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Social Insect-inspired e-Learning: Open Research Questions

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Abstract

New research drawing on theories of self-organisation and trail formation in social insects suggests an alternative to traditional design processes in e-learning. This short paper provides an introduction to this promising area, describes results from initial experimentation with the techniques and suggests a number of topics for further research.

1. Introduction

Identifying the sequence of courses to be followed to achieve a given competency level has traditionally been the responsibility of curriculum designers. Using knowledge of teaching methods and pedagogy, designers specify routes to be followed by learners. Although some degree of freedom may be afforded to learners through alternative, optional courses, routes by which learners can arrive at their learning destinations are often highly constrained.

Critique of this situation can be found in constructivist curriculum theory [1, 2], which views curriculum development as a dynamic process involving learners, with sequences “emerging in the interaction between the learner and the environment” [3]. However, in the absence of a curriculum as an educational wayfinding aid, students require other forms of guidance to avoid becoming lost in e-learning space [4] and not reaching their goals, or taking unduly long to do so.

Work in the area of Intelligent Tutoring Systems [5, 6] has investigated knowledge-based approaches to course sequencing guidance for learners. The work revolves around the modelling of conceptual domain knowledge (what is related to what in the domain), the modelling of knowledge pre-requisites (what must be learned before what) and the modelling of learner knowledge (what does the learner already understand) so that automatic planning processes can perform

curriculum sequencing. These modelling efforts are highly demanding, both in terms of initial creation and ongoing knowledge base maintenance, leading to brittle e-learning environments.

As a response, a growing research community is investigating the application of techniques from the world of social insects as a viable approach to educational wayfinding support.

2. Systems inspired by social insects

Self-organisation is “the spontaneous formation of well-organised structures, patterns or behaviours, from random initial conditions” [7]. Bonabeau, Dorigo and Theraulaz [8] give ant foraging trails as an example of the structures which emerge as a result of self-organisation. Paths identified by ants are not pre-planned, but emerge, spontaneously, as a result of indirect communication between members of an ant colony. Dorigo and Di Caro [9] describe how ants deposit a chemical substance known as pheromone which can be sensed by other ants. This process of indirect communication exploited by members of ant colonies is known as stigmergy. In their overview article Theraulaz and Bonabeau [10] state, “The basic principle of stigmergy is extremely simple: Traces left and modifications made by individuals in their environment may feed back on them.... Individuals do interact to achieve coordination, but they interact indirectly, so that each insect taken separately does not seem to be involved in coordinated, collective behavior”

These ideas can be applied in e-Learning by making use of the of learners’ interactions which are automatically maintained in e-learning systems. The time-stamping of these interactions allows sequences to be identified which can be processed and aggregated to derive pheromones favouring paths along which more learners have been successful. This information can be fed back to other learners, providing a new

source of navigational guidance indicating “good” ways towards learning objectives – a self-organising, stigmergic approach to wayfinding support.

This approach has a number of attractive features including its self-sustainability, scalability and reliance on machine-generated rather than handcrafted meta-data. As a result, a number of institutions around the world, including our own, are investigating social insect-inspired e-learning [11-15].

2. Experimenting with Learner Ants

In order to examine whether these promising techniques from the world of social insects do indeed have positive effects on educational wayfinding, we augmented the Moodle e-learning environment with functionality exploiting principles of stigmergy. This environment was then used in a large-scale experiment.

The experiment involved offering learners advice on best next steps, based on the number of times a module had been successfully completed. Underlying the approach is a transition matrix which maintains an overview of successful transitions between modules. The pheromones in this situation reflect success rates, aimed at helping learners make better choices based on “tried and tested” sequences.

This approach is illustrated in the transition matrix shown in Figure 1. If we imagine a learner having just completed the module labelled ‘A’ and en route to a goal which requires A, B, C, D and E to be successfully completed, following, removal of those modules already completed, a list is first drawn up of all the successful transitions made from A by all previous learners (i.e. 4 from A to B, 2 from A to C, 5 from A to D and 1 from A to E). The advice is identified by drawing one item randomly from this list. The result is that the most frequently followed next step has a higher probability of being selected (in this case A to D), although, to prevent sub-optimal convergence to this path, there is a chance that the other paths (A to B, A to C and A to E) will be selected.

A study programme was developed consisting of 11 modules on the use of Internet. Each module was designed to take an average of two hours to complete, with formal completion being established through the use of a short test consisting of five equally weighted questions. Achieving a score of 60% or more indicated competence in the topic covered by the module. Completion of all 11 modules entitled the learner to a certificate. No restrictions were placed on the order in which the modules had to be completed.

Two copies of the modules were created – one for the experimental group, which received an additional advice-giving facility, and one for the control group, which used the standard e-learning environment. Over eight hundred learners enrolled for the 3-month course, and were divided over the two groups.

	A	B	C	D	E
{}	1	3	2	4	5
A		4	2	5	1
B	2		2	1	3
C	3	4		1	2
D	4	2	4		5
E	1	2	5	3	

Figure 1. A matrix showing learner transitions from modules (rows) to other modules (cols).

The results of our experiment, which are described in detail in [16, 17] lead us to conclude that stigmergy-based wayfinding support enhances effectiveness in e-learning: a significantly higher amount of progress and higher completion rates in the experimental group were observed in the experimental group, together with convergence around sequences of modules.

3. Open Research Questions

Our initial experimentation leads to a number of questions which provide the basis for a research agenda:

- Pheromone type: could improved effects be seen if a different type of advice were to be offered (information on the fastest route, the route with highest success or satisfaction rates, or a combination of several of these leaving it to the student to choose between these options)? Could advice on avoiding the worst steps have better effects (anti-pheromones)?
- Standardised log-data: are there standardised sets of e-learning log data which could be relied upon to be available in e-learning systems so that social insect inspired tools could be more easily plugged and played?
- Extended meta-data: could better effects be achieved by incorporating user characteristics in the pheromone calculations (show me the steps taken by others like me, show me the steps taken by elderly people, or lorry drivers)?
- Study time: Would the same effects be seen in an experiment over a longer period of time (eg years)? How to deal with revisions in study programmes which may invalidate advice?

- Study programme size: is there a minimum number of modules under which effects are not seen? A maximum?
- Timing of feedback: should the advice be offered as soon as information is available, or only when a certain amount or type of information is available?
- Critical mass: is there a group size under which the effects are not seen?
- Extended history: are better results achieved by extending the length of the path used when identifying next steps (eg all modules already completed by the learner as opposed to merely the last completed module);
- Extended advice: similarly, are better effects achieved by extending the advice beyond the next best single step to show a next best sequence or full path to a learner's objective?
- Visualisation: how should alternative paths be presented to learners?
- Simulated learners: could pre-populating the system with simulated learners lead to better results?

Answering these and other questions will ensure that this new area of e-learning technology will continue to produce exciting, intriguing and applicable research results targeting a cost-effective, flexible and implementable approach to educational wayfinding.

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