Using the Ant Colony Algorithm
to Establish the Best Path of Learning Activities

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Abstract. This paper will introduce a new procedure to establish the best learning path. In our approach, the learning process is described by a set of activities carried out to acquire elementary pedagogical objectives. In the operationalization phase of learning scenarios, the same pedagogical objective can be described in several methods. Each method implements activities described by different teachers. To improve their learning, the learners seek methods that best meet their needs. In this case, they make more effort to achieve a pedagogical objective by visiting inappropriate links. To resolve this problem, we propose a procedure inspired by ants’ colony algorithm which allows us to differentiate the links that connect the various activities. The collective work of learners is a sufficient motivation for choosing this algorithm.

Keywords: ants’ colony algorithm, pedagogical objective, activities, domain model, adaptation, regulation, best learning path

1 INTRODUCTION

Several studies have indicated that learning occurs more effectively when the learning objectives are associated with teaching methods [11] and when the activity is at the center of the learning process [9], [16] and [17]. On other hand, several approaches have been proposed to present the learner with content that fits
his level of knowledge [13] and [15] and his/her learning styles [2] and [8]. These approaches are based on the learners’ interactions with the hypermedia system. However, the learners’ failure in the attaining the objectives is not necessarily related to the learner himself, but may depend on how the activities is operationnalized.

The contribution of our paper focuses on ants’ colony algorithm to detect activities which gave the most results (formative assessment in support) and to detect blocking situations.

This paper is organized in four sections. The first one presents the introduction. The second section is devoted to describe how to prepare the domain to be studied. As for section 3, we propose a new procedure which offers the best path to the learners. Finally, section 4 presents conclusions and perspectives.

2 Preparing the area to be studied

To facilitate the adaptation and regulation of learning, we use a domain model in accordance with pedagogical modeling approaches [3]. This model consists in involving the learner in the learning process through the development of approaches and tools to make him aware of his strengths, weaknesses and motivations. Then we use an effective assessment process for continuous monitoring of the evolution of the learner's knowledge model. This evaluation process is a key element to differentiate paths followed by learners.

2.1 Domain model

In our approach, we proceed to split a learning unit on three levels. Each level describes the resource type (concept, elementary pedagogical objective, global pedagogical objective) which is implemented as well as the type of entity (elementary activity, step, and scenario) for a description of its progress [3].

The production of learning scenarios passes through two important steps:

– The design of pedagogical scenario models: in this phase, the pedagogical designer defines the pedagogical objectives structure as well as constraints and rules of navigation (Figure 1).

![Figure 1. Elementary pedagogical objectives structure (presented in [3])](image-url)
The scenarios pedagogical operationalization: according to the rules and constraints defined by the pedagogical designer, the teacher is supposed to operationalize the various learning situations. He/she shall specify the activities required for the acquisition of an elementary pedagogical objective. Each activity may represent a presentation (pdf, word, video ...), exercise, a solution, a discussion forum, a discussion with a tutor, etc.

For example, an elementary pedagogical objective defines the following activities: states the problem, reads presentation, does an exercise, corrects exercise, discusses in forums and synthesizes.

### 2.2 Assessment procedure

It is necessary to know the learner's level of knowledge to be able to determine his/her knowledge and skills. On the other hand to assess implicitly the path that led the learner to obtained results. We will adopt the solution proposed in [4] [6] and [10] to calculate the student’s score and his/her degree of mastery of each elementary pedagogical objective $DM(OE(i))$ calculated as follows:

$$DM(OE(i)) = \frac{\Sigma score(question(i,j)) \times WQ(i,j)}{n}$$

Where:

- $score(question_{(i,j)})$: score obtained in question number $j$ related to "OE(i)"
- $WQ(i,j)$ the weight of question$_{(i,j)}$ in "OE(i)"
- $n$: number of questions related to the elementary pedagogical objective “$OE(i)$”
3 THE SELECTING MODULE OF THE BEST PATH of ACTIVITES

3.1 Ants’ colony algorithm

Ants’ colony algorithm is a member of the ant colony algorithms family, in swarm intelligence methods, and it constitutes some metaheuristic optimizations. The goal was aiming to search for an optimal path in a graph, based on the pheromones of ants seeking a path between their colony and a source of food.

The amount of pheromones differs from one path to another due to the evaporation process. The pheromones evaporation is made depending on the following equation [1], [14], [12] and [7]:

$$\tau_{i,j}(t+1) = (1 - \rho) \cdot \tau_{i,j}(t) + \sum_{k=1}^{m} \Delta \tau_{i,j}^k(t)$$  \hspace{1cm} (2)

Where:

- $\rho$: an evaporation factor.
- $\tau_{i,j}(t+1)$: The pheromone amount between nodes “$i$” and “$j$” at instant “$t + 1$”.
- $\tau_{i,j}(t)$: The pheromone amount between nodes $i$ and $j$ at instant $t$.
- $\Delta \tau_{i,j}^k(t)$: The pheromone amount laid by ant “$k$” between nodes “$i$” and “$j$” at instant “$t$”.
- $m$: the number of ants that have moved between the nodes “$i$” and “$j$” until the instant $t$.

According to this equation we find that the progress of pheromones quantity depends on the number increase of ants that pass between the nodes “$i$” and “$j$”. This reflects the importance of the path between these two nodes.

The best path in the ants’ context, is the path that contains a large amount of pheromones. Therefore, to find the best solutions (trajectories) connecting the colony nest to the food, is obtained by detecting the pieces of trajectory which compose the complete path.

3.2 Adaptation of ants’ colony algorithm to our problematic

In a learning platform, we find the same elementary pedagogical objective “OE” operationalized by different teachers. Each teacher describes the activities required to acquire the “OE”.

The result of this phase is a learning graph $(\Omega, \tau)$ mentioned in Figure 3.

Where:
\( \Omega \) represents the set of nodes. Each nod \((A_i,T_u)\) is a learning activity \(A_i\) presented by a teacher \(T_u\).

\( \Delta \) represents a set of arcs. Each arc \(\tau_{i,j}\) is a navigation link between the activity \(A_i\) and the activity \(A_j\).

Figure 3. Example of an elementary pedagogical objective operationalized by three teachers.

In this graph, a free navigation is provided for the students: they can navigate between the different activities of the graph (for all teachers) without constraints. During the learning session, students take different paths as they move between activities to find content that better suits their cognitive expectations. To establish the best learning path, we should find all arcs leading learners to have good results.

3.3 Implementation

The learner’s failure or success in an elementary pedagogical objective does not only depend on the learner’s level, but may also depend on the activities done. Thus an efficiency coefficient is associated with each arc taken. This coefficient represents the pheromones amount deposited by the learners (artificial ants). This amount increases in case of success, and decreases in case of failure [5]. The amount of pheromones in each arc \((A_i,T_u) \rightarrow (A_j,T_v)\), depends on the number of learners who have visited these arcs and on their scores in elementary pedagogical objective.

3.3.1 Regulating the amount of pheromones

The variation of pheromones amount may depend on the learners’ level of knowledge and on duration to accomplish the pedagogical objective:
For the learners’ level of knowledge, learners do not react the same way with the learning system. This diversity is due to the heterogeneity of their level (analytical ability, skill level...). Treating all students in the same way in calculating the best path may disrupt the learning system favoring certain arcs compared to others. To differentiate the quantity of pheromone deposited by each learner, we divide the learners according to their efficiency degree ($\alpha$).

In our approach, we divide the population of learners into three categories: 

- Learners in trouble ($\alpha = \alpha_1$),
- learners with a medium level ($\alpha = \alpha_2$) and
- learners with a good level ($\alpha = \alpha_3$).

$\alpha_1$, $\alpha_2$ and $\alpha_3$: are configurable to check and monitor the influence of each category on the path established.

To judge the effectiveness of an arc in a consistent way and faithful to reality, we will consider that learners with a medium level have a remarkable effect compared to the other two categories: ($\alpha_2 > \alpha_1$ and $\alpha_2 > \alpha_3$).

- For the duration made to accomplish the pedagogical objective, learners do not make the same time to complete the various activities. Thus, a degree of speed ($\beta$) is used to differentiate the quantity of pheromone deposited by each learner.

In our approach, we divide the population of learners into three categories:

- Slow learners ($\beta = \beta_1$),
- fast learners ($\beta = \beta_2$) and
- very fast learners ($\beta = \beta_3$).

$\beta_1$, $\beta_2$ and $\beta_3$: are configurable to check and monitor the influence of each category on the path established.

### 3.3.2 Updating the amount of pheromones

In this section, we will establish our formula for updating the pheromones amount. Two cases arise:

- The amount of pheromones is increased by $\Delta \tau_{i,j}^k(t).\alpha^k \beta^k$ in each visited arc linked activities “$A_i$” and “$A_j$” by learner “$k$”, after a good results in elementary pedagogical objective:

$$\tau_{i,j}(t + 1) = (1 - \rho).\tau_{i,j}^k(t) + \sum_{k=1}^{m} \Delta \tau_{i,j}^k(t).\alpha^k \beta^k \quad (3)$$

- The amount of pheromone is decreased by $\Delta \tau_{i,j}^k(t).\alpha^k \beta^k$ in each visited arc linked activity “$A_i$” to activity “$A_j$” by learner “$k$” due to a failure in elementary pedagogical objective.

$$\tau_{i,j}(t + 1) = (1 - \rho).\tau_{i,j}^k(t) - \sum_{k=1}^{m} \Delta \tau_{i,j}^k(t).\alpha^k \beta^k \quad (4)$$

Where:

- $\tau_{i,j}(t + 1)$: The amount of pheromone on the arc linked activity “$A_i$” to activity “$A_j$” at time t+1.
Ant colony algorithm

$\Delta \tau_{i,j}^k(t), \alpha^k, \beta^k$: The amount of pheromone on the arc linked activity “$A_i$” to activity “$A_j$” deposited by learner “$k$” at time $t$;

$\alpha^k$: efficiency degree of the learner “$k$”;

$\beta^k$: rapidity coefficient of the learner “$k$”.

At the beginning of learning, arcs are not differentiated (Figure 3). Then, after several iterations of our algorithm, the arcs that led learners to most successful are distinguished by the amount of pheromones. For example, the graph in figure 4 indicates that the path with the arcs (1,2,3,4,5) is the best path of learning.

![Figure 4. Updating the pheromones quantities in the arcs between activities](image)

4 CONCLUSION & PERSPECTIVES

In this paper, we proposed a procedure inspired by ants’ colony algorithm which allows us to differentiate the links that connect the various activities. This procedure is based on the learners’ collective work.

In our next work, we will improve our research procedure by using a detailed analysis of the learners’ behavior to find the best path.

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