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Applying Goal-Oriented Modelling for Machine Learning Based Rehabilitation Care

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Abstract. Virtual coaches can support patients who need continuous rehabilitation due to an acute illness in the home environment. These coaching systems have to give medically correct instructions on the one hand and on the other hand respond individually to the patient. Hereby, machine learning algorithms could enable the adaptation and personalization of the rehabilitation process. In order to capture the necessary medical knowledge in a structured form and let the system technically make use of it, approaches of conceptual modelling have proved to be effective. On the basis of a virtual coaching scenario, we demonstrate how such a coaching application could be conceptually structured with the help of the goal-oriented modeling language i* in comparison to BPMN as process modelling approach and how machine learning algorithms could be implemented.

Keywords. Goal-oriented modeling, e-health, virtual coaching, machine learning

1. Introduction

A suitable rehabilitation after an acute episode or a chronic disease is important for the affected people in order to live independently and enhance their quality of life, especially in their home environment. Virtual coaches (VCs) could help these patients to engage in personalized rehabilitation programs [1]. In order to provide individualized rehabilitation, on the one hand coaching systems have to accompany the patient with medically correct instructions and on the other adapt flexibly to patient preferences. Process modelling is a well-known method to provide clinical knowledge in technical systems [2]. Machine learning approaches promise possibilities to make rehabilitation more flexible through continuous learning [3]. However, regarding the personalization of this clinical knowledge by means of machine learning, process models could limit the extent of adaptability due to their deterministic character. Therefore, more flexible approaches could be considered for these scenarios in order to foster the machine learning process.

In the following, a virtual coaching scenario for home rehabilitation will be used to analyze how a machine learning process based on goal-oriented knowledge modelling could be implemented. The following chapter describes the underlying use case and the steps from knowledge modelling to machine learning implementation. Chapter 3

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presents the results of the concrete approach. The last chapter concludes with a discussion and proposes further research steps.

2. Methods

The underlying use case is embedded in the EU-funded *vCare*[2] project which addresses the rehabilitation of chronic disabilities caused by an acute disease that leads to bodily limitations. A VC accompanies the patients during the rehabilitation at home by monitoring behavior and motivating the execution of practical exercises. Therefore, a dedicated technical architecture has been implemented in order to enable the VC solution. The foreseen procedures within require the modelling of medical knowledge necessary for the coaching process, first. This will be done as a clinical pathway [4] using an extended version of the standardized modelling language *BPMN*[3] and transformed into the machine-readable *HL7 FHIR* resource *PlanDefinition*. This initial and general pathway information will be forwarded to a professional portal, where a clinician can personalize pathway parameters for each patient and enrich the FHIR resource with individual values. From this, a wrapper for clinical pathways is used to generate an instance of the underlying ontology, which will then be processed in order to personalize the initial patients' pathway with machine learning algorithms using context information detected from system components like sensor data [5]. In particular, the reinforcement learning algorithm, contextual bandits, is applied to personalize rehabilitation for the patient. Through iterative interactions with the patient, the algorithm learns the mapping from patient states to appropriate recommendations [3].

Based on this approach, the knowledge modelling shall be replaced by a goal-oriented approach, namely the *i** language as a widespread framework [6]. Therefore, an exemplary rehabilitation scenario which describes the VC activity of monitoring the patients' daily activity and providing appropriate feedback will be used as single case study and thereby, transformed from BPMN (see Figure 1) to i* in order to see if the semantic modelling concepts of the different approaches can be matched. An attempt is then made to map the identified modelling concepts to the FHIR resource PlanDefinition. Finally, it will be examined whether this has an impact on the machine learning process.

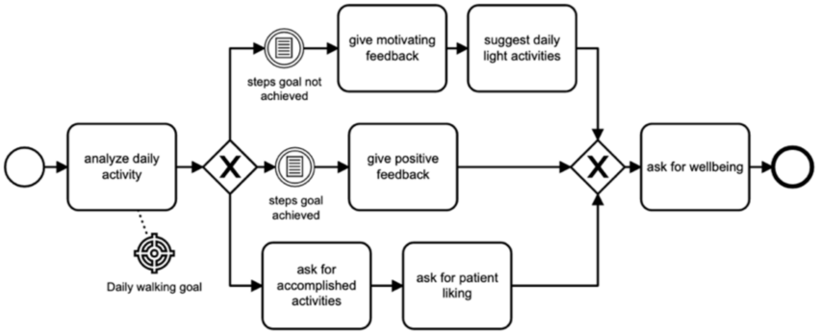

Figure 1. Exemplary virtual coaching use case represented with BPMN.

[2] See: https://vcare-project.eu

[3] See: https://www.bpmn.org

3. Results

The stated use case scenario and therefore, the underlying rehabilitation process information could be modelled using the i* language (see Figure 2). Compared to the initial process modelling with BPMN, the most noticeable difference is the modelling of different involved actors which in this use case includes, next to the VC, the patient's perspective. Additionally, the differentiation between *goals* and *softgoals* and their *contributions links* as well as the concept of *resources* that link actions between the actors in the system is new in this use case setting and needs to be considered.
The next step is to see whether the new concepts can be mapped to the FHIR resource PlanDefinition. For the system execution only the activities of the VC need to be taken into account, as the patient activities are monitored and thus, can be neglected during further processing. Likewise, the i* concept of resources does not need to be explicitly mapped, as this corresponds to the data generated by the system from involved components and with which the pathway information is enriched while processing.

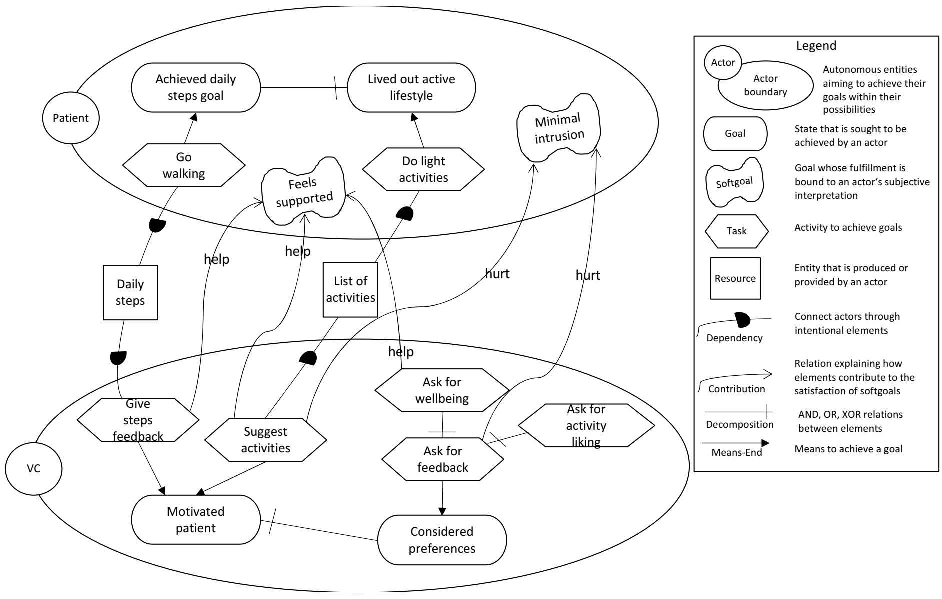

Figure 2. Virtual coaching use case represented with i*.

Table 1 compares the mapping of BPMN and i* concepts of the demonstrated use case to the FHIR resource PlanDefinition[4]. Differences are highlighted in cursive print.

Table 1: Different application of the FHIR resource *PlanDefinition* attributes to BPMN and i* concepts

FHIR attributes used with BPMN	Description	FHIR attributes used with i*	Description
PlanDefinition.action. title	Actions represent the intended coaching activities performed by the VC, e.g. "ask for patient liking"	PlanDefinition.action. title	Actions represent the intended coaching activities performed by the VC, e.g. "suggest activity"

[4] See: https://www.hl7.org/fhir/plandefinition.html

PlanDefinition.action. code	A coding system is used to trigger system services, e.g. questionnaires or feedback	PlanDefinition.action. code	Could be adopted for the same reason as with BPMN
PlanDefinition.action. condition	Conditions describe criteria that will start the execution of an action, e.g. "steps goal achieved"	*PlanDefinition.action. selectionBehaviour*	Could be used to represent decom-position links, e.g. "AND" with FHIR attribute "all"
PlanDefinition.action. relatedAction.relationship	Used to describe the sequential action flow, e.g. before-start or after-end	*PlanDefinition.action. requiredBehaviour*	Could be used to represent contri-bution links, e.g. "hurt" with FHIR attribute "could"
PlanDefinition.goal. description	Used to define goals that should be achieved with or during actions, e.g. "daily walking goal"	PlanDefinition.goal. description	Could be adopted for the same reason as with BPMN, e.g. "achieved daily steps goal"
PlanDefinition.goal. target.measure	Defines the actual parameter value that needs to be tracked, e.g. number of steps	PlanDefinition.goal. target.measure	Could be adopted for the same reason as with BPMN
		PlanDefinition.goal. category	Could be used to differentiate between goals and softgoals
		PlanDefinition.action. goalID	Could be used to indicate which goals the action supports

The most significant difference between the attributes used is the representation of the relationship between the activities, which is in the nature of the two modelling languages. While the activities of BPMN follow an execution sequence, the activities in i* are flexibly selectable and their execution is based on the fulfilment of the defined goals. For the underlying architectural setting, this would mean that the ontology must be adapted accordingly in order to adequately represent the relationship between the activities. The differentiation between goal categories is new to the initial setting. Yet, this offers the opportunity to integrate and use this differentiation in the reward function of the machine learning algorithm and would allow for a more differentiated handling of goals regarding their importance. The execution of activities would therefore not be bound to conditions, but rather to how much the activity supports the set goals. Apart from that, this has no effect on the functioning of the machine learning algorithm. With goal-oriented modelling, the algorithm actually would have more possibilities and flexibilities to achieve rehabilitation goals. In the setting with BPMN, the learning process is bound to conditions when executing and suggesting activities and is dependent on related activities. With goal-oriented modelling, recommendations could be set depending on the observed states and iteratively it could be assessed which activities best support the rehabilitation goals set.

4. Study Limitations and Conclusions

Although goal-oriented modelling as a basis for the machine learning process could have the described advantages, its use also poses some challenges. First, the outcome of the recommendations by the VC is not predictable as it is with BPMN. This in turn would require a lot of trust in the system by clinicians and patients as the system must be safe from a medical point of view. Also, differentiating the various goals in terms of the importance of achieving them requires medical expertise and therefore, close interaction with clinicians in the initial set-up of the system. The comparison of BPMN and i* in the given example suggests that i* is much more complex in representation than BPMN and thus, could be difficult as a basis for communication between technicians and medical professionals. Another aspect, which has not been considered yet, is the representation of time constraints. While the standard of BPMN provides a timing event in order to consider dates, repetitions or durations, this concept is not explicitly represented in the i* language. Since the architectural setting of the underlying rehabilitation scenario as the basis for the machine learning process does not change for both modelling languages considered, only the ontology and the transformation into the FHIR standard have to be slightly changed, a combined scenario could be considered. This could be designed in such a way that process modelling is first used as the structural basis for the system, on the one hand to give the clinical managers security in the ML process through deterministic and rule-based system behavior, and on the other hand to familiarize the patient with the system through recurring processes. Subsequently, the ML process could be implemented on the basis of goal-oriented modelling in order to adapt the process more individually to the patient and to personalize the coaching activities.

In the present work, it could be shown on the basis of a virtual coaching scenario for home rehabilitation that the goal-oriented modelling language i* can be used on the one hand to first map the coaching knowledge necessary for the system and then to transfer it to the HL7 FHIR standard in order to integrate the mapped information into an ML process. Further research should investigate the actual implementation of the proposed approach in order to analyze its potentials and acceptance compared to the process modelling approach. Additionally, the consideration of the timing perspective should be investigated to see how timing constraints could be considered in the goal-oriented modeling approach.

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