The Teams Information Model for Software Engineering Management

Oleksandr Nesterenko
Institute for Applied System Analysis
National Technical University of Ukraine "Igor Sikorsky Kyiv Polytechnic Institute"
Kyiv, Ukraine
ORCID 0000-0001-5329-889X

Yurij Selin
Institute for Applied System Analysis
National Technical University of Ukraine "Igor Sikorsky Kyiv Polytechnic Institute"
Kyiv, Ukraine
ORCID 0000-0002-7562-8586

***Abstract* — Authors of the study consider the impact of software development team dynamics on Information System Development processes. It is determined that management should be based not only on the characteristics of projects but also on the personal characteristics of programmers according to the methodology of group dynamics and communications. An ontological model of the domain area is proposed as a basis of knowledge base to support management decisions.**

Keywords — Information System Development, Software Engineering Management, group dynamics, ontologies, knowledge base, decision making

I. Introduction

In our time of information society and digital transformations, when an information system becomes the engine of technological development, software engineering is a key area of computer science. According to the Curricula Recommendations Software Engineering (SE 2004), SE is the integration of mathematics, computer science principles with engineering approaches designed to produce tangible material artifacts. In SE, as in other industries, humans implement production processes. At the same time, software engineering differs qualitatively from other engineering disciplines by the immateriality of the source product – software, and the discrete nature of its operation. Creating and maintaining software is also a collective activity, which is also globally distributed. Only teams with a certain culture (software culture) and maturity can produce high-quality and reliable software [1].

Most software processes are so complex that cannot be made by one or two people. Therefore, as a rule, groups (teams) are usually formed, which nature as well as features of individuals, play a very important role in the creation and maintenance of software products. Based on this, the development of advanced information technology, the world practice of innovation requires a shift of emphasis from the individual work of individual performers to the activities of multifunctional teams.

At the same time, such a transition requires not only a new approach to the organization of the program development process, but also new methods and tools for managing teams' activities, to justify the parameters of the project – funding, timing, composition of the development team. This is driven by the fact that general human features under the influence of professional activity begin to act as specific professional skills. In addition, a SE teams specifics is roles differentiation within the group and differentiation of the groups themselves. Therefore, most of the successes and failures of software projects are caused by human factors rather than technical ones.

Thus, the motivation and science of this article is to develop solutions to current problems of providing management to teams of software developers in the new reality, and the formation and effective functioning of teams considering human factors.

II. Group Dynamics and Management

A. Influence of Team Dynamics

For more than half a century of SE development, many publications – from fundamental publications such as [2 - 4] to publication in scientific journals and conference proceedings – demonstrate a broad panorama of topics covering all stages and technologies of SE development. They present the full range of processes leading to the creation of software from the initial development of system requirements and further through the design, direct programming, and certification to the modernization of software systems. However, despite this, the focus of SE remains on the sharpest topics: how to cultivate talents and how to motivate them in modern environment, what is needed to effectively adapt new employees, how to make important production processes interesting, how to manage teams in the new reality, and finally, why people are the company's most valuable resource?

Considering team development and paradigms of culture, answers to such questions should be provided by a scientific direction of group dynamics and communications (GDC). Influence specifics of professional aspects of GDC within the team, requirements for personal qualities of software engineers, a set of in-group and inter-groups socio-psychological processes and phenomena, interrelated acts of transmission and perception of information in group interaction – all these largely determine the success of the business [5]. The job profile of a software engineer includes not only so-called "hard skills" (such as pointing, programming, or building architectures), but also "soft skills" such as awareness of team effects and similar human factors [6]. Effective use of the GDC methodology provides higher moral spirit of the software developers' team and leads to increased productivity and staff discipline in the team. Research [7] has shown that the maturity of small working groups, in particular team agility, from a psychological point of view, is closely related to the positive effect of training such a team on in-group developmental psychology. There is a huge potential in the preparation of team agility in this topic. In addition, the positive effects can cover the entire software development organization.

A special topic in the field of software engineering is Software Engineering Management (SEM) - managing the work of software developers' team in the process of implementing a project plan. Determining the criteria for the

effectiveness of the team and evaluating the processes and products of projects using general methods of work planning and control are directly related to the GDC methodology (Fig. 1). In [8] it is noted that one of the problems in software development is the problem of atrophy of knowledge on these issues. To investigate this, authors have studied several factors of command dynamics that affect Knowledge Management Processes (KMP) in Very Small Entities (VSEs). The results demonstrate that team dynamics impact on a well-organized knowledge process can prevent software development organizations from suffering.

B. *Decision Making in Management Processes*

Features of SE management at the current stage is the growth of the dynamics of all processes, which is reflected in a sharp increase in the information required for processing. This domain area is characterized by a significant number of aspects or features that affect the quality of management decisions. In general, this leads to the fact that decision-making tasks are usually multi-criteria. In these conditions, the search for new knowledge comes to the forefront of management to support decisions as the quintessence of the information process.

Researchers and specialists offer several approaches to support decision-making in such an environment. Most of them are based on expert methods, which to some extent allow solving the tasks (for example, the Delphi method, AHP, etc.). At the same time, if we analyze the research in this area, we can conclude that the support of decisions in management, especially in multi-criteria cases, is directly related to the presentation of the information model of the domain area (DA).

Therefore, the purpose of this article is an attempt to offer an approach to providing information support for management decisions in the tasks of SEM, the definition of human resources based on information models. Such models should adequately reflect the hierarchical and network structures of elements (objects, factors, criteria, etc.) inherent in these tasks and consider their mutual influence in a multifactorial environment.

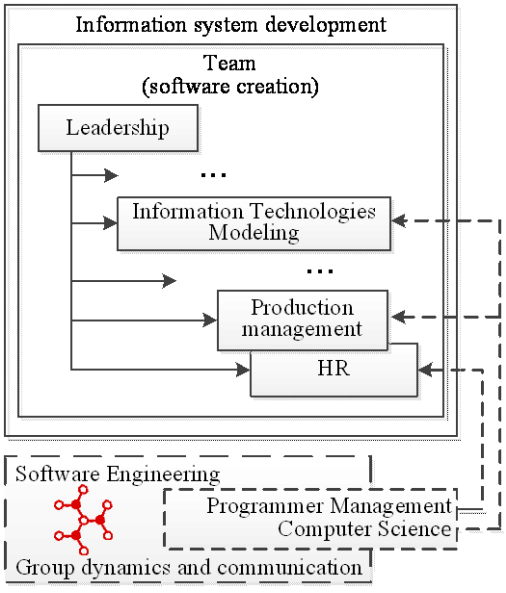

Fig. 1. Role of Group dynamics and communications in Information System Development and Software Engineering Management

III. Information Model for Information System Development and Software Engineering Management

As previously noted, the development of computer programs in modern realities is a mass profession, but at the same time, it is one of the most difficult professions. The difficulty is that, according to a well-known saying, a programmer must have the ability of a first-class mathematician to abstract and think logically, combined with the talent to build anything from zeros and ones. The programmer must combine the accuracy of the accountant with the insight of the spy, the imagination of the author of detective novels with the sober practicality of the economist. In addition, the programmer must have a passion for teamwork, understand the interests of the community and customers of software products.

In mature organizations, staff capabilities are directly related to business efficiency. Staff capabilities are a matter of competitiveness and a source of strategic advantage. Carnegie Mellon SEI's People Capability Maturity Model (People CMM) concept helps to develop staff capabilities and address important staffing issues. Based on current best practices in areas such as human resources, knowledge management, and organizational development, P-CMM helps organizations to identify the capabilities of their HR practices, establish continuing staff development programs, set priorities, integrate staff development with process improvement, and implement a culture of excellence.

A. *Projects and Recruitment*

The organizational basis for software development is the project. The project involves all stages of development from the formation of the terms of reference to the release of the product on the market. The project has limitations – development time, stages of development, the desired result at each stage, and the budget [9]. Given the wide range of project challenges faced by software development teams, it is clear, that teams need to be flexible in their approaches.

This is especially true for large groups, which require broader professional communication and significant organizational costs, and therefore have a higher risk than smaller teams. It is clear, that the teams working on the program project, with five people, with 20 people, or with 200 people will work in completely different ways. Therefore, the complexity of managing a group of software developers requires a more flexible team structure through enterprise architecture and management strategies for development.

The main problems that affect both the process of team building and their functioning in general are determined based on project analysis. This is, first of all, the quality of recruitment, which is related to the tasks to be solved and the budget for the project. Usually, the project team is formed from individual professionals. This labor market is significantly affected by globalization, which is inherent in the field of information technology. All this leads to multi-criteria and uncertainties in decision-making.

Thus, the general statement of the task of multi-criteria personnel evaluation can be formulated as follows.

Given:

1) $P = \{P_i\}$, $i = (1,n)$ - set of team's portfolio projects;

2) $O = \{O_i\}, j = (1,m)$ - set of persons to be involved in the implementation of projects;

3) $K = \{K_a\}$, $q = (1,l)$ - set of evaluation criteria;

4) each person O_i is assigned a tuple of grades according to all criteria $S = \{S_{jq}\}$.

Needed:

1) to rank O_i taking into account the preferences of managers;

2) to find the integrated cardinal estimation of each person, that is to define set $R = \{R_j\}$ of person s' ratings.

The set of criteria by which individuals have evaluated forms a hierarchy, and it can be asymmetric. Criteria can be of two types: quantitative and qualitative. Thus, the formulation of criteria is a purely creative process, which is currently difficult to formalize. The quality of the recommended wording directly depends on the level of professionalism and responsibility of managers' decisions. When formulating the criteria, it is necessary to take into account not only the significance and clarity of the criterion, but also the possibility of obtaining estimates of alternatives to them, and the number of different possible estimates. Therefore, at this stage, it is advisable to encourage the most experienced managers, and use the "brainstorming" methods to find consistent definitions of these categories. This process takes place based on group expert evaluation methods with feedback, for example, the method of direct evaluation, the method of linear pairwise comparisons, and others.

Therefore, when approving the decisions made, it is necessary to consider the degree of trust to recommendations provided by managers, and the peculiarities of human perception of the very fact of preparation of the decision.

Thus, an important factor in organizing the participation of group and project managers in the preparation of the necessary data and choosing the best solution is the need to have some idea of how a person makes decisions. Modern understanding of this process is associated with the perception of conceptual or mental model of the world around, which is used by person to predict the consequences of their actions. It is believed that this model consists of the perception of the external environment by the senses, their transformation into images and the creation of logical ideas about the world. Together, they participate in decision-making, but it has been experimentally confirmed that their impact may be inconsistent and a person's response to questions may deviate from the expected logical answers. The ability to overcome the impact of inconsistencies in the levels of this model is associated not only with the clarity of the problem but also with the quality and completeness of the information collected and presented.

B. The Ontology Formalization

Thus, regardless of what approaches are used to evaluate team staff, it is necessary to ensure the collection, presentation and analysis at various levels of a significant set of heterogeneous data to support decision-making in a complex information space.

On the one hand, these data characterize set of projects, for example, according to PMBOK (Project Management Body of Knowledge) international recommendation. On the other hand - data describing the socio-psychological characteristics of staff according to the GDK methodology, in particular in accordance with SEI People Capability Maturity Model (for Software) recommendation.

To ensure high-quality processing and increase the objectivity of the formation of characteristic vectors, DA must be presented in the form of a certain information model. This model should most accurately reflect the structuring and detailing of DA to clearly define indicators, characteristics, criteria, and other information, as the quality of the resulting solution depends on it in the first place. Errors at the stage of data structuring usually lead to the formation of erroneous decision-making models that lead to incorrect results.

One of the methods to solve this problem is the ontological representation of DA as a detailed description of the subject area using a conceptual scheme consisting of a hierarchical data structure and containing information about properties and the relationship between concepts and objects [10 - 13]. In the general case, the ontology contains information descriptions based on an object-oriented formalization procedure, and each model can be represented by a specific taxonomy. This structure reflects the decision-makers' understanding of the problem. In these conditions, the information support for solving management problems is the application of the manager's ontological model of DA by transformations based on interpretive selection functions, which control the process of supplying information resources for processing based on ontology. These functions determine the rules for using and processing ontology concepts in solving certain problems [14]. Thus, the ontology allows you to present a description of all its components in a formal language, which can be interpreted by some procedure (algorithm) and be implemented by information technology.

Thus, DA, or the world in which decision-making processes for SEM take place, is usually a large system of taxonomies that reflect a clear hierarchy of interaction between concepts defined by binary relations (Fig. 2). On the one hand, it is a taxonomy of set projects *P*, on the other, it is a taxonomy of GDC concepts that describe the socio-psychological characteristics of set of persons (*O*). Of course, such a model should take into account indicators of the professional level of individuals and, on the other hand, budget constraints.

The crucial element of modern decision-making support are information and analytical systems. And an important element of such systems is the knowledge base, which represents the information model of the SA. Among the existing approaches to the construction of such knowledge bases in recent years, the most adequate is the use of computer ontologies [15-16]. Attributive descriptions (properties) of criteria can be presented in the form of frames, the slots of which contain the corresponding numerical or linguistic data [17]. Managers in their decision-making process for staff appraisal should use this data. This problem is quite complex and has both theoretical and methodological aspects, and organizational, which requires standardization of these indicators because only in this case you can build a holistic hierarchy of aggregate models.

IV. CONCLUSIONS

Effective software engineering management should be based on group dynamics methodology. To support making decisions on the selection and support of personnel, it is advisable to build an ontological model of the domain area and create an appropriate knowledge base.

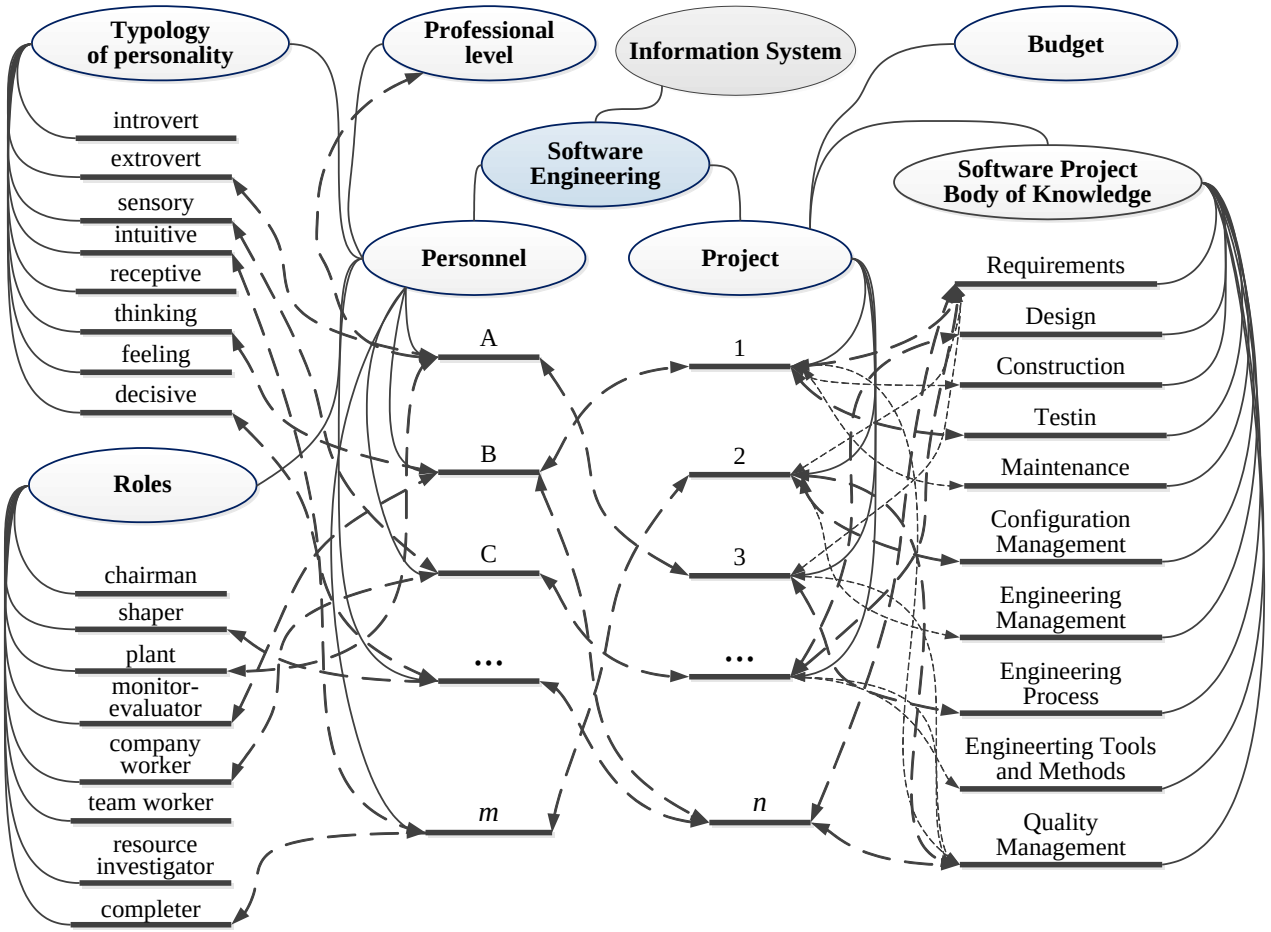

Fig. 2. The Ontology model for Software Engineering Management domain area

The limitations of the proposed approach can be removed by developing a method to support the work of experts in solving the task of multi-criteria staff evaluation and projects ranking, taking into account the preferences of decision-makers.

REFERENCES

[1] N. A Sydorov, "50 years of software engineering," Problemy prohramuvannia, vol. 4, pp. 30-44, April 2018

[2] Richard C. Gunther, Management methodology for software product engineering,. John Wiley&Sons, 1978.

[3] Ian Sommerville, Software Engineering, 6th Edition, Vyliams, 2002.

[4] F. Y. Andon, H. Y. Koval, T. M. Korotun, E. M. Lavryshcheva, V. Yu. Suslov, Fundamentals of software systems quality engineering, Akademperyodyka, Kyev, 2007.

[5] M. S. Pasieka, "Features of group dynamics in software engineering", Naukovyi visnyk NLTU Ukrainy, vol. 25.3, pp. 391-395, 2015.

[6] L. Grena, A. Goldmanb and C. Jacobsson, "The perceived effects of group developmental psychology training on agile software development teams", IEEE SOFTWARE, vol. 37, issue 3, pp. 63-69, 2020.

[7] O. V. Mnushka and V. M. Savchenko, "Forming and managing a team of software developers", Visnyk Natsionalnoho tekhnichnoho universytetu "KhPI", vol. 3, issue 1, pp. 99-112, 2020.

[8] S. Basri and R. O'Connor, "The Impact of Software Development Team Dynamics on the Knowledge Management Process", Proceedings of 23rd International Conference on Software Engineering and Knowledge Engineering (SEKE 2011), USA, July 2011.

[9] M. Kuhrmann, H. Femmer and J. Eckhardt, "Controlled Experiments as Means to Teach Soft Skills in Software Engineering Overcoming Challenges In Software Engineering Education: Delivering Non-Technical Knowledge And Skills," Advances in Higher Education and Professional Development Book Series, pp. 180-197, August 2014.

[10] R. J. Destefano, L. Tao and K. Gai, "Improving Data Governance in Large Organizations through Ontology and Linked Data," Proceedings 3rd IEEE International Conference on Cyber Security and Cloud Computing, CSCloud 2016 and 2nd IEEE International Conference of Scalable and Smart Cloud, SSC 2016, pp. 279–284, August 2016.

[11] C. Calero, F. Ruiz, M. Piattini, Ontologies for Software Engineering and Software Technology, Springer‑verly, 2006.

[12] A. V Palahyn and N. H. Petrenko, "On the issue of system-ontological integration of domain area knowledge," Matematychni mashyny i systemy, vol. 3,4, pp. 63–75, 2007.

[13] V. V. Lytvyn, V. A. Vysotska, D. G. Dosyn, Methods and means of processing information resources based on ontologies, Lviv: LA «Piramida», 2016.

[14] V. V. Prykhodniuk and A. E. Stryzhak, "Multiple characteristics of ontological systems," Matematychne modeliuvannia v ekonomitsi, vol. 1-2, pp. 47–61, June 2017

[15] O. V. Nesterenko, "Ontologi-driven information systems in administrative management," Matematychne modeliuvannia v ekonomitsi, vol. 2(15), pp. 57–68, June 2019.

[16] O. Nesterenko and O. Trofymchuk, "Patterns in forming the ontology-based environment of information-analytical activity in administrative management," Eastern-European Journal of Enterprise Technologies. vol. 5/2 (101), pp. 33–42, August 2019

[17] V. V. Lytvyn, Knowledge base of intelligent decision support systems, Lviv: Vydavnytstvo Lvivskoi politekhniky, 2011.