by the application and stored in the application database for further analysis.

Work sampling session lasted 10 working days (two weeks). Alarms were emitted randomly 7-10 times per day and team member. The minimum time difference between two emitted alarms was half an hour and the maximum was 1,5 hours. Due to the page limitation constraint, only part of results can be presented in the following section.

3.2 Results of the test work sampling session

During the work sampling session, a total of 1357 alarms were emitted, and for 1193 alarms team members responded (high response rate of 87,9 %). The number of responses per team member ranged from 57 to 100 during the sampling period.

Crucial for the relevance of the study is the time needed by the team member to fill out a questionnaire that appeared with emitted alarm. The period required for completing the questionnaire is defined as the time difference between the time stamp when team members completed a questionnaire (for emitted alarm) and the time stamp of emitting an alarm. During the study, 69,7 % of questionnaires were answered within first 15 minutes. Additional 8,8 % was filled out in the next 15 minutes (up to half an hour), which makes the results representative for drawing conclusions about the work sampling session (Fig. 2).

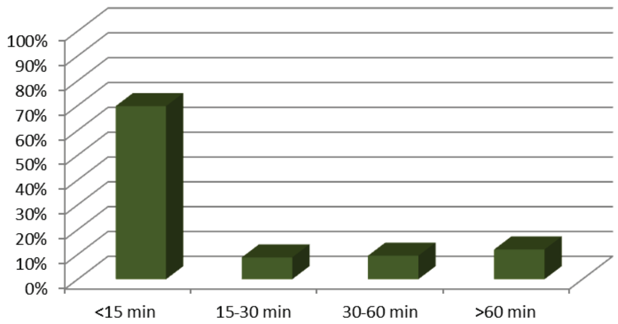

Figure 2 Percentage of answered alarms within particular period after alarm was emitted

Required number of sample-points for this study was calculated using work sampling equations [3]. Collected number of sample points enabled detection of a task accounting for 5 % of working time, with ±20 % precision, and 90 % confidence in that precision. If, for example, particular task was calculated to account for 5 % of working time (i.e., 24 minutes for standard 8-hour working day), then it could be stated with 90 % confidence that the actual time percentage spent on that task was between 4 % and 6 % (i.e., between 19,2 and 28,8 minutes of working time) [5, 6].

From work sampling results, it is possible to notice that individual technical activities are dominating the responses with 67,9 % of total number of sampling points, being followed by teamwork activities with 14,8 %, breaks with 10,1 % and 7,2 % of individual administrative activities. Fig. 3 shows time percentages spent on different work types (teamwork divided into its subtypes: *Discussions, Meetings, Report writing and Team meetings*).

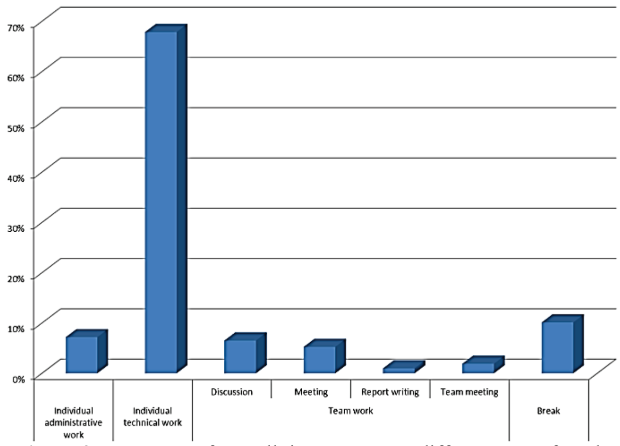

Figure 3 Percentage of overall time spent on a different type of work

Analysis of the activity contexts indicates that during the work sampling period and within the individual technical work and teamwork, product aspects such as electronics, mechanical and software were dominating (Fig. 4). Context related to process issues, such as manufacturing, installation and maintenance, had a significantly lower portion during the sampling session.

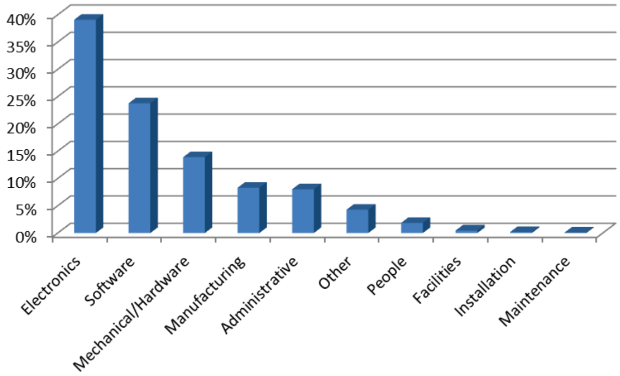

Figure 4 Percentage of overall time spent on different product, process, and other aspects

In the next step, several perspectives of sampled activities were coupled to conduct more detailed analysis. The percentages of the time that team members spent on individual technical and team work in combination with PD context and motivation are shown in Tab. 1.

As a part of individual work, team members spent most time working on *electronics* and *software* related development activities. These results were expected taking into consideration background of the projects and professional profile of team members. Teamwork activities that took most time were *informal discussions* (also mostly related to the context of *electronics* and *software*). Second most frequent teamwork subtype was *Formal meetings* (two persons) with 5,88% of time. The results also revealed that *Report writing* activities were mostly focused on the *software*, *employees* and *infrastructure* issues. *Motivation level* in individual and teamwork was highest for the activities related to the *product context*. A higher level of motivation was present during *individual* and *team work* that belongs to the context of the *product lifecycle*, but also within *teamwork* related to the context of the *infrastructure*.

Table 1 Product development context versus work activity type and motivation level for specific activity/context

		Individual technical work			Team work															Individual administrative work			Overall		
					Discussions (informal)			Meetings (2 people)			Report writings			Team meetings			Overall team work								
Product development context		CR	PT	IM	CR	PT	IM	CR	PT	IM	CR	PT	IM	CR	PT	IM	CR	PT	IM	CR	PT	IM	CR	PT	IM
Product-related	Electronics	365	34,05%	3,62	43	4,01%	3,47	5	0,47%	3,60				6	0,56%	3,00	54	5,04%	3,43				419	39,09%	3,59
	Mechanical/ hardware	139	12,97%	3,27	8	0,75%	2,63	1	0,09%	3,00	1	0,09%	4,00				10	0,93%	2,80				149	13,90%	3,24
	Software	210	19,59%	3,92	24	2,24%	3,79	10	0,93%	4,00	6	0,56%	4,50	5	0,47%	4,00	45	4,20%	3,96				255	23,79%	3,93
Process-related	Manufacturing	79	7,37%	2,92	2	0,19%	2,50	5	0,47%	3,40	1	0,09%	2,00	2	0,19%	3,00	10	0,93%	3,00				89	8,30%	2,93
	Installation							2	0,19%	3,00							2	0,19%	3,00				2	0,19%	3,00
	Maintenance	1	0,09%	3,00																			1	0,09%	3,00
People		1	0,09%	3,00				14	1,31%	2,57	2	0,19%	1,00	3	0,28%	2,00	19	1,77%	2,32				20	1,87%	2,35
Facilities					1	0,09%	3,00	1	0,09%	3,00	2	0,19%	4,00	1	0,09%	3,00	5	0,47%	3,40				5	0,47%	3,40
Administration																				86	8,02%	3,20	86	8,02%	3,20
Other context		15	1,40%	2,87				25	2,33%	2,84				6	0,56%	2,17	31	2,89%	2,71				46	4,29%	2,76
Overall		810	75,56%	3,55	78	7,28%	3,45	63	5,88%	3,08	12	1,12%	3,58	23	2,15%	2,87	176	16,42%	3,25	86	8,02%	3,20	1072	100,00%	3,47

Legend: CR – count of responses, PT – percentage of total time, IM – individual motivation level

From the analysis of the PD activities, it seems that *Conceptualization/Design* and *Detailing/Coding* activities were dominating the individual technical work (Tab. 2). *Measurement and Analysis* activities were also quite frequent, and they were among the leading activities within the teamwork. The most common team activities were *Planning, Analysis,* and *Conceptualization/Design.*

Table 2 Percentage of product development activities within individual technical work and team work

PD Activity type	Individual technical work	Teamwork	Overall
Conceptualization/Design	32,35%	13,07%	28,90%
Detailing/Coding	26,67%	0,57%	22,01%
Measurement	10,62%	11,93%	10,85%
Analysis	10,00%	14,20%	10,75%
Reporting	5,56%	2,84%	5,07%
Innovation/Improvement	2,47%	7,95%	3,45%
Planning	0,62%	15,34%	3,25%
Other individual	3,83%	0,00%	3,14%
Decision making	1,36%	8,52%	2,64%
Monitoring	2,59%	0,57%	2,23%
Resolving conflicts	1,23%	5,68%	2,03%
User support	0,37%	5,68%	1,32%
Sale/Procurement	0,86%	2,84%	1,22%
Resource assignment	0,49%	3,41%	1,01%
Other teamwork	0,00%	5,11%	0,91%
Selecting/Evaluating	0,49%	2,27%	0,81%

During the individual technical and teamwork, product development activities were conducted in various manner and using different resources (Fig. 5).Team members most often reported usage of *Engineering software* during individual work, but *Office software* and the *Internet* were also used quite frequently. During the teamwork, activities were mostly conducted *Face-to-face*, but also using some other ways of communication, such as *Email* and *Video-conference.*

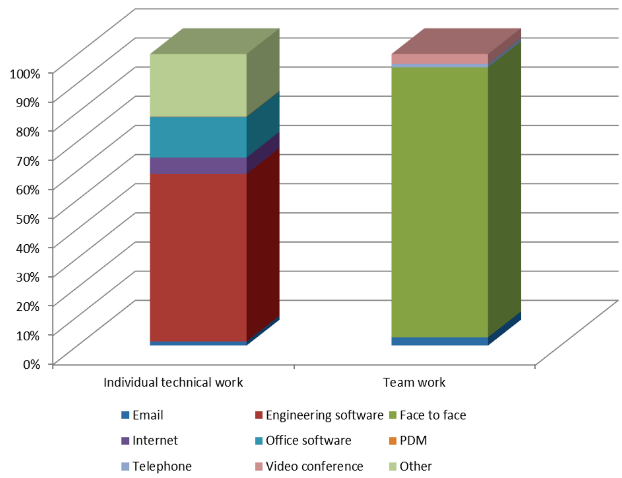

Figure 5 Percentage of the activities conducted in particular manner

4 Discussion

In presented case study, the work sampling was conducted by using the developed mobile application. Since the application was developed for the Android platform, selection of the sampling participants was directly dependent on the type of the mobile phone they have, influencing the profile of the participants. Although the participants had installed application one day before and tested it, after the sampling session in feedback discussion it was found that there were a few difficulties with understanding certain menu items.

As was mentioned before, the sampling period lasted for two working weeks, and it is important to emphasize that this duration is certainly not enough to make general conclusions. For general conclusions, it would be necessary to carry out work sampling of activities over a longer period. Due to the relatively short duration of sampling study, there was a need to emit a larger number of alarms per day to collect enough data and afterwards conduct an analysis with sufficient credibility.

Since work sampling session was carried out directly after the preparation of the application, within the application there were still present some technical problems. Due to technical issues (such as synchronization with the central database and an insufficient number of alarms per day) at the beginning of the second week team members were asked to install the updated version of the application. Usage of the new application version caused an increase in the number of alarms during the second week. However, the overall number of alarms for each team member during the sampling period was on average below 8 per day making this study representative [5, 6]. The difference in the number of completed questionnaires between individual team members stems from a random number of alarms per team member and the smaller share of the answered questionnaires by some of them.

A large number of received responses in the first 30 minutes after the alarms were emitted contributed significantly to the relevance of the study. Quickly filling in the questionnaires after the alarms were emitted, points to the successful adaptation of team members on study requirements and data collection in real time.

By analysing the work type results, predominance of individual technical work was noticed that corresponds to the fact that team members were working in the final stages of the projects. In that stage, all technical requirements were defined, and technical issues were mostly clarified. Also, the roles and tasks were defined and assigned to individual team members. For this reason, the share of teamwork in the analysed period is lower than in other comparable studies [6, 14, 22, 23].

Share of teamwork activities (14,8 %) is similar to those obtained in a study conducted by Webster and Higgs [22] of 11,3 %, but is significantly different from the 40,4 % of team activities in Robinson’s [6] research. Webster and Higgs [22] conducted their study in engineering drawing offices what explains lower share of teamwork, while Robinson [6] made his study in blue-chip manufacturing engineering organization.

Ranking and ratio between the various subcategories of team activities are in concordance with Robinson's research, though values significantly differ. The share of discussions (6,5 %) is significantly different from the 26,3 % obtained in Robinson's research. Formal meetings in here presented study occupy 5,88 % of team activities what is less than in comparable studies. Robinson et al. [6] and Lowe et al. [14] report that the proportion of meetings in their study was approximately 13 %, and Marsh [23] 9 %. Results related to reporting activities coincide with Robinson's research (5,03 % ≈ 4,78 %).

The most significant difference was noticed comparing the shares of individual technical work. During the sampling period, the individual technical work had the largest share of 67,9 % and was significantly different from Robinson's 37,9 % for technical and individual work [5, 6]. On the other hand, 58 % of the individual technical work in Lowe et al. [14] is much closer to the value obtained during the conducted sampling. It should be noted that differences in the work type categorizations in different research studies hamper their comparison and that these differences partially lead to differences in the results of comparable studies.

Activities related to *electronic* and *software* parts of the product were expected given the nature of the development projects and the professional profile of team members sampling (degrees in Electrical Engineering and Mechanical Engineering). Also, with respect to their activities and responsibilities it is not surprising that the *Conceptualization/Design* and *Detailing/Coding* are the two most frequently reported activities. The relatively high proportion of *Planning and Analysis* activities as a part of teamwork should be emphasized. *Innovation/Improvement* activities were more often carried out by the team (8,0 %) than at the individual (2,5 %) level but have a lower share in comparison to other activities.

A large proportion of the individual technical work was carried out using *Engineering software* what is reflected in its leading position among the manners of conducting activities. As in Robinson's study [6], about half of the activities were carried out by using computer tools. However, in our study the share of the *Engineering software* usage is almost three times higher (38,7 % > 12,5 %).

Team activities were mostly carried out *Face-to-face*, and this type of manner is common for the product development processes if team members are collocated. Also, the ratio of time spent in *Face-to-face* and *Email* communication is 3,6:1, while in Robinson’s research ratio is 2,3:1 [6]. Due to the common location of team members in here presented case, email is less frequently used mode of communication, even though numerous studies (e.g. [24, 25]) stress its importance in the engineering context. Research done by Patrashkova-Volzdoska et al. [26] (included different industries such as aerospace, automotive, public utilities, electronics) suggests an even distribution of different communication means within engineering teams, but our results cannot confirm their research outcomes. Difference between these results could arise from the granularity of the work sampling process.

Although the work sampling application is designed in a way that provides an easy and convenient way for gathering the data, this approach incurs additional effort on team members. While such problems do not exist when conducting surveys or acquiring data from corporate IT systems, work sampling daily requires multiple data inputs by the team members and interrupts team members in the current execution of activities. For long-term studies, it is necessary to consider the optimal number of alarms per day for each team member. Data collection approaches that require relatively intense engagement of team members should be usually accompanied with certain forms of extrinsic motivation (e.g. compensation). Indeed, if the sampling period lasted longer, motivation of team members could become an issue, and therefore a strong support from the higher management levels of an organization is needed.

5 Conclusions

In this paper, the work sampling mobile application was developed and used for gathering data about development activities of individuals and teams in engineering domain. The application was used for an empirical study of engineering development process in real organizational settings. The goal of the study was to depict and analyse actual product development activities from various perspectives such as: work type, activity type, context, participants, execution manner, information transaction and motivation. Each perspective has its purpose and can describe and support management of the development process. Application menus were created by combining insights from the literature review and industry practitioners. Insights about individual and team performance could be used by project managers to better understand the working routines and to modify existing practices related to the team composition, resource planning, knowledge needs, and activities execution.

As part of future work, the focus should be on tailoring the data collection process for monitoring and understanding of the project health in terms of the socio-technical aspect, and identification of the related organisational and project risks. Proposed data gathering approach with mobile application enables comparison between different teams and organizations. The combination of results obtained by work sampling with other data collection methods like questionnaires or interviews will enable deeper understanding of individual and teamwork performance during product development process activities.

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6 References

[1] Thamhain, H. Managing Risks in Complex Projects. // Project Management Journal. 44, 2(2013), pp. 20-35. DOI: 10.1002/pmj.21325
[2] Cicmil, S.; Williams, T.; Thomas, J.; Hodgson, D. Rethinking Project Management; Researching the actuality of projects. // International Journal of Project Management. 24, 8(2006), pp. 675-686. DOI: 10.1016/j.ijproman.2006.08.006
[3] Robinson, M. A. Work sampling: Methodological advances and new applications. // Human Factors and Ergonomics in Manufacturing & Service Industries. 20, 1(2010), pp. 42-60.
[4] Badiru, A. B. Handbook of Industrial and Systems Engineering. 2nd ed. CRC Press, 2013. DOI: 10.1201/b15964
[5] Robinson, M. A. An empirical analysis of engineers' information behaviors. // Journal of the American Society for Information Science and Technology. 61, 4(2010), pp. 640-658. DOI: 10.1002/asi.21290
[6] Robinson, M. A. How design engineers spend their time: Job content and task satisfaction. // Design Studies. 33, 4(2012), pp. 391-425. DOI: 10.1016/j.destud.2012.03.002
[7] Škec, S.; Štorga, M.; Tečec Ribarić, Z.; Marjanović, D. Work sampling approach for measuring intellectual capital elements in product development context. // ICED 2015 Proceedings of the 20th International Conference on Engineering Design, Milano, Italy, 27 - 30.07.2015.
[8] Dickson, W. M. Measuring Pharmacist Time Use: A Note on the Use of Fixed Interval Work Sampling. // American Journal of Hospital Pharmacy. 35, 10(1978), pp. 1241-43.
[9] Pape, E. S. Work sampling. In: S. Gael (Ed.), The job analysis handbook for business, industry, and government. NewYork, Wiley; 1988, pp. 518-535.
[10] Finkler, S. A.; Knickman S. R.; Hendrickson, G.; Lipkin, M. Jr; Thompson, W. G. A comparison of work-sampling and time-and-motion techniques for studies in health services research. // Health Services Research. 28, 5(1993), pp. 577-597.
[11] Buchholz, B.; Paquet, V.; Punnett, L.; Lee, D.; Moir, S. PATH: a work sampling-based approach to ergonomic job analysis for construction and other non-repetitive work. // Applied ergonomics. 27, 3(1996), pp. 177-187. DOI: 10.1016/0003-6870(95)00078-X
[12] Harpole, L. H.; Stechuchak, K. M.; Saur, C. D.; Steffens, D. C.; Unützer, J.; Oddone, E. Implementing a disease management intervention for depression in primary care: A random work sampling study. // General Hospital Psychiatry. 25, (2003), pp. 238-245. DOI: 10.1016/S0163-8343(03)00023-9
[13] Pedgley, O. Capturing and analysing own design activity. // Design Studies. 28, 5(2007), pp. 463-483. DOI: 10.1016/j.destud.2007.02.004
[14] Lowe, A.; McMahon, C.; Culley, S. Information access, storage and use by engineering designers, part 1. // The Journal of the Institution of Engineering Designers. 30, 2(2004), pp. 30-32.
[15] Donaldson, S. I.; Grant-Vallone, E. J. Understanding self-report bias in organizational behavior research. // Journal of Business and Psychology. 17, 2(2002), pp. 245-260. DOI: 10.1023/A:1019637632584
[16] Kirwan, B.; Ainsworth, L. K. A guide to task analysis. London: Taylor & Francis Ltd, 1992. DOI: 10.1201/b16826
[17] Ahmed, S.; Štorga, M. Merged ontology for engineering design: Contrasting empirical and theoretical approaches to develop engineering ontologies. // Artificial Intelligence for Engineering Design, Analysis and Manufacturing. 23, 4(2009), pp. 391-407. DOI: 10.1017/S0890060409000146
[18] Sim, S. K.; Duffy, A. H. B. Towards an ontology of generic engineering design activities. // Research in Engineering Design (RED). 14, 4(2003), pp. 200-223. DOI: 10.1007/s00163-003-0037-1
[19] Allard, S.; Levine, K. J.; Tenopir, C. Design engineers and technical professionals at work: Observing information usage in the workplace. // Journal of the American Society for Information Science and Technology. 60, 3(2009), pp. 443-454. DOI: 10.1002/asi.21004
[20] McAlpine, H.; Cash, P.; Storton, A.; and Culley, S. J. A Technology Selection Process for the Optimal Capture of Design Information. // ICORD 11 International conference on research into design, Bangalore, 10 - 12.01.2011.
[21] Cash, P. Characterising the relationship between practice and laboratory-based studies of designers for critical design situations [dissertation]. University of Bath, 2012.
[22] Webster, J.; Higgs, P. An analysis of drawing office activities. // Building Services Engineer. 40, (1973), pp. 246-257.
[23] Marsh, R. The capture and utilisation of experience in engineering design [dissertation]. University of Cambridge, 1997.
[24] Gopsill, J. A.; Jones, S. L.; Snider, C. M.; Shi, L.; McMahon, C.; Hicks, B. J. Understanding the Engineering Design Process Through the Evolution of Engineering Digital Objects. // In: DS 77: Proceedings of the DESIGN 2014 13th International Design Conference. Dubrovnik, Croatia, 19 - 22.05.2014.

[25] Wasiak, J. O. A Content Based Approach for Investigating the Role and Use of E–Mail in Engineering Design Projects [dissertation]. University of Bath, 2010.
[26] Patrashkova-Volzdoska, R. R.; McComb, S. A.; Green, S. G.; Compton, W. D. Examining a curvilinear relationship between communication frequency and team performance in cross-functional project teams. // IEEE Transactions on Engineering Management. 50, 3(2003), pp. 262-269. DOI: 10.1109/TEM.2003.817298

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