Flexible Process-Aware Information Systems Deficiency Management in Construction

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Abstract. Deficiency management (DM) is an important subfield of the construction domain which is characterized by a high demand for immediate and flexible reactions to unexpected problems. Thus, there is a high potential for flexible process-aware information systems. We propose a deficiency management system (DMS) to support the DM process in a flexible manner supported by knowledge-sharing of best-practice processes. We acquired a set of requirements concerning process support and knowledge sharing for DMS and present first steps towards the development of a working prototype.

1 Introduction

To retain the competitive advantage of today's companies, the streamlining of business processes is increasingly important to develop new performance-enhancing features, to accelerate the internal efficiency, and to reduce costs [1,17]. Moreover, the economic success of a company heavily depends on its ability to flexibly respond to changes in its environment and to take advantage from arising opportunities. Hence, the ability to quickly change processes or to deviate from a pre-set course of action is essential. As a consequence process-aware information systems (PAISs) are a desirable technology in many domains as these systems support the operational business of a company based on models of the organisation and its processes [17]. PAISs include traditional workflow management (WFM) systems as well as modern business process management (BPM) systems. Current research particularly addresses approaches for increasing the flexibility of PAIS [1,4]. Recent research in PAIS has also recognized the need for knowledge management through process reuse from best-practice process collected in repositories [1]. Knowledge sharing and reuse becomes a central prerequisite for enabling process flexibility, in order to address the increased need for decision making on the process level.

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Deficiency Management (DM) is an important subfield of construction domain that particularly needs to deal with unforeseen changes, demanding high flexibility by all involved parties. Generally speaking, a deficiency in construction is a negative deviation of the actual state of construction of a building from the specified or expected conditions [15, p. 5]. Thus, a deficiency is always unexpected and requires immediate remedial actions, which lead to changes of the current plans. Therefore, we expect that there is a high potential for flexible PAIS in the field of DM [7]. In this paper, we derive a set of requirements concerning process flexibility and process reuse in deficiency management systems (DMS) that are relevant for future more advanced approaches. We present a related concept as well as first steps towards the development of a working prototype.

2 Flexibility in Process-Aware Information Systems

A PAIS is "a software system that manages and executes operational processes involving people, applications, and/or information sources on the basis of process models" [4]. In order to operationalize process models, a PAIS typically includes a WFMS as a generic component for the execution of workflows. Traditional WFMSs strictly separate build time and run time of a workflow. During build time, a workflow definition is created to operationalize a business process (or a part of it). During run time, this workflow definition is repeatedly instantiated to execute the occurring business cases in exactly the same manner over and over again. For about 15 years, various approaches are discussed to address the flexibility needs of PAIS [5,16,13,17]. Schonenberg et al. [17] present a classification of flexibility approaches into four types: flexibility by definition, flexibility by change, flexibility by deviation, and flexibility by under-specification. *Flexibility by definition* refers to the ability to consider alternative execution paths in the process model during the modelling (build time). Traditional WFMS already support this type of flexibility. It can only take into account foreseen and predictable events and changes. *Flexibility by change* describes approaches that permit changes of process definitions and/or instances during run-time while maintaining consistency. *Flexibility by underspecification* refers to the ability to execute process descriptions which are not fully specified. Thus, certain decisions can be deferred to an appropriate point in time during process execution. Late modelling and late binding are two techniques used for this purpose. *Flexibility by deviation* refers to the forth and so far only rarely explored class of approaches that offers the possibility that the real-world process execution differs from the modelled process without the need to modify the process definition in advance.

An essential characteristic of all flexibility approaches is the fact that process modelling and execution are not strictly separated any more as in classical workflow systems [1,13]. Thus, a modification or a late modelling during runtime can be considered a re-modelling of the workflow that immediately effects its execution. However, modifying a workflow requires significant skills in the domain as well as in process modelling. Decisions must be taken concering how

the workflow is modified and how this modification is formalized in the underlying workflow modelling language. Hence, methods are required that support users in performing such modifications. ADEPT/AristaFlow [16] and CAKE [3,13] are two advanced workflow systems which support flexibility by change and underspecification and which include methods to support users in reusing best-practice workflows.

3 Introducing Process Flexibility into Deficiency Management Systems

Based on an analysis of current DMS in construction available on the German market in summer 2014 [6] and four interviews with construction experts, we now derive a set of requirements for future more advanced DMS. We mainly focus on those requirements that related to the support by flexible PAIS. Additionally, we show how these requirements can be implemented based on the generic framework CAKE for integrated process and knowledge management. To provide a general understanding of the DM, we sketch the main processes and characteristics of this domain firstly.

3.1 Deficiency Management in Constructions

The entire DM process consists of several sub-processes addressing different steps of the overall DM process. It begins with logging a deficiency. General information like issuer name and company are recorded, as well as specific information such as deficiency description, floor, space, required action, and additional issuer notes. Motzko and Racky [14] point out the importance of a comprehensive record keeping of the deficiency in a centralized and dedicated area due to regulatory demands and further business needs. The entered information is verified and complemented by a responsible person inside the construction company. Next, the particular kind of deficiency must be identified. For example, deficiencies like wall cracks are described by different criteria such as appearance (e.g. a single or a bundle of cracks), crack width, or possible impacts such as impairment of the structural integrity. Depending on the reported deficiency, a visual on-site inspection is necessary in order to define the correct deficiency type and to decide an applicable rectification method. Further, it has to be check if it is eligible for deficiency rectification (DR) under warranty, for instances, if the deficiency was caused by liable a subcontractor. In addition the DR has to be assigned to construction workers for execution. The processing of the DR has to be controlled until its completion to ensure the timely finalization in accordance with the contract. Therefore, the accurate tracking of all open DRs is important. Overall, DM must incorporate all involved parties, including all subcontractors [14]. DMS aims at supporting DM by providing IT support for the relevant activities involved in DM. Today, a large variety of DMS exists, with different strengths and weaknesses. Thus, we analysed the process flexibility approaches implemented by these systems and determined that more advanced

flexibility approaches than flexibility by definition are not implemented in any of the investigated systems [6].

3.2 User Requirement

The below described requirements have been derived based on the results of the interviews, also considering general regulatory requirements in DM [8] where necessary. We illustrate the most important requirements by examples, providing typical use cases of an envisioned future DMS.

R1: Support for process flexibility. Future DMS must enable flexibility by change and by underspecification. In particular, ad-hoc changes of workflow instances must be supported as well as late binding. An additional argument in favour of these methods is the fact that process instances must remain aligned with the activities in the real world in order to support tracing of DM processes as well as their accurate documentation. Further, flexibility by definition is required due to the high process variability. *Example:* An assigned construction worker receives a work order to fix a wall crack based on a process for elastic sealing. On the construction site s/he investigates the cracks and after cleaning s/he recognises that there is no need for an elastic sealing as due to drying shrinkage it is likely that the cracks will stabilize. Therefore, a structural strengthening non-elastic injection system is more effective. Using a mobile device, the worker immediately modifies the running process. S/he deletes those activities that are not relevant any more, i.e., "Prepare elastic sealing material" and "Apply two layers with the injection system". Then, s/he adds the activity "Prepare non-elastic injection material" followed by the activity "Inject material into crack" at the appropriate position in the workflow instance.

R2: Collaboration support and role-based access control. A process-oriented collaboration platform is needed for coordinating all activities involved in DM and for supporting the necessary communication and documentation needs. As a large variety of parties and persons are involved in DM, such a platform requires a role-based access control. The access control must enable a detailed control of access rights for all resources, in particular on the level of individual tasks. *Example:* The investigation of a reported deficiency yields that it was caused by a liable subcontractor. Hence, several tasks of the DR process must be assigned to some of the subcontractor's employees. Therefore, the responsible project leader from the subcontractor accesses the DMS. Due to her/his access rights s/he is able to make the respective assignments, but only for those tasks, his company is in charge of.

R3: Knowledge-sharing of best-practise processes. Future DMS supporting process flexibility should also support knowledge-sharing of best-practice workflows. Successfully finished DM processes should be captured and stored in a repository. Further, the reuse of best-practice workflows should be supported, thus asking for appropriate means for navigation and search in the repository. This requirement particularly arose in the interviews and is considered a means to improve efficiency and quality in the context of the large variability in DM. *Example:* After the successful termination of the DR process for repairing a

crack, the project leader can store the particular workflow instance as a best-practise workflow in a repository. During this process, all case-specific data is removed and the workflow is generalised towards a workflow definition. At some later point in time, a similar type of crack must be fixed. By search in the repository, the previously stored workflow definition is found. It can be instantiated (and adapted if necessary).

In addition to these three requirements addressing process flexibility and closely related aspects, several further, more general requirements must be met as well by future DMS. For example, the usability of such a system must be particularly ensured by an intuitive user interface enabling to control the flexibility functions of the PAIS. Also a simple graphical modelling language for workflows is required to enable staff from construction companies to perform workflow modelling without the need to involve their IT personnel. Further, providing access to the DMS via mobile devices is important, as deviations from planned DR processes are mostly discovered at the construction site.

3.3 CAKE – Collaborative Agile Knowledge Engine

We now briefly describe CAKE, a generic framework for integrated process- and knowledge management [3] and explain how it could be used to fulfil the identified requirements. CAKE integrates an agile workflow engine with a so-called knowledge engine that supports process reuse as a particular kind of knowledge-sharing. The agile workflow engine is used for the enactment of agile workflows and supports their collaborative modelling and adaptation in a consistent manner. The workflow engine enables flexibility by change as it allows users to model and change workflow definition and instances at any time, provided that the user is granted the respective access right. Further, a simple graphical modelling language is available that allows modelling, execution monitoring, and adaptation of workflows within a browser-based editor. The modelling language includes placeholder task, thus late binding is supported. So, CAKE is in line with requirement R1.

The purpose of the knowledge engine is to support users in finding, defining, and adapting workflows according to their current needs. The knowledge engine implements a process-oriented case-based reasoning (CBR) method [12]. CBR is an established AI methodology for problem solving based on the assumption that similar problems have similar solutions [2]. The CAKE knowledge engine maintains a repository of workflows which can be semantically annotated using terms from a domain ontology. It supports workflow reuse by similarity-based retrieval of workflows. Thus CAKE is in line with requirement R3.

Finally, the CAKE framework consists of a storage layer that implements a role-based access control mechanism for all resources managed by CAKE, in particular workflows, tasks, documents, services, etc. The access control mechanism is a decentralized discretionary access control with subject-object relationships specified in access control lists. Thus CAKE is in line with requirement R2. The overall CAKE software is implemented as Web-based system. The client user interfaces enable access to all workflow related functions such as workflow

modelling, execution, similarity-based retrieval, and adaptation using a standard browser. Further, the CAKE Server API also allows mobile applications to directly connect to CAKE, e.g., to support the mobile execution of tasks on an Android-based device.

3.4 Applying CAKE for Building a Prototype for Deficiency Management

We build the first version of a prototype for demonstrating and evaluating the benefits of process flexibility in DM. For this purpose, we selected a subfield of frequently occurring deficiencies in construction, namely cracks in facades and masonry[1]. We collected technical background documentation and a set of process descriptions of respective DR processes from the construction companies contacted during the interviews. Based on this documentation, we developed an ontology of the relevant DM tasks and building materials, as well as a deficiency ontology to classify and describe different kinds of cracks. Further, we formalized the provided process descriptions using the CAKE workflow editor and thereby we created a repository of initial best-practice workflows. The resulting domain-specific CAKE instance can then be used to support the DR process as illustrated in the following use case.

Use Case: A series of cracks is a reported to the project manager of a construction company. An initial assessment of the cracks takes place, leading to a description of the cracks w.r.t. the deficiency ontology. Based on this description, the project manager searches for applicable workflows in the best-practice repository. S/he selects a DR workflow for "elastic sealing of cracks", starts a new workflow instance for this case, and assigns a construction worker to the repair tasks. While performing the first activity of the workflow, which is the cleaning of the cracks, the worker recognises that most of the cracks exceed the maximum size allowed for sealing with a flexible injection system. To clarify which alternative method could be used, s/he searches for similar workflows in the best-practice repository. The knowledge engine of CAKE retrieves several workflows which are similar to the present workflow but which are in addition suitable for larger cracks (see Fig. 1). After inspecting the proposed workflow s/he decides to apply the method of stitching instead of sealing for repairing the crack. Thus, the workflow editor of CAKE is used to adapt the workflow to include the new activities "drill holes on both sides of the crack" and "grout in u-shaped metal units". The worker now follows the adapted workflow to complete the repair, guided by the CAKE workflow engine.

4 Conclusion, Related, and Future Work

In this paper, we have revealed that DM in construction is a new and very promising application area for flexible PAIS. Due to the fact that deficiencies

[1] See http://theconstructor.org/concrete/methods-of-crack-repair/886/.

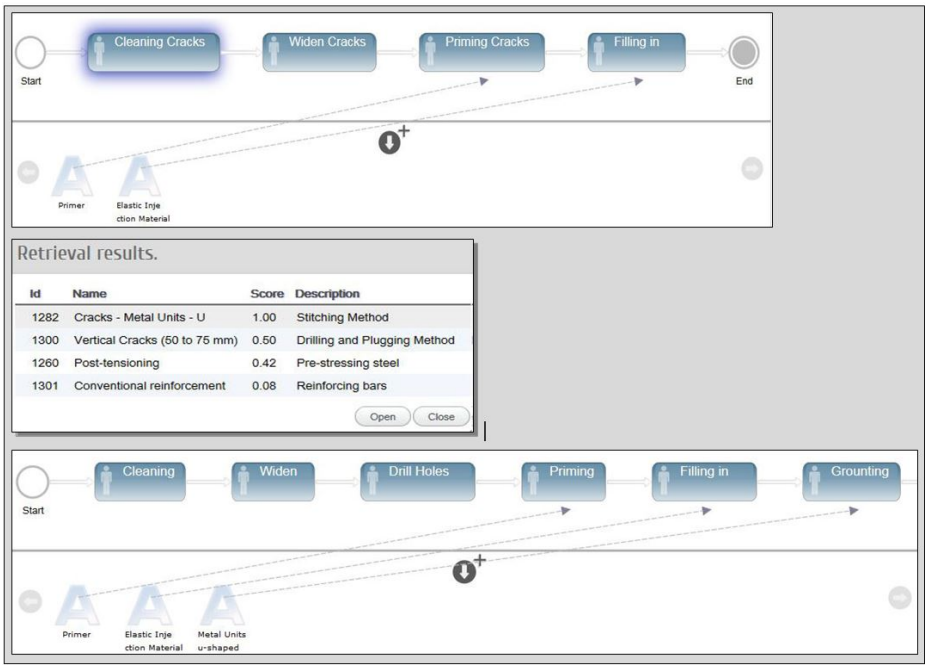

Fig. 1. Screenshots from the DM prototype built using CAKE

always occur unplanned and often require an immediate remedial action, it is essential that resulting process changes are performed during runtime. High process flexibility ask for flexibility approaches by change and/or underspecification. We have presented a concept and an initial prototype for a PAIS that addresses these needs based on the prototypical generic software system CAKE for integrated process and knowledge management and briefly demonstrate its feasibility by a first use case.

The application of process management and workflow systems in the construction industry is discussed for more than ten years in the scientific literature. Rüppel and Klauer [9] developed a workflow application that supports construction projects, but they do not consider the needs of process flexibility related to foreseen and/or unforeseen changes. Körten [11] comprehensively investigates the use of information technology to support construction processes. The BauVoGrid project aims at developing a grid-based framework for supporting construction processes. It also includes workflow components as well as semantic technologies. The project results demonstrated in the field of DM [10]. However, process flexibility is not addressed by this project. Although the investigation of unforeseen changes within process execution in construction was already considered in 2005 [9, p. 118], we are not aware of any in-depth research on this topic so far.

Future work will focus on tailoring CAKE for DM and on developing a full prototype that can be demonstrated to the construction industry. Based on such a prototype, more detailed case studies concerning the usability and potential benefits in DM can be performed. Another potential direction of future research is the investigation of new approaches for flexibility by deviation, which have the potential to void the need for explicit workflow adaptation. Such approaches might be able to better support processes in DM where only the purpose is known in advance, but not the precise order of steps that need to be executed.

References

1. Van der Aalst, W.: Business process management: A comprehensive survey. ISRN Software Engineering (2013)
2. Bergmann, R.: Experience Management: Foundations, Development Methodology, and Internet-Based Applications, LNAI, vol. 2432. Springer (2002)
3. Bergmann, R., Gessinger, S., Görg, S., Müller, G.: The Collaborative Agile Knowledge Engine CAKE. In: Proceedings of the 18th International Conference on Supporting Group Work. pp. 281–284. GROUP '14, ACM, New York, NY, USA (2014)
4. Dumas, M., van der Aalst, W., ter Hofstede, A.: Process-aware Information Systems: Bridging People and Software Through Process Technology. John Wiley & Sons, Inc., New York, NY, USA (2005)
5. Fleischmann, A., Schmidt, W., Stary, C., Augl, M.: Agiles Prozessmanagement mittels Subjektorientierung. HMD Praxis der Wirtschaftsinformatik 50(2), 64–76 (2013)
6. Frei, K.: Mängelmanagement im Bauwesen – Marktübersicht von Software zum Mängelmanagement und Nutzenpotenziale agiler Prozessunterstützung. Master thesis, University of Trier (2014)
7. Gessinger, S., Bergmann, R.: Potentialanalyse des prozessorientierten Wissensmanagement für die Baubranche. In: Henrich, A., Sperker, H.C. (eds.) LWA 2013. Lernen, Wissen & Adaptivität ; Workshop Proceedings. pp. 212–219 (2013)
8. Hechtl, A.: Kooperation im Bauwesen. Bautechnik - Zeitschrift für den gesamten Ingenierbau 79(6), 396–401 (2002)
9. Klauer, T.: Eine prozessorientierte Kooperationsplattform für Bauprojekte auf Basis eines internetbasierten Workflow-Managements. Ph.D thesis, Shaker (2005)
10. Klose, S., Angeli, R., Dollmann, T., Ernst, T., Fellmann, M., Hilbert, F., Hoheisel, A.: Spezifikation der mobilen Workflow Enactment Engine, der entwickelten Referenzprozessmodelle und der mobilen Dienste. Tech. Rep. BauVOGrid-Bericht A-5.1 (2010)
11. Körtgen, M.: Optimierungsansätze zur prozessorientierten Abwicklung komplexer Baumaßnahmen unter Einsatz neuer Informations- und Kommunikationssysteme. Ph.D thesis, Kassel University Press, Kassel (2010)
12. Minor, M., Montani, S., Recio-García, J.A.: Process-oriented case-based reasoning. Information Systems 40, 103–105 (2014)
13. Minor, M., Tartakovski, A., Schmalen, D., Bergmann, R.: Agile Workflow Technology for Long-Term Processes - Enhanced by Case-Based Change Reuse. In: Methodological Advancements in Intelligent Information Technologies: Evolutionary Trends, pp. 279–298. IGI Global (2010)
14. Motzko, C., Racky, P.: Erfolgsfaktoren für eine reibungslose Abnahme. Baumarkt und Bauwirtschaft 101, 30–33 (2002)

15. Oswald, R., Abel, R.: Leitfaden über hinzunehmende Unregelmässigkeiten bei Neubauten. Bau-Verlag (1996)
16. Reichert, M., Weber, B.: Enabling Flexibility in Process-Aware Information Systems: Challenges, Methods, Technologies. Springer, Berlin-Heidelberg (2012)
17. Schonenberg, H., Mans, R., Russell, N., Mulyar, N., Aalst, W.v.d.: Process Flexibility: A Survey of Contemporary Approaches. In: Advances in Enterprise Engineering I, pp. 16–30. No. 10 in LNBIP, Springer Berlin Heidelberg (2008)