2009 Ninth IEEE International Conference on Advanced Learning Technologies

A Trace-Based System for Technology-Enhanced Learning Systems Personalisation[1]

Lotfi S. Settouti[1,2] Yannick Prié[1] Jean-Charles Marty[2] Alain Mille[1]
[1] *Université de Lyon, CNRS*
Université Lyon 1, LIRIS, UMR5205, F-69622, France
[2] *SYSCOM - Université de Savoie*
Campus Scientifique / 73376 Le Bourget-du-Lac cedex, France
LotfiSofiane.Settouti, Yannick.Prie, Alain.Mille@liris.cnrs.fr, marty@univ-savoie.fr

Abstract

This paper deals with the subject of personalisation in Technology-Enhanced Learning (TEL) Systems. As we want user centred solutions, we claim that considerable advantage can be gained from allowing observation and interpretation of learners' interactions traces in TEL systems. The key concepts of our approach are modelled traces, and trace transformations. These transformations such as abstraction or filtering enable a better understanding of the interactions taking place in the TEL systems and allow to provide services for personalisation.

1. Introduction

There is an increased need for personalisation in Technology-Enhanced Learning (TEL) Systems. Personalisation must be grounded on users' interactions with the system or with other users (collaborative learning). We thus need to observe their interactions, i.e., to track and interpret the information that might be relevant for adaptation. In this approach, one of the core parts of such TEL systems is thus a mechanism for *representing* the *learner-computer interaction traces* and *reasoning* about the *knowledge and assumptions* that learners acquire during the learning activity.

Tracking learners' activities is a common approach for observing and capturing information about learners. In the field of TEL environments, a research domain has recently focused on the concept of *learning trace*, as demonstrated by the numerous projects (TRAILS [1]; ICALT [2]; IA [3]; DPULS [4]) related to the subject. *Interaction traces* has been exploited in order to improve control, progress and support of computer-based learning situations. An *interaction trace* can be a set of information explicitly linked to the learning task (learner's action, creation of a text, answer to a question), or a more implicit set of knowledge elements or indices reflecting the learner's behaviour or characteristics. However, it is not an easy task to provide a human or an artificial agent with appropriate meaning for observing, evaluating or personalizing learning situations. Hard work on traces is needed for collecting, filtering, structuring and interpreting them.

Indeed, personalisation in TEL systems is essentially dependent on their capacity to produce exploitable, reusable, shareable and relevant traces of the individual or collective learning activity.

The goal of this paper is to define trace-based systems as core modules of TEL systems, aiming at facilitating their personalisation. The purpose here is to provide users of TEL systems with application-independent mechanisms for modelling and exploiting traces in order to represent, and reason about learner activities traces.

The paper is organized as follows: section 2 briefly explains the role of traces for activity personalisation regarding several actors. Section 3 describes our trace-based framework and sets up the notion of modelled trace and trace transformations. Section 4 describes a TEL system that exploits and implements our framework by describing an experimentation we have made.

2. Traces and TEL personalisation

Traces (a.k.a. trails[1], tracks[2][5], protocols[6] or more commonly as log-file) have been tracked and used in various systems to enhance learning and teaching activities. Individual and collaborative traces of user's interaction have proven their usefulness, particularly by contributing to

1 This work has been completed in the context of the project "TEL systems Personalisation", funded by Rhône-Alpes region.

978-0-7695-3711-5/09 $25.00 © 2009 IEEE
DOI 10.1109/ICALT.2009.159

understanding and improvement of learning activity personalisation [1][4].

In this context, we define personalisation as the modification of TEL systems in their configuration or behaviour by using information about their users. It is hard to imagine a much broader definition of personalisation, as many works [1][7][8] have addressed the subject. Some definitions of personalisation are limited and focus on altering TEL web-page or targeting content at users based on their expressed interests [8]. However, as TEL systems need to personalise the learning process, task or activity, they require more than expressed learner's preferences. Besides tracking and observing learner's interactions, such TEL systems need to understand, interpret and analyse the traces of observation.

We claim that the *learner-computer interaction trace* is central to any sort of personalisation. Important efforts have been devoted to the exploration of the various uses of interaction traces in personalisation and how services, tasks, devices, interfaces, learning activity can be adapted from information observed during the learner activity [8]. The notion of trace has received substantial attention since it appeared that several actors involved in learning sessions can exploit such learner's interaction traces (cf. Figure 1). In literature many works have been proposed that consider traces as personalisation sources for: improving awareness in activity of learners and teachers [2][3]; monitoring learner's tasks [9]; adapting a TEL content and navigation [7]; mirroring and guiding learners or groups [6][10]; supporting a pedagogical designer [5]; providing a data-source for researcher analysing a learning session [11].

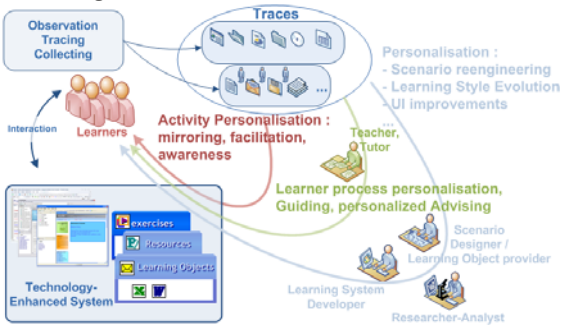

Figure 1: Trace-Based Personalisation

When we argue that interaction traces can be valuable sources for personalisation, others claim that there is not enough contextual information within traces to perform valuable analysis [12]. In fact, learner interactions can actually be analysed at several levels of abstraction [3]. Physical events (pressing keys, moving mouse) constitute the lowest level, while goal related interactions like indicating activity progress are in the most abstract level. Ideally, generic personalisation techniques should be able to exploit interaction-traces at multiple levels of abstraction, both in an on-line and an off-line manner.

By considering *interaction traces*, our idea is to model the observation of learners' interactions and to constitute the whole history of an activity at several levels of abstraction so as to "*explain*" or "*interpret*" low level interactions using high level ones. The Trace-based system (TBS) is an attempt to make homogeneous the heterogeneity issues raised by processing traces and personalisation.

3. Trace-Based System Framework

Although it seems to have become common sense that *traces* are important matters for TEL personalisation, there is no shared understanding of what a *trace* is. In this paper, we consider interaction traces as *a sequence of observed elements* recorded from a learner's interaction and navigation through a TEL system. The term *Sequence* refers to an existing order relation representing a history of the user's learning process during the observed activity. *Observed Elements* indicate that the trace data result from an observation. Such elements could represent an action, a message, a learning object, or a production.

3.1 Modelling Interaction Traces

It is natural for each TEL system to record useful traces in varying heterogeneous schemas[2] and formats[3]. This has yielded to a large number and a variety of techniques and tools. Such differences between traces schemas and formats lead to problems that go beyond those related to the redundancy of techniques and tools [3] : not being able to cross-exploitation, differing traces can mask interesting episodes or reusable patterns in performing, describing and reusing TEL personalisation techniques.

Ideally, it is advisable to have flexible schema and format that can unify different traces. Providing a single, common and extensible model conceptually conforms to widely accepted trace exploitations is hence desirable. Such a homogeneous model would allow exploitation across several traces, facilitating the reuse and comparison of techniques and also helping to reduce the number of tools needed to exploit traces. However, designing such common trace schema and format requires a standardized

2 A schema is a structure representing data within a TEL system.

3 A format is a particular way to encode data for storage.

model with precise semantics that would be more complete than existing formats or schemas (e.g. Common Log Format). We claim that it is too soon to try to standardize such trace format or schema (as in [3]), because that would require agreement at the level of the ontologies (what is described), not just at that of schemas or formats.

Indeed, all interaction traces have a (ontology-like) model, which can be explicit or implicit. In our approach, each trace can be described by a (ontology-like) model, which describes their elements[4]. In TBS, we use the term *trace model* to refer to the ontology that defines and structures explicitly the sequentiality and content of a trace.

3.2 Architecture of Trace-based System

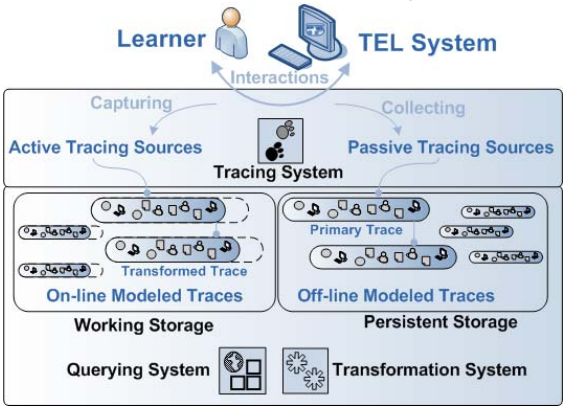

Figure 2: Trace-Based System Architecture

This paper assumes that trace-based processing uses abstract system architecture as shown in Figure 2. At the top of the general architecture of a TBS is the *tracing system*, which captures or collects the observed data from different input sources (log files, streamed actions, video records, interface events, etc.). The *tracing system* elaborates so called *primary traces* (often low level) from active or passive tracing sources. Conceptually, observed elements are stored in two partitions: *working storage* containing on-line traces captured from active tracing sources and *persistent storage* for off-line traces collected from several passive tracing sources or stored after the observation.

A *Transformation System* can perform operations on traces like applying filters, rewriting and aggregating elements, computing elements attributes, etc. so as to produce so called *transformed modelled traces* that can be more easily reusable and exploitable in a given context than primary traces.

Transformations can also be considered as semantic abstractions when associated with models (ontologies) like pedagogical activity scenario. The *Querying System* enables the extraction of episodes and patterns from the traces.

Users[5] or TEL systems may query, transform or visualise off-line or on-line traces. The working storage is persisted automatically on demand or periodically. Persistent queries and transformations are registered in the transformation or querying systems. Results of queries of transformations may be streamed to users or another TEL system or materialized in the TBS.

To define and implement such a system, we have specified a framework, defining languages to model, query and transform interaction traces. Modelling, representing and processing trace elements involve having a precise language with well-defined semantics. As explicit semantic admits a wide variety of forms, we have formally defined the concepts of trace and trace-model. Unlike to [5], our generic framework is set up over a common formal model avoiding ambiguities in reasoning, computing, resolving queries and transformations in off-line and on-line exploitations.

Thus, our approach towards common model and semantics uses a declarative language with well-defined semantics for expressing modelled traces, queries and transformations. Due to space limits and scope of this paper, we do not present its syntax and semantics here, we will rather focus on a presentation of a simple real example demonstrating some of the multiple possibilities offered by our TBS approach.

4. EMediatheque: a TEL system based on modelled Traces

EMediatheque is a synchronous and collaborative e-learning platform developed by eLycée[6] to implement the concept of virtual classrooms. EMediatheque was developed to enable students to work together in real time, as they would in a real classroom, with shared access to on-line tools and resources as a Web co-browsing, shared whiteboards, a chat system, a video-conferencing service, synchronous media players.

In this context, it is crucial for the learner to be aware of many aspects related to his/her individual and collaborative activity. In particular, we need to personalise learner activity by addressing the problems of awareness and reflexivity in the context

4 Foremost in our approach is overcoming a historical tendency to make trace files cryptic in order to save space with flat model.

5 Learners or teachers or any user granted with the necessary privileges and authorisations.

6 Elycée (http://www.elycee.com) is a young and innovative e-learning company proposing a French language e-learning service to expatriated French-speaking students.

of different pedagogical situations. However, eMediatheque is a neutral platform, which does not implement pre-defined pedagogical activities. The content is managed by a Course Management System (CMS), similar to Moodle, and delivered through web pages and media files preloaded by eMediatheque (using web services). Thus, the learner's activity reflexivity requires making a personalisation mechanism dependent on pedagogical activities not yet specified or defined at platform-design time. To tackle this, we have coupled eMediatheque with a TBS that allows personalizing learning sessions, thanks to interpreted traces that make sense for the learners according to the context of their specific activities.

Thus, the main originality of eMediatheque is that it encourages the awareness and reflexivity of learner activity and his/her metacognitive process by means of trace-visualisation of learning activity based on a TBS. The learner's activity is fully traced and the resulting primary trace of the tracing system is composed of perceivable actions meaning that each action is an interaction between the user and the platform, providing a perceivable feedback. EMediatheque proposes several activities mostly based on multimedia document co-construction, in groups, which can be published as portfolios or in weblogs.

4.1 Tracing System

In eMediatheque, most of the user's actions are tracked. The design was from the beginning articulated around the notions of modelled traces involving concepts *action* and observable *entities*. Unlike traces based on very low level events (keyboard and mouse interactions), the event granularity in eMediatheque is in much coarser, and can thus afford a higher level event semantics. One of the benefits is to be able to interpret an action more easily for reflexivity purpose.

However, eMediatheque is a set of tools that can be opportunistically used and adapted by teachers in the context of specific activity. As far as trace modelling is concerned, we describe two different types of trace models. (1) The *primary trace model*, created by the designer of the system, represents the history of actions performed by the user. It is a "*tool-oriented*" trace model, as its semantics only describes the "*objective*" usage of the platform, independently of the activity of the user. Figure 3 shows a tree-view representation of a primary trace[7] fragment produced by eMediatheque. The first level nodes are actions, where icons represent action types and labels identifiers of the main object manipulated by the action. (2) A *Transformed trace model* is a more abstract trace model, and includes some semantics of the pedagogical activity. In this case, a trace model is an ontology describing the traced activity. The next section gives an example of a transformed *trace model*.

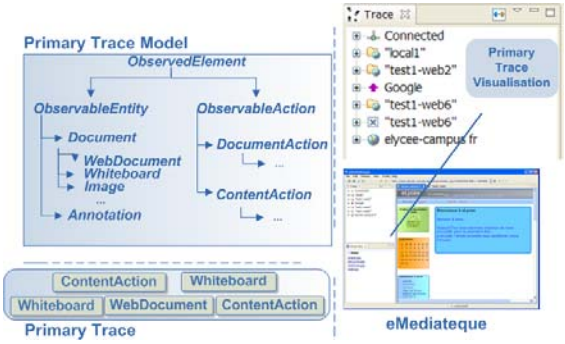

Figure 3: Primary Trace: model and visualisation

4.2 Transformation of the primary trace

To prove the robustness of TBS approach, we did experiment the concept of traces transformation in the context of a simple example of a pedagogical activity on eMediatheque. The experimented activity is a "*cartoon translation*" where learners are organized in groups of two students. In each group, learners collaborate to translate a cartoon from English to French. They write the translation they propose in a shared document (a whiteboard) and can communicate through a chat to articulate the activity and negotiate the translation.

Figure 4 gives the corresponding trace model of this activity. This trace model asserts that only four types of actions (and similarly five types of entities) are significant in the context of this activity: to read a resource, to send a message via the chat, to edit a text inside a balloon and to search a word in a dictionary.

To get a trace following this model, transformation rules have to be applied to the primary trace. These rules are designed by an "activity designer" who has the required skills for modelling the pedagogical activity, implementing the specialized trace model of that activity and the transformation rules into the TBS part of eMediatheque. These tasks are done offline as a preparation of the learning sessions; once the session is launched, the transformation rules are fixed and automatically applied. At runtime, when a new action appears in the primary trace, it is matched and detected by the transformation rule, which refreshes the specialized trace. For instance, the

7 Obviously, being too verbose and technical, this visualisation is not meant to be presented to learners. However, it gives a good overview of the kind of information found in the primary trace.

transformation rules will transform all objects of type image containing the original cartoon will be transformed into an entity of type *Cartoon*. Every *DocumentAction* involving an entity *Whiteboard* produce a *WriteAction* in transformed trace, etc.

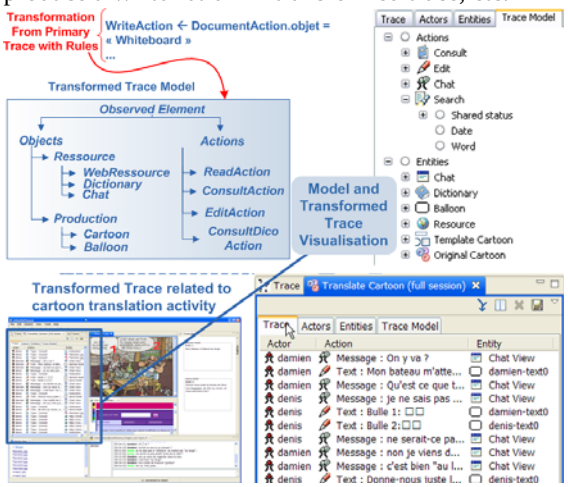

Figure 4: Transformed Trace related to cartoon translation activity: model and visualisation

The interactive trace visualisation in eMediatheque involves two transformations. The former (performed by activity designer) is to transform the primary trace into a specialized trace that makes sense to the learner in the context of his pedagogical activity (cartoon translation). The second is done by the learner him/herself, and consists in interactively transforming the specialized trace (i.e. filtering rules, rewriting rules, merging rules, etc.). Each of the above transformations is described in a TBS language. The presentation interface recalculates the trace viewed by the learner whenever a change to the *learner's transformation* is performed, or whenever the specialized trace is modified by former transformations. The presented trace is very volatile; it is a personalized graphical transcription of the specialized trace, transformed by the system and/or learner.

4. Conclusion

In this paper, we have presented the notion of Trace-Based System as core module for TEL systems. We have described a TBS architecture and the associated concepts of modelled traces and transformations as means for representing, abstracting and processing traces for personalisation purposes. To validate and demonstrate this approach, we have presented an implementation of a collaborative platform (eMediateque) equiped with a TBS. We have experimented this platform in the context of cartoon translation activity by providing to learners a personalized and interactive real-time visualization of their traces.

TBS can be exploited in the context of several others activities. Actually, our approach is developed and experimented in several contexts: TBS-based learner modelling for the ITS Ambre-Add; TBS-based indicators reusable calculus for Moodle. Of course, the presentation of TBS and its exemplification in such a narrow format implies inevitably reductive simplifications. The example synthesised here involves actually more complex trace-models and transformations.

5. References

[1] TRAILS, *Personalised and collaborative trails of digital and non-digital learning objects*, http:// www.dcs.bbk.ac.uk/trails/index.html, 2004.

[2] ICALT, *Interaction & collaboration analysis' supporting teachers & students' selfregulation*, http://www.rhodes.aegean.gr/ltee/kaleidoscope, 2004

[3] IA, *Interaction analysis supporting teachers and students self-regulation*, 2005.

[4] DPULS, *Design patterns for recording and analysing usage of learning systems*, at http://www.noe-kaleidoscope.org, 2005.

[5] Choquet C. and Iksal S. *Modeling tracks for the model driven reengineering of a tel system*, Journal of Interactive earning Research, vol. 18, no. 2, pp. 161–184, 2007.

[6] Harrer A., Bollen L. and Hoppe U. *Processing and transforming collaborative learning protocols for learner's reflection and tutor's evaluation*, in European Conference on Articificial Intelligence ECAI 2004,.

[7] Brusilovsky P., Peylo C. *Adaptive and intelligent web-based educational systems*, IJAIED, pp. 156–169, 2003.

[8] Brusilovsky P., Kobsa A., and Nejdl W. *The Adaptive Web, Methods and Strategies of Web Personalization*, vol. 4321, Lecture Notes in Computer Science. Springer, 2007.

[9] France L., Heraud J-M., Marty J-C., Carron T., and Heili J., *Monitoring virtual classroom: Visualization techniques to observe student activities in an e-learning system*, in ICALT. pp. 716–720, 2006.

[10] Soller A., Martinez A., Jermann P., and Muhlenbrock M. *From mirroring to guiding: A review of state of the art technology for supporting collaborative learning*, IJAIED , vol. 15 (4), pp. 261–290, 2005.

[11] GaBner K., Jansen M., Harrer A., Herrmann K., and Hoppe U. *Analysis methods for collaborative models and activities*, International Conference on Computer Supported Collaborative Learning , 2003.

[12] Avouris N., Komis V., Fiotakis G., Margaritis M. and Voyiatzaki E. *Logging of fingertip actions is not enough for analysis of learning activities, AIED. 2005.*