Towards Interaction Modelling of Asynchronous Collaborative Model-Based Learning

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Abstract. In the last decade, the design of collaborative discovery learning environments (CDLE's) has received increasing attention. Such a design perspective brings up to the educational context the possibility of exploiting the so-called Model-Based Reasoning approach, by providing to learners the opportunity of collaborating while building models to represent observations. In this paper, we are concerned with the design of CDLE's in which building models instantiates as a theory formation process. Such a process is provided as a synergetic combination of both inductive and hypothetical-deductive approaches. The "moving engine" allowing a theory to evolve is the notion of contradiction: learning is supposed to occur as a side effect of contradiction detection and overcoming during theory formation by learners guided by a coordinator. Inspired in recent relevant work concerning Computer Supported Collaborative Learning (CSCL) architectures, we propose an architecture to support the process of asynchronous theory formation, allowing a student both to work individually and to contribute to the group discussion. Out of the proposed architecture, we draw-up related questions that would address supporting a coordinator to guide discussions on the basis of group interaction analysis.

Keywords. Model-based learning, CSCL architectures, asynchronous communication, supported coordination.

1 Introduction

In Educational literature, Discovery Learning appears as an approach in which the learner builds up his/her own knowledge by performing experiments within a domain and inferring/increasing rules as a result. Such an approach "[...] has appeared numerous times throughout history as a part of the educational philosophy of many great philosophers particularly Rousseau, Pestalozzi and Dewey, 'there is an intimate and necessary relation between the process of actual experience and education **[1]**'. It also enjoys the support of learning theorists/psychologists Piaget, Bruner, and Papert, 'Insofar as possible, a method of instruction should have the objective of leading the child to discover for himself' **[2]**" **[3]**. Such a constructivist approach has been largely exploited for the design of computational artefacts with learning purposes, the so-called Discovery Learning Environments (DLEs). One known feature of such environments is the autonomy degree required for students to succeed while handling a domain.

In his introduction **[4]** to the book "Collaborative learning: cognitive and computational approaches" P. Dillenbourg considers the notion of collaborative learning in a three-dimension space generated by the following three axis: *(i)* the scale of the collaborative situation in terms of the amount of people involved, *(ii)* what is actually concerned to learning, and *(iii)* how collaboration is provided (face-to-face or computer-mediated, synchronous or not, etc.).

In the last years, several scholars have been investing efforts to bring together both collaborative learning and discovery learning, thus leading to the emergence of the collaborative discovery learning approach **[5]**. In order to show the effectiveness of the collaborative discovery learning approach, a number of systems have been designed, such as Belvedere (groupware for learning scientific argumentation) **[6]** and GARP **[7]**.

Current efforts on CSCL include the design of computational models of collaborative learning interaction such as to improve support and guidance to humans taking part in the process. In such a context, relevant work has been invested in asynchronous interaction analysis, e.g. **[8]**, however, the major focus is often on free-speech discussion. On the other hand, whenever communication is structured (model-based), efforts have often been invested either on synchronous interaction or the charge of coordination is yet considerable for participants (e.g. CMapTools).

In this paper we are concerned with the challenge of approaching interaction analysis by considering, as a first step, an environment for asynchronously collaborating by building models. Based on a forum structure, our conjecture is that such an environment facilitates perception by the group of its work as such. In §2, we propose an architecture for collaborative learning environments to support the asynchronous construction of models by a students group. Then in §3, interactions within such an environment are illustrated through a scenario and a discussion is opened on how the proposed architecture would facilitate the design of artificial agents capable of positively influencing collective model construction. Finally, in §4 we present our concluding remarks and point out both ongoing and further work.

2 On asynchronous collaborative model-based learning: an architecture

In **[9]**, the author describes several possibilities of architectures for CSCL environments. These architectures are presented upon the design pattern known as Model-View-Controller (MVC): "*Model* is an internal representation of a semantic model of the problem of interest. The *View* displays the model in some visual representation", and a "[…] *Controller* enables the user or the environment to modify the state of the Model".

Inspired in Suther's discussion, we draw-up our architecture on the basis of the MVC design pattern. Figure 1 shows our architecture named *AC-Hybrid*, where "A" stands for Asynchronous and "C" for Collaborative. We recall those features further below. In Figure 1, *Client A* and *Client B* are each representing a participant's machine (abstractly speaking). *Server* is representing a machine controlled by the group's Coordinator. In a general manner, a *Model* is the result of representing an observation. We distinguish three kinds of Models, namely *Individual Model*, *Global Model*, and *Collaborative Model*. By handling an Individual Model, a student has the opportunity to organize his/her ideas in a private manner, before he/she feels able to propose them to the group. Such a Model lives in a Client and is both viewed and controlled by the participant owning it. Individual Models may be replicated in Client machines in order to account for memory versioning, but a single version is modifiable at a time (the more recent one).

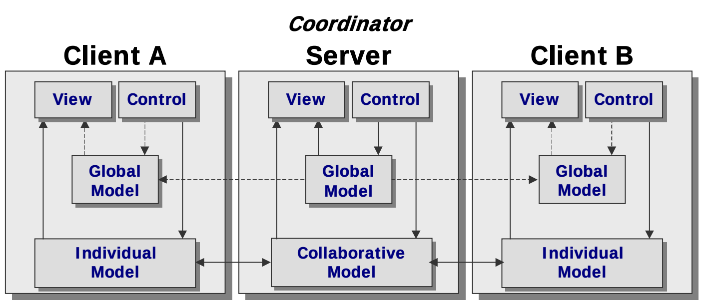

Figure 1: AC-Hybrid Architecture.

The Global Model should represent group consensus at a given moment. On the one hand, it should be *stable* such as to be usefully exploitable for the group's further elaborations. In other words, it would serve as a current group memory available anytime to be inspected by group members. On the other hand, a Global Model is supposed to continuously *evolve* such as to capture the group's cognitive progress. Similarly to Individual Models, Global Models may also be versioned such as to keep track of group evolution. These two features assigned to Global Models – stability and predisposition to evolve – have suggested us the need for an additional Model justifying thus the "AC" part of our AC-Hybrid architecture: the Collaborative Model.

The Collaborative Model plays the role of an intermediate Model candidate to replace the Global one. It arises as a suggestion from a group member who aims at modifying the Global Model. Such a suggestion would then be submitted to the group's analysis, and thus, it would trigger a debate. The environment in which the debate takes place borrows the main structure from a forum. While the idea of asynchronous communication seems convenient here to hold a discussion, our objective is however to provide a group with a mean to reach a consensus, a kind of drawn-up conclusion about one's suggestion. The idea of using Models rather than free-speech usually considered within forum tools appears here to respond to that objective, thanks to a Model's underlying structure. It is up to the Coordinator to decide when to stop a debate and to replace the Global Model. Careful analysis of interactions is crucial to allow the Coordinator both to guide the debate and to decide about Model replacement.

We see then the MVC design pattern as a suitable one for the purposes of the above depicted architecture, since several models may exist in a given moment (*m* Individual, 1 Global, *n* Collaborative), each one viewed/controlled by eventually different users, according to the intended dynamics.

3 An illustrating scenario

In this section we develop a scenario aiming to illustrate some possible interactions between participants supported by a system based upon the proposed AC-Hybrid architecture. These interactions would allow the evolution of the group's Global Model through a discussion relying on Collaborative Models. For such, we consider the following:

- Models constructed by participants are considered here to be logical theories;
- A classical toy domain widely exploited by scholars on Artificial Intelligence;
- A conceptual model - called Phi-calculus - originally proposed to support human-computer collaboration during theory formation **[10]**. Phi-calculus was then instantiated into the context of Human Learning, grounding the design of a Web-served Learning Environment which was submitted to real learners in Law[1] **[11]**. The theory formation process underlying the model is supposed to promote learning as a side-effect. Our first elaborations aiming at extending Phi-calculus to a human-human collaborative educational context are reported in **[12]**.

Phi-calculus relies on a synergetic combination of both inductivist and *hypothetical-deductive* rationales. The "moving engine" of the theory formation process is the notion of contradiction **[13]**: a theory is supposed to evolve by contradiction detection and overcoming. Contradiction should arise during confrontation between current theory and incoming experiment (Examples/Counter-examples). It is supposed to reveal disagreement between individual's observations and the current available theory. Recent relevant work on collaborative environments has confirmed the interest of socio-cognitive conflict theory to learning **[14]**.

During the theory formation process, communication between a human agent and his/her Artificial Agent takes place by means of *constrained dialogues* **[15]**. These correspond to messages formalized under the form of the speech acts *Ask* and *Tell* **[16]**, representing, respectively, *(i)* agent A asks something to agent B (or vice-versa) and *(ii)* agent A informs something to B (or vice-versa). Also, messages in constrained dialogues rely on exchanging (asking and telling) what we have called *knowledge types* within Phi-calculus. Such types are not exploited here: they should account to the states that an evolving theory (or a concept being formed) should assume.

Recalling the AC-Hybrid architecture from §3, interactions between a student and his/her own machine to modify his/her Individual Model are based upon original Phi-calculus model of human-computer collaboration. It is important to notice that within our current implementations, the system interface renders the above mentioned formalism totally transparent to the user-learner. In addition, the student is provided with a machine support to the theory construction process: an *induction engine* **[17]**, accounting for Learning from Examples approach.

Before depicting our scenario let us state that one can contribute to a debate by either *questioning* a Model or *proposing* a solution by suggesting a candidate Model to replace the Global one. In both cases, the contribution appears as a Model along with a justification for the question or solution. The speech acts *Ask* and *Tell* are used to represent, respectively, the questioning situation and the proposition one.

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Let us now start our hypothetical scenario by supposing that a History class interested in the study of historical monuments intends to formalize the concept of "Arch". We begin by considering that a Global Model is available: it has been previously constructed by the group out of some images supplied by the Coordinator. The annotation of each image fits on the Model. The whole situation is illustrated in Figure 2.

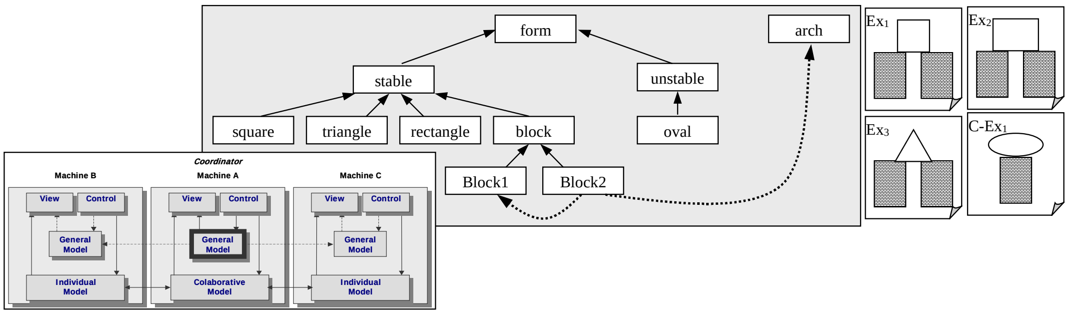

Figure 2: Global Model, version 1 (In order to hold the structured object annotations, concepts and their relations to each other are built up).

Now let us suppose that the Coordinator opens up a debate by proposing an object that contradicts the current theory (represented by the available Global Model). In Figure 3, a screenshot illustrates how a pair student-agent could detect contradiction after having imported the Global Model to work it out individually, and then annotating the proposed object by clicking on a grid.

Let us now suppose that, after finding a solution to overcome contradiction, the student suggests a candidate Collaborative Model to replace the Global Model. The (annotation of the) object supplied by the Coordinator justifies the incoming suggestion. The situation is illustrated in Figure 4.

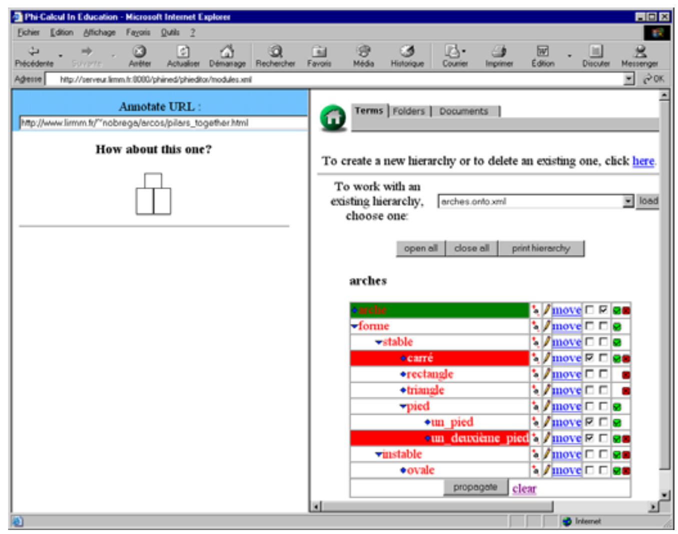

Figure 3: Individual Model (imported from Global Model): a student annotating the object and then system detecting contradiction.

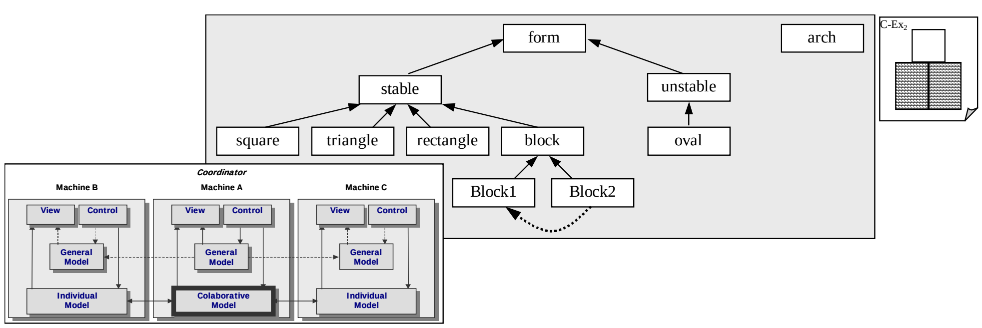

Figure 4: Collaborative Model: suggestion from one student (relation *Block2* →*Arch* is deleted to overcome contradiction provoked by the - annotation of the - proposed object).

Another student then points out a problem with his/her colleague's suggestion by stating that such a theory is unable to distinguish two of the previous objects. The situation is illustrated in Figure 5.

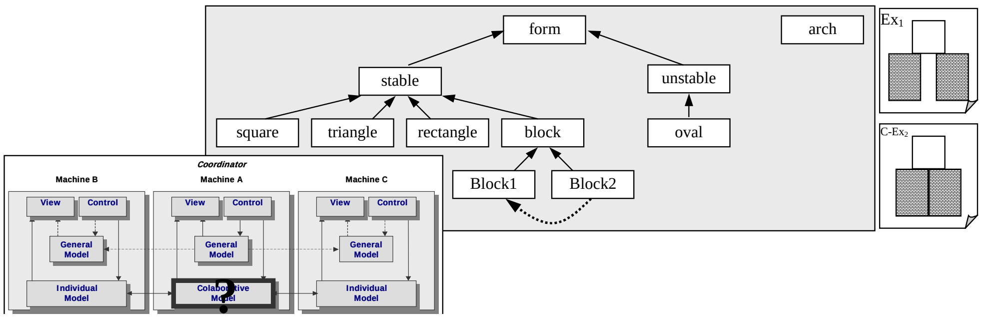

Figure 5: Collaborative Model: question from another student (why the Model cannot distinguish the two objects?).

The scenario might be continued by considering a suggestion to solve the problem identified by the above student[2].

From the above architecture and its illustration the following questions might deserve deeper discussion. From the learner's perspective, how could one get some assistance to find out the actual contribution of his/her Model to the discussion? Thanks to a forum structure being exploited here, various Collaborative Models may arise as a result of propositions by different students. When proposing a Model, one possibility would be to dispose of an artificial agent, which would be able to check out for eventual conflicts with respect to existing candidates.

Concerning the Coordinator's perspective, what would be the right moment for him/her to decide to update the Global Model? Should it mean that a consensus has been reached? In addition, it may happen that several candidate Models exist intending to replace the current Global Model; in such a case, which one to choose? One possibility would be to assume that Models deeper placed in the forum structure represent those more warmly discussed. On the other hand, even when choosing a Collaborative Model to replace the Global Model, the current discussion may yet be kept open (promising candidate Models do not necessarily need to be forgotten).

Finally, we believe that the forum structure along with model-based reasoning might facilitate qualitative interaction analysis, often more suitable and hardly accounted than quantitative one. Such an assumption lies on the basis of the fact that proposing a Model should reflect student's active participation in a discussion, as constructivist theories claim.

4 Conclusion

In the paper we propose an architecture for CSCL environments particularly concerned with the asynchronous collaborative construction of models by students. Even if aware of the early stage of our current research, we suspect it to be promising on the basis of both previous work and the conjecture that structured model-based discussion facilitates automated interaction analysis (in spite of its pedagogical value).

We are currently working to achieve an architecture mature enough to allow us to invest on its implementation, and then to submit it to real educational experiences, as we previously did within a human-computer collaborative context. Further work includes investing on interaction analysis such as to provide and to assess coordination guidance.

[2] One possibility is to reformulate the vocabulary in order to capture the distance between the two base blocks, then to find out new relations among the terms.

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