Science of Computer Programming 88 (2014) 54–81

Contents lists available at ScienceDirect

Science of Computer Programming

www.elsevier.com/locate/scico

Evaluating a graphical notation for modeling collaborative learning activities: A family of experiments

Ana I. Molina *, Miguel A. Redondo, Manuel Ortega, Carmen Lacave

Departamento de Tecnologías y Sistemas de Información, Escuela Superior de Informática de Ciudad Real, Universidad de Castilla-La Mancha, 13071-Paseo de la Universidad, 4, Ciudad Real, Spain

HIGHLIGHTS

- The use of graphical notations can facilitate the specification and design of learning systems.
- Our interest is centered on the design of CSCL systems and the modeling of group learning activities.
- We propose the use of the CIAN notation for modeling this type of learning activities.
- We describe three empirical studies to measure the adequacy of that notation to model collaboration.
- The results denote positive perceptions about the use of the CIAN notation for this purpose.

ARTICLE INFO

Article history:
Received 1 May 2013
Received in revised form 14 February 2014
Accepted 17 February 2014
Available online 26 February 2014

Keywords:
Educational modeling
CSCL
Notation assessments
Empirical study
Eye tracking

ABSTRACT

It is increasingly common to use languages and notations, mainly of a graphical nature, to assist in the design and specification of learning systems. There are several proposals, although few of them support the modeling of collaborative tasks. In this paper, we identify the main features to be considered for modeling this kind of activities and we propose the use of the CIAN notation for this purpose. In this work, we also try to empirically analyze the *quality* (in particular the *understandability*) of that notation. To this end, three empirical studies have been conducted. In these experiments we used several sources of information: subjective perception of the designers, their profiles and their performance on a set of understandability exercises, as well as the physical evidence provided by an *eye tracker* device. The results obtained denote positive perceptions about the use of the CIAN notation for modeling collaborative learning activities.

1. Introduction

The use of specification languages and standards for the design and modeling of *eLearning* systems is an open challenge that aims to promote the application of practices from *Software Engineering* (SE) and *Requirements Engineering* (RE) in the development of educational software. Thus, the development process of such applications could become more of an engineering and less of a traditional one. In this sense, the use of specifications or higher level abstraction notations, as well as the use of educational modeling languages (EMLs), constitutes an open research line [1]. Their use provides a number of advantages, among which we can mention that apart from promoting the reuse of design solutions, they provide better documentation and understanding of the designs. Moreover, these graphical notations are a good communication tool among members of development teams of this type of systems [2] (teams characterized, in many cases, by their multidisciplinarity).

* Corresponding author.
E-mail addresses: AnaIsabel.Molina@uclm.es (A.I. Molina), Miguel.Redondo@uclm.es (M.A. Redondo), Manuel.Ortega@uclm.es (M. Ortega), Carmen.Lacave@uclm.es (C. Lacave).

http://dx.doi.org/10.1016/j.scico.2014.02.019
0167-6423/

There are many proposals of *educational modeling languages* in the literature. Among them, we highlight the proposals of Martínez-Ortiz et al. [3], PoEML (*Perspective-oriented EML*) [4] and E2ML (*Educational Environment Modeling Language*) [5]. Each one provides interesting aspects, being semantically rich and flexible, mainly due to their graphical nature. In particular, among the EMLs, our focus is on those that support the modeling of *computer supported collaborative learning* (CSCL) [6] systems. In this paradigm, there are a number of specific features that must be specified in a suitable and precise way: coordination, information sharing, collaborative activities, distribution of responsibilities, etc. In this regard, we noted that the aforementioned languages do not include the necessary support for *modeling of group activities* [7]. Next, we state the minimum features that we consider should be incorporated into a modeling language for these kinds of systems:

- *Organizational issues modeling*. Due to the fact that we want to specify CSCL environments, they should support the specification of *actors*, *roles*, *software agents*, as well as the grouping of the aforementioned, giving rise to *groups*; that is, groups of actors with homogeneous responsibilities, or *work teams*, consisting of several roles. Relationships between members of the organization should be able to be specified. You should at least be able to describe *acting* relationships (actors playing roles), *inheritance* (specialization of roles) and *hierarchical* relationships (that affect the delegation of responsibilities between roles).
- *Group learning activities modeling* (modeling of different levels of abstraction). The notation must support the modeling of the *structure of group learning activities*, i.e. the division of complex activities into simpler ones.
- *Learning activities flow modeling*. They should support the modeling of the flow of learning activities which can be related to each other by a set of *temporal operators*. We need a complete set of operators which enables us to specify complex group learning scenarios. We are not only interested, however, in specifying *order* between activities (i.e. *qualitative temporal information*), but we also need to specify *quantitative temporal information* (periods of time, dates, etc.) [8]. In addition, the tasks flow can be enriched with the specification of *information passing* between activities. And finally, in order to specify coordination completely, the notation must support the specification of *notification*, as well as triggering *events* between activities. Thus, activation and coordination between activities can be specified.
- Support (preferably in a graphical manner) for *resource* specifications (*information* and *software*) used in the *context* of the learning activities. And, in the case of group learning activities, the ability to specify *shared context* [9].
- Support to *express graphically and jointly* the relationship between elements specified (*activities*, *roles* and *resources*).

In previous works, we have proposed a notation called CIAN (*Collaborative Interactive Application Notation*), which allows modeling of group work and human–computer interaction issues [10]. CIAN can be used for collaborative learning modeling systems, adding higher levels of abstraction in the development of educational applications in specified standards, such as IMS-LD [7]. It has been shown that this language can be used to specify CSCL activities and systems, even in mobile contexts [11]. In addition, CIAN includes instrumental support (by means of a tool called CIAT) that facilitates the edition and validation of diagrams created with this notation [12].

Most notations and techniques for requirement specification (including CIAN) have a major deficiency which is the absence of its suitable *assessment*. Therefore, the main contribution of this paper is the description of several empirical studies to evaluate CIAN. These studies are based on the *subjective perception* of designers [13], as well as on physical evidence obtained using an *eye tracker* device [14]. In these experiments, we began characterizing the CIAN notation using the *cognitive dimensions framework* [15]. As a result of this heuristic characterization, we identified the positive and negative aspects of our proposed notation. With the aim of contrasting these aspects with the opinions of designers and software engineers, we performed several empirical studies. In the first one, the participants were final-year Computer Science students. In this experiment, we used an opinion questionnaire which we designed ourselves. This experience allowed us to obtain the initial empirical feedback about our proposal. The second experiment involved a more representative sample of participants (professional in software engineering) and used a more contrasted and well-founded survey for assessing requirements modeling methods, proposed by [13]. In this second study, we also contrasted the use of the CIAN notation with another notation which also allows modeling cooperative tasks (the CTT notation) [16,17]. However, as with the first experiment, the results obtained are based on purely subjective perceptions of designers about both notations. The use of subjective surveys has the inconvenience of the existence of biased answers. With the aim of solving this problem, we propose the use of a more objective source of information: the use of an *eye tracker* device. The use of *eye tracking* techniques provides objective evidence (complementary to other sources of information) that allows us to perform a more complete analysis and comparison of results. In the final experiment, we performed a controlled experiment in which we incorporated this last objective source of information.

This paper is organized as follows: first, a review of graphical notations for modeling CSCL environments is included. Then, the CIAN notation is briefly introduced. Next, the main approaches for evaluating modeling languages (mainly of a graphical nature) are reviewed. In Section 5, the experiments carried out to evaluate the use of CIAN are described. And finally, conclusions are drawn and the main lines of future work are exposed.

2. Related works: Graphical notations for specifying CSCL environments

In this section, we present and provide references for some of the main contributions in the field of graphical modeling of *e-learning* and CSCL environments.