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An Overview of Tools for an Integrated and Adaptive Healthcare Approach

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***Abstract*—Integrated care approaches are becoming increasingly relevant with the current aging population. In the context of an integrated healthcare project, we developed a smart adaptive case management system for professionals that is currently being used for clinical trials. In this paper, we present the modeling requirements for integrated healthcare applications and use them to categorize and compare existing implementation approaches used in practice.**

***Index Terms*—Modeling, Adaptive Case Management, ACM, Healthcare**

I. Introduction

The demographic change in Europe is leading to a significantly aging population. The number of aged chronic patients increases. The objective of the Personalized Connected Care for Complex Chronic Patients (CONNECARE) project is to provide an integrated patient-centered health-care approach [1]. This research project focuses on medical aspects, information and communications technology evaluated within clinical trials at four hospitals across Europe. Conceptually, the prototypical system contains Smart Adaptive Case Management (SACM), which is used by clinical professionals, and the Self-management System (SMS), which provides patient-centered mobile applications that provide instructions prescribed by the clinical professionals. In the following, we are focusing on aspects of SACM. In [2], we present a holistic model-based adaptive case management approach for healthcare that focuses on challenges of integrated care approaches, iteratively derived requirements, conceptual features of user interfaces and related conceptual model elements. In [3], we present a practice-proven reference architecture for model-based collaborative information systems that is used as a core modeling engine to provide Adaptive Case Management (ACM) support.

This paper presents an overview of tools based on our derived requirements from [2]. A summary of the high-level requirements is provided in Section II, a sample use case from the clinical trials is described in Section III, and the existing tools are categorized, summarized and compared according their related requirements in Section IV.

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II. Requirements

We iteratively collected and adapted the high-level SACM requirements for each hospital. The high diversity across the different sites lead to several agile iterations. The initial requirements presented in [2] as follows:

R1	***Support a model-based full stack approach*** To cope with the high diversity across treatments and hospital sites, a fully model based approach should be used, and the treatment or site-specific adaptations should be applied within the related meta-model including different clinical questionnaires or languages.
R1.1	*Support data schema models* Data that are generated during the execution of the process models need to be modeled. In addition, they are needed to model data that will be integrated from third-party systems, e.g., patient data from hospital information systems.
R1.2	*Support adaptive process models* The system needs and support to define adaptive treatment plans that are customized to the specific needs of the hospital and treatment. As a reference methodology for defining the processes, Adaptive Case Management (ACM) should be used. To support integrated care, these processes need to be synchronized with other subsystems.
R1.3	*Support role-based access right models* The system needs to support granular role-based access control mechanisms to define which clinicians are allowed to access which patient data. In addition, clinical tasks need to be assigned based on roles.
R1.4	*Support simple user interface models* In general, the user interface needs to represent each model element in a generic model-based manner. To support clinical use cases, special representations need to be generated that can also be reused as a model elements.

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R2 ***Support third-party system integration*** The system needs to use centralized user identity management, orchestrate processes across system boundaries, and support external data sources.

R2.1 *Support external user identity management* The system needs to provide a Single Sign-On (SSO) for professionals; therefore, external user identity management must be supported. To simplify integration, foreign identifiers should be used as internal primary keys.

R2.2 *Support process orchestration for third-party systems* To provide integrated care, the system needs to support the orchestration of external systems. External systems processes, such as processes of the SMS, should be seamlessly integrated to provide an aggregated interface for professionals.

R2.3 *Support integration of external data sources* Hospital information systems with extensive amounts of patient data exist. Therefore, the system architecture needs to consider enhancing internal data with external data sources.

R3 ***Support coordination and communication*** The system needs to support notifications, text messages, unstructured case notes, and clarify where individual contributions are needed.

R3.1 *Support notifications* The clinicians can prescribe patients certain tasks via the SMS system such as measure your blood pressure every morning. If the blood pressure exceeds a individually specified threshold, the system should notify the responsible clinician. Unforeseen technical situations should also lead to notifications of the professional users.

R3.2 *Support continuous communication* Case-based clinician-to-clinician messages need to be supported for information exchange. Therefore, all involved clinicians should be able to follow ongoing conversations. To provide integrated care, direct communication with the patient needs to be supported in a separate conversation.

R3.3 *Support case notes* In addition, to the semi-structured workflow, the system needs to provide a wiki-based notes area where clinicians can collaboratively document unstructured information as well. Individual predefined templates should be provided depending on case definitions.

R3.4 *Indicate needed contribution* A single case contains many tasks that need to be accomplished by either a professional or the patient. The system needs to support assigning tasks to professionals based on their roles. Normally, professionals have multiple cases, therefore the system needs to provide a dashboard to indicate where contributions are needed.

III. Sample Use Case

This section characterizes the modeled workflow for a clinical case study according the structural degree defined by [4]. Figure 1 illustrates in color the structural degree: 1) fully structured processes that do not allow any exceptions during the process execution and are classically modeled with BPMN, 2) structured processes with ad-hoc exceptions to cope with exceptions such as skiping a task or repeating a task, which is a classical ACM use case, 3) unstructured processes with pre-defined fragments that combine fragments as needed to cope with not exactly predictable situations, which is a classical ACM use case, and 4) unstructured processes that are unpredictable and are executed on an ad-hoc basis without a template. Structured processes are characterized as predictable and have low flexibility, the degree of automation is high, and the process execution is not knowledge intensive. Conversely, unstructured processes are characterized as unpredictable and have high flexibility, the degree of automation is low, and the process execution is knowledge intensive.

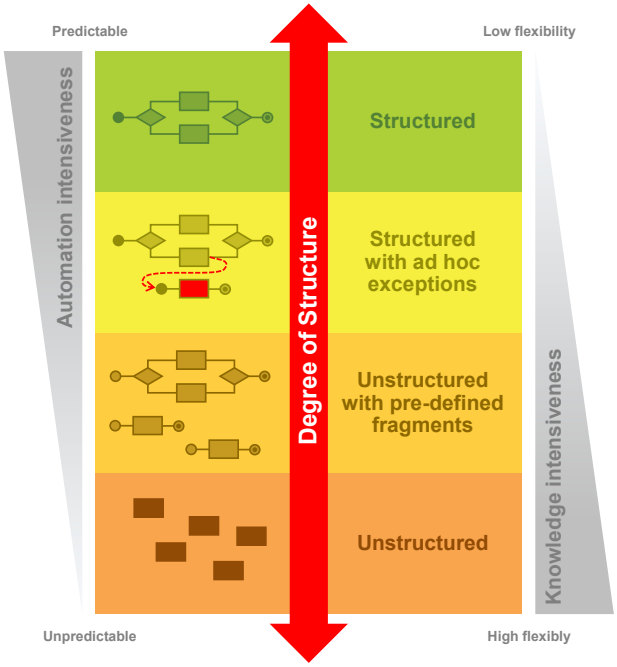

Fig. 1. Structural degrees for workflows according to [4].

Figure 2 illustrates a case study of a clinical trail notated in CMMN. The presented case study is structured in four stages that are colored according the general structural degree. Within the structured **Case Identification** stage, the users for the various professional roles are assigned, the patient consent form is checked, and two initial clinical questionnaires are completed. During the **Case Evaluation** stage, several clinical questionnaires, e.g., Charlson[1], are performed to define a patient-centered treatment plan. This stage is repeated over time to track the patient's progress. This process is structured

[1]http://www.bgs.org.uk/pdfs/assessment/cci.pdf

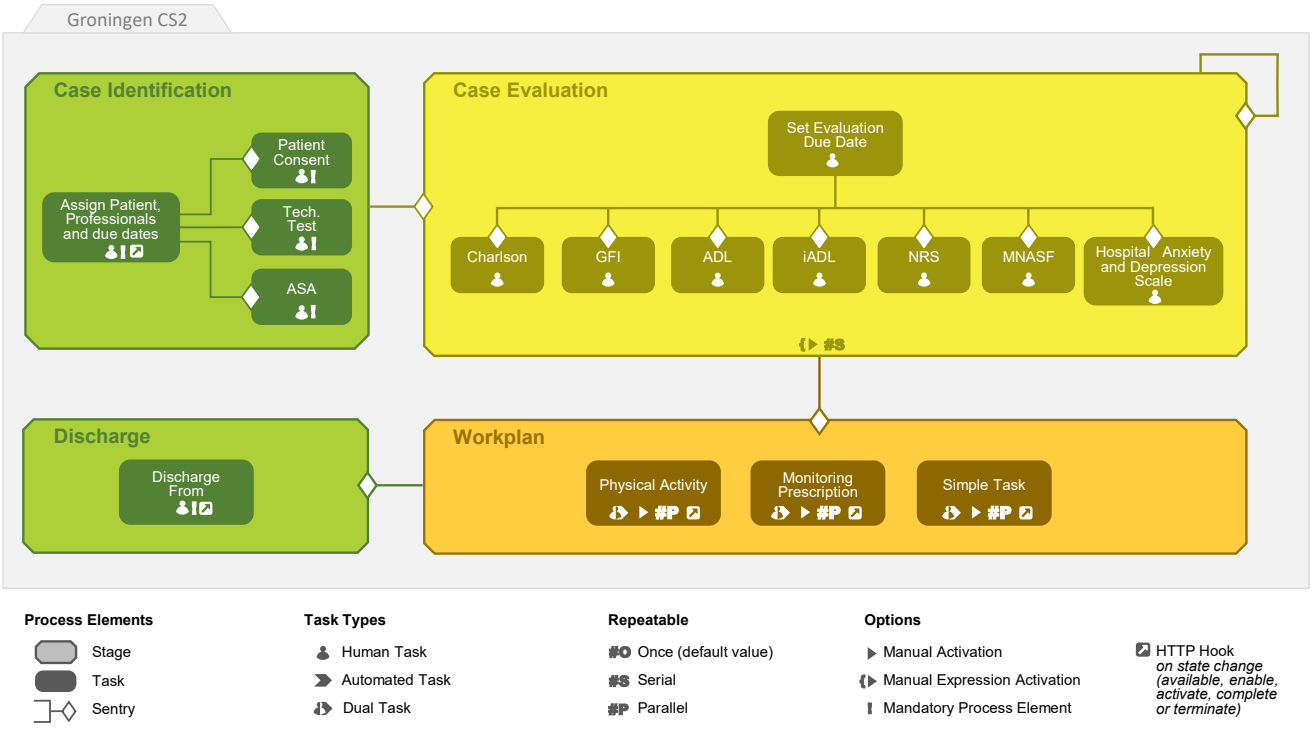

Fig. 2. A sample case of the clinical trails modeled in CMMN and colored according to the degree of structure.

with ad-hoc exceptions such as skipping a questionnaire if its not applicable to a certain patient. In the **Workplan** stage, clinicians define an individual patient-centered treatment plan based on the predefined process fragments. Compared to the previous stages, this stage is very knowledge intensive due to the high flexibility during workplan execution. The defined tasks are then performed by the patient and continuously monitored by the clinician. Finally, in the **Discharge** stage, a discharge form is completed. During the case execution, unstructured information exchange is necessary, e.g., similar to a wiki page.

IV. Tool Overview

This section analyzes existing tools that can be used or combined to provide an integrated care software solution. Process modeling is a software area where new tools and new functionalities are continuously appearing, so this analysis of the solutions is framed during the time the CONNECARE project was active. We selected an essential set of promising, well-known, and state-of-the-art tools based on the expertise and discussions between the chairs in the CONNECARE Consortium. We used for the analysis of the tools, publicly available information such as documentation, tutorials, which we extended it with gained knowledge from attending vendors workshops.

It is primary to indicate that all the analyzed tools can be adapted to address the requirements of the integrated care solution. We described in Section III the variating degree of process structure within a clinical case study and explains the significant differences across stages. Based on the process model strategy, we assumed four main approaches (i.e., BPMN, ACM, Ad-hoc Task-Centric, and Data-Centric Approaches) that can be used to categorize the tools based on the typical problems they claim to solve. Therefore, we classified the tools into capabilities which are needed to provide a holistic, integrated care solution. Table I presents a summary of existing tools that are group according to the following categories:

- **BPMN Approaches** The Business Process Model and Notation (BPMN) is used as a de-facto standard to express highly structured processes [5]. The tools in this category comprise two main components, the process modeler, and the process engine. The process modeler allows the domain experts to create process models in BPMN using a Graphical User Interface (e.g., *OMNINET BPMN* and *Bonita BPM*). Then, the process engine can execute the process and manage all the running process instances(e.g., *OMNINET BPMN* and *Bonita BPM*). Additionally, the tools can be integrated with existing information systems. Even though these tools cover the essential requirements for modeling structured process (e.g., R2), we found limitations to support the clinical case study entirely. First, the lack of mechanisms to allow and reuse the changes that could emerge in the operational environment. Second, the data modeling capabilities are limited to forms linked to process steps, which

TABLE I
TOOLS ACCORDING TO THE PROCESS STRUCTURAL DEGREE AND THE SACM REQUIREMENTS.

Tool	Structured	Structured with ad hoc exceptions	Unstructured with ad pre-defined fragments	Unstructured	**R1 Support a model-based full stack approach**	R1.1 Support data schema models	R1.2 Support adaptive process models	R1.3 Support simple user interface models	R1.4 Support role-based access right models	**R2 Support third-party system integration**	R2.1 Support an external user identity management	R2.2 Support process orchestration for third-party systems	R2.3 Support integration of external data sources	**R3 Support coordination and communication**	R3.1 Support notifications	R3.2 Support continuous communication	R3.3 Support case notes	R3.4 Indicate needed contribution	Link
OMNINET BPMN	●	◐	○	○	◐	●	○	◐	○	◐	●	◐	◐	◐	○	○	○	◐	de.omnitracker.com
Bonita BPM	●	◐	○	○	◐	●	○	◐	●	◐	○	◐	○	◐	○	◐	○	◐	www.bonitasoft.com
Camunda	●	●	●	◐	◐	●	●	◐	●	●	●	●	●	◐	○	○	○	◐	camunda.com
Ground Lion	●	●	●	◐	◐	●	●	◐	○	◐	●	●	○	◐	○	○	○	◐	www.groundlion.be
IBM Case Manager	●	●	●	●	◐	●	●	◐	●	●	●	●	●	◐	○	○	○	◐	www.ibm.com/de-en/marketplace/case-manager
PEGA	●	●	●	●	◐	●	●	◐	●	●	●	●	●	◐	○	○	○	◐	www.pega.com/de/node/72986
todoist	○	○	○	●	○	○	○	○	○	◐	○	○	●	◐	○	○	○	●	de.todoist.com
Trello	○	○	○	●	○	○	○	○	○	◐	○	○	●	◐	○	○	○	●	trello.com
Wunderlist	○	○	○	●	○	○	○	○	○	◐	○	○	●	◐	○	○	○	●	www.wunderlist.com
Wordpress	○	○	○	●	○	○	○	○	○	○	○	○	○	◐	○	○	◐	○	de.wordpress.org
Durpal	○	○	○	●	○	○	○	○	○	○	○	○	○	◐	○	○	◐	○	www.drupal.org
Typo3	○	○	○	●	○	○	○	○	○	○	○	○	○	◐	○	○	◐	○	typo3.org
Tricia	○	○	○	●	◐	●	○	○	●	◐	●	○	○	◐	○	○	●	○	infoasset.de
Confluence	○	○	○	●	○	○	○	○	○	○	○	○	○	◐	○	○	●	○	de.atlassian.com/software/confluence
MediaWiki	○	○	○	●	○	○	○	○	○	○	○	○	○	◐	○	○	●	○	www.mediawiki.org
Semantic MediaWiki	○	○	○	●	◐	◐	○	○	○	○	○	○	○	◐	○	○	●	○	www.semantic-mediawiki.org
backendless	○	○	○	●	◐	●	○	○	○	◐	○	○	●	◐	●	○	○	○	backendless.com
Firebase	○	○	○	●	◐	●	○	○	○	◐	○	○	●	◐	●	○	○	○	firebase.google.com
Parse	○	○	○	●	◐	●	○	○	○	◐	○	○	●	○	○	○	○	○	parseplatform.org
SACM	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	connecare.eu/sacm

Legend: ● full supported ◐ partly supported ○ not supported

has implications for adding social features (e.g., R3) to the process and support customizable user interface models (e.g., R1).

- **ACM Approaches** Adaptive Case Management (ACM) is classically used for knowledge-intensive use cases where the degree of automation is low [6]. *Camunda* is an open source workflow engine for large-scale processes that support BPM, ACM and decision modeling. Compared to similar tools the implementation is conceptually close to the Case Management Model and Notation (CMMN)[2] standard specified by the Object Management Group (OMG). Within the eco-system of *Camunda* micro-services such as 1) a CMMN based modeler, 2) a generic case interface which might be a bit overwhelming for none-technical users, and 3) a visual case tracing tool which helps to detect eventually occurring bottlenecks during case execution exists that can be individually assembled to an application landscape. An impressive

[2]https://www.omg.org/spec/CMMN/1.1/PDF (Accessed on 8th of Aug. '18)

feature is nesting an ACM subprocess into a superordinate BPMN process. *Ground Lion* is a sophisticated Belgium enterprise ACM tool provider that provides as well a generic case client comparable with *Camunda*. The license fees for a minimal test setup are a few thousand EUR even for academic usage (Offered from the customer service during a call last year). *Camunda* and *Ground Lion* offers the possibility to model simple forms a custom user interface representation. Other illustrative examples are *PEGA* and *IBM Case Manager*. *PEGA* is a platform for process automation that supports BPM and case management mainly for customer relationship. The *PEGA* platforms emerge from the CRM and marketing fields to reuse the most essential elements to engage customers. Additionally, it provides smooth integration with several enterprise areas such as Marketing, Sales, Customer Services, etc. On the other hand, *IBM Case Manager* provides complete generic case management capabilities. However, the separation between the user interface models and the process and data-models requires coding skills or specific languages knowledge (e.g., layouts components to align input fields). Whereas none of those supports to extend generic the user interface representation with domain-specific representations such as a threshold based coloring for numeric values, or a body visualization that indicates the patients health status (R1.3). All tools support a significant part of the full-stack model approach (R2) but lack mainly supporting the required coordination and communication (R3).

- **Ad-hoc Task-Centric Approaches** Ad-hoc task driven approaches are used for unstructured not repeating use cases. *Trello* uses the Kanban principle to organize the ad-hoc task whereas *Wunderlist* and *todoist* using a list based approach. All three tools support granting access rights to collaborating members, to accomplish tasks collaboratively. Delegating tasks is as well as possible. The task state handling is solved in different ways, *Trello* changes the state by e.g. moving a task into the archive and both other tools allow to check a task. Conceptually, all three tools are close to each other, all support indicating needed contribution (R3.4) and support the integration of external data sources (R2.3) via REST APIs. Simple access rights are supported but they not role bases as required (R1.4). *Trello* provides simple notifications created based on task meta-model such as a task is overdue but does not support the integration of custom domain specific notifications (R3.1). In addition, all three tools are only available as SaaS which is critical from the legal perspective.
- **Data-Centric Approaches** Data-Centric approaches are based on the document management approaches and traditional social software [7]. These cases, the process must be mapped to a basic operation (i.e., `Read`, `Create`, `Update`, and `Delete`) over the data. Therefore, the modeling process starts with the definition of the content model (e.g., the content types, fields, and their relations). The content model is fixed in cases such as *Wordpress*, *Typo3*, and *Confluence*, as a result, the process can be mapped only to the content workflow. However, other tools such as *Drupal*, *MediaWiki*, and *Trica* are based on explicit dynamic types so that the process can be mapped to the changes in the content and content types workflow. With the development of mobile technologies, a new set of tools has emerged based on the dynamic content to support integration with different formats of content (e.g., mobile notifications in *Parse* and *Firebase*). The flexibility to create, maintain and evolve data and models in these tools, which can be extended using a user interface and role-based access rights models (i.e, R2), and the support of social features and mobile devices (i.e, R3) makes these tools a valid candidate to implement the clinical case study. However, the main limitation of these tools is the lack of mechanisms to incorporate steps (e.g., computer tasks) to the process that are not related to the data, which are necessary to document and reuse the process.

V. Conclusion

Considering the clinical case study described in Section III, that leads to the requirements illustrated in Section II, there is currently to the best of our knowledge no off-the-shelf approach, that provides a holistic model-based approach for healthcare such as the SACM system. Alternative scenarios are 1) extending an open source available data-driven tool to support process and communication capabilities, 2) extending existing work-flow engines with data-modeling and communication capabilities, or 3) using a generic workflow engine that is embedded in a hard-wired use-case-specific application. Currently, based the best practices presented during a *Camunda* workshop in Munich in November 2016, the most common examples and solutions that scale to several large-scale enterprises are the elaborated based on scenario three.

However, the main limitation is the needed effort building a use-case specific application. As a thumb rule, it was mentioned that on average approx. 10,000 case instances are required that the effort is worth it. During the CONNECARE project we noticed that even if the conceptual objective of a case study is the same, the case model differs significantly. For example, site-specific questionnaires with customized scales are developed and used over the years.

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