DEPARTMENT OF INFORMATICS

TECHNISCHE UNIVERSITÄT MÜNCHEN

Guided Research in Informatics: Business Information Systems

Evaluating the Usability of Acadela: a Domain Specific Language for Defining Clinical Pathways in Integrated Care Platforms

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Evaluierung der Benutzerfreundlichkeit von Acadela: eine bereichsspezifische Sprache für die Definition klinischer Pfade in Plattformen für integrierte Pflege

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I confirm that this guided research in informatics: business information systems is my own work and I have documented all sources and material used.

Munich, 22.10.2021 Felix Eckert

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Abstract

The definition of adaptive clinical pathways in e-health systems can be complex and time-consuming. Therefore, we propose Acadela, a non-technical oriented, modularizable Domain-Specific Language to assist modelers in constructing clinical pathways. Acadela enables users to define responsible medical experts, and processes in a clinical pathway. To evaluate the accuracy and usability of the DSL, we conducted a user study with medical experts working as surgeon, gynecologist, dermatologist, physiotherapist and psychotherapist participated in the user study. In the first stage, three doctors were asked to model a simple pathway and state their impressions. In the second stage, five experts provided clinical pathways for modeling. The doctors were shown a demonstration of the models, and feedback was collected. The user study showed, that doctors prefer the models to be created by people with technical backgrounds, but could see themselves adapting pre-made models. Additionally, the medical experts perceive the clinical pathways were overall accurate.

Kurzfassung

Die Definition adaptiver klinischer Pfade in E-Health-Systemen kann komplex und zeitaufwändig sein. Daher schlagen wir Acadela vor, eine nicht-technisch orientierte, modularisierbare domänenspezifische Sprache, die Modellierer bei der Konstruktion klinischer Pfade unterstützt. Acadela unterstützt Experten aus dem medizinischen Bereich, Phasen und Aufgaben in einem klinischen Pfad zu definieren. Um die Genauigkeit und Benutzerfreundlichkeit der DSL zu bewerten, haben wir eine Benutzerstudie durchgeführt, in der die Experten aus den Bereichen Chirurgie, Gynäkologie, Dermatologie, Physiotherapie und Psychotherapie teilnahmen. In der ersten Phase wurden drei Ärzte gebeten, einen einfachen Pfad zu modellieren und ihre Eindrücke zu schildern. In der zweiten Phase stellten fünf Experten klinische Pfade für die Modellierung zur Verfügung. Den Ärzten wurden die Modelle vorgeführt, und sie wurden nach ihrer Meinung gefragt. Die Nutzerstudie zeigte, dass die Ärzte es vorziehen, wenn die Modelle von Personen mit technischem Hintergrund erstellt werden, dass sie sich aber auch vorstellen können, vorgefertigte Modelle anzupassen. Außerdem sind die medizinischen Experten der Ansicht, dass die klinischen Pfade insgesamt genau sind.

Contents

1 Introduction

Treating and diagnosing diseases is complicated and requires a lot of information. The process is supported by clinical pathways which define the steps as well as the needed information for the treatment and diagnosis. This gives doctors a guideline to follow. Overall, clinical pathways set out to contribute to two primary goals: ensuring precise and timely treatment procedures and guide the workflow [1].

While clinical pathways are a well-established and useful tool, the modeling tools for creating them are intricate. One efficient way for the creation is providing a purely text-based interface. One approach to achieve a text-based human-computer interaction interface is Domain Specific Language (DSL). They define grammar-based languages which are in contrast to regular programming languages bound to one application area. By specializing the language to suit the domain, an abstraction of the language is possible, which simplifies the usage compared to a general purpose language [2].

Other research proposes different approaches on how to leverage DSLs for modeling clinical pathways and/or the management of the healthcare sector. Due to a lot of required technical knowledge, a focus on specific medical fields or a lack of focus on individualisation for each hospital, the existing solutions can not fully reflect real life clinical pathways.

Our hypothesis in the study is using DSLs with medical, colloquial language and intuitive grammar for modeling clinical pathways could enhance the ease of learning and usability to technical experts, which increases the user experience, productivity and could even allow doctors to adapt models by themselves. We want to explore the potential of the DSL to model clinical pathways with varying complexity and from different medical application areas.

To validate our hypothesis, a two-stage user study with medical experts in different departments was conducted. In the first stage the participants modeled a simple clinical pathways using the DSL to gain insights on how comfortable they feel and who they see fit to to which part of the modeling. In the second stage, the medical professionals submitted clinical pathways from their field of expertise. Those pathways were modeled using the DSL and given to the experts for the evaluation of the accuracy.

The result of the user test showed, that medical experts show a interest in modeling clinical pathways by themselves, but often lack the time and technical background to implement them by themselves. Nonetheless, they feel confident to make small changes themselves. Being given a prepared model, they see a value added to their daily routines and perceive the clinical pathways as mostly accurate.

2 Related Work

Prior suggestions for DSLs for clinical context as well as the evaluation for usability of DSLs have been made. In the following the most relevant research is introduced.

Jennifer Munnelly et al. develop the DSL Aspect Language for Pervasive Healthcare (ALPH) with the goal to develop high quality software in the healthcare sector. To achieve this, their proposed approach focuses on abstracting the complexity of programming and increasing software quality through modularisation of concerns. ALPH suggests using aspect oriented programming to encapsulate domain crosscutting behavior in libraries. As a result, when building a full application for the healthcare industry, ALPH can be used for the definition of ubiquitous healthcare functionality, while the base application is implemented in Java [3]. While this concept seems promising to reduce the size of code and contributes to good code quality, having to learn two languages, one of them being a general purpose programming language, will complicate the learning process and might hinder medical experts without technical background from doing small changes to functionality by themselves.

Heß et al. tackle the issue that existing approaches to model clinical pathways are often too low level. Often they also do not reflect domain specific knowledge either. They see a DSL as basis to model clinical pathways, that can be integrated into a information system, which is able to handle the intricacies of the routines in hospitals. Within an iterative process in cooperation with a hospital, the research team developed a model language and a graphical interface to please their stakeholders wishes. While all core concepts could be easily identified, the design of a generalized model that takes all necessary attributes into account turned out to be difficult. Because of the complexity of the research goal, their focus stayed on oncology rather than for all medical fields [4].

Burwitz et al. address that current healthcare applications mostly focus on documentation, while neglecting the potentially highly useful transformation, execution and formal interpretation of the collected data. A DSL is proposed that in user-tests performs a decent ability to model clinical pathways, take aspects of evidence-based medicine into account and perform tasks of a workflow management system. One topic that they propose further research on is caused by the lack of predictability in the everyday routine of hospitals. Having a easy to change model that is flexible and can be adapted to fit individual hospitals needs permanently would help solve said problem [5].

3 Adaptive Clinical Pathway

3.1 Clinical Pathways

Clinical pathways have been introduced to the healthcare system in the 1980s and are used to standardize the treatment process [1]. Through standardization variation is reduced and the quality of the treatment improved. Clinical pathways define suggestions for medical staff to follow during the treatment process [6]. Usually, the suggestions are specified for patients that can be clustered by age and/or similar health conditions. The resulting limitation of pre-identified variation in patient outcomes and costs allows for a fast and efficient treatment without reduction of quality [1].

3.2 Elements of Clinical Pathways

Despite the large variety of application fields and therapies in the medical field, clinical pathways can abstract recurring elements. One aspect that should be explicitly defined are responsibilities. Especially in fast paste environments like hospitals, every staff member needs to know which parts of the process they are in charge of as well as which parts they are not authorized to execute. The assignment of responsibilities can be instantiated to individual people or by using roles. Roles are labels that categorize groups of stakeholders with equal access rights.

Within the process of one treatment process, different responsibilities can be selected for smaller sub-tasks, namely stages and tasks. The tasks are further differentiated by three sub-classes: *human*, *automated*, and *dual tasks*. They are in the same order executed by a human, by a third-party system or both consecutively. A *human task* could for example be typing in the result of a cytological test or selecting the age group of a patient. *Automated tasks* are usually calls to an Application Programming Interface (API) that can trigger internal or external events like the evaluation of possible complications when describing various medication combined. A *dual task* combines a *human* and *automated* task.

The different tasks can be bundled into stages. The grouping allows for concise overviews over tasks that need to be completed within the same time frame or to conditionally unlock tasks depending on certain preconditions. Stages can be defined to be executed once or to be repeated multiple times.

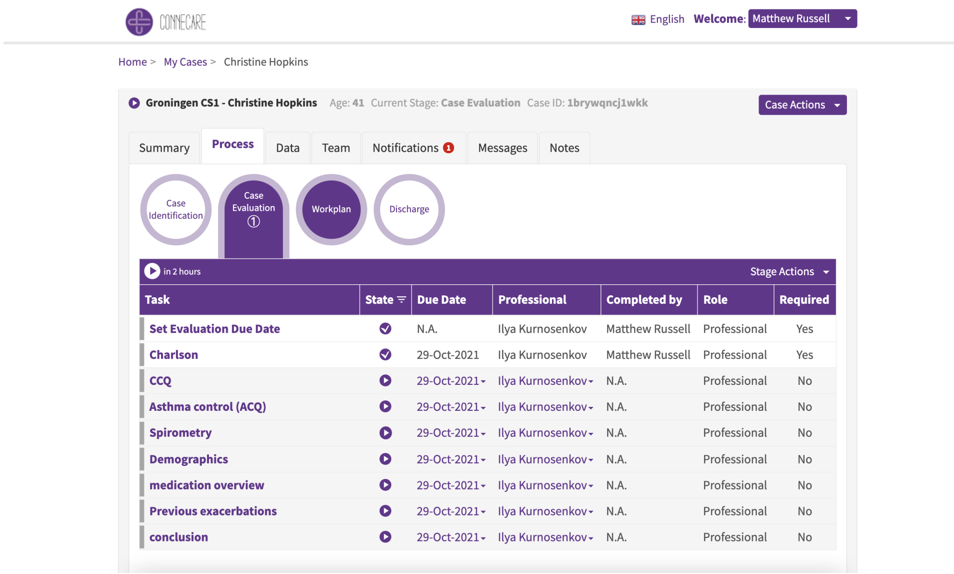


Figure 3.1: Example screenshot of SACM showing a selection of stages and tasks. Activated stage are highlighted in purple. Clicking on a stage will display all its tasks. In this case, the Case Evaluation stage is shown along with its pending and completed tasks.

3.3 Clinical Pathways in E-health systems

In clinics and hospitals using E-health systems, doctors and other medical staff document patient information digitally. Clinical pathways help structure the recording of data through the assignment of stakeholders to tasks. After the experts execute the tasks delegated to them, new stages and tasks are unlocked depending on the predefined conditions that applied to the assembled data or the status of the stage. Through the conditional unlocking of stages according to already given data, the experts only see relevant information for the current patients situation. The resulting display of existing data as well as currently needed information streamlines the treatment to make it more ascertainable and efficient.

3.4 Smart Adaptive Case Management (SACM)

We use SACM to visualize the execution of clinical pathways. SACM allows the orchestration of all relevant stakeholders independent of their association to a institution while preserving the hierarchy of access and editing rights. The system is focuses on patient-centric treatment across organizational boundaries by providing a customizable solution that caters to the needs of different hospitals, treatment, and patients [7]. The treatment process can be displayed and interacted with in a web-application. As exemplary shown in Figure 3.1 SACM displays stages in circles at the top of the "Process" tab with the corresponding tasks as a list below. Stages that are unlocked and not completed yet are highlighted in purple, while tasks to be completed are marked with a light grey background.

The goal of SACM originates from long ongoing and pressing problem: there are no digital and flexible tools for integrated care, despite it being a promising method for patient-centric treatment. Today's communication and documentation is nearly always paper based or handled by custom-built and rigid IT systems. The existing digital systems are not able to represent the huge variety of edge cases, nor are they able to adjust to the evolutionary nature of modern hospital routines.

Sociocortex tackles this problem by providing a cooperative and purely meta model based digital system for integrated care. Those models can be used to describe treatment plans independent from the application area and adjustable to individual needs. The given models are formatted in the semi-structured language Extensible Markup Language (XML). This allows for a flexible usage of data from existing systems or applications. The XML model is then transformed into Java Script Object Notation (JSON) format. The JSON generates the *CaseDefinition*, which is the digital representation of a clinical pathway in the system [7].

4 A DSL for Modelling Clinical Pathways

4.1 Goals of Acadela (Adaptive CAse DEfinition LAnguage)

The TextX based language Adaptive CAse DEfinition LAnguage (Acadela) was defined to ease the modeling process of clinical pathways while preserving the flexibility and adaptability of SACM. To noticeably reduce the complexity, three overarching goals were set. The documents should be shorter, grammar should be simplified, and Acadela allows to be supported in an Integrated Development Environment (IDE). Because of those measures, the general workflow can be sped up and streamlined as well as medical experts could be able to make minor changes to existing models without the help of trained technical staff. Nonetheless, the correct portrayal of the real-life treatment is of the utmost importance.

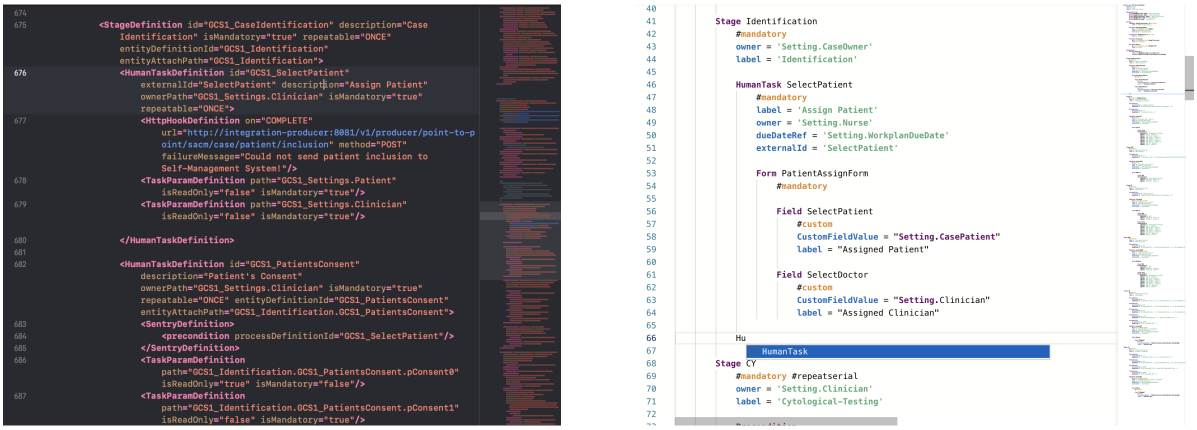
4.2 Reducing document size

One approach of simplifying grammar is by shortening documents to a concise, yet human-understandable form. By cutting down the size of text needed to describe a clinical pathway, Acadela aims to reduce the time needed to create documents, contribute to it being clearly laid out, and fasten the navigation within. Compared to SACM, Acadela is not based on XML, but on TextX. As seen in Figure 4.1a the definition of clinical pathways for SACM in XML uses closing tags. The removal of those closing tags for each element as displayed in Figure 4.1b drastically shrinks the needed amount of text. On top of that, is XML bound to key-value assignments. Some attributes can be used without a key in the DSL further minimizing the needed text.

Additionally, Acadela shortens the keywords, boiling them down to their descriptive use. Exemplary for that, "StageDefinition" becomes just "Stage". Other keywords analogously are shortened.

Furthermore, redundancies are removed. SACM requires one definition of data for the data schema and one for the visualization. Acadela on the other hand combines these two definitions to remove duplication.

Last but not least, the document size is reduced by being able to import elements from other documents. Various elements like Stages, Tasks, Fields can be loaded from external files. The import not only shortens documents but also enables modelers or medical experts to reuse common processes or attributes in various treatment plans. For example, blood pressure measurement is used in the diagnosis of hypertension, but it is also used in the diagnosis of other cardiovascular diseases. Acadela enables modelers to import the blood pressure measurement task when modeling the clinical pathways for these diseases.



(a) Patient selection described in XML

(b) Patient selection described in Acadela

Figure 4.1: In Figure4.1a, a clinical pathway using XML is displayed. For the description, closing tags and all attributes need to be used. The used code highlighting is generalized to XML. In Figure 4.1b, a clinical pathway in Acadela is depicted. Fewer attributes are needed and the elements do not need to be closed. A custom code highlighting is applied and the auto-complete option for a dummy "Stage" can be seen.

4.3 Simplifying grammar

For a DSL to be simple to use, the grammar should be intuitive and convenient. The aforementioned reduction of the duplicate description of elements assists the creator of a clinical pathway in Acadela by reducing the possibility of error, occurring from an accidental different definition or potential lookups between the two definitions.

Acadela allows for using personally preferred style by supporting some syntactic freedom. The DSL is case and indent insensitive, meaning that the capitalization of words and the usage of whitespace like tabulator for formatting are irrelevant. Both single and double quotation marks can be used as String markers and no delimiter is needed at the end of a line. Even the order of elements in the same hierarchy level can be sorted arbitrarily. Those characteristics support new users in focusing on the core aspects of the language instead of getting stuck with minor syntax errors.

Contributing to the ease of use are predefined default values. The most commonly used attributes are often used when no further information is given. This makes the model more coherent for beginners, shortens unnecessary information, but does not limit the possibilities, as the values can be overwritten.

4.4 IDE support

Another way Acadela tries to simplify the development process is by adding IDE support. As seen in Figure 4.1b an IDE can be used to enhance Acadela with multiple convenience features. A code highlighting specific to the syntax of Acadela is used to signal different classes of keywords. Additionally, auto-complete can be used to create dummy elements that have predefined keywords, so that the author of the document has a guideline to work with and only needs to fill out variables and adapt attributes according to their needs. To further increase the convenience, automatic indents for a more pleasant visual experience could be added to the IDE.

4.5 Acadela transpiler

A transpiler translates one language to another [8]. Acadela functions as a transpiler by using the Acadela DSL as source language and translating it into JSON which can be interpreted by SACM. This is done by first parsing the source code based on grammar to extract elements of a clinical pathway. Next, it constructs the objects of these elements in Python. Acadela processes the constructed elements to ensure that their values conform to the required format and constraints from SACM. Finally, Acadela exports the elements in a JSON format that is readable by SACM and thereby skips the need to use the usual XML structure as interim representation.

5 Evaluation

5.1 Goal

The main purpose of the research was to find out if Acadela is able to model clinical pathways from diverse medical treatments or procedures in a way that doctors consider accurate and find satisfactory. With the help of user tests, the evaluation took place in a two-stage process. The emphasis of the first stage, the pre-evaluation, was to find out, who should do the main work of the modeling, while the second stage, the user test, focused on the accuracy of modeled clinical pathways from their respective fields. A special focus was laid on the correctness of Stages, Tasks, and Stage transitions. With the collected information, the strengths and shortcomings of Acadela can be showcased and further adapted to fulfill the needs of medical experts.

5.2 Participants

For the user tests, we only selected participants who actively work as doctors. Overall six doctors took part in our research. With the goal of covering a diverse set of medical fields, one surgeon, gynecologist, dermatologist, physiotherapist, and two psychotherapists were chosen. Five out of six medical experts had at the point of the user study up to five years of experience, the other doctor had more than thirty years of work experience.

5.3 Pre-evaluation

The pre-evaluation of the research was centered around the question, if doctors themselves would want to use Acadela to create clinical pathways themselves, or if, as currently the norm, they should be created by technicians with a technical background. In pre-evaluation, the three medical experts were explained the concept of DSLs and introduced to Acadela.

This stage used the diagnosis and treatment of obesity as an example case. This case was chosen because it does not require any specialized knowledge and all participants were familiar with the procedure. Also, the relatively simple and linear structure of the treatment process allows the introduction of the most basic concepts of the DSL, while at the same time not overwhelming the doctors with specialized features. The case consists of four stages. First "Admit Patient" which includes the two tasks of selecting a patient and a clinician. After that in the "Evaluation" stage, the systolic and diastolic values are measured to determine the blood pressure. In the third stage "Treatment", the clinician can prescribe up to 3 antihypertensive drugs, their daily dose, and additional medication. Finally, "Discharge" allows the possibility to document a post-treatment recommendation.

After the introduction, the participants were shown an exemplary implementation of the case. They then had to implement it themselves in the Acadela IDE. During their task, they were encouraged to ask questions and give comments. After finishing the exercise, they were qualitatively interviewed on their opinion.

Despite one of the participants having knowledge in programming, all of them stated, that they would find it difficult to completely implement a new clinical pathway from scratch by themselves if they would not receive intensive training. Another concern that each participant mentioned, was that in their daily work routine, they were so caught up with the treatment of patients, that there would not be any time left for additional administrative work as the creation of clinical pathways and their digital representation. Nonetheless, all were confident, that they could make smaller adaptions to the model, like renaming tasks or adding options to a drop-down select menu. Overall, the application was seen as a useful enrichment/assistant for many treatments, if the base models are created by technicians with the option to edit small details by the doctors themselves.

5.4 User test

The user test aimed to evaluate the correctness of a given treatment plan. In this stage, five medical experts participated. The medical experts were contacted to obtain clinical pathways which they used in their daily routines. As the two psychotherapists are working together, a single clinical pathway is sufficient for the user test. The four individual pathways were modeled in Acadela by people with a technical background.

5.4.1 Selection of antipsychotic for schizophrenia

The psychotherapists work on a clinical pathway for the selection of antipsychotics for Schizophrenia. Medication for schizophrenia can have multiple side effects. To avoid or mitigate unwanted side effects, doctors and patients should in cooperation select a suitable medication. In the first step, the patient preferences like the goal of the treatment, the to-be-avoid side effects, and other information are collected. Afterward, the treating clinician adds medical data, for example, concomitant diseases, age, gender, etc. into the system. Then, the psychotherapists and patients organize a therapy session where the psychotherapists suggest antipsychotics and discuss the efficacy and side effects of these drugs with the patients. The patients choose the antipsychotics to be used in their treatment. To finalize the process, the psychotherapists prescribe the drugs and close the session [9].

5.4.2 Breathing exercise

For the physiotherapist a breathing exercise that when practiced helps improve the lung condition of Chronic Obstructive Pulmonary Disease (COPD) Patients. Before conducting the breathing exercises, patients specify their stress levels, the struggle of breathing, wellness of sleep, presence of mucus, and whether they can cough the mucus out. Afterward, patients start to conduct a breathing exercise under the supervision of a physiotherapist. During the exercise, the physiotherapist checks whether the patient inhales and exhales correctly sits in a straight posture, and does not raise their shoulder up excessively, which is defined as above 1 cm. After finishing the exercise, the physiotherapists can optionally ask the patient regarding their struggle of breathing, stress level, and shortness of breath, and whether the patient can cough out the mucus after the exercise [10].

5.4.3 Diagnosis of class two smoke inhalation

The clinical pathway submitted by the surgeon concern the diagnosis of class two smoke inhalation. The diagnosis is determined by immediate signs, potential signs, symptoms, and the results of a laryngoscopy. Depending on the outcome, the doctor can suggest further treatment of the patient. The treatment plan consists of 7 stages. After admitting a patient, step for step the situation of the patient is evaluated and conditionally decided if the patient is diagnosed with class two smoke inhalation or not [11].

5.4.4 Diagnose cervical cancer

A plan to diagnose cervical cancer was handed in by the gynecologist. The seven stages of the clinical pathway take the age of the patients and the result of one or more cytological and/or HPV tests to determine if and when a colposcopy needs to be done or if the patients can return to the routine screening procedure [12].

After the given clinical pathways were modeled, the resulting model was shown in the web application of SACM. The doctors were asked to evaluate how accurate the system reflects their expectations with a special focus on states, tasks, and state transitions.

The first two clinical pathways were linear descriptions of the workflow, while the other two guided the experts' decisions with the help of prior entered data. The conditional nature of the last two makes the models more complex.

5.5 Result

The results of the user test originate from the qualitative interview of the participants in addition to the quantitative form with free text questions and Likert scale ratings of statements. Overall, the received feedback was positive. The statements to be rated covered the correctness of the modeled stages, the tasks inside the stages, the stage transitions, the visualization of the medical condition, and the proposed treatment. As can be seen in Figure 5.1 the all participants agreed or strongly agreed with each statement.

Both the quantitative and qualitative questioning suggests, that the case of the surgeon and physiotherapist reflected their expectations very well. The psychotherapists were content with the system being used for documentation purposes but hoped for more detailed information on the tasks, free text options for the addition of non-predictable patient information, and an evaluation of the potential side-effects of drugs prescribed in combination with the help

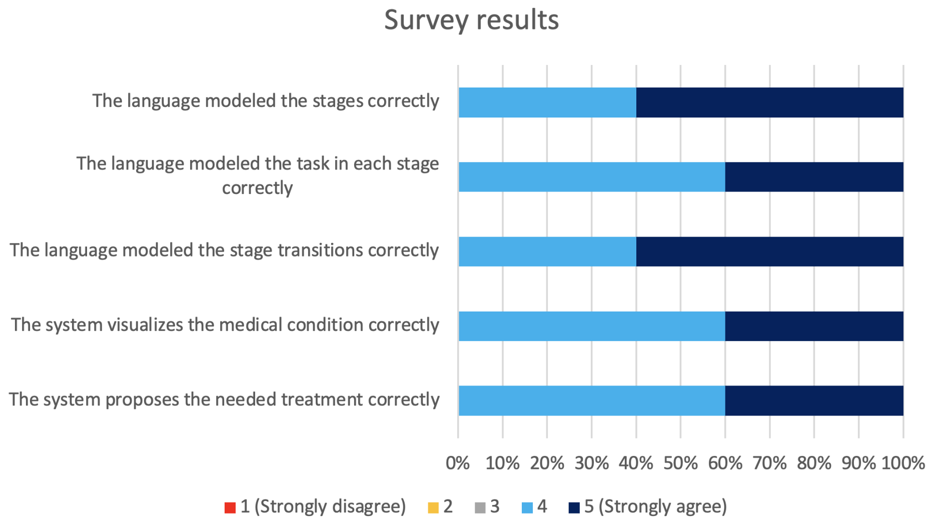


Figure 5.1: The result of rating the shown statements on a scale of one (strongly disagree) to five (strongly agree). All given answers were either a four or a five.

of an external system. The physiotherapist mentioned that she would like to see additional exercises and medical practices in the treatment process, as they are useful for treating individual cases of COPD patients. For the clinical pathway of the gynecologist, a properly functioning recurring event, that conditionally unlocks a stage outside of the iteration and proper advice on the time for the next testing was seen as necessary improvements.

6 Discussion

6.1 Representation of clinical pathways

The results from chapter 5 show that Acadela is capable of modeling most clinical pathways in a satisfactory manner. Especially the division of the workflows into stages and tasks is a promising concept to represent the real-life application of clinical pathways. While linear pathways can often be displayed only by connecting those elements with simple stage transition, many more complex cases require conditional unlocking of stages to fully portray their decision-tree-like structure. Acadela offers an adequate feature set for the modeling of clinical pathways, while at the same time reducing the complexity of the original modeling concept of SACM. The user test showed, that people with a technical background are able to build accurate digital clinical pathways with the help of Acadela.

6.2 Limitations

6.2.1 Limitations of SACM

Many of the shortcomings of the modeled cases that were mentioned by the participants are caused by limitations of the underlying system. As Acadela only transpiles its code for further processing and usage in SACM, the missing features also affect the DSL at test. During the modeling of the given pathways, especially the more complex cases with many preconditions and dependencies were limited. Conditionally triggering of stages that would have been necessary to model but were restrained by SACM includes using preconditions on tasks, values from different stages as a precondition, and the latest value from an iterative stage as a precondition. While a recurring stage is possible, SACM only will observe the value from the first submitted stage for preconditions of other stages. The stage with the precondition can still be triggered if the first stage of the iterative stage is corrected. That does not reflect the expected behavior of the system though. On top of the constraints regarding preconditions, SACM also does not enable the proper display of text in certain scenarios. There are no simple text fields for explanations or other information for doctors, and dynamic fields, which are able to display text conditionally, can not do so taking the values of fields from other stages into account. Acadela is not meant to work with SACM only, yet in this study, clinical pathways were only modeled using Acadela in a SACM-compatible syntax. For this reason, the language is restrained by the underlying system. However, Acadela can still define the missing features, like the conditionally triggered tasks.

6.2.2 Limitations of DSL

Aside from the inherited drawbacks from SACM, Acadela cannot define how an e-health system should react when it receives requests from external systems. For example, if an external system sends an update about the blood pressure of the patient, the DSL cannot define how this input should be validated before storing it in a database.

6.3 Internal validity

As discussed in Section 6.2, the models were constructed based on the capability of the SACM. Since SACM cannot simulate conditionally triggered tasks, we model these tasks as stages in the treatment process. Although this is considered accurate by the participant, it could be modeled in a more precise procedure if SACM can construct conditionally triggered tasks.

Another limitation of the study is, that the model has not been tested during the treatment, so the modeled process has not been tested in practice with actual data that could cause unexpected exceptions.

6.4 External validity

It was not tested if Acadela can export data compatible with another e-health system. Hence it cannot be verified if Acadela can model clinical pathways in systems other than SACM. Additionally, due to the limited time and the limited availability of doctors, only a small number of user tests could be conducted. In order to generalize the findings, a larger number of tests with multiple cases from other fields of medicine need to be conducted.

7 Conclusion and Future Work

In this study, we propose Acadela, a domain-specific language for modeling clinical pathways in e-health systems. Compared to SACM, Acadela shortens the document size needed to shortens compared to SACM the document size needed to describe a clinical pathway, simplifies the grammar, and can offer customized support for IDEs. At the same time, it is able to model clinical pathways from different clinical pathways from various medical fields at an adequate level, by modeling the stages, tasks, and data fields to collect medical information at different stages of a medical procedure. To evaluate the accuracy and usability of the language, the DSL was tested in a two-stage user test, that first determined the preferences on who should create the treatment models and second let doctors evaluate in advance modeled pathways of their respective domain. The results showed that the majority of modeling work should be left to people with technical backgrounds due to the lack of time and programming knowledge of medical experts. Further, it could be observed that overall the doctors were satisfied with the presented clinical pathways. The language is limited by its subsystem SACM when it comes to conditionally decide preconditions. Another shortcoming of the current version of Acadela is the lack of possibilities to respond to input from external systems.

In the future, SACM and Acadela could be adapted to fully reflect the conditional behavior of certain clinical pathways. Alternatively, transpiling Acadela code to a model, that can be used by a different base system, which could also be a way to address current limitations as well as a possibility to showcase the general applicability of Acadela DSL in the field of healthcare.

Additionally, more user tests covering a larger variety of clinical pathways and medical fields should be performed. One area not covered by this research is for example eastern medicine or cardiology.

List of Figures

Acronyms

Acadela Adaptive CAse DEfinition LAnguage. iv, v, 6–10, 13–15

ALPH Aspect Language for Pervasive Healthcare. 2

API Application Programming Interface. 3

COPD Chronic Obstructive Pulmonary Disease. 10, 12

DSL Domain Specific Language. 1, 2, 6–9, 13–15

IDE Integrated Development Environment. 6, 8, 10, 15

JSON Java Script Object Notation. 5, 8

SACM Smart Adaptive Case Management. vi, 4–6, 8, 11, 13–15

XML Extensible Markup Language. 5, 6, 8

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