Mobile Game Based Learning Based on Adaptive Curricula and Location Change

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Abstract. With the diffusion of mobile technologies, the classic learning process of class room learning as well as e-learning has changed. Mobile devices enable individuals to learn anywhere and anytime, even if only little time is available. Usually, m-learning is often seen as e-learning on mobile devices. This disregards the real potential of m-learning. Instead, the characteristics of mobility should be taken into account when designing m-learning, namely different places of learning and the process of location change. In this paper, we therefore introduce the concept of location-sequence-based learning (LSBL) that explicitly considers these characteristics. Then, we combine LSBL with the concept of game based learning (GBL) in order to even enhance the motivational aspect of both concepts.

Keywords: M-Learning · Sequence-based learning · Location-based learning · Education

1 Introduction

In a traditional manner, teaching is a location-bound communication process. In most cases, knowledge is transferred by word of mouth. But like other areas of communication, education has been extensively influenced by new information technologies. Starting from multimedia based systems, e-learning systems passed through tremendous developments, now providing sophisticated intelligent tutoring tools with automatic generation and marking of exercises, e.g. [18, 20, 22], or being game based learning systems based on commercial games, e.g. [2, 7, 9], or developed for special purposes, e.g. [1, 21]. With the emergence and increasing use of mobile technologies in the past years, mobile learning (m-learning) has gained much importance as an e-learning domain. Often, m-learning is just seen as e-learning but with mobile devices. However, from our perspective, the core of the matter is not entirely conceived yet. M-learning is not based on the mere extended spectrum of portability of existing e-learning concepts [23] but offers rich opportunities for new e-learning concepts. Indeed, mobile devices are the crucial technical innovation which led to the development of particular m-learning concepts, but the emphasis on mobility should not focus on the technology. It is just a means to an end. Substantial innovation lies with the learning process. Latter has changed radically due to the mobility and locomotion of the learning individual.

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In this paper, we want to deliberate location-based learning and introduce the concept of location-sequence-based learning (LSBL). Therefore, in the next section, we first have a look at the concepts of e-learning and m-learning. Then, we discuss location-based learning and introduce the idea of LSBL. In Sect. 4, we develop this idea and show how game based learning (GBL) can benefit from this concept. In Sect. 5, we formalize location-sequence-based game based learning and give an example of use in Sect. 6. The paper closes with a summary and some limitations in Sect. 7.

2 E-Learning and M-Learning

Diverse forms of learning can be differentiated that are not mutually exclusive i.e. tutored learning, collaborative or work group learning and ego-learning. Subject to the curriculum and educational objectives, the approaches may complement one another in a reasonable manner and therefore are with good cause. Both, tutored learning and collaborative learning are communicative forms of learning. Dialogue-oriented processes of this kind require chronological synchronism of individuals involved in the learning process. Spatial synchronism is often beneficial, but not in any case.

Knowledge transfer in tutored learning is unidirectional. As for collaborative learning, the distributed knowledge fragments of work group members are gathered and combined. In common use, it is referred to as socialization of knowledge. With regard to the transfer of knowledge, respective control and the measurement of learning success are unspecified. In case of ego-learning, documented knowledge is internalized by means of self-study [16]. Respective success depends on fitting knowledge documents, prior education, and intellectual constitution of the learning individual.

Any kind of synchronism, both chronological and spatial, requires to some degree coordination and a provision of resources. Linked transaction costs must be compensated with synchronization benefits. E-learning imparts curriculum to groups and individuals non dependent on time and location. It serves to present and distribute digital teaching materials [15].

Leidner and Jarvenpaa (1995) refer to virtual learning as to the use of diverse information technologies such as IP conferencing or distributed work spaces in order to transcend physical boundaries of the classroom and therefore annihilate spatial synchronism [11]. The independence of time and location implies that learning becomes a continuous process. At the same time, it can be suited to the individual learning requirements. Both, the temporal progress and the intensity of knowledge generation can be harmonized with regard to the learning individual and lead to an improved education [11].

At first, these independencies of e-learning and computer-based learning respectively have been considered as the crucial improvement to allow for separated study groups [19]. IT-based interpersonal communication as a characteristic aspect of e-learning is of course linked to it [8]. But the pure peripheral use of information technology within learning processes should be regarded just as the most rudimental form of e-learning. The actual task rather is to replace humans as tutors and study group participants with some sort of teaching machine i.e. an intelligent software solution.

In recent years, the propagation of mobile technologies advanced rigorously. Mobile devices and wireless data communication are almost ubiquitous. Hence, m-learning is in the focus of attention as an emergent e-learning domain [13]. The all out technical configuration of mobile devices caused e-learning to proceed on the go and thus use idle time in a reasonable manner. The high accessibility of mobile devices can significantly improve dialogue control and as a result preserve time synchronism to a certain degree. For example, the questions of the learning individual can be answered promptly by ever attainable and qualified tutors or members of a study group. This leads to expeditious learning achievements and avoids the threat of meanders.

E-learning in general is characterized as location independent, yet only m-learning as a special form enables people to acquire knowledge anywhere and at any time. However, it is subject to the precondition that the learning process can be halted and resumed regardless of the location without any problems.

Nevertheless, m-learning exceeds porting of existing e-learning solutions with regard to technical specifications of mobile devices. Suppose that a learning process is initiated at location A and continues at location B. In use of non-mobile technology, it is referred to as classic e-learning without consideration, though we often mistake such a succession as m-learning if mobile IT is deployed. Likewise, the distance between A and B is of no relevance. But for classification purposes, just a change of location seems appropriate. Hence, m-learning has to be considered literally as e-learning on the go.

Separate aspects of m-learning bear on returned ambient data of the mobile device. In this respect, dynamic context and positioning data has to be mentioned at first. But in addition, vital data may be returned as well e.g. in order to coach an athlete and point out running flaws. In principle, such data can be used to monitor the learning process and/or adjust the curriculum to the learning environment. The respective situational learning may in turn cause an initial effect to be observed at a much earlier stage. In this regard, sequence-based learning and location-based learning represent the genuine innovation of m-learning. We should refer to e-learning as m-learning but in this kind of appropriation.

3 Location-Based and Location-Sequence-Based Learning

M-learning may be classified as location-based learning and/or location-sequence-based learning (LSBL). Both forms are closely linked to a location or relocation and are characterized by a location-adaptive and/or situational learning process. With regard to location-based learning the curriculum adapts to the learning environment. The interactive museum guide is a popular example. Depending on the current position, relevant information about works of art is made available to the visitor on his museum tour [10].

Mobile position-fixing can be based on GPS, RFID or use of integrated image recognition [5]. In specific scenarios it is conceivable that not just the location, but also the sequence of location change may affect the curriculum and learning process. In case of mutual dependent curricula, e.g. knowledge which requires knowledge of a different kind, lessons can be learned subject to the specific location sequence. We refer to such use as sequence-based learning.

Intelligent solutions will direct users across concerted lessons and supervise the sequence-based learning process. Given such kind of sequence-sensitive m-learning within the context of the before mentioned example, the respective sequence can alter with regard to the greater educational objective. Thus, visitors can look at the works of art in a different order and learn about different aspects – either about distinct schools of art and techniques or about artists of a specific epoch. We call this sequence-sensitive m-learning location-sequence-based learning.

Mobile technologies are just a basic prerequisite to enable mobile learning. Classic e-learning applications on mobile devices are not the key innovation, albeit just as legitimate. The true potential of m-learning lies with the altered learning process.

Both, location-based learning and LSBL are pure forms of contextual learning. Under the terms of such paradigms, learning proceeds if the learning individual handles new information put in a contextual order which seems sensible [17]. The context exists in situ. Thus, people rather accept the depicted knowledge which for this reason will have a quasi everlasting effect. On this account, it is of major importance to delve into the aforementioned forms of m-learning.

4 Location-Sequence-Based Game Based Learning

Depending on the sequence of visited points of interests, e.g. sights of a city, objects of art in a museum or subsequently used vivariums in a zoological garden, the taught curricula differ, when using sequence-based learning. Therefore, the learning objectives are not, compared to location-based learning, bound statically to a place, but they are determined by the individually chosen "learning path" of the learning individual, i.e. the sequence of visited points of interest.

Sequence-based learning systems shall be flexible enough to generate and present meaningful information through a user-defined sequence of points of interest. Although an integrated recommender system can generate proposals how to continue the learning path in a most "reasonable" way, a strong paternalism with restrictive learning sequences is not intended. Such flexibility allows the learner to choose his learning path regarding to his individual curiosity so that certain locations may be visited with priority and others may be ignored. A learner's curiosity defines his effort to gain and learn specific information. Thus, open learning environments with places of self-determined acquisition of information foster the psychic energy of individuals to learn. With the accompanying engagement in an issue, learning can take place [4].

Sequence-based learning systems cannot cultivate the curiosity of a learner, but in such systems the curiosity can unfold freely and individually as it is not trimmed by a preset learning process. This fosters the intrinsic motivation of an individual to deal with certain issues and to learn about them [14]. If curricula are strictly preset because the learning path respectively the learning process is determined a priori, a learner's curiosity and with this his willingness to learn is verifiable inhibited [3]. This allows for the assumption that free, sequence-based learning can lead to an increased learning success because of the learner's pure intrinsic motivation contrary to an often enforced extrinsic motivation by institutionalized learning.

LSBL alone already offers great opportunities to stimulate the intrinsic learning motivation of individuals. This motivation can even be enhanced if we combine LSBL with GBL, another often used method for the motivation of learners. While the potential of GBL is its interactivity and its capability to demonstrate topics in a manageable and closed surrounding [6], LSBL offers a flexible basis of individual learning paths for such interactive surroundings. Because LSBL is more a concept than an instance of e-learning, it is not restricted to specific applications but can easily integrated in GBL settings. Then, the GBL part offers the setting of the game and the game play while LSBL offers the relations between the lessons to be learned.

A typical example for the combination of GBL and LSBL is an adventure game in which the learner takes the role of the hero who has to solve a quest (GBL setting). The adventure is composed of different places where the player can travel to (virtually as well as physically). At each place, information is hidden that comprises the lessons to be learned (LSBL part). The player can choose which information he acquires in order to solve his quest (LSBL part). Several solution paths are conceivable so that it is not necessary to gather all information provided (LSBL part). The player wins the game if he manages to solve his quest (GBL).

5 The Location-Sequence-Based Game Model

In general, the learning environment of a location-sequence-based game system consists of several points of interest (places) where the different lessons to be learned are located. The combination of places and lessons shall be called curriculum. Each lesson belongs to a superior field of teaching that is classified into different issues. Then, at each place, learners can choose which lesson of that specific place they want to learn. The available lessons at each place depend on the knowledge that a learner acquired beforehand. The formal model for the system can be described as follows: The learning system L is a hexatuple, consisting of a set P of N places, a set I of M issues, a set C, of curricula, the player's dynamic knowledge K, a similarity function *sim* and an access function *access*:

$$L_s = (P, I, C, K, sim, access) \tag{1}$$

The N places p_n, $n = 1, \ldots, N$, build the set P of points of interests:

$$P = \{p_n | n = 1, \ldots, N; N > 1\} \tag{2}$$

The field of teaching is classified into M different issues i_m:

$$I = \{i_m | m = 1 \ldots, M; M > 1\} \tag{3}$$

At each place, different issues can be taught. The combination of a place p_n and an issue i_m is called curriculum. A curriculum is the specific instance of an issue at a given place. The set of curricula is defined as:

$$C = \{c_{nm} | (p_n, i_m) \in P \times I\} \tag{4}$$

The curricula of each issue i_m at different places p_n can be compared among themselves in regard to their similarity:

$$sim{:}C \times C \times I \rightarrow [0, 1] \tag{5}$$

The similarity function $sim()$ shall be 1 for $sim(c_{nm}, c_{nm})$ and symmetric so that $sim(c_{nm}, c_{km}) = sim(c_{km}, c_{nm})$. The learner starts the game at a random place $p_r \in P$ and passes through the learning process in a variable sequence of places. This first place is chosen by the learner as a starting point, driven by his individual curiosity and intrinsic motivation. At this point, the learner chooses the curricula c_{rm} of the place p_r that he is interested in. The set of those chosen curricula is his initial knowledge K_1 of the game:

$$K_1 = \{c_{rm} | c_{rm} \in C; learner\ is\ in\ p_r; 1 \leq r \leq N\} \tag{6}$$

The learning process will be continued with this initial knowledge and expanded continuously at each place. Let

$$P_v \subseteq P \tag{7}$$

be the set of points of interest that the learner has visited during the game, p_j the actual new place, and K_l the learner's gathered knowledge. Let $\sigma \in [0, 1]$ be a predefined system parameter acting as a threshold for the similarity of curricula. Then, the learner gets access to all curricula of place p_j that exceed the similarity threshold σ if compared to all curricula of his knowledge already gathered beforehand:

$$access(p_j, P_v, K_l) = \{c_{jm} | sim(c_{jm}, c_{nm}) \geq \sigma; c_{nm} \in K_l\} \tag{8}$$

Out of this set of curricula, the learner can choose which curricula he wants to look at. After that, his complete knowledge is:

$$K_{l+1} = K_l \cup \{c_{jm} | c_{jm} \in access(p_j, P_v, K_l)\} \tag{9}$$

6 Example

Subsequently, we illustrate the game design presented in the previous section with the example of a detective story in a zoological garden. Players are exposed to the following setting.

Mama Marmot has collected a basket of blueberries that she placed in front of her cave. But when she wanted to give the berries to her children, the basket was completely empty. Help Mama Marmot to find out who is the berry thief.

Players can visit four places where different animals live: The house of marmots (p_1), the house of elephants (p_2), the house of cougars (p_3), and the house of bears (p_4). The available issues shall be limited to the topics genus (i_1), habitat (i_2), diet (i_3), and behavior (i_4). The similarity of the species in regard to the issues $(i_1, \ldots, i_4)$ is shown in

Fig. 1. At the outset, knowledgeable experts must explicitly determine the respective degree of similarity.

	Genus				Habitat				Diet				Behavior			
	p_1	p_2	p_3	p_4	p_1	p_2	p_3	p_4	p_1	p_2	p_3	p_4	p_1	p_2	p_3	p_4
marmot p_1	1.0	0.2	0.4	0.5	1.0	0.1	0.8	0.8	1.0	0.8	0.2	0.7	1.0	0.7	0.3	0.5
elephant p_2		1.0	0.1	0.2		1.0	0.2	0.5		1.0	0.3	0.5		1.0	0.4	0.6
cougar p_3			1.0	0.6			1.0	0.8			1.0	0.6			1.0	0.2
bear p_4				1.0				1.0				1.0				1.0

Fig. 1. Similarity of the species in terms of issue

Now, the player can choose which place he wants to visit first. As a starting point, the house of marmots may be suitable to find out more about the circumstances of the crime. There, the player can choose which curricula he wants to have a look at. The player does not possess any previous knowledge. Therefore, he reviews all available curricula so that his knowledge is initiated with $K_1 = \{c_{11}, c_{12}, c_{13}, c_{14}\}$. As the visitor opts for the marmot enclosure (p_1) as the starting point of the tour, he sets to a certain extent the issue-related focusing of the following learning process. He learns about the marmot living in America, Asia and Europe, being primarily an herbivore but also eating insects or snails, and living in small colonies.

The next place the player visits shall be the house of elephants (p_2). The curricula available to the player depend on the knowledge he gathered beforehand and the similarity threshold that we assume to $\sigma = 0.5$. That means that the curricula on the elephant's diet and behaviour are provided to the player (see Fig. 2).

	elephant p_2			
	i_1	i_2	i_3	i_4
marmot p_1	0.2	0.1	**0.8**	**0.7**

Fig. 2. Similarity of marmot and elephant concerning player's knowledge K_1

The player decides to learn about the elephant's diet and learns that elephants, like marmots, are herbivores. Thus, his knowledge is extended by curriculum c_{23} to $K_2 = \{c_{11}, c_{12}, c_{13}, c_{14}, c_{23}\}$. In addition, also the set of all visited places $P_v = \{p_1, p_2\}$ is

	bear p_4			
	i_1	i_2	i_3	i_4
marmot p_1	**0.5**	**0.8**	**0.7**	**0.5**
elephant p_2			**0.5**	

Fig. 3. Similarity of marmot and elephant with bear concerning player's knowledge K_2

extended by p_2. Thereafter, the player visits the bear (p_4) and again the similarity between the players knowledge and the curricula concerning the bear is considered (see Fig. 3).

Because of the similarities between the marmot and the bear, the player is provided with all curricula concerning the bear. The player decides to learn curricula c_{42} and c_{43} telling him that bears live in the northern hemisphere but once lived also in northern Africa, being omnivores. Extending his knowledge with curricula c_{42} and c_{43}, his new knowledge is $K_3 = \{c_{11}, c_{12}, c_{13}, c_{14}, c_{23,}c_{42}, c_{43}\}$ and the new set of visited places is $P_v = \{p_1, p_2, p_4\}$.

In the next step, the player visits p_3 being the only place where he has not been before. Due to the similarity with marmot and bear concerning habitat and with the bear concerning the diet (see Fig. 4), both curricula of the cougar are provided. The player decides to have a look at both curricula learning that the cougar is a pure carnivore living in North and South America. His knowledge is extended with both curricula c_{32} and $c_{33,}$ to $K_4 = \{c_{11}, c_{12}, c_{13}, c_{14}, c_{23,}c_{32,}c_{33,}c_{42}, c_{43}\}$ and the set of visited places is $P_v = \{p_1, p_2, p_3, p_4\}$.

		cougar p_3			
		i_1	i_2	i_3	i_4
marmot	p_1	0.4	**0.8**	0.2	0.3
elephant	p_2			0.3	
bear	p_4		**0.8**	**0.6**	

Fig. 4. Similarity of marmot, elephant, and bear with cougar concerning player's knowledge K_3

Now, the player analyses his knowledge excluding the cougar from the list of thieves because of being a carnivore that does not eat berries. He discovers that still two suspects remain, both eating berries. One of them, the bear, lives in the same region as marmots do. Concerning the habitat of the elephant, the player did not gather any information. Therefore, he decides to go back to the elephant. Because his current knowledge K_4 is greater than the knowledge K_1 was when he first visited the elephant, more curricula about the elephant are now available to him (see Fig. 5). Therefore, the curriculum c_{22} concerning the elephant's habitat is now provided. The player extends his knowledge to $5 = \{c_{11}, c_{12}, c_{13}, c_{14}, c_{22,}c_{23,}c_{32,}c_{33,}c_{42}, c_{43}\}$ and learns that elephants live in the savanna

		elephant p_2			
		i_1	i_2	i_3	i_4
marmot	p_1	0.2	0.1	**0.8**	**0.7**
cougar	p_3		0.2	0.3	
bear	p_4		**0.5**	**0.5**	

Fig. 5. Similarity of marmot, cougar, and bear with elephant concerning player's knowledge K_4

and the jungle of Africa and Asia, but not in the mountains or steppes like marmots do. Finally, the player can conclude that the bear has stolen Mama Marmot's berries.

7 Conclusion

Curricula can be imparted through location-based learning and LSBL in a new manner. Contextual and situational learning of this kind can add to faster acquisition of knowledge because of stimulating the intrinsic motivation of learners. In combination with GBL, the motivation of individuals to learn can even more be fostered. Thus, it is a future challenge to develop location-sequence-based game based learning environments which get essentially accepted and are forthright employed. Since recreation for many people is an expensive good, it is crucial to escape work life in time off. Concerning this matter, simulations, games, and role play seem most suitable for peripheral learning [12]. Such forms of learning are entertaining, reduce perceived idle time and stimulate the self-determined development of knowledge. In the end, the effect of learning seems most sustainable if people verily enjoy learning in recreational pauses.

In this paper, we presented the concept of such a learning system. Despite its great motivational advantages, there are still some limitations. First of all, the similarity function has to be designed very carefully for each application. If not, it may be possible that players cannot solve the game because they cannot gather all information that is needed for the quest. Then, this will discourage the player. Secondly, due to the quest to be solved, there are usually some information that players have to acquire in any case. This restricts the flexibility of the LSBL to some degrees.

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