Modelling Influence of Motivation on Efficient Tasks Distribution for Given Team-project Correspondence

Valentina Y. Guleva[a], Egor N. Shikov[b] and Klavdia O. Bochenina[c]
National Center for Cognitive Research, ITMO University, Kronverkskii Prospect 49, Saint-Petersburg, Russian Federation

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Abstract: The mathematical model of project execution, considering motivation effects on personal productivity is suggested in the paper. The main supposed application of the model is the task allocation problem during project management, which is restricted by the parameters of correspondence between tasks and team competence and interests, and execution deadline restrictions. In this way, motivation is considered an influential factor, and we explore how it affects team productivity and how can it be managed by task allocation strategies on the basis of personal motivation control. Namely, we explore the effects of personal motivation factors on overall project success. For this purpose, we consider motivation and competence factors in the model at the agent level, and take into account the initial abilities of a team, with given competence and motivation, to implement a project requiring a number of skills. To measure the effect of motivation and its role in project management, we perform a set of experiments showing (i) optimistic project execution times on the basis of team abilities against project requirements, (ii) possible effects of motivation on project execution and possibilities of its management, and (iii) effects of managerial approaches on team productivity (competence and motivational growth and their effects on tasks execution). The results show that poor correspondence between team and project competencies and interests can tenfold decrease team productivity, which can be partly eliminated by task assignment strategies, aimed at motivation control.

1 INTRODUCTION

AI is actively being introduced into everyday life, in particular, in project management. Personal assistance for professional deals meets dualism in personal and firm interests, which criticality is increasing for artificial professions and science. Motivation factors may significantly decrease personal productivity (Vansteenkiste and Ryan, 2013), affect professional burnout (Scott, 2020), and overall project success. In this way, building managerial systems for tasks distribution, aiming at satisfying both, organisation and employee interests, is of great importance. In this case, personal assistants are necessary for employee needs identification, and macro-level algorithms are required for a system of assistants configuration, dependent on team-project correspondents, firm deadlines, and other requirements. Despite major interest in managerial approaches in enterprise and great number of experiments, the existing conclusions about possible effects on personal productivity are weak formalised, in particular, the formal mathematical model of these processes are absent, for the best of our knowledge. Therefore, the one is suggested in the current article.

The current study prepares material, which can be useful for enterprise task management and for the corresponding systems of personal assistance configuration (Guleva et al., 2020). It provides a minimal model, reflecting 1) effect of motivation and competencies on personal productivity, related to a task assigned, 2) effects of tasks assigned on personal competence growth and motivation by measuring the correspondence between competencies, necessary for task execution and personal ability, 3) personal contribution to system state variables at the macrolevel, and 4) allows to distribute tasks aiming at personal motivation increase or at quicker project execution. This dynamics at microlevel allows for exploration of motivation influence on project success under different initial conditions, like firm deadlines and correspon-

[a] https://orcid.org/0000-0002-1555-9371
[b] https://orcid.org/0000-0001-5749-4222
[c] https://orcid.org/0000-0001-6025-0552

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dence between project requirements and team abilities, which restricts possible best cases in team productivity.

The project model contains tasks with a certain level of necessary competence for their implementation and a team with their interests and competencies in various topics. During the simulation, accompanied by the task allocation process, personal motivation can increase or decrease if the task is interesting or not, and personal competencies increase depending on the correspondence between the complexity of the task and personal abilities. On the other hand, the task assignment management process affects the dynamics of the system by taking into account changes in personal motivation, which affects the task completion time.

Further, we construct an experimental stand and investigate the dynamics of the project described by the mathematical model above, which allows us to explore possible options for task assignment based on competencies, as well as more complex cases with motivational effects.

2 RELATED STUDIES

2.1 Competence and Motivation Growth Mathematical Models

The vast majority of competence and motivation studies are difficult to formalise, therefore they content observations from the learning process and are based on questionaries to small sets of users, allowing for manual analysis. Mathematical models are few and concern narrow applied scenarios. This results in the necessity of model development for competence and motivation growth for our particular case of project management scenario and its further calibration and verification. Therefore, we make some observations from the studies below and incorporate them into our model for further exploration.

Motivation changes due to task assignments are explored in a model of educational activity at the teacher-group level, which is focused on the task of filling the "knowledge repository" with tasks of various topics and complexity (Kusztina et al., 2010). The motivation function of the teacher and the student depends on the complexity of the task and its similarity on the topic. Similar model is explored for student projects scheduling aiming at maximising the number of project teams to perform complex project tasks (Bakhtadze et al., 2020).(Koeppen et al., 2008) reviews current issues in competence modelling and assessment, including an overview of competence acquisition models, where competence is a composition of cognitive, psychometric, and domain-specific abilities.Similar decomposition is suggested in other review (Salman et al., 2020), concluding competence influence on work visual progress and its quality. The studies about domain-specific competence measurement (Chung et al., 2008; Van Der Linden, 2005), observed in the review (Koeppen et al., 2008), aim at automated knowledge evaluation like in teaching-learning process.

Our model for task assignment and project evolution also requires microlevel dynamics of competence growth, which should reflect effects of task scope and complexity on its execution time, time required for competence growth, and measure of competence growth. MacGrath et al. (McGrath et al., 1995) understand a competence in the context of firms development as a resource for reaching objectives, and competence growth as a new source of competitive advantage. They analyse team productivity on the base of their responses and explore correlations between comprehension, competence, deftness, culture, and sector, which a firm belongs to. Search for competence growth measurement also results in sports study (Fransen et al., 2018), where authors explore personal and team performance dependence on a leader competence-thwarting or supporting behaviour. Performance is measured as a time of task evaluation for single persons as well as for team.

2.2 Task Assignment

Task assignment (TA) problems are usually formulated in terms of fixed execution times for a pair (worker, task) given by a cost matrix (detailed typology of such problems may be found in (Pentico, 2007)). The goal of TA is to find a correspondence between tasks and workers to minimize a total cost. Although, there are TA problems accounting for agent qualification (by placing additional restrictions) and allowing for multiple task assignment for the same agent, a cost is assumed to be static and known in advance. This assumption is reasonable for highly predictable environments (job scheduling for a static set of computing units (Topcuoglu et al., 2002) or in a multi-robot setting (Luo et al., 2011)), but is not necessarily to be true for human-centric systems. The uncertainty and the variability of worker's productivity bring an additional level of complexity to TA problems; however, studies of TA in this context are less numerous.

There are several factors of uncertainty in a worker's outcome for a task that are investigated in human resource allocation problems (Bouajaja and Dridi, 2017). Performance may be influenced by the personal features of a worker (e. g. competencies effecting on productivity for the industrial performance optimization (Boucher et al., 2007)). Authors stress the performance is influenced by the level of competencies of workers and competence trajectories, as well as the ability to allocate and coordinate competencies along with business processes. Workers may operate collaboratively, increasing or reducing each other's productivity (Younas et al., 2011), which may contribute to team result as a non-linear function of its members. R&D process is characterized by a high level of uncertainty of executions times (Su et al., 2020), which are predicted as a step of a three-step TA model by a neural network, which uses estimated satisfactory degree of knowledge for a given team and a task as an input. In turn, these values are provided by an additional Task-Knowledge-Team (TKT) graph.

2.3 Validation Possibilities – Data Sets

The formulation considered in this article is similar to one used in various issue tracking systems such as Jira, Redmine, and others. There are a number of open repositories collected from data based on these programs (Ortu et al., 2015; Rahim et al., 2017; Lenarduzzi et al., 2019; Claes and Mäntylä, 2020). They contain a large number of issue reports and comments, as well as task assignment and resolution timestamps. However, there are some difficulties in validating the model on these datasets. For instance, it is often quite difficult to determine interests of users, as well as their competencies, especially considering that the latter may change. This can be achieved only by using additional data sources and competence acquisition methods. Also, text descriptions of tasks are usually written using task-specific terms,which makes it difficult to identify the real values of task competence vectors.

2.4 Discussion

The goal of current review was to find appropriate mathematical or simulation models, showing competence and motivation dynamics during project execution. Despite we have note found actual models, appropriate for our exploration of task assignment process and possibilities of digital assistance,one can resume the main patterns, determining personal productivity, on the base of literature review. They are:

1. task complexity and similarity of a topic affects personal productivity (Kusztina et al., 2010);
2. competence affect productivity (Koeppen et al., 2008; McGrath et al., 1995);
3. competence frustration as barrier to motivation and performance (Fransen et al., 2018);
4. task understanding affects productivity (McGrath et al., 1995);
5. feeling of competence increase intrinsic motivation (Fransen et al., 2018);
6. performance is measured as time for a task (Fransen et al., 2018).

Therefore, personal productivity is measured as time for a task execution by a user; the time is inversely proportional to competence and motivation, and motivation is related to similarity between task topic and personal interests.

These patterns are reflected below in the proposed mathematical model of project evolution with motivation changes due to properties of tasks assigned. Nevertheless, we suggest additional parameters, making model a bit more flexible and personalised to capture possibilities of validation by means of available data, and for possibility of exploration with personal assistants.

3 PROJECT EVOLUTION MODEL WITH MOTIVATIONAL FEEDBACK

Let consider a project Π as a set of tasks $\mathcal{E} = \{e_k\}_{k=1}^{M}$, $M \in \mathbb{N}$, and each task is characterised by competencies in a topic space, necessary for its performance. Then, each user $u \in U$ has their interests $u_i \in \mathbb{R}^Z$ and competencies $u_c \in \mathbb{R}^Z$, where Z in the number of topics forming the interest space, which is Hilbert space with Euclidean norm. The introduction of both interests and competence for users allows distinguishing things they are able to do from ones they would like to.

3.1 Dynamics

Motivation to do a single task is supposed to be interest-dependent,[1] while global user motivation accumulates their satisfaction of previous assigned tasks, which results in formulae 1, 2.

$$m(e,u) = cos\big(e_c, u_i\big) \qquad (1)$$

$$u_m(t+1) = (1-\varepsilon)\cdot u_m(t) + \varepsilon \cdot m(e,u) \qquad (2)$$

[1]For arbitrary number of factors, affecting motivation, a general form is: $m(e,u) = \sum_k \gamma_k \cdot f_k(e,u)$, where f_k is attractiveness from the viewpoint of k value, and $\{\gamma_k\}$ is personal values vector.

Since user satisfaction of tasks assigned is supposed to reflect the vectors collinearity, and we would like them to be normalised for different time stamps (for Eq. 2), the cosine function fits these restrictions well. Here (Eq. 2) we meet the first parameter for calibration, which is related to personal "patience" – the ability to do routine with minimal motivation decrease – the ε-parameter regulates contribution of recent events in contrast to the newest, which can also be captured by a width of time window, affecting motivation.

In this way, each task assignment affects motivation and may increase project efficiency by influencing task completion time (Eq. 3):

$$\tau(e,u) = \frac{1}{m(e,u)} \cdot \frac{||c(e)||}{||c(u)|| \cdot cos\big(c(e), c(u)\big)}. \quad (3)$$

This implies time decrease with increase in motivation and user competence. The correspondence of user competence to task difficulty is evaluated as user competence vector projection on the task competence vector, after which their norms are compared, which is reflected by the second multiplier in Eq. 3.

Changes in competence are also involved in personal dynamics evaluation, and proportional to the difference between personal and task competence (Eq. 4). The γ multiplier provides restriction on competence increase for similar tasks evaluation, and it is the second parameter for calibration, which reflects speeds of obtaining and forgetting knowledge. The γ can also be interpreted as / related to "adaptability".

$$u_c(t+1) - u_c(t) = \frac{c(e) - c(u)}{\gamma}. \quad (4)$$

In this way, the model contains two drivers of employee activity, two kinds of feedback links, and result of tasks assignment at task level as completion time, which is observed at system state variable after aggregation over project.

Therefore, task attractiveness for a user, to be considered by a personal assistant and for project management, should be based on the balance between firm and employee satisfaction, which is implemented as the dependence on current motivation level:

$$\Phi(u,e) = u_m \cdot cos(u_c, e_c) + (1 - u_m) \cdot cos(u_i, e_c), \quad (5)$$

where $cos(u_i, e_c) = m(e,u)$ generally. In this way, higher motivation corresponds to more energy to do any task, therefore, a task, appropriate for firm necessity can be assigned as attractive enough. At the same time, low motivation is a sign of burnout and a reason to increase it by an interesting task, which is captured by Eq. 5.

3.2 Personal Assistance and Project Requirements

Each person demonstrates different critical values of patience, after which low motivation does not allow for efficient project execution. Personal efficiency for project goals can be managed by a personal assistant. On the other side, a project may have strict deadlines, which restricts number of possible managerial scenarios, or it may contain time gaps to increase people competence and motivation for more efficient further work, which also can be managed by a project assistant to contribute to further firm development. The third side is restrictions in project implementation, arising from the correspondence of its topic and difficulty to team's abilities and interests. This restricts the range of project states for any quality of management.

Maintaining constant productivity of employee is more efficient for project execution performance than sprint-strategy with longer recovery time intervals (e. g. there are time limits, required for recovery, obtained for sport competitions (Moxnes and Moxnes, 2014)). Therefore, digital personal assistants aim at maximisation of user satisfaction, control project state, and at minimization personal productivity fluctuations at the same time. Therefore, a personal assistant is supposed to monitor motivation changes in order to minimise fluctuations in productivity. In contrast, urgency of project execution requires minimal consideration of motivation, which is captured by special α parameter. Eq. 5 is adapted by scalar α, s. t. zero-alpha focuses on motivation, $\alpha = 1$ uses competencies for task assignment, and $\alpha = 0.5$ uses optimal task preferences depending on current motivation level:

$$\Phi(u,e) = \alpha \cdot u_m \cdot cos(u_c, e_c) + (1 - \alpha) \cdot (1 - u_m) \cdot cos(u_i, e_c) \quad (6)$$

α should be tuned by a personal assistant depending on current requirements for project evaluation and an observed user state. This modifies task attractiveness function by potentially optimal parameter of personal efficiency α_u^*.

From the global viewpoint, short- and long-term planning restricts α-s at system level. Planning restrictions are combined with people's ability to project execution. Therefore, the global α averages personal α-s, and its minimal and maximal values of motivation consideration should be stated on the basis of requirements and system configuration restrictions.

3.3 Global State Variable

Project success is estimated as a number of tasks completed (Eq. 8), or as time for all tasks completion (Eq. 9). In this way, the main managerial goal is to distribute tasks between users to minimize project realization time and maximize users' satisfaction and competence increase to provide further firm development.

$$s(e,t) = \begin{cases} 1, \ complete \\ 0, \ otherwise \end{cases} \tag{7}$$

$$s(\Pi,t) = \frac{\#\{e | s(e,t) = 1\}}{\#\mathcal{E}(\Pi)} \tag{8}$$

$$T(\Pi) = \max_{j=1:N} \left\{ \sum_{k=1}^{Z} b_{kj} \tau(e_k, u_j) \right\}, \tag{9}$$

where $s(e,t)$ determines a task state at time t, $\{b_{kj}\} = B$ is a task assignment matrix, having ones, if task is assigned to a user, and zeros – otherwise.

The system explored and project success are restricted by the correspondence a between tasks topics and team competence (from one side) and by the correspondence b between user interests and task topics at the system level. In this way, we will observe project success $s(\Pi,t)$ and $T(\Pi)$ in the connection to restrictions like a and b, and show, how much project execution times can be regulated by means of employee motivation control for different configurations of these parameters.

4 EXPERIMENTAL SET UP

The experiment is aimed to explore effects of **motivation consideration** (α) during tasks assignments B to a team, according to their **interests** u_i and **competence** u_c, in order to decrease projects execution time $T(\Pi)$ and increase team ability and motivation potential for further projects. Possible project success is restricted by the correspondence between task topics and difficulty and team interests and competence, determined by a and b parameters (Table 1).

In this way, we consider three sets of experiments, aimed at determining (i) optimistic project execution times, (ii) possible effects of motivation on project execution and possibilities of its management, and (iii) effects of managerial approaches on team productivity (competence and motivational growth and their effects on tasks execution).

Table 1: Motivation-sensitive project model parameters at global scale.

Restrictions		Parameters		Observations	
a	correspondence between project and employee competence	α	motivational necessity (from task urgency vs. further efficiency focus)	$s(\Pi,t)$	number of tasks completed
				$T(\Pi)$	project execution time
b	correspondence between project topic and employee interests			$\Delta\overline{u_c}$	competence increase per time
				$\Delta\overline{u_m}$	motivation increase

4.1 Optimistic Project Execution Times

Since initial correspondence between team abilities and suggested tasks restricts the best execution times, we firstly explore them for fixed motivation and assign task according to competencies only. That is task execution time $\tau(e,u)$ (Eq. 3) is evaluated with $m(e,u) = 1$, and task attractiveness $\Phi(u,e) = cos(u_c, e_c)$ (Eq. 5), since $u_m = 1, \ \alpha = 1$. In this way, we vary a and obtain average times and deviations of project completion for the cases of correspondence between tasks and team competence ($a = 1$) and for the opposite case ($a = 0$).

4.2 Effects of Motivation

When certain values of project execution times are known for the case of the highest motivation ($u_m = 1$), we explore the effect of motivation-sensitive dynamics on project success. For this case, the initial motivation values are fixed for all users and then they are changed during simulations depending on tasks assigned. Tasks are assigned a) according to competencies ($u_m = 1, \ \alpha = 1$ in Eq. 5), b) in order to increase motivation if it is low ($u_m(t) \not\equiv 1, \ \alpha = 1$, Eq. 5). For both cases we explore how the correspondence between tasks and user interests affect project execution times. The resulting times are compared to times, obtained from the first experiment.

4.3 Effects of Managerial Approaches on Team Productivity and Growth

The goal of this experiment is to understand how quickly the project can be evaluated and how it can affect further team efficiency. In this way, we vary α for task attractiveness evaluation and measure project execution time, motivation increase and competence change. Generally, the efficiency notion should be introduced in order to measure current team state and its ability to execute tasks. This issue also leads to question of optimal "efficiency" level determination.

Algorithm 1: Task assignment method with motivation effects on execution time and task attractiveness and user states dynamics.

U - set of users
$\boldsymbol{E}$ - set of tasks
$\hat{\boldsymbol{E}}$ - set of not completed tasks
$t = 0$
while $\hat{\boldsymbol{E}}$ *is not empty* **do**
  for *u in U* **do**
    for *e in* $\hat{\boldsymbol{E}}$ **do**
      $\Phi(u,e) = \alpha \cdot u_m \cdot cos(u_c, e_c) + (1-\alpha) \cdot (1-u_m) \cdot cos(u_i, e_c)$
    end
    $e_u = argmax(\Phi(u,e))$
    $u_m(t+1) = (1-\varepsilon) \cdot u_m(t) + \varepsilon \cdot m(e_u, u)$
    $u_c(t+1) - u_c(t) = \frac{c(e)-c(u)}{\gamma}$
    $\tau(e_u, u) = \frac{1}{m(e_u,u)} \cdot \frac{||c(e_u)||}{||c(u)|| \cdot cos\left(c(e_u), c(u)\right)}$
    $busy_u = busy_u + \tau(e_u, u)$
    if $busy_u < 0$ **then**
      $\hat{\boldsymbol{E}} = \hat{\boldsymbol{E}} \setminus \{e_u\}$
  end
  $t = t+1$
end

5 RESULTS AND DISCUSSION

5.1 Optimistic Project Execution Times

Project and team are initialised with different correspondence of their competence (a change). At the same time, different concentration values of Dirichlet distribution results in uniform or peak values in vectors, which affects difference between task and user competence vectors for low a values. In this way, high concentration ($conc = 1.00$) demonstrates similar project states for various a (Fig. 1). At the same time, low concentration values results in $T(\Pi) \approx 500$ for completely different competence of project and team and to $T(\Pi) = 30$ for similar competencies. This states the restrictions for project success, depending on initial conditions of competence for a considered system configuration.

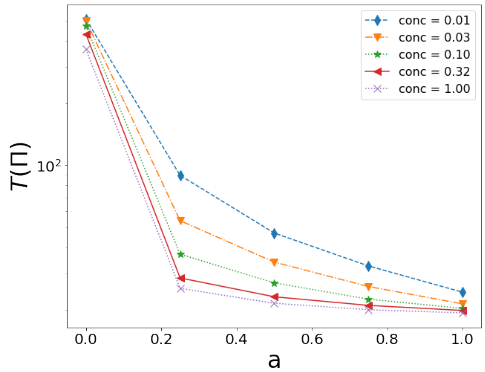


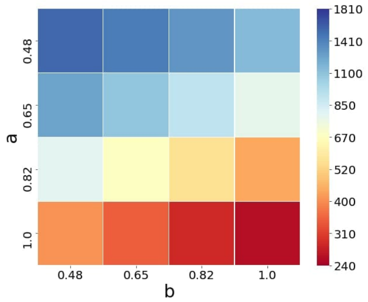
Figure 1: Dependence of project execution times on the correspondence between task and user competencies. $T(\Pi)(a)$ shows certain values of execution times (for 90 % of all project tasks) and deviations for $a \in [0;1]$. Concentration values of Dirichlet distribution reflect difference between peak and the lowest values of competence in user and task distributions (low conc. for high difference and majority of equal values for conc. = 1). Equal values of task and user competencies ($conc. = 1$) correspond to their better fit, therefore, for $a = 1$, $conc = 1$ gives the best execution times.

5.2 Effects of Motivation

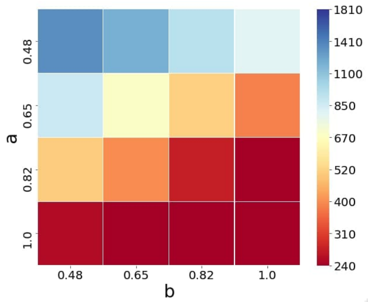
Let initialise motivation for all users as $u_m(0) = 0.5$. This will increase tasks execution time, but will allow for implementation of different task assignment strategies. The motivation is changed depending on tasks assignment, and task attractiveness uses motivation changes by a) $\alpha = 1$ (Fig. 2a) or b) $\alpha = 0.5$ (Fig. 2b). The resulting execution times are greater for all a values, in contrast to the first experiment, since motivation affects execution time, but it is not used during tasks assignment process. As a consequence, the consideration of motivation during task assignment decrease execution times (Fig. 2b).

In this way, if motivation affects project success it can be managed. At the same time, correspondence between interests and project affects more in the case of skill-oriented tasks assignment for high competence correspondence, while it affects more for low competence correspondence.

In addition, one can see significant difference in project execution times for combinations of a and b. This demonstrates at global scale, that lack of correspondence between interests and skills may ten times decrease team productivity, while changes in managerial approaches increase productivity less significantly.

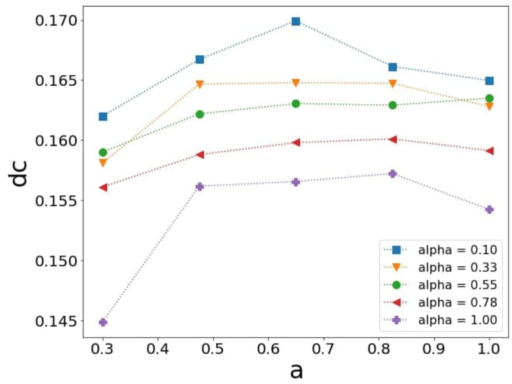


(a) Competence-based tasks assignment, urgent case, $\alpha = 1$.

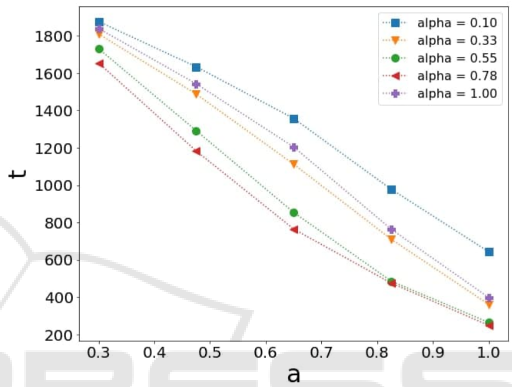


(b) Motivation increase during tasks assignment, $\alpha = 0.5$.

Figure 2: Effects of motivation changes due to tasks assignment on project execution times.



(a) Competence increase.



(b) Times for motivation-sensitive task assignment.

Figure 3: Motivation-sensitive tasks assignment influence on team competence growth and motivation.

5.3 Effects of Managerial Approaches on Team Productivity and Growth

In order to analyse influence of managerial approaches (during project implementation) on team productivity we observe competence increase depending on tasks assignment approach (α variation). Figure 3 shows average competence increase is higher for the cases of planning controlling motivation, while urgent task assignment, based on competence correspondence, demonstrate the lowest competence increase. This is accompanied by time dynamics, showing better performance for middle values of motivation share ($\alpha \in \{0.55;\ 0.78\}$), while the worst results are for competence-centered and motivation-centered edges.

6 CONCLUSION

Motivation is an important factor for project success, which may compensate lack of competence in a positive case, or may contribute negatively in the case of demotivation. This complicates a problem of tasks assignments by additional feedback links in a project organization system, affecting project state dynamics by microlevel effects. In order to manage motivation at personal scale, we develop a model, incorporating motivation and competence feedback links at microscale of user-task interaction, which is connected to macrolevel by task execution times, inversely proportional to user motivation and competencies, based on theoretical results from psychological and management studies.

The analysis of project execution process model is performed for different team-project correspondence in competences and interests. Results demonstrate how much team productivity depends on this correspondence and how can it be managed by task assignment strategies, which take motivation factors into account.

The results can be applied to create digital personal assistant systems and to select effective task assignment strategies for this correspondence between the team and the project.

The developed models can be used for project evolution simulation or employee behaviour after ε and γ tuning. In addition, the model is well suited for describing the issue tracking task in software development, therefore it can be adapted for corresponding tasks. Nevertheless, absolute fit requires additional methods of data preprocessing, to extract motivation and competence information.

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