iLD-Apps: Usable Mobile Access to Linked Data Clouds at the Shop Floor

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ABSTRACT

This position paper argues for adapting the Apps-approach to industrial interactive Linked Data applications (iLD) and presents a design study for a small application that is applicable whenever an information foraging task at hand may be described as carefully examining the neighborhood of a concept. This little App is primarily being developed for industrial device diagnosis tasks. However, it is easily adaptable to other navigation and information processing tasks that have similar information needs. We argue that a collection of individually extremely limited but highly usable applications will eventually have the potential to provide the means for application orchestration as a complement to industrial Linked Data Clouds and service orchestration. We present the concept of a generalizable mobile user interface that hides the complexity of the underlying Linked Data Network from the user.

Author Keywords

Linked Data, Application Orchestration, Mobile Interaction, Industrial use of Linked Data

ACM Classification Keywords

H.5.2 Information Interfaces and Presentation: User Interfaces—*Theory and methods*

INTRODUCTION

Due to ever shorter release-cycles and growing pressure to innovate, independent small and medium enterprises are entering short-term cooperations to be able to develop and produce marketable products. In particular in fast moving markets, the concept of virtual companies (a loosely coordinated set of complementing companies that temporarily work together) promises a competitive advantage over larger enterprises.

While several approaches to meet this challenge have been attempted in the past, there is still no single accepted standard for controlling and exchanging data over the companies' *boundaries of trust*. This is even true for monolithic companies if one takes the complete information life cycle of a plant into account. Conventional paths to unify the "standard" ERP systems, for instance after a merger, are usually very time-consuming. In the process and manufacturing industries, several approaches to come up with a single unified world-model (for instance STEP with its domain-specific APIs [5] or more recently ISO 15926 [3]) have been tried. Yet, all these world model approaches have turned out to be too complex and too unspecific to meet the individual requirements without customization. So far, the most promising approaches in that area seem to be metamodels (e.g. CAEX – Computer Aided Engineering Exchange) which provide enough formalism to allow transformations between particular implementations of different partners during the life cycle of a product or a production plant.

If the higher requirements for trusted and secure information exchange are neglected for a moment, the need to coordinate large distributed information islands is quite similar to that of the public semantic web. Efforts to organize the immense amount of unstructured or semi-structured data available on the web face the same challenges. However, there are organizations such as the *Linking Open Data* movement (LOD, [6]) that strive to give more structure to the data cloud through Linked Data. The basic idea of Linked Data is to augment the large amount of publicly available data by exposing it through a computer interpretable structure, based on web technologies. It uses URIs as names for things so that people (and machines) can look those names [9, 21] up. The URIs also provide useful information, for instance the relation to other things. Independent information spaces are interconnected by means of ontologies, mitigating the problem of synonyms. While the challenge of correctly detecting and fixing inconsistencies is still a topic of ongoing research (e.g. [14]), there are several commercial of the shelf and Open Source products readily available, to distribute, query and retrieve information from large-scale distributed information spaces. Nevertheless, the Linked Data approach still seems to lack recognition in commercial domains – despite of the huge amount of readily available content in form of corporate knowledge. [17] attribute this to the complexity of search and missing end user applications.

In the following sections we will give a survey on recent

Workshop on Visual Interfaces to the Social and Semantic Web (VISSW2011), Co-located with ACM IUI 2011, Feb 13, 2011, Palo Alto, US.

interfaces to Linked Data Clouds. We then propose to identify generalized information handling tasks that allow us to create a set of interactive Linked Data Applications (iLD-Apps) which have the potential to be highly usable. As an example of this approach the analysis of a shop floor maintenance scenario is given. The cognitive process when diagnosing a problem during a maintenance course involves the evaluation of attributes of the device under inspection by comparing it to observations in its neighborhood. This neighborhood can be represented by specific relations of a directed graph constructed from Linked Data. A generalizable mobile user interface concept that hides the complexity of the underlying Linked Data Network from the user has been developed.

RELATED WORK

Linked Data Browsers

Displaying and navigating RDF data in a user-friendly way is a problem addressed by various types of applications using different representation paradigms. According to [19] at least the following types can be identified: keyword search, faceted browsing, explicit queries and graph visualizations. The later enable users to visualize the available information and navigate along its incoming and outgoing links. Current linked data browsers such as relfinder [4], Disco [2] or Tabulator [7], however, address an end user who knows how to interpret Linked Data and/or RDF. This knowledge is necessary, because the browsers act directly on the Linked Data Cloud and the RDF representation.

Recognizing the general need for presenting RDF content to users and wanting to promote the exchange of presentation knowledge [19] has designed Fresnel as a browser-independent vocabulary of core RDF display concepts. Fresnel is the basis for server-side applications such as Marbles [10] or browsers such as LENA [12].

Mobile Linked Data Browsers

All of the mentioned approaches call for large displays and are designed with the WIMP-Metaphor in mind. Therefore, these concepts may not be transfered directly to mobile devices. It is not surprising that as of today one can find only a small number of mobile Linked Data applications.

A rather prominent instance is *DBpedia Mobile* [1, 8], a location-centric DBpedia client application for mobile devices consisting of a map view, the Marbles Linked Data Browser and a GPS-enabled launcher application. [22] try to map RDF graphs directly towards appropriate multimedia visualizations to allow for semantic navigation within the football domain. An optimal graph layout is computed on the server-side, the mobile device works on an XML representation. Nevertheless, real showcases that could illustrate the huge potential of Linked Data in industrial environments are not yet available.

MOBILE MAINTENANCE SCENARIO

Currently available Linked Data Interfaces address very high level generic tasks such as searching, visualization and navigation. While these paradigms are highly generic for industrial applications we propose some adaptation.

We suggest to find and implement interaction metaphors that are closer to the task. This means on the one hand to rely on asserted task specific invariants of the linked data cloud, on the other hand to allow for changing relations and sets of attributes.

A prerequiste for the delevopment and orchestration of this kind of interaction metaphors is a sound task analysis. Before we go into details of a single metaphor concept for diagnostic tasks in operation and maintenance, we therefore describe the environment and task at hand.

Environment

As industrial manufacturing facilities have become more and more autonomous, management and monitoring have become increasingly centralized in large control centers, which are not necessarily located close to the facilities themselves [23]. Hence, there is an increasing demand for remote control and remote maintenance. Service and maintenance personnel has to face greater heterogeneity of the contextual constraints and increased diversity of tasks. The individual responsibility and autonomy of a maintenance engineer is constantly growing and the demand for mobility and flexibility is rising. This leads to a growing demand for ubiquitous access to relevant information as well as guidance and decision support for successful task performance.

While the demand is clear, the design and roll-out of mobile devices in this environment is challenging. We know that the prevalent WIMP-Style is not really suitable. However, harsh environmental conditions such as dirt, humidity, noise and bad lighting dramatically decrease reliability and detection rate of alternative interaction styles such as voice and gesture recognition systems. Stylus- or touch-based interaction is virtually impossible under working conditions that require one-handed or even free-handed operation in variable working posture, wearing mandatory protective clothing including helmet and heavy gloves. The major drawback of most conventional mobile systems is the increased physical workload. System properties such as weight, body placement, noise or heat-dissipation may cause decrease of performance as well as physical and psychological stress during long-term use [24]. Especially heavyweight hardware such as wearable computers and head-mounted displays are critical parts in mobile systems [15], [24]. System design, in particular the design of the user interface, and body placement may cause distraction or obstruction during typical activities. These shortcomings are well-known and have already been addressed extensively, e.g. in [16], [23] and [24]. A comprehensive analysis of the requirements for mobile systems in industrial environments can be found in [25]. To overcome these obstructions, development of mobile systems must become considerably more focused on usability and simplicity than on technical refinement [11].

Maintenance and Diagnosis Tasks

A requirements-analysis in cooperation with industrial partners has lead to the hierarchical task model shown in figure 1. The goal *perform maintenance circuit* is comprised of two operations and one sub-goal. The sub-goal *complete task* is comprised of six operations. It must be noted that the model only reflects the mobile part of the fieldwork. Additional parts like negotiating access to the plant control room, getting dressed or preparing equipment have not been considered.

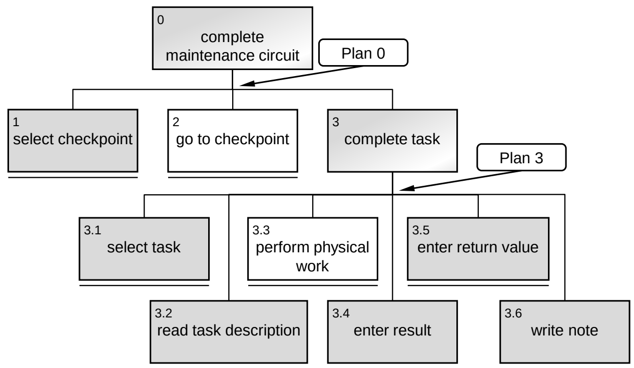

Figure 1. Hierarchical task model of a maintenance circuit

The task model consists of two plans. Both plans are shown in figure 1. According to *plan 0* the user has to select a checkpoint, go there and then has to complete all necessary tasks. *Plan 0* is performed repeatedly until all checkpoints have been completed. *Plan 3* describes the necessary workflow to complete a specific task.

In our use case we assume for subtask *3.3* to be a diagnosis task at the checkpoint. The process value given by a measurement device has to be inspected and evaluated. A common strategy is to compare the reading of the device under inspection with other measurement devices that reside up- and downstream. To identify these reference devices, one follows all the connections along intermediate instruments in a piping and instrumentation diagram (P&ID - a graphical 2D representation of the piping and process flow together with devices). When a dependent measurement device that informs about the particular process value is found, it can be systematically assessed.

Linked Data Model

With todays computer-aided engineering systems, all of the information necessary to generate a Linked Data cloud is potentially available. Information on devices, equipment, pipes, materials, as well as their relationships can easily be retrieved. Figure 2 illustrates the case of a measurement device `P0001` that indicates pressure at `Tank010`. `Pump010` delivers the medium from the tank into `Stream010`. The pressure in that stream (after the pump) is observed by indicator `P0002`.

Orchestration of Applications

It has been observed that mobile users tend to individualize their devices with a personal selection of applications addressing their needs for mobile information. Drawing from this phenomenon, our approach builds on a set of specialized small applications focusing on an informational need that is common on the shop flor.

```
<#P0001> rdf:typeOf <#meas_device>.
<#P0002> rdf:typeOf <#meas_device>.
<#Stream010> rdf:typeOf <#stream>.
<#Tank010> rdf:typeOf <#storage>.
<#Pump010> rdf:typeOf <#equipment>.
...
<#P0001> svg:isConnectedTo <#Tank010>.
<#Tank10> svg:isConnectedTo <#Valve010>.
<#Pump010> svg:isConnectedTo <#Stream010>.
<#P0002> svg:isConnectedTo <#Stream010>.
...
```

Figure 2. Formal Representation of Plant Structure

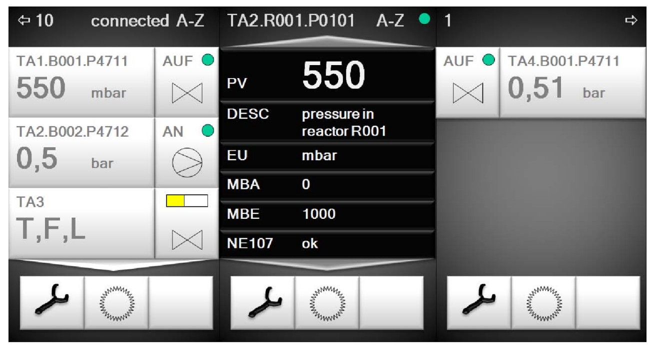

Figure 3. Mockup of the Neighborhood Browser

The orchestration of simple single-purpose applications is also useful in the industrial sector, e.g. as a front end to available services. These services implement the needed operations on the Linked-Data-Cloud, such as SPARQL queries. Depending on the context (various platforms, various stakeholders), well-adapted applications can be provided for the services. Model-driven development methods can support and accelerate the development of such applications. The orchestration itself, i.e. collection, arrangement and interaction of the individual applications, can also be effectively supported by automated model-driven methods.

The portfolio of applications can be expanded and updated, without the need to reprogram the mobile front-ends. By simple adaptation of the orchestration, the mobile front-ends can efficiently be adapted to changing workflows and user roles, again without having to reprogram the applications. Thus, a previously unknown degree of flexibility, innovation and usability is achieved. At the same time, the applications have the potential to become more consistent, require less maintenance, be safer and more reliable.

Neighborhood Browser

In industrial contexts various informational needs may arise, e.g. during commissioning and loop checks. Several of these needs may be addressed by the proposed neighborhood browser. Off course the details – i.e. which particular “things” are of interest – are quite variable. However, to the authors understanding, this is exactly the strength of the loose coupling in a Linked Data world.

In order to evaluate a particular measurement device, maintenance personal needs to obtain information about the connected devices. Based on the findings in [18] and [20] regarding multiple views of the same system and supported by a workshop held with an experienced process control engineer with several years of professional experience, we have developed the interface concept shown in figure 3. It provides a task-centric view of an industrial facility that can be complemented by other Apps providing different perspectives of the same system.

It has proved to be advisable to provide the complete tags (i.e. unique labels) of the devices and display process values as well as engineering units. Maintenance engineers need to be able to grasp all necessary information on the type and state (open, close, on, off, powerless) of the intermediate equipment at first glance. Neighboring devices can be chosen as the new "center of the universe" to be displayed in the center of the screen. The application can obtain the identifier of the device to be investigated e.g. by RFID or Data Matrix code [25]. All of the direct attributes (according to a sorting and aggregation ontology) are to be displayed as rows of the middle panel. The formulation of SPARQL queries or Fresnel expressions to select the neighboring measurement devices for the left (upstream) and right (downstream) panel as well as the interconnecting devices is straightforward.

Unlike most of the related work (see section Related Work) the proposed Neighborhood Browser operates on a Linked Data Cloud without exposing its complexity to the user while its interface is optimized for touch interaction and usage on mobile devices.

For different use cases different interface patterns must complement the Neighborhood Browser. Therefore, to complete the application orchestration, it is an ongoing work to identify further mobile interaction patterns. Timelines and calendars immediately come to mind – they could be presented in a linear form (as in *Tabulator*) or in form of tubes or worms (as in *DySoN*) [13]. For 2D map oriented information retrieval and presentation DBpedia Mobile already delivers an interesting pattern.

We are currently investigating on further iLD-App patterns that address other aspects of mobile day-to-day work in process and manufacturing industries. For further promotion in industries an extensive evaluation of user experience with this approach will be conducted.

Generalization

The particular presentation and interaction scheme, as presented above, may be easily generalized to other information foraging tasks that focus on the close neighborhood. Just to illustrate the basic idea, figure 4 shows the SPARQL-query that would be necessary to gain information about closely related programming languages from DBpedia. In combination with a set of concept specific sorting, aggregation and presentation ontologies and a basic set of interaction-metaphors the proposed concept may be easily converted to a programming language browser.

```
PREFIX dbpprop: <http://dbpedia.org/property/>
SELECT ?left ?leftname ?right ?rightname
WHERE {
  { <http://dbpedia.org/resource/XML>
    dbpprop:extendedTo ?left .
    OPTIONAL { ?left dbpprop:name ?leftname }
  }
UNION
  { ?right dbpprop:extendedTo
    <http://dbpedia.org/resource/XML> .
    OPTIONAL { ?right dbpprop:name ?rightname }
  }
}
```

Figure 4. SPARQL Expression for the Neighborhood of Programming Languages

CONCLUSION

Orchestrated iLD-Apps can be a usable approach to meeting the challenges of data exchange in virtual companies. Task-centric applications, based on Linked Data, help to obviate cumbersome interaction of maintenance engineers with devices during diagnosis-tasks. The proposed Neighborhood Browser can be generalized to similar use cases.

The best practice of how to adapt the proposed approach to address schemes, diagrams and plans which are of utmost importance to industrial engineering has not yet been conclusively found. Nevertheless, the authors are convinced that the Linked Data approach, utilizing model-driven development paradigms, is well-suited for the rapid development of a highly usable ecosystem of specialized but generalizable applications.

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