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The research behavior/attitude support model in open learning systems

E. KUSZTINA[1], O. ZAIKIN[2], and R. TADEUSIEWICZ[3]*

[1] West Pomeranian University of Technology, 49 Zolnierska St., 71-280, Szczecin, Poland
[2] Warsaw School of Computer Science, 19 Lewartowskiego St., 00-169, Warsaw, Poland
[3] University of Science and Technology, 30 Mickiewicza Ave., 30-059 Cracow, Poland

Abstract. The article contains the concept of developing a motivation model aimed at supporting activity of both students and teachers in the process of implementing and using an open and distance learning system. Proposed motivation model is focused on the task of filling the knowledge repository with high quality didactic material. Open and distance learning system assures a computer space for the teaching/learning process in open environment. The structure of the motivation model and formal assumptions regarding the task of solving the model were described. The proposed approach to solving the task bases on the games theory.

Key words: motivation model, computer learning platform, knowledge repository, non-cooperative game.

1. Introduction

Open and Distance Learning Systems can be considered as a new stage of information system evolution in the distance learning domain [1]. Basic concept comes from Open and Distance Learning (ODL), which is an idea of the learning/teaching process organization in higher education institutions [2]. The "distance" aspect describes an educational situation, where the student is situated in a different place than the source of knowledge and the other participants of the teaching/learning process. All the communication and socialization is maintained by the information system. The "open" aspect of ODL is visible at many levels: social, technical, computer and organizational [3].

Implementation of Open and Distance Learning Systems [4] will most probably introduce changes to the entire organization of the education process at higher education institutions, and consequently – changes in the role and relationship between all participants of the learning process while still maintaining status-quo regarding the traditional mission of a university: preparing highly-qualified staff.

In traditional education the level of competence a student obtained at a university depended on various factors [5], the main of which are: education process organization at all levels (starting from the curriculum, syllabuses, up to the classes themselves), equipment, ergonomic conditions, and most importantly – the staff qualification. The position of each university among others is decided on the basis of a ranking [6] that considers basic activities of each teacher and the university as a whole: didactic, research, and educational.

ODL can be considered as a new teaching technology, it is as good as well it expands everyone's possibilities to learn in every life-situation, practically without constraints, however, the teachers charisma [7], one of very important motivation factors, becomes lost. Open learning joined with the distance learning mode requires students to become active, almost equal to teachers participants of the education process. It is cause by two factors:

1. In ODL conditions students' preferences highly influence the market position of a university.
2. Lack of direct contact with the teacher calls for an conscious student, creating his or her cognitive process independently.

Under the influence of these factors, the education organization management system should consider the new position of the student and reflect it in the frames of a proper motivation model. Source of the research behavior/attitude:

- Teacher and students should elaborate a new product – the didactic materials repository;
- There is the opportunity to direct collaboration between students and the teacher;
- Student has opportunity to consciously choose a task in accordance with his/her own criteria (e.g. level of task's complexity).

The final result of the student's learning process depends on his/her involvement in the repository development.

The problem of motivation is one of the more important research subjects of psychology and pedagogy. There are many definitions of this concept [8, 9], according to which motivation as a phenomenon can be seen as:

a) a system of factors (needs, motives, goals, plans, etc.) determining human actions;
b) a process that supports human activity at a certain level.

When developing a motivation model as a part of an information system aimed at managing an education organization

*e-mail: rtad@agh.edu.pl

in ODL conditions, one has to define the place of this model in the system, its criteria function and solution method.

2. Focusing the ODL process on active cooperation between students and the teacher

In the conditions of no direct contact between the teacher and students the scope and way of performing the knowledge-based actions (didactic, research, educational) changes significantly [10]. Moreover, the current teaching/learning process, where accumulating knowledge resources guaranteeing vocational career takes a long time more and more often does not fulfil its purpose due to rapidly changing situation on technology market. Examples may be such domains as: computer science (continuously incoming new software frameworks), printing (new pdf-based workflow), banking (new banking products), etc.

In traditional learning motivation occurs through assessing knowledge (tests, exams etc.). Didactic materials play secondary role compare to the teacher, who acts as a middleman between the knowledge source and the student's cognitive process he/she controls [11]. As a management object, the student's cognitive process is characterized by high level of entropy, but through direct contact, through exchanging information, the teacher, on the basis of his/her own competence, continuously lowers the entropy level, meaning that the teacher controls the student's cognitive process in certain boundaries. The effectiveness of this control depends highly on the intensity of interaction and on the interpersonal skills of the teacher.

It was shown in [4] that the role of didactic materials in ODL conditions becomes more and more important and comes from the assumption that knowledge is a visual and textual information structured according to the goal and level of education.

Processing information received by a human into the form of knowledge takes place with the help of internal cognitive operations like [12]: structuring, coding and clustering as well as creating a kind of internal semantic network, which we can consider subjective ontologies [13].

In order for the didactic material to be in any way capable of playing the role of a broker between the source of information and the cognitive process of a student, it should contain the ontology of the taught subject, developed by the teacher. A more detailed description of constructing didactic materials on the basis of an ontological model was described in [14].

Preparing and making available the ODL didactic material through appropriate computer environment (repository) requires great efforts regarding intelligence and working time of the teacher. The computer aspects of the repository were already discussed in [14] and the proper repository development involves substantial money capital and consumes a lot of time. Resulting from previous researches shows the need to motivate the teacher to supplement his/her duties with developing and monitoring the state of the repository.

The second difficulty is the necessity to motivate the student to get highly involved in working independently during the education process, what guarantees obtaining a level of competence comparable to traditional education. Assessing knowledge on the basis of traditional tests in the distance learning mode loses its meaning as an instrument of motivation, as it deprived of all the consequences of direct contact with the teacher and other students (cognitive ones, emotional ones, etc.). A substitution way of rising the activity of the person learning something is a "game", understood as an active cooperation, the result of which will be an object of interest for both the teacher and students (players). In the management sense it means that the interests of each participant of the cooperation should be described as individual motivation functions that make up one goal function.

The repository is the result of this cooperation, from the didactic point of view it is an open, for everyone, storage of didactic materials, including ontologies, tasks, example solutions etc.; from the scientific point of view it is a copyrighted knowledge resource of a university; from the software-technical point of view it is an information system based on an appropriate network platform.

3. Motivation model interpretation in the context of an education situation

A motif (the reason of action) is a consciously understood need for a certain object, position, situation, etc., therefore we can state that the motif comes from a requirement, becomes its current state and leads to certain actions [15]. During the realization of the mentioned chain "need – motif – action", at each step we are dealing with a decision-situation, meaning: many motifs can lead to a certain action, many needs can make up one motif, many motifs come out of one need. Making a choice is a cognitive process that cannot be observed directly [16]. This means that it is only possible to define the quantitative relationships between the choice parameters through exterior registration of the choice results.

The motivation model can be developed in the form of a certain game scenario, where the activity of a teacher and a student will be supported by their own interests [17]. Developing the motivation model in a specific education situation (subject, goal and education level) is possible with the following assumptions:

- the set of elements of the mentioned chain is defined and contains alternatives,
- the choice is made in a specific education situation,
- the result of a multiple choice made according to the chain is the obtained competence,
- the result can be registered,
- there is a system of assessing the choice results,
- students and teachers have access to observations and evaluations of the choices made,
- the result of a choice has to be evaluated by the student as a needed and wanted one (usability of the result),
- the student has to be certain that the wanted result can be achieved, in a given education situation, with probability higher than zero (subjective probability of achieving the result).

Research's discussion about motivation model can be addressed to different area of educational system. The conducted analysis of information-processing in judgmental tasks allows to prepare cognitive-motivational model of decision satisfaction [18]. In proposed model confidence serves a role of a major contributing factor of learning motivation. However, more details investigation proves that the motivation is a set of several components. The ARCS Motivation Model [19] is based on four-factor theory. The student's motivation is hooked up with student's attention, relevance, confidence, and satisfaction. The ARCS model also contains strategies that can help an instructor stimulate or maintain each motivational element. Other researchers shown that personally valued future goals are core for motivation [20]. Moreover the cultural discontinuities and limited opportunities in students' learning environment may weaken the motivational force of the future [21].

The form and content of motivation model is also strong depended of object to be motivated and environment, where motivational action takes place. On the one hand motivation model can be designed for artificial or human object. In [22] is proposed a motivation model for virtual humans such as non-player characters. The motivation model based on overlapping hierarchical classifier systems, working to generate coherent behavioral plans. On the another hand different environment creates individual needs for motivation model. Such situation is causes mainly by multicultural differences [23].

4. Stating the motivation problem in a specific ODL education situation

In ODL conditions, as a motivation model we consider scenario of a game (interaction, interplay) of the teacher and students performing actions in a specific education situation aimed at rising the level of involvement of a student in the task subject and extending the repository with new tasks and their solutions.

The education process in every education situation includes the didactic, research and education aspects and takes place at the following levels: cognitive, information and computer-based. At each of these levels the teacher and the students have their own roles and involvement intensity. At the cognitive level assumptions are made and tasks are solved, at the information level information is exchanged between the participants of the education process, the computer-based level is characterized by repository organization and ability to use it. The role of the teacher is to develop an ontological model reflecting the subject of the education situation, showing the source information, formulating tasks and presenting methods and examples of solving them present in the repository. All ontological models are stored in the repository.

In the discussed approach tasks are created on the basis of the ontology and differ in their complexity level [14]. The proposed scenario assumes that the role of the student is to choose a task and solve it. The final grade depends on the correctness of the solution and the complexity level of the task. A task solved by a student and highly graded by the teacher is placed in the repository and will serve as an example solution for other students. All materials stored in the repository are copyrighted. This way the student participated in the didactic activity and we assume that it will raise his/her self-esteem, what has a positive influence on learning, meaning that it will be a part of the *student's motivation function*. At the same time filling the repository with a wide spectrum of high quality solved tasks gives satisfaction to the teacher, for his/her laborious, requiring intelligent efforts primal stage of preparing the repository. And this will make up the *teacher's motivation function*.

Teacher's and student's interaction with the repository can have a research character. We assume that thematically the content of the repository is in concordance with the teacher's scientific-research interests, what causes appearance of tasks differing from the common ones in complexity in the repository. For helping to solve these tasks, the teacher will be willing to pay more attention and spend more time with a student. We can assume that for a certain part of students participation in common research is a challenge and participation in the obtained results all the more.

The educational aspect is reflected in making the broadening of the repository a common success of all participants of the education process. Making the material copyrighted shows and visualizes the input and share of each participant. Feeling the synergy effect motivates to develop cooperation skills and tolerance. Cooperation over distance requires a more logical formulation of questions and answers. All this reflects the interests of both the teacher and the students.

Figure 1 shows the functioning schema of the described above scenario of filling the task repository in an ODL system.

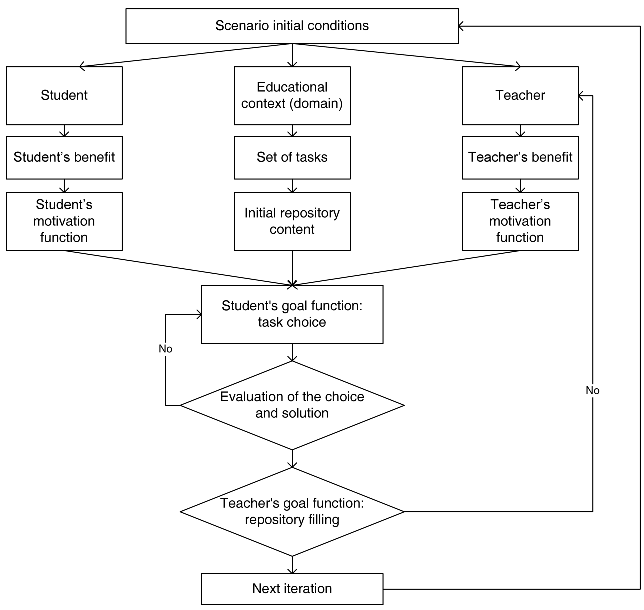

Fig. 1. Scenario of filling and using the repository

The *educational situation* can be characterized by a proper ontology, a part of which is conformant with the task ontology (in the sense of the amount and depth of concepts being used).

The *teacher's interest* is in maximizing the level of repository filling with tasks of different complexity for every considered educational situation at given domain. The criterion regarding placing a task in the repository is decided by the teacher on the basis of: complexity level, graphical quality, language correctness etc. The possibility to realize teacher's interests is limited by his/her resources considering time in the quantitative and calendar aspects and other informal preferences.

The *teacher's motivation function* is concerns maximizing the coverage of the educational situation with tasks (prepared and solved) with defined: topicality of the task's subject from the teacher's point of view and the individual resources he/she is prepared to appoint to a student for solving a certain task (consultation time, access to scientific material, equipment, etc.).

The teacher defines his/her motivation function before students gain access to choosing tasks to solve – this function has to be known to them.

The *student's interests* depend on individual preferences and can be divided in two groups. The first group of students is interested in achieving the minimal acceptable success level, meaning meeting only the basic requirements for obtaining a positive grade for solving the task (low complexity of the task, minimal acceptable grade) while saving the maximal amount of their time. Such task-solutions will not be placed in the repository. The second group of students is interested in filling the repository with the maximal possible success, meaning solving tasks of high complexity that will later be placed in the repository as their own, copyrighted part of didactic material.

The *student's motivation function* considers obtaining the maximum level of fulfilling one's interests during choosing and solving the task, with given constraints regarding time (one's own and the teacher's) and the way of grading the resulting solutions.

The statements made above show that both motivation functions depend on the complexity level of a task and have common constraints on time resources. Supplementing the repository with new tasks can be interpreted as accrual of the knowledge resource. Increasing motivation of both students and teachers increases and quickens the accrual of this resource.

Therefore, the *motivation model in an ODL system* (regarded to as simply "motivation model" from now on) should include parameters describing activities of each interested side: the student and the teacher. The measure of successfulness of their cooperation is the accrual of knowledge in the repository, which can be evaluated through the intensity of its filling with properly solved tasks. When developing a motivation model, one has to consider a very important factor: the stochastic character of students arrival, which is mainly a result of individual education mode and stochastic character of students' motivation parameters. The motivation model regulates the process of a student choosing a task to solve within the scope of a certain subject on the basis of his/her own motivation function and with consideration of teacher's requirements and preferences.

The entire process, from the moment of formulating tasks to the moment of evaluating them and placing in the repository, followed by creating a new set of tasks waiting for the next group of students prepared to solve them can be described by a game scenario. The presented scenario is universal in every educational situation aimed at obtaining not only a portion of knowledge, but rather a competence based on it. Modelling a game scenario requires formulating motivation and goal functions of the game participants with regard to the repository filling.

5. Formalization of the motivation problem

Let us consider the *basic components* of *the motivation model*

1. *Education process participants*

N – *teacher* (leads of the subject, disposer of the subject repository),

$S = (s_1, s_2, \dots, s_j, \dots)$ – students coming to choose and solve tasks in real time,

$\pi(s) = \{\chi, \lambda\}$ – parameters of stochastic process of students arrival,

where χ – distribution law, λ – intensity of arrival.

We accept the process $\pi(s)$ to be a markovian one, meaning that it has a stationary, memoryless and sequential character.

2. *Domain ontology*

$G^D = \{W^D, K^D\}$ – ontology graph,

where $W^D = \{w\}$ – nodes of graph (basic concepts), $K^D = \{k\}$ – arcs of graph (relations between concepts).

3. *Tasks set*

$R = \{r_i\}$, $i = 1, 2, \dots i^*$ – tasks set in the frames of a domain D,

$\Pi = \{Q(r_i), A(r_i)\}$ – parameters of task r_i, where

$Q(r_i)$ – task r_i complexity level,

$A(r_i)$ – task's topicality for the teacher.

4. *Teacher's motivation function*

σ^T – teacher's motivation function is a function which depend on tasks parameters,

$$\sigma^T = (Q(r_i), A(r_i)),$$

σ^T defines resources appointed to every task r_i. The resources can be described by vector $X(r_i)$ and mainly covered following items: didactic materials, consultation time, time of access to telecommunication channels, equipment and software, etc.

The teacher's motivation function σ^T is a monotonously rising function of a discrete argument $Q(r_i), i = 1, 2, \dots i^*$.

5. *Student's motivation function*

σ_j^S – motivation function of each arriving student s_j.

In general case function σ_j^S depends on parameters of tasks $\sigma_j^S = (Q(r_i), A(r_i))$.

From the point of view of learning objectives the whole group of students can be divided generally into two mentioned above extreme groups. For the first group of students (interesting in achieving the minimal acceptable success level) the motivation function σ^S is a jest monotonously falling function of a discrete argument $Q(r_i), i = 1, 2, \ldots i^*$, meaning the task complexity. For the second group of students (interesting in filling the repository with the maximal possible success level) the motivation function σ^S is monotonously rising function of the same argument $Q(r_i)$.

6. *Goal function of student's task choice*

Under effectiveness of the decision made we understand maximal satisfaction of student's and teacher's interests with maximal summary motivation function. The form of satisfying the teacher's interests is placing in the repository a properly solved task of a significantly high level of complexity. The form of satisfying the student's interests is minimal summary time costs while obtaining a high grade, which also depends on the complexity level of the task. The period of filling the repository is limited by a calendar interval depending on the educational situation.

The fact of making the decision can be described by a binary argument, y_i^j

$$y_i^j = \begin{cases} 1, & \text{if student } s_j \text{ chooses task } r_i \\ 0, & \text{otherwise} \end{cases}, \tag{1}$$

Then, the goal function has the following structure:

$$\Phi(y_i^j) = \alpha\sigma^T + \sigma_j^S = \max_Y, \tag{2}$$

where

$$Y = \left\{y_i^j\right\}, \quad i = 1, 2, \ldots i^*, \quad j = 1, 2, \ldots j^*,$$

α is waging coefficient.

Both elements of the goal function depend on the same argument $Q(r_i)$. As shown in Fig. 2 the element σ^T is a monotonous rising function of argument $Q(r_i)$, while σ_j^S in dependence on kind of student is monotonously falling or rising function of the same argument $Q(r_i)$.

7. *Teacher goal function of repository filling*

The *teacher goal function* reflects the influence of each task on the accumulation of knowledge in the repository (ΔW). The current state of knowledge in the repository is characterized by two parameters: domain ontology graph G^D and the level of its coverage with properly solved tasks, topical for the teacher – graph G^P. Each solved task r_i ensures a proper accrual of knowledge in the repository $G(r_i) \subset G^P \subset G^D$, meaning $\Delta W(r_i) = G^D \cap G(r_i)$. We assume that tasks with a higher complexity level provide a greater increase of knowledge than tasks with a low complexity level.

Let us consider:

$G^D = \{W^D, K^D\}$ – domain ontology graph,

$S = (s_1, s_2, \ldots s_j, \ldots)$ – students coming to choose and solve tasks,

$\mathrm{T}(s) = (\tau_1(s_1), \tau_2(s_2), \ldots, \tau_j(s_j), \ldots)$ – stochastic process of students arrival,

$\widetilde{R} = \{r_i(s_j)\}, r_i \in R, s_j \in S$ – set of tasks chosen by students according to their goal function

$$\Phi(y_i^j) = \underset{Y}{\mathrm{Max}}\ (\alpha\sigma^T + \sigma_j^S),$$
$$i = 1, 2, \ldots, i^*, \quad j = 1, 2, \ldots j^*, \tag{3}$$

$G(r_i(s_j)) = \{W_i^j, K_i^j\}$ – solved task $r_i(s_j)$ ontology subgraph,

G^P – summary graph of ontologies of tasks placed in the repository in the interval $\tau \subset [0, T_0]$,

$$G^P = G(r_1(s_1)) \bigcup G(r_2(s_2)) \bigcup \ldots \bigcup G(r_i(s_i)) \bigcup \ldots, \tag{4}$$

where

$$\tau_1, \tau_2, \ldots, \tau_{j\cdot}, \ldots \in [0, T_0],$$

U^T – accrual of knowledge in the repository in the interval $\tau \subset [0, T_0]$

$$U^T = G^D \bigcap G^P \tag{5}$$

In a certain calendar interval $[0, T_0]$ knowledge accural in the repository has to be maximal:

$$U^T = G^D \bigcap G^P = \underset{N}{\mathrm{Max}};. \tag{6}$$

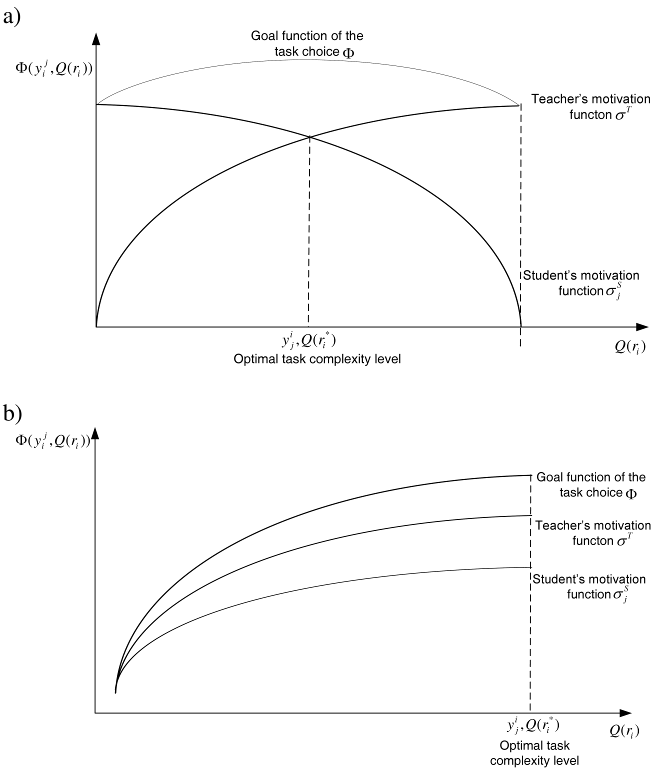

Fig. 2. Extreme cases of task choice function on the basis of motivation and preferences functions: a) students interesting in achieving the minimal acceptable success level; b) students interesting in achieving the maximal acceptable success level

6. Formulating the repository filling motivation model

For the given:

1. Domain D and its ontology graph G^D,
2. Set of tasks $R = \{r_i\}$ and task parameters: $\Pi = \{Q(r_i), A(r_i)\}$,
3. Stochastic students' arrival pattern $\pi(s)$ and arrival process parameters $\{\chi, \lambda\}$,

One has to:

a) form the teacher's motivation function σ^T regarding repository filling,
b) optimize each arriving student's s_j goal function of the task choice $r_i(s_j)$ according to his/her motivation function σ_j^S

$$\Phi(y_i^j) = \underset{Y}{\mathrm{Max}}\ (\alpha\sigma^T + \sigma_j^S), \tag{7}$$

c) choose properly solved tasks among the ones made by students according to the grade

$$G^D \bigcap G(r_i(s_j)) \neq \emptyset \tag{8}$$

and supplement the repository with chosen tasks

$$G^P = G(r_1(s_1)) \bigcup G(r_2(s_2)) \bigcup \ldots \bigcup G(r_i(s_i)) \bigcup \ldots \tag{9}$$

Repository filling criterion
U^T – knowledge accrual in the repository on a calendar interval $[0, T_0]$

$$U^T = G^D \bigcap G^P = \underset{T}{\mathrm{Max}}\,. \tag{10}$$

Constraints

a) summary resources (time-related, technical, didactic, staff) offered to students for solving tasks:

$$\sum_{s_j \in S} \overline{x}(r_i^j) y_i^j \leq \overline{X}, \tag{11}$$

where
$\overline{x}(r_i^j)$ – resources appointed to task $r_i(s_j)$,
$\overline{X}$ – summary resources for the subject lead by the teacher,

b) calendar interval $\tau \in [0, T_0]$, appointed to students for choosing and solving tasks

$$\underset{j}{\mathrm{Min}}\, \underline{\tau}(r_i^j) \geq 0, \qquad \underset{j}{\mathrm{Max}}\, \overline{\tau}(r_i^j) \leq T_0, \tag{12}$$

where $\underline{\tau}(r_i^j)$, $\overline{\tau}(r_i^j)$ – appropriate moments to start and end solving task r_i^j by student s_j.

7. Motivation model identification in the games theory terminology

Interpretation and solution of the developed model can be conducted on the basis of the games theory, which allows studying the activity of a system depending on the players behaviour. The proposed model refers to the class of non-cooperative games with a defined number of steps and full information about participants activities in real-time. The game has an arbitrary sum of participants' *wins*: the *win* of the teacher is accrual of knowledge in the repository, the *win* of the student depends on his/her strategy: maximal number of points for a task solved or minimal time loss. The equilibrium is obtained as a result of a dominant strategy, what compared to other strategies gives the game participants the possibility to obtain their maximal *win* regardless of actions of the other participants.

Using game theory terminology the motivation model can be seen as a stimulation task, where motivation management signifies direct rewarding an agent (student) for his actions. The formulated model is consistent to a multi-agent two-layer stimulation system which consists of one centre (teacher) and n agents (students). The strategy of each agent is to choose an activity, the centre's strategy – to choose a stimulation function, i.e. relationship between the win of each agent and his actions.

Participants' preferences are reflected by goal functions. The centre's (teacher's) goal function is the difference between his/her reward (ΔW) and the summary reward paid to the agents (sharing one's own resources ($\overline{X}$)). By goal function of each agent we understand the difference between the reward obtained from the centre and the losses connected to solving the task. At the moment of making the decision (stimulation function for the centre and choice function for the agent) the goal functions and acceptable actions of all participants are known. The centre has the right of the first move, when it chooses a stimulation function, before the agents, with known stimulation functions, choose activities that optimize their goal functions. The centre's choice of a stimulation function takes place on the basis of a simulation meant to serve in foreseeing random characteristics of the basic students knowledge and parameters of the process of their arrival Agents choose their strategies independently and do not exchange information or wins, this signifies that we are dealing with a relational dominant strategy.

Let us denote: M – a set of acceptable stimulation methods, $Y(\sigma)$ – a set of game solutions (strategy of agents having balance in their stimulation method σ). Management (stimulation) effectiveness means obtaining maximum value of the goal function $U(\sigma)$ on an appropriate set of game solutions.

$$U(\sigma) = \max_{y \in Y(\sigma)} f_(\sigma, y), \tag{13}$$

where σ is a simulation function of the centre, y is a binary argument of agent's choice.

The task of optimization stimulation function synthesis is about searching for an acceptable stimulation function with maximum effectiveness:

$$\sigma* \in Arg \max_{\sigma \in M} U(\sigma). \tag{14}$$

When solving the model, algorithms described in [24] and [25] can be used.

8. Concluding remarks

1. The motivation model has to be an obligatory element of an open and distance learning system.
2. The motivation model covers two motivation functions: teacher's and student's, which describe their interests in filling the knowledge repository.
3. The measure of success in cooperation between the teacher and students, according to the presented scenario, is the level of repository content expansion in the given time.
4. The proposed motivation model can be solved on the basis of one of the known algorithms realizing a non-cooperative game with the dominant strategy (RDS).
5. Example of practical application of the model presented and considered in this paper can be found in paper [26].

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