# Information Processing for Smart Indicators

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**Abstract**. Learners need various types of information in order to monitor their progress while performing a task. Indicators help learners to organise, orientate, and navigate through complex environments by providing contextual information that is relevant for the performance of learning tasks. In this paper we discuss a service-oriented implementation of an architecture for indicators, which is applied in a co-operative learning scenario. The services of this implementation utilise learning technology specifications, which provide semantics for modelling educational scenarios. This paper implies that the given learning technology specifications are suitable for modelling learner support for non- and informal learning, but further research is required on analysing context dependent factors of learner support.

# Introduction

Learners need various types of information in order to monitor their progress while they are performing a task. This information is provided by what we call *indicators*. Indicators provide simplified representations of the state of complex system that can be understood without much training. Furthermore, they help to focus on relevant information when it is needed, while the actors don't have to bother about this information most of the time.

Learners depend on indicators in order to organise, orientate, and navigate through complex environments by utilising contextual information [BW95, We03]. Contextual information on the learning process has been proven as important to support the learning process. It stimulates the learners' engagement in and commitment to collaboration [Be04, Li05, Ra06]; it helps to raise awareness of and stimulates reflection about acquired competences [Kr04, KK02]; and it supports thoughtful behaviour in navigation and on learning paths [NOBK06]. Despite this evidence on the effects of indicators on learning processes, little research has been conducted on the problem of adapting indicators to the changing needs of the learners throughout their learning process.

The overall question of the research presented in this paper asks for the utilisation of indicators to make learning more attractive in non-formal and informal settings. It has been argued that indicators are part of the interaction process between learners and

learning environments [CSK07]. As such, indicators depend on information about previous learning activities and their contexts. The information processing for this purpose can be modelled as four operational layers: a sensor layer, a semantic layer, a control layer, and a presentation layer.

The research question of this paper is how to provide smart indicators to learners in an unstructured community environment. The answer two this question is based on two problems. The first problem is related to the development of learner models [Br01, Mc93] and context models [De01, DAS99], which then can be used by the learners. The second problem is the modelling of context aware adaptation strategies that define which resources can be used to generate the appropriate information according to a learner's context.

In this paper we address the second problem and discuss how semantics that are given by learning technology specification can be used for modelling adaptation strategies. Based on an experimental scenario, we analyse the key factors for indicators to support learning interactions. These factors were used to develop an architecture for smart indicators, which is presented in the fourth section of this paper. Finally we discuss how this architecture has been implemented by a set of services that utilise learning technology specification semantics to specify adaptation strategies for smart indicators.

## Experimental Scenario

In order to develop a better understanding of supporting strategies for learning interactions we implemented a web-based prototype of smart indicators. The prototype integrates indicators into a community system. This system combines the community member's web-logs, del.icio.us[1] link lists and tag clouds. The indicator provides information on the interest and the activity to the learners. It contains two core components: An interest tag cloud and an activity chart. To maintain these indicators the system tracks selection activities, tagging activities, and contributions. The system adapts the presented information according to a learner's activity and interest level: It provides richer information the more a learner contributes to the community. Therefore, new participants will have different information indicated than those who contribute regularly to the community. The community system acknowledges that its participants might already use a web-log or del.icio.us instead of offering similar services. However, it is not a requirement for participation to have both. When learners register for being "members", they can provide a URL to a feed address of their web-log and their nick-name on del.icio.us. This personal data is used for creating a *learner profile.* Therefore, the community system provides only a portal to recent contributions, while the actual content is external to the system.

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[1] http://del.icio.us

Each action within the system is considered as a learning activity and learners score "learning points" with each action they perform in order to indicate their learning progress. However, some actions require more effort than others. For example, accessing content provided by other users is easier to perform than contributing content through a web-log. Because of these differences, the actions have different scores.

The indicator system is based on immediate and delayed interaction monitoring by interaction sensors. Immediate monitoring is implemented only for selections (so called click-through), through which the system gathers information about requests of web-log entries or links from the link list. Data about contributions is accumulated from RSS2[2] or ATOM[3] feeds independent from a learner's actions on the user interface. Information on the collected links and associated comments is gathered through del.icio.us' RPC interface[4]. The tagging activities are extracted from the data on tag clouds that is provided from both the link lists and the learner's web-logs. A learner tags an external link or a web-log entry if a tag is added to the contribution.

In a second step the system enriches the collected data using activity aggregators and an interest aggregator. This part of the system analyses the sensor data according to a definition given by the aggregators. Different to data collection, this layer is not limited to organising incoming sensor data, but it uses the aggregators to *transform* the sensor data into meaningful information.

In order to adapt to the learner context the system provides a control layer, which handles how the indicators adapt to the learner's behaviour. The prototype implements two elemental adaptation strategies. The first strategy aims at motivating learners to participate to the community's activities. The objective of the second strategy is to raise awareness on the personal interest profile and stimulate reflection on the learning process and the acquired competences. The prototype adapts the strategies according to a learner's participation to the community.

Finally, the indicator is generator is generated by an indicator layer. The purpose of this layer is to integrate the values selected by the control layer into the user interface of the community system. The indicator layer provides different styles of displaying and selects appropriate styles for the incoming information. Two graphical and one widget indicator are provided by the prototype. One graphical indicator is used during the first level of the control strategy. This indicator shows the amount of actions for the last seven days. A second control strategy uses a different graphical indicator. It displays the activity in comparison to the average community member. The maximum value on the scale in this indicator is the most active community member. Finally, the indicator layer provides a tag cloud widget for displaying the interests of a learner. In principle this widget is a list

[2] http://blogs.law.harvard.edu/tech/rss

[3] http://tools.ietf.org/html/rfc4287

[4] http://del.icio.us/help/json/

of hyperlinks. The tag cloud indicates higher interest values for each topic through the font size of the related tags.
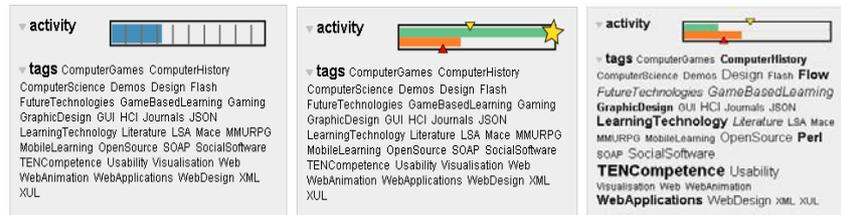


**Fig. 1.** Sample Indicators on different strategy levels

# Defining indicator systems

In the introduction we have highlighted some principles of indicators. With regard to learning technology, feedback and recommender systems meet these principles. Therefore, it is necessary to distinguish indicator systems from them. Feedback systems [PJ04, RTTC96] analyze user interactions to inform learners on their performance on a task and to guide the learners through it. Recommender systems analyze interactions in order to recommend suitable follow-up activities [AT05]. The objective of both system types is to affect a learner's future activities by providing useful information. Both approaches are tightly coupled to goals or processes that are shared within a learning community. In contrast, indicator systems provide information about past actions or the current state of the learning process, without making suggestions for future actions. Having these considerations in mind, we define indicator systems as follows:

*An indicator system is a system that informs a user on a status, on past activities or on events that have occurred in a context; and helps the user to orientate, organize or navigate in that context without recommending specific actions.*

It is a fundamental insight that humans actively search for relations to their previous interactions, in particular for indicators that provide information on the success and the value of their actions. This is especially the case if the actions are based on strategies that require alignment during the interaction process [JCW04, We03]. In other words, people continuously seek for indicators that help them to verify or modify their actions, tactics and strategies.

One can argue that this applies to learning processes as we learn from research on feedback and self-regulated learning [BW95, LY01, Mo03, Or99]. Indicators on learning are important facilitators of these processes and are based on three general principles [DA00, Kr04, LY01]:

- Indicators rely on monitoring of the learning actions and the learning context.

- Indicators have to adapt according to a learners' goals, actions, performance, outcomes, and history as well as to the context in which the learning takes place.

- Indicators are responses to a learner's actions or to changes in the context of the learning process, where the response is not necessarily immediate.

Most indicators implement a static approach of providing information to learners rather than adapting to the learning process [CV05b, FB05, Gr98, KDM04, Kr04, MMDY06]. These approaches are considered as static as they follow a fixed rule-set to collect, to aggregate and to indicate information to learners. In contrast, *smart indicator systems* adapt their approach of information aggregation and indication according to a learner's situation or context. In our setting context is defined by the temporal context of the learning progress.

# An architecture for smart indicators

A smart indicator is a component of a context aware system that traces a learner's interactions as well as contextual data in order to provide meaningful information in response to learning actions. In this section we describe a system's architecture for smart indicators.

We applied an architecture for context aware systems as it has been described in Zimmermann, Specht, & Lorenz [ZSL05]. The architecture has four layers and specifies operations on the data and information flow through a system from the learner input to the system response (see **Fig. 2**). The layers are the sensor layer, the semantic layer, the control layer, and the indicator layer.
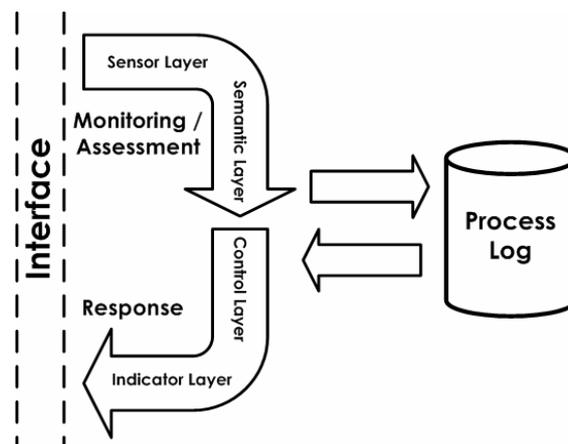


**Fig. 2.** Layers for context-aware information processing

The *sensor layer* is responsible for capturing the interaction footprints. A *sensor* is a simple measuring unit for a single type of data. The objective of sensor layer is to trace learner interactions. It also includes other measures that are relevant for the learning process which are not a direct result of an interaction between the learner and the system. Sensors that do not gather information about a learner's interactions are called *contextual sensors*. Examples for contextual sensors are standardised meta-data, or tagging activities and contributions of peer-learners. In the architecture the sensor layer adds data to process log in order to allow the adaptation to the interaction history.

The *semantic layer* collects the data from the sensors and from the process log and aggregates this data into higher level information. The semantic layer defines operations or rules for processing sensor data [CC03]. The definition of how the data from one or more sensors has to be transformed is called an *aggregator* [De00]. These rules can be named according to their meaning, for instance *activity* or *interest*. The aggregated information is interpreted by the *control layer* according to the history and context of a learner. The specific approach for interpretation is called a *strategy* [CC03]. It defines the conditions for selecting and combining aggregators as well as their presentation according to the learner's context. A strategy also controls the personalization of aggregators. Finally, the aggregated information has to get presented to the learner. The *indicator layer* handles this part of the interaction. At this level the actual response is created by translating aggregated values into representations that are not just machine-readable but also accessible to humans. The active strategy of the control layer selects these representations and provides the aggregated information to them.
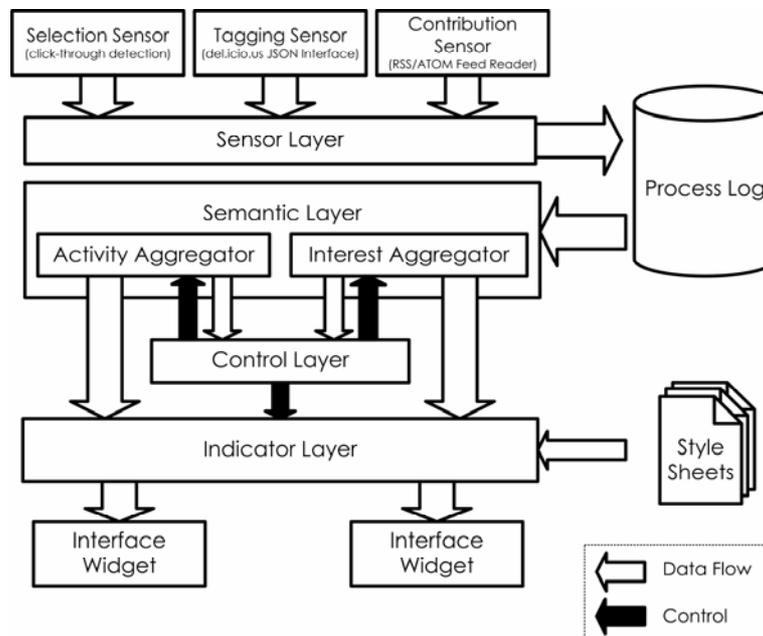


**Fig. 3.** Component interaction of the prototype

Many approaches in adaptive hypermedia implement adaptation on the level of the semantic layer, while the main strategy at the level of the control layer does not adapt to the learning process [e.g. ABF05, BV01, CV05a, CV05b, CV06, FB05, Va04]. In contrast, our approach of smart indicators adapts the strategies on the control layer in order meet the changing needs of a learner. By doing so, the adaptation strategies are adaptable to the different phases of the learning process.

In order to develop better understanding of supporting strategies for learning interactions we implemented a web-based prototype of smart indicators. **Fig. 3** shows the data-flow between the different layers of the architecture. According to the architecture the prototype has four functional layers: A sensor layer monitors the learners' activities and collects traces of interest. A semantic layer provides two aggregators to transform the data provided by the sensors. A control layer controls the indicator behaviour according to the results of the aggregators of the semantic layer. The indicator layer transforms the information into widgets that are integrated into the user interface of the system.

## Under the Hood

Each layer of the architecture has been implemented as a separate web-based service for the prototype. The main reason for this approach was to enable reusability of parts of the system for other projects. The approach for implementing the services is similar to REST [Fi00], although our approach makes greater use of HTTP 1.1 functionality [Fi99] for simplicity and performance. REST is basically defined as a two step protocol, where the first step tells the service which operation and on which object has to be performed. In response to this initial request the service sends a unique resource identifier (URI) [BFM05] to that operation. With this URI the caller can then actually perform the operation. This URI can be used only once and triggers a HTTP error if it is used for a second time. In contrast to REST, our approach defines a single step protocol in which the operation of the service is defined by the HTTP command (GET, PUT, POST, DELETE) and the URI of the service. Unique operation calls are assured by additional information in the HTTP headers.

By default, the services operate on data in a XML format. However, alternative input and output formats are provided in order to ease interactions with different approaches of web-application technologies. The input data format is defined in the HTTP "Content-Type" header [Fi99]. The service of the sensor layer depends on this information as it accepts incoming data as plain text (for single value sensors), form encoded data, JSON [Cr06], and XML. The incoming data is unified before it is further processed. A specific output type can be requested by adding a file extension to the URI of the service. This is achieved by assigning internal XSLT style-sheets [W3C99, W3C06] for the different data formats. This approach is respectively used by the service of the indicator layer: while the XSLT style-sheet transforms the output of the semantic layer into a SVG image, the service further transforms this image into the PNG or JPEG format if one of these types is requested by the caller. In case that a service cannot provide a certain output format the caller will receive a HTTP error.

The sensor layer accepts data coming from different sensors and origins. For this reason, the clusters the incoming data into named sensor groups. If a sensor needs to report data to the sensor layer, the sensor puts the data to the sensor layer's URI that has been extended by the name of the sensor group. In the experimental scenario there are six named sensors implemented. A calling service can get access to the sensor data by submitting a GET request to the service for the named service. If no sensor is specified the service returns the list of all sensor groups registered with the service. The entire information is available in a so called *process-log*, which is implemented as a SQL database. The process-log stores the incoming sensors according to the activity data structure that is defined by the IMS Learner Information Package specification (IMS LIP) [STR01].

On the semantic layer the sensor data is enriched. The related service has direct access to the process log and manipulates the sensor data according to predefined rule sets. These rule sets are loaded and interpreted dynamically by the service. We used the semantics of IMS LD level B conditions [KOA03] as a starting point for the aggregation rules. IMS LD level B conditions provide a simple mechanism for analysing the state of learner and context information and reacting to these changes by setting properties or changing contexts. However, IMS LD level B does not provide a complete set of operations for analysing IMS LIP activity data structures, because of the data-type limitations for IMS LD level B properties [KOA03]. Therefore, we adapted the IMS LD level B conditions in order to be able to analyse the learner and context information in the process-log. The given implementation of the semantic layer is in so far limited as it implements only a subset of the syntax rules given by the specifications. This subset contains to the restricted needs of the aggregators of the prototype. A detailed description of the aggregators is provided in Glahn, Specht, and Koper [GSK07]. In order to access the results of the aggregators, the aggregator names and the context in which an aggregator is applied, is encoded into the URI of the related service.

The control layer interprets the pre-designed adaptation strategies and analyses the user behaviour on the user interface according to them. The strategies on the control layer are defined by using a sub-set of IMS LD level B [KOA03]. A strategy is a set of IMS LD properties and activities which define which indicator should be used under which conditions. In IMS LD, activities are defined by pre- and post-conditions and a set of resources that are used with the activities. Because the conditions depend on IMS LD level B properties they have to be modelled with the strategy with the strategy. According to the IMS LD specification, the definition of the property may contain a metadata set that describes a property and is specified by IEEE LOM [IEEE02]. According to the IMS LD specification such external properties have to get designed as global properties. That way it is possible to provide to abstract the calls to the semantic layer on the modelling level for checking the contextual constraints of each step of the strategy. Within these constraints the behaviour of the indicator is defined as resources for the related activity. There are two types of resources used for the strategy modelling. The first resource type is the aggregator definition that is used as the source for the indicator, and the second resource type is the presentation style-sheet that is used to display the information from the semantic layer.

The final transformation for presentation is performed by a service of the indicator layer. In the prototype all indicator style-sheets are defined as XSLT style-sheets. These style-sheets are provided as resources from the control layer. Furthermore, the control layer also informs the indicator layer about the style-sheet and the core data that has to be used with the active learner.

# Conclusions and questions of further research

In this article we proposed a system architecture that is applied in a first prototype for smart indicators. The prototype is applied in an experimental scenario of cooperative learning. We addressed the problem of modelling adaptation strategies for learner support by analysing the use of semantics across the different layers of the proposed architecture. The used semantics were adopted from learning technology specifications to the special purpose of learner support in non-formal learning.

The application of the standards for the prototype showed that learning technology standards can be used to model context sensitive adaptation. However, the applied adaptation strategy for context adaptation is sequential and matches therefore the conceptual model of IMS Learning Design. Thus, further research will have to investigate how different kinds of adaptation strategies can be modelled by applying the approach discussed within this paper.

# Acknowledgements

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