# EVALUATION OF USER PRACTICES DURING COLLABORATIVE PROCESSES THROUGH PROPOSED HISTORICAL PROJECTION

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**ABSTRACT**

*The paper focuses on the domain of user behaviour evaluation in the collaborative processes performed in a virtual user environment. Proposed historical projection of activities performed in such an environment provides several analytic perspectives materialised in form of different tools, but all of them are based on suitable visualization and extraction techniques. The differences are based on different analytical tasks to be supported by particular analytic tools. We will describe two of these analytic tools, but only one in more details because of our direct involvement in the design and implementation of this tool as project partner in the IST European project called KP-Lab. The main technological output of this project is represented by KP-Lab System as an original platform for support of collaborative working and learning practices based on knowledge creation metaphor. The first analytic approach is based on interactive visualisation of available historical data based on user requirements in simple and user friendly graphical formats as graphs or charts. The second analytic approach provides historical retrospective of performed collaborative processes based on timeline form visualisation of performed events with different selection a patterns' search capabilities. These two approaches can be used instead of often used manual methods of user behaviour evaluation e.g. in a learning course. Manual evaluation is much more time consuming and tedious for teachers or researchers from several reasons: necessary collection of all materials from students, laborious analysis of their communication channels etc.; e.g. in this case it is difficult to identify the real involvement of each student. Suitable visualisation of automatically collected data with the possibility to define constraints based on users'needs provides easier approach, mainly in the case of large students' groups. In our paper we will describe our motivation, related works, briefly the first analytical approach and the second one in more details as an important output of our research group.*

***Keywords:*** *processes, quantitative characteristics, timeline, patterns*

## 1. INTRODUCTION

Technology-Enhanced Learning (TEL) refers to the support of any learning activity through suitable technological solutions. Typical learning activity can be described by several key aspects as learning resources (creation, sharing, distribution and editing of digital content), actions (communication, collaboration, interaction with environment), context (time, duration, surrounding people and location), roles (various type as teacher, student, facilitator, etc.) and objectives (learning goals, individual or group). Each learning activity can be understood as composition of all these aspects and it is interesting to analyse how it works.

This is the main motivation behind our proposed analytical approach based on data automatically collected from a virtual learning or working environment. Obtained information can be used for further improvement of user practices in order to achieve more effective realization of performed processes.

Typical example of mentioned collaborative process is preparation and publishing of a group deliverable. In this case, virtual environment is needed in order to provide space for sharing, communication and collaborative relations. Advanced systems provide in addition also some other features such as commenting, displaying of paper versions and direct collaborative editing. The whole evolution process starts with creation of initial draft with definition of responsible persons. This blueprint is used for initial tasks proposal and division of labor. Each user gets its own task with defined deadlines and instructions for publishing of partial versions. These publishing procedures generate relations between users based on their roles, knowledge or theoretical background. The whole process finishes with publishing of final version. It is sometimes important and useful to evaluate used practices and users' involvement. This evaluation is in our case based on the ability to trace performed steps and visualize them through timeline in order to provide historical overview in chronological order. The created timeline displays the whole progress and relations between related events, objects and users. Important part of historical projection is patterns discovery, because they can result in some critical points, positive or negative, in investigated processes.

The whole analytical process consists of several phases as acquisition of necessary data in suitable format, application of relevant analytical services based on user expectations or requirements, presentation of obtained results in understandable way. This process is tightly connected with investigated virtual environment through necessary two-way communication links with presentation layer in order to obtain necessary information representing performed events, specification of user queries and visualization of obtained results within selected display format. Effective communication in this case is important condition for consistency of event repository.

Our paper consists of several main chapters as introduction with simple description of our motivation and proposed solution; the second chapter presents several related works that inspired our approach and have some similar characteristics; the next chapter deals with detailed information of proposed analytical services with some graphical examples. The paper closes with a short summary in last section.

## 2. RELATED WORK

When looking on the TEL domain we found several European projects that deal with various kinds of evaluation and analytic approaches, e.g.:

- The aim of the Argunaut[1] project was to develop tools that assist tutors in visualising e-discussions as an aid for their moderating tasks ('awareness tools'). Human facilitators are still needed in the discussion, but the support of an advanced artificial intelligence based system enables them to concentrate on tasks that require their unique human capabilities.
- The Palette[2] consortium intended to provide innovative learning models and technical solutions that increase the overall quality of learning in communities of practice and contribute to the development of standards in the domain.
- Kaleidoscope[3] was funded as a Network of Excellence with sharing of knowledge and tools, developing agreed vocabularies, a common theoretical framework and methodologies and identifying important research issues. Other issues were training of researchers, and exploring innovation and commercialisation of research. [7]
- KP-Lab[4] project aims at developing theories, tools, and practical models that enhance deliberate advancement and creation of knowledge as well as transformation of knowledge practices. Outcome of this project will be a collaborative environment that facilitates sustained working for creating and advancing knowledge, jointly reflecting on it, and making knowledge practices visible.

Besides these large project initiatives several other interesting approaches can be identified with similar orientation (see below). Each of them has his advantages and disadvantages based on used format of input data, integration and interaction with investigated environment, method of outputs visualization, etc.

Data mining and its methods is one of the typical representatives for analyses of historical data. In this case, some suitable methods can be identified as association rules, clustering and sequence mining. If we apply typical data mining methods within concrete conditions and adapt to them, we will derive other interesting approaches as educational data mining and process mining.

Educational data mining represents extension of classical data mining that is concerned with the exploitation of data from educational systems or environments [3]. Application of existing data mining algorithms in these settings is often insufficient by reason of temporal, noisy, correlated, incomplete, and sometimes small size of the available dataset [4], [5]. These problems are motivating factors for further involvement of used methods to get their more effective realization.

Process mining provides functionalities for extraction of potentially useful information (actual process model, comparison between planned and actual process model, identification of deviations in process structure, performance statistics, time overview, social network analyses) from event logs, mainly representing business processes modeled as workflows. The main representative of this approach is ProM framework [1], [2], that receives inputs in the Mining XML format (MXML). Currently, this framework has many plug-ins for process mining, analysis, monitoring and conversion of obtained data from examined virtual environment to MXML. We provided several experiments with our data in this application, but we identified several problems that must be solved for the effective usage of ProM with this type of data.

An interesting approach to analyze interactive activities in collaborative virtual environments is represented by a method based on Social Network Analyses methodology [6]. The obtained logs describe events in a web-based system oriented toward collaborative processes with shared documents. It is possible to identify social structures, knowledge building processes and interesting relations or interactions.

Hardless and Nulden proposed the Activity Visualization (AV) as technical supporting functionality for understanding of learning processes in virtual environment. AV uses information from the environment to visualize aspects of the whole learning process, in order to give users the opportunity to view activities, progress, and usage patterns from various perspectives [10], e.g. analysis of message lengths to reveal usage patterns and relationships, message counts in relation to time, usage patterns showing complete overview of when, where, and how to give a feel for what's happened, possibility to give individual feedback as opposed to public messages, and mood indicators to improve understanding of context.

A similar approach is described in [9] that presents a constraint-based analytical approach for pattern discovery, i.e. defining filters during the pre-processing phase that reduces the search space; constraints during the mining phase (used methods as association rule mining, sequential pattern analysis, clustering and classification) in order to accelerate and control pattern discovering; defined constraints in the evaluation phase make obtained patterns user friendly and simpler evaluated. The results are visualized through intuitive graphic charts and tables in order to make discovered patterns easy to interpret.

The idea to visualize logged events through a timeline appears in a couple of systems, from which we selected here the most relevant ones. Semantic Spiral Timelines is an interactive visual tool aimed at the exploration and analysis of information stored in collaborative learning environments [8]. It provides an interesting way of presenting the events in the form of spiral timeline that contains sequences of color-coded events. These are ordered clockwise with the oldest data at the centre of the spiral and the outermost data depicting the most recent event. The actual form of visualization can be changed with various filters such as orientation of individual person, selected type of actions, selected time interval, etc.

[1] http://www.argunaut.org/
[2] http://palette.ercim.org/
[3] http://www.noe-kaleidoscope.org/telearc/
[4] http://www.kp-lab.org/

The patterns are understood here as typical histograms of frequencies of various types of events in time.

The presented list of related works represents various approaches for evaluation of learning activities based on obtained data from examined virtual environment. The common denominator in most cases is automatic character of analytical approach, but users need sometimes possibilities to manually identify interesting sequences of actions, not only based on output from algorithms, but as a result of their own understanding. This was one of the motivating factors for our solution.

The others were needs for generic logging mechanism independent from the type of virtual environment; integration on middleware layer by reason of bilateral communication with presentation layer and repositories; various visualization methods. The whole design process started with detailed state-of-the-art in relevant domains and identification of user requirements. Combination of these two inputs resulted in initial proposal for implementation phase. This phase resulted in the first prototype that was used for testing and identification of necessary modifications and improvements. The next prototype was used for experiments with recorded data from real courses realized within KP-Lab System. At the moment implementation phase is finishing in order to provide stable solution with all planned functionalities.

## 3. HISTORICAL PROJECTION

Historical projection in this case covers a set of services for logging, manipulation with data, extraction and visualization. Extracted and visualized information represent complex view of user behaviour during collaborative processes, e.g. timeline-based visualization, quantitative statistics, level of collaboration, tacit relations, patterns, etc. All these approaches are depending on collected historical data that are described in next two chapters.

### 3.1. Data and acquisition

Proposed logging mechanism (logging services and log repository) was designed as a generic solution with the aim of integration with various systems. This integration has to be realized with respect to required conditions as integration of logging services on the user interface level, possibly in more parallel systems, communication with existing repositories, integration of visualization services, etc.

Historical data in this case are represented by performed user actions in virtual environment, we call them events. The events are recorded on the presentation layer and stored into separate repository called log repository (see Fig. 1).

The log repository is implemented within MySQL relational database in order to provide scalable and responsive solution. This repository has its own log format of logs that will be described in next section. Fig. 1 provides a schematic look on the common approach of integration that was tested with selected environments as Moodle, KP-Lab System and Claroline [11].

The experiments realized within Moodle cover design and implementation of a new web service responsible for

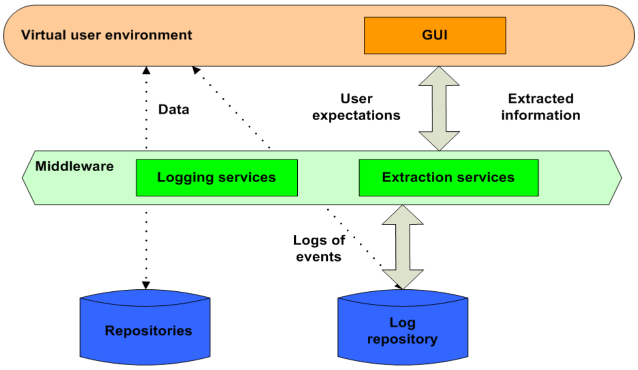


**Fig. 1** Integration procedure of logging services

cooperation with internal Moodle logging system. This communication link transfers the data from Moodle internal repository within defined log format. In the case of KP-Lab System, logging procedure was integrated on the middleware layer to obtain data from user environment in cooperation with monitoring services on this level. Integration with Claroline system dealt with updates and changes in internal Claroline logging API. This approach was not successful because of low support for possible extensions of this API, insufficient documentation of the whole system and necessary changes in the source code. We plan continuation of similar experiments in order to collect data from other systems for analytical purposes.

### 3.2. Data format

Proposed log format represents complex but generic structure that is simply extendable based on investigated collaborative system. It is possible to add new parameters or eliminate existing ones. Actual version consists of 12 parameters that characterize each of the logged events:

*[ID, Type, Actor, Actor Type, Actor Name, Entity, Entity Type, Entity Title, Belongs to, Time, Custom properties, Custom data]*

- *ID* – unique identifier of the log entry;
- *Type* – a type of the performed action, e.g. creation, modification, deletion, etc;
- *Actor* – unique identifier of the actor who performed given event;
- *Actor Type* – user role that is delegated based on relevant part of the user environment;
- *Actor Name* – user name obtained from the user management module based on its system logging information;
- *Entity* – unique identifier of the shared object that motivated given event;
- *Entity Type* – type of the shared object, e.g. task, document, link, wiki page;
- *Entity Title* – concrete title of related shared object
- *Belongs to* – unique identifier of relevant part of the user environment where this event was performed;
- *Time* – time when the event was logged into database (represented in the following format: year-month-day HH:MM:SS);

- *Custom data and properties* – these parameters are used in situation when end-user application will store some properties or data that are typical for it.

In the case of KP-Lab System we have collected more than 15 thousand of logs at the moment and this value increases each day. Example of stored logs is displayed on Fig. 2 as screenshot of the designed and implemented web interface for direct browsing of log repository.

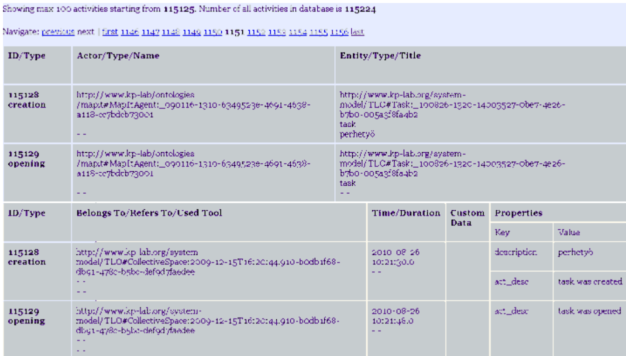


**Fig. 2** Example of event logs

## 3.3. Quantitative statistics

Quantitative statistics cover the summarized information about performed actions in analyzed processes or their parts in a tool called Visual analyzer [14]. In our case summarized information represents various aggregations of available data, e.g. number of participants involved and number of actions performed by each of them; number of shared objects used / changes made / versions produced; number of annotations defined / assigned / changed; number of comments added; number of to-do items created / fulfilled or not fulfilled; number of chats, meetings, links, etc. in given time interval, within given group or with other constraints posed by the user in the analysis phase.

These statistics represent outputs on user expectations or requirements that can be defined through simple user interface. This definition is transformed into query similar to SQL request and executed on historical data. Outputs of realized query are visualized in form of a chart or a graph. In the main cases these graphs display individual or group contributions, distribution of various actions in selected time interval, user orientation of related actions and many other combinations. Presented GUI (see Fig. 3) was designed and implemented in University Paris Sued (other KP-Lab project partner, see. e.g. [14]).

User interface visualizes data from extraction services that are implemented as middleware component. Similar services are used for timeline-based visualization too. Visual analyzer usually calls the following aggregation middleware service:

String *activityAggregation* (Query *query*,
List<AggregationFunction> *aggregationFunctions*,
Set<GroupBy> *groupBy*)

- *Query* as parameter describes constraints which will be used for filtering of the actions included in the aggregated view. Query object encapsulates the following constraints already specified for log repository: *Type, Entity, Actor, timeRange, Belongs To*; and two additional constraints for more specific description, as *filter* - set of key value pairs which will be compared with events custom properties, *excludeFilter* - true or false, whether include or not events which do not have properties from the filter present in them.
- *AggregationFunctions* specify the list of aggregation functions included in the view computed from the set of selected events as *NumOfActivities*; *NumOfActors*, *NumOfEntities*, *TimeSpan* - starting and ending date of investigated time period.
- *GroupBy* specify clause for the grouping of the result. It is possible to specify the following values: *Actor*, *Entity* and *Type*.

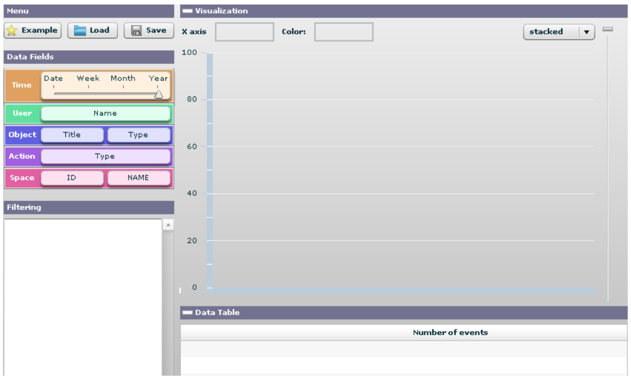


**Fig. 3** User interface for query definition and outputs visualization

Example of a result of the following call of the service described above: is showed on Fig. 4
GroupBy (Actor Name, Type), Query(timeRange (09-2009,01-2010)), aggregationFunctions = NumOfEvents

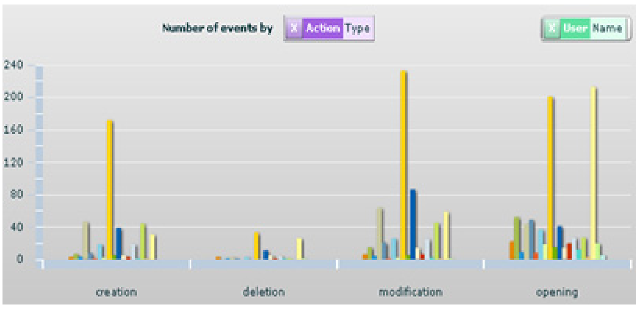


**Fig. 4** Types of action per user

## 3.4. Timeline-based visualization

Timeline-based visualization contains features and methods to display the whole process or a particular part of it with relevant interactions and relations (e.g. with respect to some group, some shared objects within particular time-frame). This approach produces a complex view of performed events and gives the possibility to focus on potentially interesting facts. This complex view provides another, completely different way to monitor ongoing processes and learn from past instances. This is also one way to reflect on the existing practices and following their transformation into innovative ones.

The main functionalities provided in the timeline-based visualization are the following.

- Sequences of performed events in chronological order are visualized via defined (one or more parallel) time-line(s), see Fig. 5.
- Visualization of all interactions and relations between selected relevant elements based on user requirements.
- Possibility to filter the list of properties shown in the timeline based on users requirements.
- The users are able to comment elements visualized on the timeline.
- Basic time-line visualization consists of automatically-collected events that are performed in monitored collaborative systems. In some situations, it is necessary to include elements called external events (performed outside monitored system) that are relevant to analyzed process and this operation is performed manually by the user. This functionality is also supported in our approach.

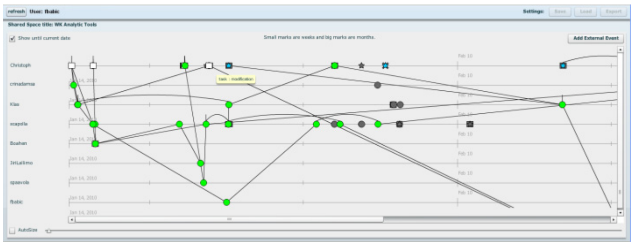

**Fig. 5** Timeline for selected group of users

A strong point of the proposed solution is the possibility to identify subsets of activities that may have crucial importance. This identification is performed by user, because only users have knowledge about advantages or disadvantages of selected approach to solve given problem or reach the given goals. These subsets of events could be marked as critical (or working) patterns.

### 3.5. Patterns

The patterns usually lead to some critical moments, which can mean, for example, a significant progress, discovery of new knowledge/approach, or on the other hand they may indicate non-success of a particular process or its early finish. Such kind of patterns may also conceptually represent interesting practices emerged within particular process or activity – either being positive (something like best practice), or negative (worst practices). The main issue in this case is the representation of the patterns and their identification.

Manual selection of interesting patterns is based on historical overview within timeline that provides possibility to construct pattern based on user requirements.

Pattern is represented as a sequence of pattern elements, where each pattern element represents one generalized event. In the pattern element, which is essentially a list of key-value pairs, user specifies which

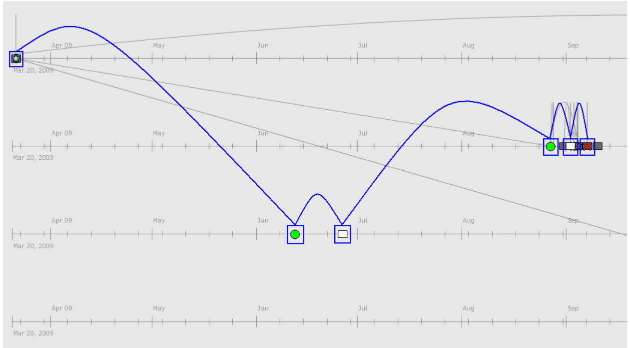

**Fig. 6** Example of pattern definition

parts of the generalized event are important and which should be generalized. User can specify the element based on any of the event's properties, including custom ones. Example of a pattern element specifying opening action performed by particular user on a particular Note object:

"Actor" = "http://...#MapItAgent:_080315-b5865f",
"Entity Type" = "shared space",
"Type" = "opening",
"toEntity" = "http://...#Note:_1007191650d".

Pattern service will find all matches of the given pattern within the specified time range, and within the specified shared space, if given. The service returns list of matches, each represented as an array of events, comprising the given pattern.

Current version of pattern discovery service is implemented in the emerging lisp language called Clojure[5]. In Clojure, collections are generalized into the sequences, for which most of the operations provide lazy evaluation. The lazy evaluation, easily achieved in Clojure, realizes only those parts of the result tree, which are actually used. This subsequently lessens the number of queries sent to the MySQL database, dramatically speeding up the whole matching process, if the user is interested only in small number of results.

Full source code for the pattern discovery service can be found at [12].

## 4. KP-LAB SYSTEM

The KP-Lab System represents the main technological output of the KP-Lab project. KP-Lab is an ambitious project that focuses on developing a theory, appropriate knowledge practices and collaborative learning system aimed at facilitating innovative practices of sharing, creating and working with knowledge in education and workplaces.

Theoretical foundation of this project is trialogical learning approach. Trialogical learning [13] refers to the process where learners are collaboratively developing shared objects of activity (such as conceptual artefacts, practices, or products) in a systematic fashion. It concentrates on the interaction through these common objects (or artefacts) of activity, not just among people (as it is in dialogical learning) or within one's mind (as it is in monological learning).

[5] http://clojure.blip.tv/file/982823/

The first four years (2006-2009) of this 5 years long integrated EU funded project were devoted to the research and implementation of tools, practices and theories. Existing and/or newly developed tools were designed and tested against user requirements in real cases within various pilot cases (in e.g. Finland, Netherlands, Israel, or Hungary). This last year is devoted mainly to finish the implementation, longitudinal experiments, dissemination and exploitation activities.

The KP-Lab technology builds on emerging technologies, such as semantic web and web2.0, web services and service-oriented architecture in general, real-time multimedia communication and ubiquitous access using wireless and mobile devices.

The KP-Lab System provides a virtual user environment (KP-environment) with access to all integrated tools and functionalities. These end-user applications are built on concepts underlying the learning approach, such as collaboration, shared objects, boundary crossing, etc. KP-environment has been implemented as a web-based environment with Flash technology in order to provide a flexible and interactive solution (see Fig. 7).


**Fig. 7** KP-environment

Proposed features for historical projection are integrated in this system in order to provide complex evaluation of performed processes within this environment.

## 5. CONCLUSIONS

This paper deals with proposed solution for investigation of user behavior during learning or working activities in virtual collaborative user environment. Every action is monitored and stored in separate log repository in predefined format as necessary historical data for further analytical purposes that result in interesting behavior characteristics. These characteristics contain quantitative statistics, historical retrospective through timeline, identification and discovering of user-defined patterns, visualization of relations between users. Outputs of these approaches can be used for further improvement of user practices in virtual user environment, specification of optimal input resources, selection of appropriate member for group collaboration, identification of natural leaders, evaluation of performed action sequences and construction of most effective flows, evaluation of user activity level for teaching purposes, etc.

Future implementations of the pattern service plans to incorporate more flexible definition of a pattern, including the support for specifying relationships between individual elements and the ability to specify relevance for the individual elements, which helps to find better partial matches for a given pattern.

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