MORPH: Supporting the Integration of Learning Analytics at Institutional Level

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ABSTRACT
While there is high potential in using learning analytics to provide educational institutions as well as teachers and learners with actionable information and improve learning experiences, currently only very few learning analytics tools are actually used in educational institutions. In this paper, we introduce MORPH, a platform that facilitates the integration of learning analytics modules and tools into institutional learning systems. MORPH provides a robust distributed architecture which combines batch, stream and real-time data processing using a parallel processing model to enable and support efficient processing of large amounts of data. Furthermore, it provides common management and administration features that enable the seamless integration of learning analytics research modules and tools into existing institutional learning systems.

CCS Concepts
• **Applied computing→Interactive learning environments**
• **Software and its engineering→Software prototyping**

Keywords
Learning Analytics; Institutional Learning Environments; Data Streaming; Batch Processing; Real-time Processing; Dashboards

1. INTRODUCTION
In recent years, learning analytics is evolving rapidly and garnering broad interest of both educational institutions and researchers [1]. Over the last years a lot of research has been conducted on different topics related to learning analytics and several learning analytics tools and prototype systems have been developed. However, only a very small number of such tools/systems has been adopted by educational institutions.

When designing, developing and evaluating learning analytics research tools and systems, the primary focus of researchers is often on the learning analytics research itself, including issues such as the proper collection of data from a learning system, the processing of data through different algorithms, and data visualization (e.g., through dashboards, alerts, notifications, etc.). However, general software engineering issues as well as management and administrative aspects for integrating such research modules into learning systems of whole educational institutions are often neglected. But such issues are crucial to build robust research modules that can seamlessly integrate in existing institutional systems of educational institutions.

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Furthermore, designing and implementing learning analytics for a whole educational institution typically involves complex computing and aggregating of large amounts of data which cannot be performed by traditional data management technologies [2]. However, many research modules are built and/or tested to run on limited or small-scale datasets (e.g., for one or few courses) to evaluate these research modules and their underlying algorithms. These modules often would not perform well once integrated with real-world educational systems which host hundreds of courses. Accordingly, a successful implementation of research modules in learning analytics requires a new application development paradigm to create a technical solution that effectively operates with large amounts of data and allows the integration of different research modules.

In order to address the above-mentioned problems, we designed and developed MORPH, a dynamic and evolving platform, which facilitates the integration of innovative research tools/modules in the areas of learning analytics, visualization, learner profiling, personalization and others, into existing institutional learning environments. MORPH provides a robust distributed architecture which combines batch, stream and real-time data processing, using a parallel processing model. Research modules integrated with MORPH are structured around the provided architecture which ensures that data are processed in a reliable and efficient way. MORPH provides functionalities for seamless integration, management and administration of research modules in institutional learning management systems (LMSs). With this approach, a significant burden can be taken from researchers when aiming at developing research modules that can be used in real-world scenarios, so that they can focus on research-related issues rather than on software engineering tasks.

2. LEARNING ANALYTICS IN MORPH
MORPH's architecture is built to connect research modules to LMSs while providing support for data processing and analytics of huge amounts of data as well as for management and administrative issues to integrate different research modules into LMSs used by whole educational institutions. To address the problem of aggregation and processing of large amounts of data, a distributed architecture is used, in which MORPH comprises two basic high level components: (1) Data Processing & Analytics subsystem and (2) Data Collection & Presentation subsystem, which are loosely coupled using RESTful services and Distributed Messaging System. The Data Processing & Analytics subsystem includes all information management components, i.e. data store which is separated from the LMS database, as well as components to search, transform, integrate and process data. The Data Collection & Presentation subsystem is integrated with the LMS, and provides different services related to the management and administration of research modules as well as visual components used by research modules such as dashboards, notifications, etc.

Each research module is plugged into both subsystems and could be easily disconnected (and reconnected). In addition, MORPH provides management and administrative support for administrators and teachers. Administrators can easily turn on/off research modules and make them available to teachers, while teachers can activate/deactivate research modules in their courses, and tune different settings. Moreover, MORPH provides different APIs and reusable components such as dashboards, alerts, notifications, which can be reused by different research modules.

2.1 Data Streaming and Processing

To meet the complex requirements of learning analytics modules which typically process large amounts of data in different ways, data streaming, batch processing and real-time processing needs to be supported [3]. To ensure highly efficient data processing in MORPH, a separate data store is used for storing and searching data, so no data has to be retrieved from the LMS database. MORPH extends the LMS with a Data Collection & Presentation subsystem. The Data Collection subcomponent collects events, appends other relevant data and submits event data as a data stream to the Data Processing & Analytics subsystem through the Distributed Messaging System. The Data Processing & Analytics subsystem receives the event data, classifies it and forwards the data to its subcomponents called Stream Processors which are subscribed for specific event types. Stream Processors define operations that are applied to each individual data item as it passes through (e.g., calculating the average time spent on a page, session durations, etc.). A common scenario of use of Stream Processors is to provide event counters (e.g., page views per session, unique page views, etc.), which may then be used by research modules to produce more complex information.

MOPRH offers two ways of processing (and accessing) data: batch processing and real-time processing. Batch processing is well-suited for complex calculations where access to large amounts of data is required and where results are not needed in real-time. A research module can use MORPH's APIs to specify (1) when to activate batch processing (e.g., based on a specific input such as a user event or at specific time intervals), (2) which data should be processed in batch (e.g., only last user session events or data related to a specific user), and (3) which operations should be performed on the data. MORPH provides different types of batch job APIs for research modules and handles aspects such as triggering, parallelization and failover. Once a MORPH batch job is activated, data is collected from the data store based on the provided parameters, processed using the provided operations, and then the results are stored back to the data store.

Real-time processing can be used in MORPH, for example, for providing recommendations, personalization and interventions. The goal is to respond in real-time or near real-time to certain user actions or situations identified through received events or direct requests. MORPH supports two approaches of real-time processing. The first approach is to retrieve data stored as a result of data streams or batch job processing, aggregate and process this data, run algorithms and/or analytical techniques on them, and visualize the respective output for the end user. Another approach is to extend a Learning Session Analyzer (LSA) provided by MORPH, through a research module. Such LSA allows analyzing the current and previous events of a respective learning session, as defined in a research module. A LSA is controlled and triggered by MORPH each time a user performs an action and uses a short-term data store to store the events of a learning session for processing and analysis. As the result of such processing and analysis, certain interventions can be provided to the end users.

2.2 Learning Interventions in MORPH

Besides data streaming and processing, MORPH also facilitates the process of showing actionable information and recommendations in a LMS. Several options are supported by MORPH and in the following paragraphs, two important options for learning analytics modules are presented in more detail.

MORPH provides a set of different notification types that can be presented to students (or teachers) for direct interventions within the LMS. Interruptive notifications cover a LMS page to let students know that something very important requires their immediate attention. Non-interruptive notifications appear in the right-bottom corner of the screen and display a personalized message. These notifications can have different visual appearance to indicate success or risks, and provide information and warnings. The third type of notifications are messages that are displayed above learning content and are typically used to provide information, advice or guidance. Each type of intervention can be either displayed on any page of the course or only on a specific page. For example, a message that encourages a student to take a more active part in forums can be displayed on any page in the course, while a notification that proposes additional resources to a learning object can be displayed on only that learning object.

MORPH also provides advanced dashboard functionalities that were designed to provide rich, meaningful and timely feedback to students and teachers. Dashboards are tailored on the fly for each course and each user based on the research modules activated in the course and on the user's role in the LMS. A dashboard is divided into logical sections which are presented on the same page or on different tabs, depending on the total number of widgets that are displayed. Widgets are containers which hold actual visual representations of data generated by research modules. A research module can define the type of diagram to be displayed and provide data in JSON format to populate a widget; and MORPH takes care of the visualization based on the provided parameters and data. However, if there is a need for more complex visualizations that are not supported by MORPH, it is possible to provide custom implementation for a widget.

3. CONCLUSION

In this paper, we presented MORPH, a platform that facilitates the integration of learning analytics research modules into institutional learning systems. MORPH provides different support for such integration including management and administrative support as well as support for streaming and processing of large amounts of data. As such, it enables researchers to focus more on learning analytics research rather than on general software engineering issues, while ensuring that their research modules are capable of being integrated in learning systems of whole educational institutions. Future work deals with evaluating MORPH with different research modules.

4. REFERENCES

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