Learner engagement analysis: a multi-scale visualization of heterogeneous traces

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Abstract - Many researches in the field of learning analytics provides statistical indicators such as the duration or the number of actions carried out on the tools or the resources used. These indicators generally support the monitoring and reflexivity of the learner's activities by returning information on the use of each tool and resource. But e-learning contexts are becoming increasingly complex, allowing the use of varied resources. In these new contexts, the activity of the learner becomes "heterogeneous" (with several tools and types of documents), and "discrete" (interrupted by the actions on each tool or document). Thus, statistical indicator surveys are no longer sufficient to understand the learner's activity and more particularly his involvement in the activity and the regulatory practices that have been put in place. Our research aims to provide teachers, learners and designers with visualizations of heterogeneous traces of learners with particular attention to their commitment and adaptation practices. These visualizations seek to promote the interpretation of these behaviors through analysis at several temporal and group's levels (learner, class, institution).

Keywords-component; Learning Analytics; Visual Analytics, commitment; adaptation; visualisation; multi-scale; heterogeneous traces

Introduction

The involvement of learners in an on-line training system is an issue that grows more important ad complex as much as their involvement with the on-line tools becomes larger, especially through the creation of Massive Open Online Course MOOC. However, today few tools allow the observation and analysis of this type of involvement in usable ecological conditions [3]. Likewise, learners are faced with many resources and have to develop their own autonomy. One way to help them is to allow them to observe the adaptation practices of their own activities that they have set up [7]. In order to support the commitment and the adaptation of learners in this context, our focus is on the visual representation of the heterogeneous activities of learners from their heterogeneous traces of interaction with an online learning environment. We call an activity that is carried out using several computer tools, and through different documents and which is made up of various tasks distributed over time a "heterogeneous activity". The heterogeneous traces then correspond to traces coming from the learner's actions using these various tools and documents, as that is the case on any MOOC environment. Our goal is to allow the teacher to follow all the learners' activities (individual, and class) and then to allow the learner to have a thoughtful approach to his own practices. Our particular interest is to support the understanding of learners' behavior, reflecting their commitment to the learning activity and the adaptation practices put in place. We consider that the visualization of the traces of the learners, both multi-scale (at several levels of analysis) and focused on the continuity of the activity (according to the multiple tools) is important to enable the interpretation of their commitment and adaptation practices. The first part of this paper presents the pedagogical context, the problem and the objective of our research. We present in the second part a bibliographical study of the researches related to our problem and in the third part the foundations of our proposal. The styles

Most of the styles are intuitive. However, we invite you to read carefully the brief description below.

I. Context and Research Problem

1.1 The Meta- Education project

My research work is carried out within the framework of the LMS for Jazan University , JUMP (Jazan University Multi-Platforms) project, financed by the Jazan University. The objective of the project is to develop an integrated platform of resources and services, enabling teachers and students to gain access to open and closed source resources in a single space, provide their own contents, and to have innovative services (e.g. interactive videos, "social" annotations, sharing by level group). Within this project, we aim, according to an iterative and participative approach, to observe the uses of the tools proposed according to complex educational scenarios (i.e. using innovative tools with a bank of multimedia resources), in order to improve these tools and incite new uses. As previously mentioned, the visualizations process will not only be addressed to the teacher and the learner, but also to the designer, the platform targeted by JUMP will allow the integration of the following digital tools:

- Tool #1 which will allow the linkage of media and heterogeneous contents in order to diffuse them in the form of educational paths.
- Tool #2 which will enable several users to modify the same document simultaneously, and which could also create a certain dynamic productive work, and allow the creation of mental maps of the internet resources used.
- Tool #3 which will allow the enrichment of videos with multimedia contents (text, image, audio, video, links) and then publish them in an editorial environment.

The data collected on the various tools will have to be integrated and accessed via APIs for processing and obtaining the desired visualizations. A first diagram of the data flow architecture from the traces of the learner is shown in Fig. 1.

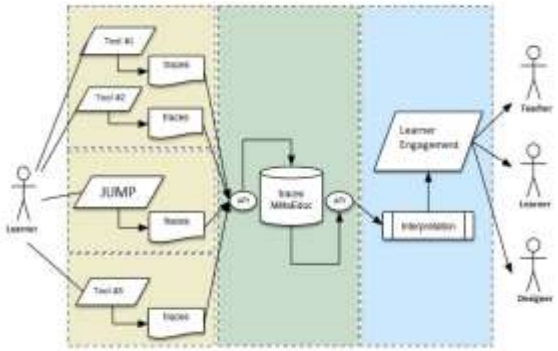

Fig. 1: MetaEducation Data Flow

All these tools share the same available resources library or created by the teachers themselves. These resources can be videos, annotated video segments, mental maps, images or educational paths. It should be pointed out that learners can create resources in the context of educational activities, but these will not be indexed in the resource bank, unless the teacher voluntarily decides it.

II. Research Proplem

The following example describes a heterogeneous activity: an educator asks his / her students to realize a duty to learn a foreign language. The assignment is to complete the transcription of a videotape of a film in English. For this purpose, the student has the tools and documents available on the JUMP system. It has a tool that allows him / her to read and make annotations on videos, a dictionary, and a text editor. It also has the video snippet subtitled with blank spaces for some words in the character dialogs, and a text document that contains the transcription of the subtitles with the same empty spaces as in the video. The student can use the "annotation" functionality of the video tool provided to place references or report any deficiencies encountered on the video. The purpose of the activity is to make a text containing the complete transcript of the video clip

We consider three observers of the learner's activities: the teacher, the tool designer, and the learner himself. Each one of them has his special needs. The teacher needs to follow the activity of the learner. The follow-up allows him, among other things, to evaluate it, to discover the activities carried out in order to try to understand its rendering, to prepare interventions and to improve its pedagogic approach. In the case of the activity's transcription previously presented, the teacher may be interested in identifying the resources used by his or her class, also at which order of use by a particular student in order to understand his / her good or bad results and his or her commitment (vs. indifference) to the learning activity. For example, the teacher may want to answer questions such as: Did the student use the online dictionary?

In what order and possibly at which part did he use the resources? Has he read the text provided first to make an idea of his subject? Did he see the entire video excerpt before beginning to fill in the spaces of the text? Did he put benchmarks on the video via the annotations and for what purpose (i.e. note-taking or thinking)? How did the use of annotations evolve during different transcription activities?

The learner as the author of the analyzed activity can benefit from visual representations of his / her activity in order to engage in a thinking approach. He needs to think about his learning process, to be aware of his progress and his level of commitment. Learners might want to compare themselves to their colleagues, or think about their activities to explore other strategies and possibly apply them. He might ask the following questions: who has had the best results in the class? How did he get it? What was his approach, his strategy? What steps have been taken to complete the transcript of the video clip? How did they use the annotations for this? The designer also needs to understand the learners' activity. They need to support activities by identifying the difficulties they are facing or why they take place, in order to evaluate their tools and to determine the links and possible levels of integration of the various tools. Thus the designer can be interested in several levels of analysis in the visualizations process. In a complete activity scenario, the designer can, for example, identify whether the dictionary resource or "annotation" functionality of the video tool has been used by the class as expected. He might also be interested about who of the students have not used it to due to possible deficiencies or resource problems (access, response time, ergonomics, lack of functionality, lack of integration of functionality among themselves, etc.) with a view to proposing improvements. The designer may also be interested in visualizations of resources or functionalities used by countries, regions, departments, communities or institutions to evolve their tools, Isolated statistical metrics such as the number of visits to the dictionary or the time spent on video may represent the rate of usage of these two resources but are not representations of the activity of learners and cannot be allowed to be interpreted as engaged behaviors (or not) in the context of these activities. Statistical assessments cannot explain why learners did certain actions, why they stayed a specific time on a resource, or why they did have some results. We believe that an approach based on multi-scale visualizations in relation to different types of analysis, constructed from traces of usage of different tools, presents an alternative to help teachers, learners and designers to answer the questions raised above.

III. Research's Objectives

Our objective is to propose visual representations to analyze the learner's commitment and adaptation practices. Such visualizations constructed from the heterogeneous traces of the learner will be multi-scale and will allow the interpretation of the learning activity in its continuity through the usage of several tools and over time (several days, weeks or months). For this purpose, we will try to answer the following questions:

1. How to identify engagement in a distributed collective context from the traces of the learners' heterogeneous activities?
2. How to present these heterogeneous traces in such a way that the activity is considered continuous, at different temporal and group levels, in order to translate the commitment of learners?

A. *State of Art*

In the following section we present work on the notion of trace as a support tool for interpretation, as well as the actors targeted in the work of representing traces of e-learning. The second part presents the work of traces visualization in the world of distant learning.

B. *Traces analysis and targeted actors*

The actions of the learners on the Meta-Education tools will provide heterogeneous traces of the pedagogical activities. Ginzburg in his "Index Paradigm" [9] establishes a close relationship between traces and clues. For him, traces become clues when the observer seeks to reconstruct the actions that have occasioned such traces. Ginzburg points out that the reconstruction of actions from traces dates back to the time when man was a hunter. Man has learned to "decipher" footprints of animals, broken branches, plucked feathers, and so on. These traces constitute indices of the actions carried out by the animals, and the reconstruction of these actions (generating traces) corresponds to the interpretation of the traces (generated). Ginzburg presents the index paradigm as a method that has already been applied to solve problems arising from science in relation to human beings (including medicine), in which characteristics of each case are peculiar. For example, the diagnosis of a disease on the basis of the physician's observation of the symptoms, the assignment of a painting to his real author from the observation of brush strokes by the connoisseur of works of art, the discovery of the assailant from the observation of the traces left in the scene of the crime by the detective. These problems can only be addressed by methods of the same type: "qualitative".

Two aspects can be chosen from this paradigm: the interpretation by the reconstruction of the actions realized, and the qualitative nature of the indices (traces) for the reconstruction of the activity. Our proposal aims at defining "qualitative indices" from heterogeneous traces to construct visual representations of all the learner's actions that are consistent with his / her activity.

The work of J. Laflaquiere [5] classifies tracing systems them into two categories: systems to support user activity, and systems to redesign computer tools. Approaches derived

from the work of learning analytics mainly support the activities of learners and teachers. Verbert et al. [14] present a comparative study of fifteen learning dashboards for these two types of users. Few studies consider other users who may be interested in trace analysis, and none of them offer visualizations for our three target users (learners, teachers and designers. For example, Fortenbacher et al. [4] present LEMO, an interactive visualization application of traces for teachers. The evolutions envisaged for the application are intended to provide visualizations for the designers, but these visualizations are not adapted to the learners. The Data Wranglers project [3] seeks to provide tracing visualizations of students to the institute's decision-makers so that they have richer information for structuring learning programs for learners. This approach does not take into account the needs of learners or teachers.

C. Traces visualization

Santos et al. [12] showed indicators computed from the time spent on each application, document and Web site, in the form of stick diagrams, motion charts, tables and timelines. Leony et al. [10] proposed GLASS, a platform that records traces of heterogeneous learners according to the Contextualized Attention Metadata (CAM) scheme [15], which are modules that contain scripts and presentation filters that allow the visualization of several statistical indicators in a dashboard. These indicators include the number of shares per day and number of shares by type. Both approaches offer statistical indicators visualizations defined from the learner's actions traces per tool used. These visual representations are not sufficient to give an overall picture of the learners' heterogeneous activity and moreover it complicates the interpretation of their behaviors, including their levels of commitment. Visualization techniques should be explored to provide "talking" representations for learners, teachers and designers. The analysis levels correspond to multi-scale visualizations. The types of analysis can be: statistical, thematic, temporal, geo-spatial and network [1]. Combinations of levels of analysis and types of analysis in visualizations can meet the particular needs of each user. We were inspired by the work of Loboda et al. [11] introduced in "Mastery Grids" which is an example of visualizations at several levels of analysis. These three-dimensional grids presented:

- the themes of the course (vertical dimension),
- the resources of the course (horizontal dimension),
- and the level of fulfillment of the tasks related to the resources available by topic which is defined by the intensity of the color of the cell).

The visualizations make it possible to go, for example, from a level which presents the completion of the tasks linked to a resource by the course's topic, to a more detailed level where the tasks related to the same resource per sub-theme of the same theme have been previously provided. Interactive visualizations can enhance the interpretation of the activity provided. The principle proposed by Shneiderman [13], "overview first, zoom and filter, then details on demand" seems to be widely applied in interactive visualizations in the learning context. For example, tool tips are used when the user overcomes the learning objects (nodes) of the graph that represent the activity of the learner [4]. The dashboard Student Activity Meter (SAM) [7] implements the zooming [5]. In SAM, the user can view part of the line graph in another window of the dashboard. In the line graph, each line represents a learner's time at the activity. A large number of learners markedly affect the readability of the graph. The examples of techniques mentioned seem to seek to solve the problems of legibility rather than to propose multi-scale visualizations

We want to propose this type of visualization, which emphasizes the representation of the temporal dimension of the learner's actions in order to support the analysis of the activity at several levels of finesse adapted to the needs of the users (i.e. learner, class, institution).

IV. PROPOSED APPROACH

Our work seeks to propose multi-scale visualizations generated from an architecture integrating heterogeneous traces. Its foundations and the method of validation envisioned are set out below. Different levels of visualization analysis are defined mainly by three criteria:

1. The use and nature of the tools,
2. The representation of the temporal dimension,
3. The subject of study (learner, class or institution).

The learners' use of tools in the activity and their nature determine the heterogeneity of the traces. The number of tools used determines whether the data trace is mono or multi-source. The nature of the tools is related to the types of resources being manipulated and to the possible actions that can be carried out by the learners. For example, a video player will allow you to perform actions on videos such as playing, stopping, flipping subtitles, increasing the volume, and so on. On the other hand, the temporal dimension can be represented from several units of time and using existing visualization techniques. The visualizations can represent the activity by sessions, days, weeks, months, etc. as required. These different levels in the representation of the traces will permit more or less fine analyzes. Temporality can also be represented by the traces of a learner or a group of learners still using the notion of "multi-scale" for the observers' benefit. We envision an incremental validation of the proposed visualizations. In a first step, the global process of collecting, storing, processing and visualizing traces will be carried out to observe the behaviors initiated and the regulation practices of the learners for a tool which

do not have it so far. We will then collect the traces of the construction activity of the educational paths by the learners themselves. The visualizations will be constructed in a participatory way with the teachers in order to identify the elements extracted from the traces making sense for them in terms of observation of the adaptation practices and the commitment of the learners. The tracing process and visualizations proposed for the first tool will then be applied to a second tool (construction of mental maps) in order to test its generalization. We will do the same with the third tool (video annotation) included in the ENT as part of Meta Education. We thus will have a variety of tools which will allow us to validate our proposal on different cases of application, using different types of resources (images, mental maps, translated videos, educational paths). Our ultimate objective is to validate our trace-processing architecture and the proposed generic visualizations in order to observe the commitment and the adaptation practices.

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