Context data learner model for classroom and intelligent tutoring systems

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Abstract. Nowadays technological advancement enables multiple education scenarios, like online learning and technology enhanced classroom learning. Both of these scenarios share a common level of knowledge about the learner and his or her learning preferences. This knowledge is limited and in most scenarios gathered via a learner survey. This situation limits system capability on delivering individualised learning experience as the learner sometimes is not able to define his or her learning style, actual preferences and other aspects. Learning session and learner context data enable more advanced adaptation in intelligent tutoring scenarios and deliver new analytical capabilities to the trainer in classroom learning. Learning context data can be captured via various means and from multiple data sources, like education institution systems and physical sensors. This paper proposes the learner context data model attributes identifies the data sources to fill this model and identifies possible techniques to enable this process automation.

Keywords. Learner context data model, context data acquisition, learning process, intelligent tutoring system, context awareness, learner analytics, learner model.

1 Introduction

Personalised learning has a potential to improve learning process and overall learning results [13], [10], [5], [9]. Personalization maybe achieved via learning content personalization and individualised learning strategy application. Therefore, it is important to gain well applicable and trustful information about the learner, including, its previous experience and knowledge level, learning style, learning preferences and learning habits and create learner model. Contextual information qualifies as one of the sources for learner model creation and could be used for an online and in classroom learning [3].

The Intelligent Tutoring Systems (ITS) [6] in most scenarios operate as a recommender system that gathers appropriate and requested learning material from the learning object/ training material repository and/or provides other recommendations about the learning material application. In more advanced scenarios, ITS assess learner's knowledge and based on the results adapt tutoring material difficulty level [1]. If the context aware system is able to identify learners who are working on a similar learning activities, the system can suggest suitable peer learners to collaborate with [3].

Any learning session happens in defined, describable and observable environment, which might be either physical or virtual, e.g., e-learning system. Such environment could be an educational institution, corporate environment, home or any other place that is suitable for education. Learning from process perspective [14] could be a course-steered, self-steered or context-steered. At universities and companies, we can find the course-steered learning as the core learning process. This learning process follows strictly defined course structure and there are very limited possibilities to provide individualised learning. Context-steered learning additionally to textual, graphical and multimedia learning objects [11] may use available human resources (problem domain experts, colleagues and trainers) and enable dynamic such resource management and utilisation.

To describe learning environment with various contexts Schmidt [14] has identified the following activities that should be performed to enable context aware learning. In other researches these activities are essentially the same, but have different wording [12]:

- Context capturing. This activity collects information about the learner and the learning session conditions. For example, assigned tasks and personal information that is relevant to learning process, like learner's previous experience, individual goals, cognitive style and other aspects. The context can be captured from multiple sources, therefore, it should be managed in a way that several applications can view, modify and update the context in a mutually enriching way.
- Development and application of context aware methods. Current online learning platforms (both academic and enterprise) support continuous learning and have a strictly defined learning path. However, context aware systems enable on-demand learning by taking only context relevant learning objects. For example, when learner is performing some task and identifies that there is a need for additional information, the context aware system could assist and assess the situation and look for applicable and suitable learning material that is not necessarily a long lasting curriculum, but might be a short how-to guide on a particular subject. The context aware systems have great application potential in work/enterprise environment, where companies might have multiple knowledge bases and other information sources. Wiki pages, knowledge management systems are common systems for almost any company and they might contain large number of tagged information that is almost ready for context-aware applications.
- Context-aware resource preparation. This activity is responsible for tutoring content preparation for further application in context-aware systems. The objective of this activity is to create context application-ready tutoring material including resource relationship definitions.

After context is captured, it is important to identify context quality level. If context quality is low, it will not be applicable in classroom and/or intelligent tutoring systems. Bellavista et al. [2] have identified, that context quality is measured by the following three parameters: context data level of trust, context data precision and context data age. Consequently, capturing, storing and verification of these parameters should be included in any context and assessed each time when new context is created/captured

or existing context is updated. These parameters, additionally to context quality assessment, could be used for context conflict management. Each context weight/significance might be based on a combination of all three parameters.

The goal of this paper is to create context aware learner model and identify corresponding context data sources for the analysed hybrid learning scenario, where traditional classroom training is provided with additional learning materials available via online ITS prototype [3]. The research contribution of this paper is twofold.

- First, context learner model is proposed for a particular hybrid learning environment (classroom and virtual) to support analysed learning scenario.
- Second, empirical contextual information data sources at Riga Technical University are identified and analysed.

The paper is organized as follows. Section II discusses the context modelling aspects. Section III presents the proposed context model. Section IV discusses the empirical results.

2 Context Modelling

For any entity or process we can find unlimited amount of contexts and consequently create unlimited number of context models. This situation requires to identify context importance and relevance for a particular application and have a good understanding about the context and the context elements. Perera et.al. [12] have adopted various context model interpretation and context attributes to define the context model and the context attribute. "*A context model identifies a concrete subset of the context that is realistically attainable from sensors, applications and users and able to be exploited in the execution of the task. The context model that is employed by a given context-aware application is usually explicitly specified by the application developer, but may evolve over time.* [7]" And context attribute as "*an element of the context model describing the context. A context attribute has an identifier, a type and a value, and optionally a collection of properties describing specific characteristics* [7]."

Any context model can be static or dynamic, have its own lifecycle, level of trust, relationships with other contexts, timelines and other attributes. Past research approaches demonstrate generic context model development where context is classified in three groups: user context, things context and system context [8]. Some context aware systems use location information for various adaption scenarios [4]. For educational domain the attributes from all three kind of contexts are relevant.

Context modelling can be done by several techniques. Straong and Linnhoff-Popien [15] have surveyed most popular context modelling techniques like Key-Value Modelling, Markup Scheme Modelling (Tagged Encoding), Graphical Modelling, Object Based Modelling, Logic Based Modelling, Ontology Based Modelling. Any of mentioned modelling techniques has its own benefits and drawbacks. The learner context model proposed in this paper will be modelled by using object based modelling, be-

cause the object based concepts are used to model data using class hierarchies and relationships. Object oriented paradigm promotes encapsulation and re-usability and is supported by modern object oriented programming languages. Previous software development knowledge can be reused for system context aware system development and integration. Moreover, object based modelling is suitable to be used as an internal, non-shared, code based, runtime context modelling, manipulation and storage mechanism [12]. Lack of built-in reasoning capabilities is not important at current research state as the context components will be integrated with other system components and consequently, reasoning will be delegated to the other system components.

For situations where a single context is being used by multiple entities, context aware system should be able to identify to which entity this context applies, how to present it (order, structure, etc.), therefore, pre-defined application scenario and/or entity identification mechanisms should be implemented in the system.

Based on a context model application domain, they may describe general information about the context and a context structure with corresponding relationships, or be very specific and describe in details each context element internal structure, behaviour and relationships with other context element. Which level of detail to choose depends on the application domain and author's/experts beliefs. Modelling can be done in a various levels- conceptual, logical and physical. Physical modelling is not needed when context components are integrated into existing system or this level is replaced with system architecture. However, it is required to define how defined context results will integrate into existing or newly created system or its components. In the learning domain context modelling could be done in several directions; learning object context, pedagogical context, student model context, learning session context, learning environment context. Any of these contexts at some degree could be used to facilitate distance learning and classroom process. This research focuses on ITS and classroom learning hybrid scenario learner context model. Therefore, the proposed model is the first iteration of continues model development and at this stage may not contain all possible learning domain contexts and context attributes. The proposed model is based on a student model proposed by Lukasenko [9], which contains the following information categories: Contact information, learner learning style, learner current state (mood, mental state, face expression, physiological state) current level of knowledge and skills, learner objectives, learning progress, used learning material, user interface setup.

All context categories and attributes are considered with the following parameters and their description is given in **Table 1**.

Table 1. Context attribute parameters description

Parameter	Description	Metric
Precision	This parameter is based on observation which characterise deviation from the planned	Error, divergence from the set target value
Reliability	This parameter might be set either by some subjec-	Probability, strictly defined levels, true or false

Parameter	Description	Metric
	tively by the system author or based on calculated results	
Granularity/ Resolution	Describe level of details.	Group or individual students, each minute, hour, second, etc.
Information/Data source confidence rank	Describes information source confidence level	Rank or rating
Data age	Describes data age	Date and/or time

Each context element has its own data source that needs to be identified. This is analytical activity where operation environment (virtual and/or physical) iteratively is reviewed as some data sources should be changed during system operation. After all available information about operation environment is gathered it needs to be evaluated by following several steps: 1st step identifies all physical and virtual sensors. As a virtual sensor might serve existing service, database, it system or application. 2nd step in case if context is composed from multiple sensors, a single logical sensor is created, where author defines sensor data merging/transformation mechanism and result data structure of this sensor. 3rd step defines data source reliability and confidence rank, desired data precision and granularity.

3 Proposed Context Model

The proposed context model is an object that consists of several sub objects which corresponds to the contexts/ context dimensions and is designed to fill in and/or verify learner model attributes. This model for classroom learning will provide more detailed information to trainer for further and more detailed student result analysis and for ITS model it will serve as additional source of information for personalised learning content delivery. The model will describe various aspects of student model. As a first step the set of learner model attributes that could be filled in from context models is proposed (see **Table 2**). Each learner model category represents learner context sub contexts which are part of the proposed context model.

Table 2. Selected relevant learner model attributes for analysed scenario from [9]

Learner model category	Attribute	Description
Contact information	Name/Surname/IDs	Attributes to uniquely identify learner in the system
	E-mail address	Parameter for communication with the learner
Personality characteristics	Learning style	A learner's learning style (theory oriented, task oriented, problem solving oriented)

Learner model category	Attribute	Description
Current knowledge and skills	Knowledge level in a problem domain	The learner's level of knowledge in the problem domain before beginning of a course
Use of system	Topics reviewed/ tasks completed in a course	The course topics that the learner has viewed/studied. The tasks that the learner has solved.
Learning progress	Attempts made/ time spent	The number of attempts committed by the learner to solve a task, and the time spent on studying a topic

3.1 Identified Data Sources

The proposed context aware learner model attributes could be filled in either manually by system author or by semi-automatic/automatic way based on data of another system or data store. Analysed learning scenario is taking place at Riga Technical University where classroom training is supported by ITS prototype. University as educational institution has multiple IT systems with various functionality. For this scenario particular interest is in an annual survey system, study system that stores information about the learner's performance, ITS prototype and e-learning platform Moodle (see **Table 3**).

Table 3. Identified data sources

Data source	Description	Data source precision
ITS prototype	Data source provides learning object metadata, system log (viewed videos, downloaded learning objects)	Trustful as each learner is accessing system with unique identifier and
University survey system	Data store provides learners survey results	Low to Medium as learners' may not be honest
University study system	Data store provides learner grades and chosen study courses	Trustful
Moodle	E-learning platform log	Medium as system author is not able to verify data quality

3.2 Identified Context Model attributes

The attributes of the proposed learner context model are analysed according to the parameters listed in Table 1, namely, attribute precision, reliability, granularity/resolution, data source confidence rank, data age and sensor type:

- Learner identification information (name, surname, IDs, email address). This combination of attributes is precise, reliable, verifiable and detailed. The data for these attributes come from university study system which is a fully trustful data store. The only exception is the email address, that is subject of occasional change. Information is captured via virtual sensors.
- Learning style. The learning style is of low precision, subject of rapid change, hard to verify and not detailed. Learning style is based on various primary and secondary contexts and data interpretation algorithms. Data sources for learning style are multiple mostly system logs. In this research these data sources are ITS prototype and Moodle log as well as annual learners' survey. The information is captured from various virtual and logical sensors.
- Knowledge level in a problem domain. The knowledge level is a subject of change and has medium level of precision; information is reliable depending on the type of knowledge assessment level of information resolution may vary. Data source confidence rank is from medium to fully trustful as the sources of information are university study system (fully trustful) and ITS knowledge assessment modules where level of trust is medium. Similar to learning style attribute, the data may come from virtual and logical sensors.
- Topics reviewed/ tasks completed in a course. This attribute is based on systems logs (ITS and Moodle), is trustful, precise and has high level of details. Data source is reliable and data is up-to-date. Information comes from virtual sensors.
- Attempts made/ time spent. This attribute is similar to topics reviewed/tasks completed and shares the same attribute characteristics.

4 Results and Discussion

Research discussed in this paper follows the 3 main context aware learning activities (see Section 1) by defining context capturing aspects, identifies context data source level of trust for further application scenarios in the classroom and intelligent tutoring system supported learning. The analysis of empirical available data set (see **Table 3**) showed, that it is possible to use this contextual data for several proposed learner model attributes semiautomatic/automatic filling. However, to automate this process there is a need for an initial effort on a data source annotation, metadata preparation, context models and context relationship definition. More advanced automation scenarios could be enabled by implementing reasoning techniques. For a small number of learners' and where high level context model description is satisfactory, learner context model can be filled with data manually by the trainer and/or expert. For the analysed context application scenario corresponding tooling is required. Additionally, the analysed data contain verifiable information, for example, the number of attended classroom lectures,

learner's employment status that might affect overall learner performance and provide additional information about the learner's level of knowledge (for example, experience with programming languages and other relevant information), therefore, some physical sensor and/or software for learner direct and indirect tracking solution/system and integration with other external systems (for example, employment and industry related skill set might come from LinkedIn social network) is required.

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