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Swarm-based adaptation: wayfinding support for lifelong learners

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Abstract. This article introduces an approach to adaptive wayfinding support for lifelong learners based on self-organisation theory. It describes an architecture which supports the recording, processing and presentation of collective learner behaviour designed to create a feedback loop informing learners of successful paths towards the attainment of their learning objectives. The approach is presented as an alternative to methods of achieving adaptation in hypermedia-based learning environments which involve learner modelling.

1 Introduction

Self-direction—the learner's assumption of "primary responsibility for and control over decisions about planning, implementing and evaluating the learning experience" [1]—lies at the heart of lifelong learning. However, self-directed learners are often challenged to assume responsibilities, and the self-directed learner may be "confronted with the problem of how to find a way into and through a body of knowledge that is unknown at the outset. Without the benefit of any explicit guidance, a self-directed learner is obliged to map out a course of inquiry that seems appropriate, but that may involve a certain amount of difficulty and disappointment that could have been averted" [2]. This description calls to mind the image of the lifelong learner as navigator, charting a course through educational waters. We follow Darken [3] in using the term "wayfinding" to describe the cognitive, decision-making navigational process carried out by self-directed learners as they assume responsibility for sequencing their learning interactions *en route* to the attainment of certain competencies. Fixed curricula serve only to restrict the possibilities for self-direction—lifelong learners need a flexible, adaptive approach to wayfinding support (termed adaptive navigation support by Brusilovsky [4]), able to respond to their changing situations and goals.

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2 Wayfinding support for lifelong learners

Flexibility in wayfinding support can be realised through so-called "learner support services" [5]. However, individualised advice is costly. As a response to this financial issue, research has explored the application of educational technologies to lifelong learning support. The authors of a recent CEDEFOP thematic workshop report [6] contend that Adaptive Hypermedia Systems (AHSs) are "particularly suited to implementing lifelong learning … because they can tailor the learning environment and content to each individual learner's needs and aptitudes". AHS continues the Intelligent Tutoring Systems research line in seeking to "build a model of the goals, preferences and knowledge of the individual user and use this through the interaction for adaptation of the hypertext to the needs of the user" [7]. The reliance on accurate, detailed and up-to-date user models is both the theoretical strength of Adaptive Hypermedia and its practical Achilles heel. Without models, or with incorrect ones, adaptation falters, and Self [8] notes the absence of a theory of learning which might be used to maintain learner models. Is there, then, an alternative approach to wayfinding guidance for lifelong learners which might provide a cost-effective, flexible solution yet which does not rely upon learner modelling?

The ideal approach would avoid pre-planning of wayfinding guides so that courses, as it were, spontaneously acquire effective structures or organisations. Such self-organisation—"the acquiring of a spatial, temporal or functional structure without specific interference from the outside" [9]—can be seen in ant foraging trails [10]. Paths identified by ants are not pre-planned, but emerge as a result of indirect communication between members of an ant colony, a process known as stigmergy. In their overview article Theraulaz and Bonabeau [11] state, "The basic principle of stigmergy is extremely simple: Traces left and modifications made by individuals in their environment may feed back on them". Stigmergy can be considered as the basis for an approach to wayfinding support for lifelong learners. We can imagine learners' interactions with learning resources and activities being recorded automatically as they progress through a body of knowledge, then processed/aggregated and finally fed back to other learners. This would provide a new source of wayfinding guidance to lifelong learners giving clues as to efficient paths through a body of knowledge. Such an approach is cost-effective, since trail creation occurs unnoticed as a side effect of learner interaction with e-learning systems, it is flexible, able to emerge from and adapt to different circumstances, and it holds the prospect of being implementable, since its adaptivity does not depend upon learner modelling but rather on the behaviour of the "swarm" of learners.

3 An architecture for wayfinding support in lifelong learning

Our work on wayfinding support is being carried out as part of the development of flexible lifelong learning facilities that meet the needs of learners at various levels of competence throughout their lives, which we term "Learning Networks" or LNs [12]. A Learning Network consists of learning events called Activity Nodes (ANs), such as courses, workshops, conferences, lessons, internet learning resources, etc.

In Learning Networks, the Learner's Position is defined as the set of ANs already completed in the LN. The Learner's Target is the set of ANs that is sufficient to reach a particular level of competence or expertise in the domain. These two concepts equate to "you are here" (position) and "there's where I want to be" (target), and the wayfinding guidance which is fed back concerns effective ways of getting from here to there, based on the behaviour of the swarm of previous learners.

Central to the approach are logs of learner information which indicate what a learner did and when. The use of internet technologies in e-learning has brought with it an increase in the level of standardisation of transmission protocols and data, and logging information is no exception. The World Wide Web Consortium has provided Common and Extended Log File Formats and a whole area of research is now dedicated to the processing and analysis of these files for various purposes, known as Web Usage Mining [13]. However, the events which are registered in these logs are extremely low level, especially when seen from the lifelong learning perspective. This complicates their analysis, making it difficult to know which users are interacting (since only IP addresses are logged) and what they are doing (since only cryptic Uniform Resource Locators (URLs) are logged). The characteristics of our domain suggest a different type of log is more appropriate, one which records not only which lifelong learner did what, but also whether or not this was successful (eg by including the results of an assessment).

Such a level of description is envisaged in the learner records data store described in the IEEE Draft Standard for Learning Technology — Learning Technology Systems Architecture [14]. This data store, specifically designed to cater for the nomadic nature of lifelong learners, is defined as a repository of "learner information, such as performance, preference, and other types of information".

With the notions of position, target and learner record in place, an architecture for self-organising wayfinding support can be introduced. Lifelong learners interact with the functionality available in a learning network. Learner-AN interaction is logged in a Learner Record Store along the lines envisaged by the IEEE draft architecture, including information on the learner, the AN, a timestamp and an indication of performance (for example, pass or fail). The lifelong learner is presented with feedback which reveals how other learners with the same target and from the same position, were successful in reaching the target. This information is derived from the collective log of learner interactions, following both filtering and processing. The filtering is used first to limit the feedback to involve only those learners with the same target, and then to limit it to relate to those learners who departed from the same position as the learner ("others with your target and position proceeded as follows"). The processing is used to rank the various next steps taken by other learners, favouring the next best step (eg the one taking the least time to complete or the one with the best chance of success). With this architecture in place, lifelong learners are given access to information hitherto unavailable to them, yet of importance to the wayfinding process. The learner is able to find answers to questions such as "How did other learners progress in this learning network from where am I now?", "Which path through the learning network offer the most chance of success?" and "What has been the most efficient (i.e. fastest) path taken by others through this Learning Network?".

4 Summary and ongoing research

This short paper has introduced the rationale behind our research into self-organising wayfinding support together with an outline of the architecture we have developed. Our approach is designed to adapt support for decisions on the sequencing of learning events not on the basis of a model of the individual learner but using information on the collective behaviour of other learners—a form of swarm intelligence.

We are currently analysing learner record information covering the many thousands of lifelong learners studying at our institution. Once our analysis is completed, we intend to simulate the introduction of an educational technology implementing the feedback loop to predict that impact of its introduction before carrying out experiments with lifelong learners to measure the actual value of the approach.

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