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Similarity Based Approach for Comparing Home Healthcare Processes Models in Portugal

Latifa Ilahi[a*], Ricardo Martinho[b], Sonia Ayachi Ghannouchi[c], Dulce Domingos[d], Rui Rijo[e]

[a]ISITCom Hammam Sousse / RIADI Laboratory-ENSI Manouba, Tunisia
[b]CINTESIS, FMUP, University of Porto and School of Technology and Management, Polytechnic Institute of Leiria, Portugal
[c]ISG Sousse / RIADI Laboratory-ENSI Manouba, Tunisia
[d]LaSIGE, Faculdade de Ciências, Universidade de Lisboa, Lisboa, Portugal
[e]ESTG- Polytechnic Institute of Leiria, Portugal

Abstract

Similarity metrics applied to business processes are used to compare and assess the similarities and differences between a set of process models. The results of this comparison can then serve as input to take management decisions, such as to prevent the proliferation of process variants. This is particularly useful in large (enterprise or governmental) organizations with multiple organizational units that share the same business processes. Examples include faculties of a university and their student enrollment process, hospitals or primary care centers of National Health Services and their medical appointment process, or even the pick and pack process across several warehouses of a large company. Due to many aspects (i.e. local policies, resources, socio-technical aspects, culture), a certain business process is individually evolved and refined across the multiple organizational units of the same organization. Organizations have then to deal with several process variants, which hampers the collection of performance indicators, optimization procedures and business process management overall. In this paper, we perform a similarity based approach to assess the similarities and differences that exist between home healthcare processes for two public primary healthcare centers in Portugal. We will achieve this by eliciting business process models according to best practices. Then, we lead a similarity based comparison between the elicited models. This is in order to show how much models are different in the same organization.

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Keywords: BPM; Similarity metrics; Modeling; Home healthcare processes; Process Governance, Flexibility;

* Corresponding author. Tel.: +351916533575; fax: +351916533575.
E-mail address: latifa.ilahi@ipleiria.pt

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1. Introduction

Business process support is mandatory in almost all business domains [1]. Examples include the healthcare domain [2, 3 and 4], automotive engineering [5], and public administration [6]. In all these domains, business process models are designed and evolved in order to have a more or less uniform record of all instances (cases) that really happen in organizations. This way, management is enhanced since metrics and process key performance indicators can be derived from similar recorded cases of a certain process model.

Adopting a business process management (BPM) based approach to tackle these domains may contribute to optimize organizational aspects and the products/services that are delivered when executing those processes. However, and specially in organizations that have multiple organizational units dispersed geographically or with some management autonomy, there are constraints regarding local policies, resource, culture or even geography that lead to a proliferation of process adaptations (variants) for a certain process. Take, for instance, the example of a student enrollment process in the distinct faculties of the same university, or even a medical appointment process across all hospitals and medical centers of the National Health Services. Managing many variants of the same process may hamper overall efforts to elicit and measure its key performance indicators, and even to take assertive decisions on its optimization. According to this, we propose in this paper, a similarity based approach to assess differences that exist between home healthcare processes for two public primary care centers in Portugal. We rely on the approach of Business Process Modeling (BPMo) to identify home healthcare processes in Portugal as we have experienced in the Tunisian case [2 and 3]. We began by performing interviews to elicit business process models according to best practices. Then we modeled these processes using the Business Process Modeling Notation (BPMN) 2.0, and sent them to validation by our interviewees. Then, we lead a similarity based comparison between the elicited models, and performed a comparison between them by applying the similarity metrics proposed in [19].

After this introduction, the remainder of the paper is structured as follows: in section 2 we briefly describe the background BPM for healthcare, best practices for BP modeling and similarity metrics. In section 3 we present our approach. Section 4 focuses on the eliciting of home healthcare processes in two public primary care centers in Portugal, and presents the results obtained from the similarity analysis we performed. Finally, section 5 summarizes the main conclusions of this research and outlines future work.

2. Background

This section begins with an introduction on Business Process Management applied to the home healthcare domain, followed by a summary on the best practices we applied to elicit the home healthcare process models and the similarity metrics used to assess their differences.

2.1. BPM for home healthcare

Business process support has been a main driver for information systems in enterprise for a long time. Its overall goal is to overcome the drawbacks of functional over-specialization and lack of process control [11]. BPM represents a valuable asset in the healthcare domain [12], given the competitiveness, rapid advancement and especially the expansion of communication techniques and new technologies in all research areas. It relies on process models to identify, review, validate, represent and communicate process knowledge [13 and 14].

Within healthcare organizations, we mostly have critical business processes to manage. These can involve the patient, the insurance management or administrative functions.

Some research works have focused on home healthcare. For example, there is a recent work [15] focusing on the case of patients with dementia. This disease requires a constant care and monitoring from a caregiver, who suffers physical and emotional overload. The authors propose an approach for the development of pervasive systems aimed at helping the care of these patients in order to lessen the burden of the caregiver while the patient continues to receive the necessary care. This work presents an ontology which represent the domain and possible situations where the environment should react according to a specific context. Also it includes architecture for development of pervasive systems.

Another work of Arbaoui et al. [8] adopts a process based approach to tackle home healthcare domain in order to highlight the importance of organizational aspects in the success of an ICT-home healthcare project. They consider that home healthcare process may comprise three sub-processes: 1) organizational-care; 2) organizational and 3) Care sub-processes. In our work, we adopt this classification to organize our elicited process models.

2.2. Best practices for BP Modeling

Business process modeling is heavily applied in practice. According to this, several best practices can be distinguished to implement business process design/modeling. In order to help the user in choosing the correct best practice when dealing with the design of business processes, Mendling et al. in [16] propose a set of seven process modeling guidelines (7PMG). The authors analyze existing research on relationships between model structure, on the one hand, and error probability and understanding, on the other hand. Proposed guidelines are: (G1) Use a few elements in the model as possible; (G2) Minimize the routing paths per element (i.e. the numbers of input and output arcs); (G3) Use one start and one end event; (G4) Models should be as structured as possible; (G5) Avoid OR routing elements since models that have only AND and XOR connectors are less error-prone; (G6) Use verb-object activity labels; (G7) Decompose the model if it has more than 50 elements. This latest guideline relates to (G1) that is motivated by a positive correlation between size and errors. With 7PMG, authors guiding process designers towards improving their models quality. It becomes more comprehensible to various stakeholders and containing a few syntactical errors.

Another starting point for our phase of eliciting the process models was the work of Piggera et al. [17]. Here, the authors propose an iterative process of the process modeling activity. They introduce the formal concept of a phase diagram through which the process modeling can be analyzed and also, a corresponding implementation to study the sequence of actions of the modeler. In fact, a good understanding of a process model has a dramatically positive impact on the success of a modeling initiative. Regarding to the business process model quality, it is seemingly highly dependent ahead the modeling process that was followed to create it. According to this, Piggera et al. affirm their opinion that, at the operational level, interactions of the modeler with the tool may consist of a cycle of the 3 successive phases of **comprehension**, **modeling** and **reconciliation**. In the first, designers should understand modeling requirements as well as the model that has been created so far. Then, for the modeling step, modelers create design elements of the process model. They may use acquired information and stored in working memory during the previous phase (comprehension) for creating / changing the process model. The final phase of reconciliation may include the move, remain or update the model elements (i.e activities, conditions, etc..). In this phase, designers reorganize the process model and utilize the process model's secondary notation. This is in order to enhance the understandability of the process model.

In the same context of best practices for modeling processes, Frederiks et al. [18] focus on the process of information modeling, its quality and the required competencies of its participants. The modeling phase contains 3 main steps: **Elicitation**, **modeling** and **validation**. They refined the first stage (**Elicitation**) into 3 sub stages. First, modelers may collect the significant information objects from domainof application. Then, they verbalize these information objects in a common language. Finally, designers should reformulate the initial specification into unifying format. **Modeling** step is intending to transform an informal specification into a formal specification. It may be composed into 2 sub stages: First, it is the discovering of the significant modeling concepts and their relationships. Then, the matching of sentence structure on modeling concept can be made. The final step of **validation** and verification is refined into 3 sub stages: First and using the information grammar and the lexicon, designers may produce by paraphrases a textual description of the conceptual model. Then, validate the textual description which can be done by comparing it with the informal specification. Finally, they should check formal specification for internal consistency.

2.3. Similarity metrics

In order to reduce costs and ensure a clear understanding of the processes used in the organization, many companies are increasingly confronted with the design of their business processes. But, due to changes in regulation, new innovations and other factors, business processes are continuously changing and evolving. Therefore, system and business analysts involved in modeling of business processes need to compare process models, diagnosing their differences and take appropriate actions (for instance, prevent the proliferation of process variants, and align all of them in a single "general" process model, to enhance management).

To compare business process models, we lead a similarity study. Existing approaches for this kind of similarity may include: lexical matching, behavioral matching, and structural matching [19]. Similarity values should be between 0 and 1, meaning the closest to 1, the similar process nodes or models are. The lexical matching is based on the comparison of labels of the elements. This comparison between labels may include syntactic and semantic metrics for determining the accuracy between labels. Likewise, other techniques for computing the string edit distance can be used, such as the Hamming distance [20]. These metrics are defined as the minimal number of needed operations to transform one string into the other. This transformation can be done using deletion, insertion, substitution of a single character, or transposition of two adjacent characters [19 and 21]. The behavioral matching approach is based on comparing the behavior of process elements, and structural matching approaches typically use techniques such as greedy algorithms, A* algorithms, and context-based similarity measures [19, 22 and 10].

3. Case study on home-healthcare in Portugal

To study home healthcare processes, we led a field research in which we interviewed actors with different roles in patient homecare processes (mainly nurse coordinators). These interviews have allowed us to perceive the details and variants that can happen on the home healthcare processes in two public primary care centers in Portugal (cities of Leiria and Lisbon). After these interviews, we optimize models by following the 7 guidelines of Mendling et al. [16]. Then we pass through a validation step with the interviewed professionals, as proposed in [18].

The aim of home healthcare is to treat the patient with a full coordination. Tasks of caregivers at home are extremely diverse. They include help with activities of daily living, transportation, medication procedures and interaction with medical personnel. We adopted in all our previous works [3, 7 and 9] the classification of Arbaoui et al. in [8], which comprises the home healthcare process as divided into three sub-processes, namely: 1) organizational-care; 2) organizational (patient admission); and 3) patient care.

In the following subsections, we present our elicited models according to the BPMN 2.0 Notation and the best practices for BP modeling referred above. Then, we present for each pair of home healthcare sub processes (Leiria and Lisbon) a comparison by applying the following similarity metrics: 1) node matching similarity (Structural similarity) and 2) graph edit distance similarity. In our context, *node matching similarity* allows us to compare nodes individually, under three similarity sub-metrics:

- Syntactic similarity: to identify that these are the nodes to compare, based on their labels syntax ;
- Type similarity, to assess the node types. For instance, to assess that the "Prepare materials" BPMN tasks are of type "manual" in both processes from Leiria and Lisbon;
- Semantic similarity, where we look at the semantics of the words within the labels. For instance, to assess the similarity between 2 task labeled "Prepare materials" and "Preparation of materials".

The graph edit similarity between two graphs (the process models) is the maximal possible similarity induced by a mapping between these graphs. The graph–edit distance between two graphs is the minimal number of graph edit operations that is necessary to get from one model to the other. We take into account different graph edit operations: node deletion or insertion, node substitution (a node is a graph is mapped to a node in the other graph with a different label), and edge deletion or insertion.

Due to space limitations, we will demonstrate below all the similarity calculations taking into account the model variants of the organizational care sub-processes from the two public primary care centers studied. For the organizational and care sub-processes, we present only the BPMN models elicited and the final similarity calculations.

3.1. Organizational care sub-processes

Figure 1 illustrates the BPMN process models elicited and modeled for the organizational-care sub-processes in Leiria and Lisbon. We then lead a comparison between these models and present the results in Table 1.

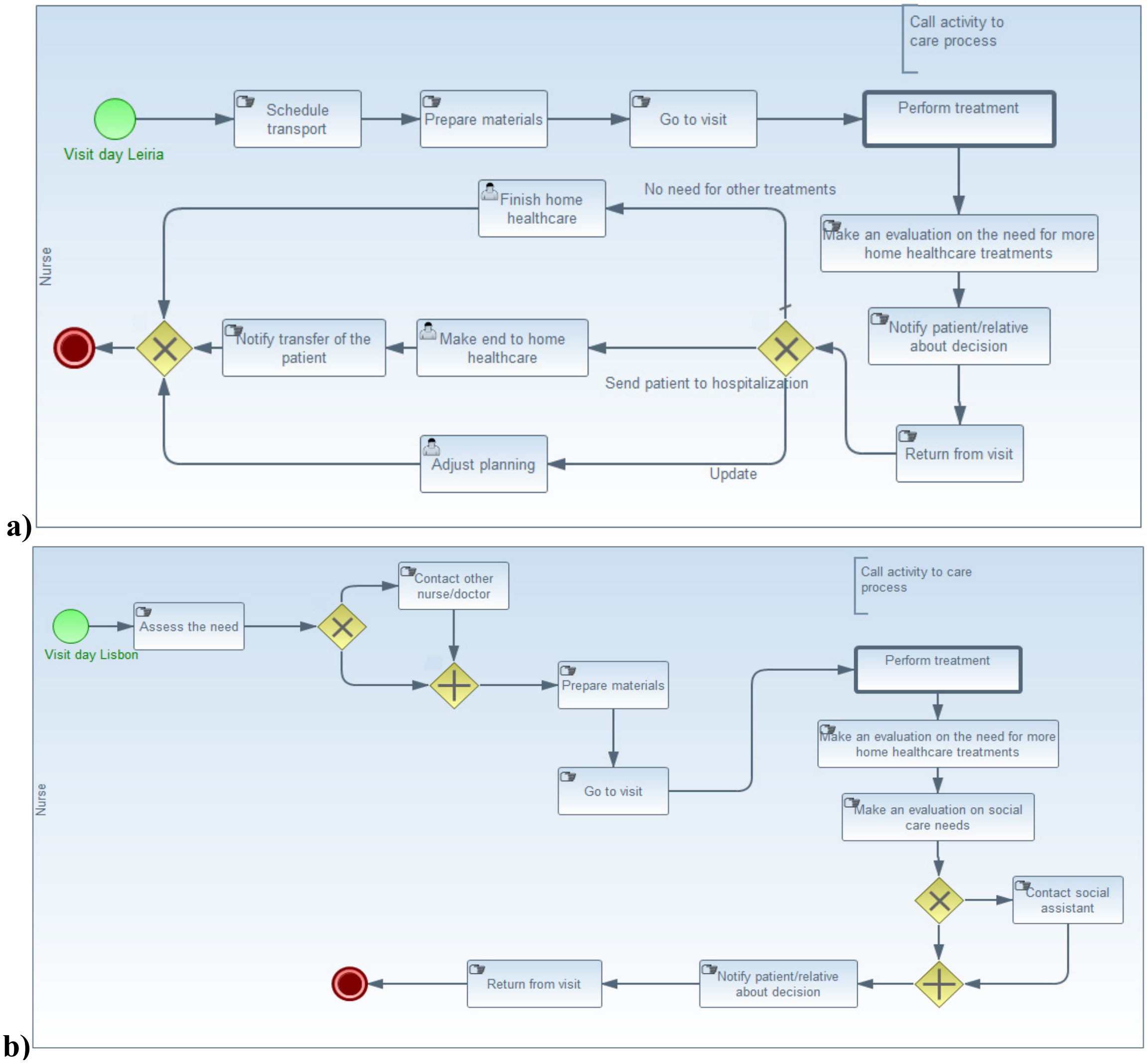


Fig. 1. a) Organizational care of Leiria region; b) Organizational care of Lisbon region.

Table 1: Similarity results of the two process model variants in Figure 1

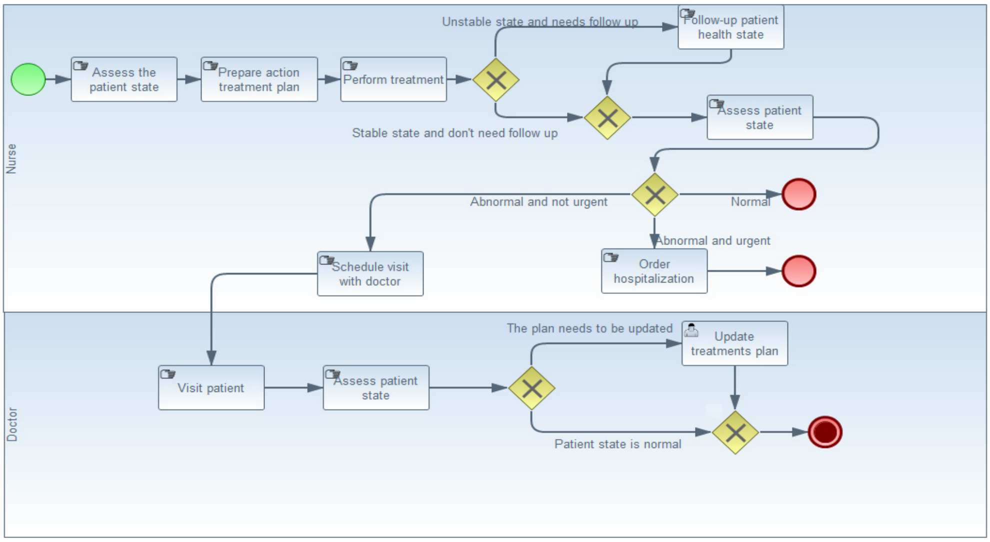
Name 1	Name 2	Type n1	Type n2	Similar Elements	Syn sim	Type sim	Sem sim	N.M sim	G.E.D. Sim
(e11) visit day Leiria	(e21) visit day Lisbon	22	23	(e11, e21)	0.375	1	1	0.79625	0.3166667
(t12) Schedule transport	(t22) Assess the need	24	21	(t13,t24)	1	1	1		
(t13) Prepare materials	(t23) contact other nurse or doctor	23	35	(t14, t25)	1	1	1		
(t14) Go to visit	(t24) Prepare materials	17	23	(t15,t26)	1	1	1		
(t15) Perform treatment	(t25) Go to visit	23	17	(t16, t27)	1	1	1		
(t16) Make an evaluation on the need for more home healthcare treatments	(t26) Perform treatment	72	23	(t17, t30)	1	1	1		
(t17) Notify the patient or relative about decision	(t27) Make an evaluation on the need for more home healthcare treatments	51	72	(t18, t31)	1	1	1		
(t18) Return from visit	(t28) Make an evaluation on social need	23	39	no similar tasks	0	0	0		
(t19) Finish home healthcare	(t29) Contact social assistant	28	30	no similar tasks	0	0	0		
(t20) Make end to home healthcare	(t30) Notify patient or relative about decision	33	47	no similar tasks	0	0	0		
(t21) Notify transfer of the patient	(t31) Return from visit	36	23	no similar tasks	0	0	0		
(t22) Adjust planning		21	0	no similar tasks	0	0	0		

In this table, we calculate the Node Matching Similarity which is based on pair wise comparisons of node labels, types and semantics. It is obtained by calculating an optimal equivalence mapping between the nodes of the two process model variants being compared. The node matching similarity overall score is given by the sum of the similarity sub-scores of the matched pairs of nodes, reduced to a scale of 0 to 1. For this particular score we obtained a value of 0.79625.

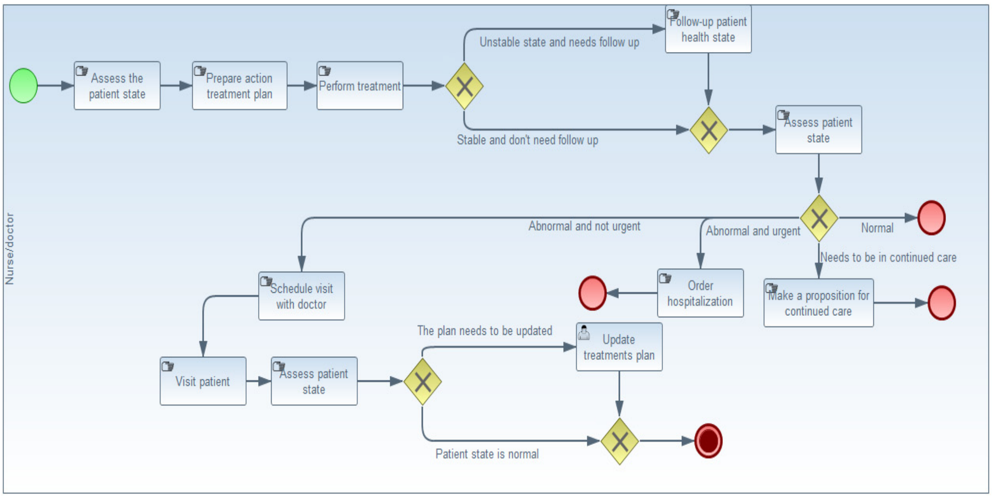
The Graphic Edit Distance (GED) is the average of the fraction of inserted or deleted nodes, the fraction of inserted of deleted edges and the average distance of substituted nodes. It represents the minimal possible distance induced by a mapping between the two processes. For the GED similarity we obtained a value of 0.31 between these models (on a scale of 0 to 1). These calculations lead us to conclude that, although the matching nodes are quite similar regarding their type and semantics, the overall process models differ substantially.

3.2. Care sub-processes

Following the same procedure, we obtained a value of 0.95 between the two models of Figure 2 for the node matching similarity. This value explains that care processes between these centers have a high degree of similarity. This can be proved by the presence of only one different task between them. In fact, the Lisbon primary care center makes a proposition for continued care in a hospital, as Leiria does not. Additionally, the graph edit similarity between them is equal to 0.96, which reinforces the high similarity considering also the overlapping of both process models.



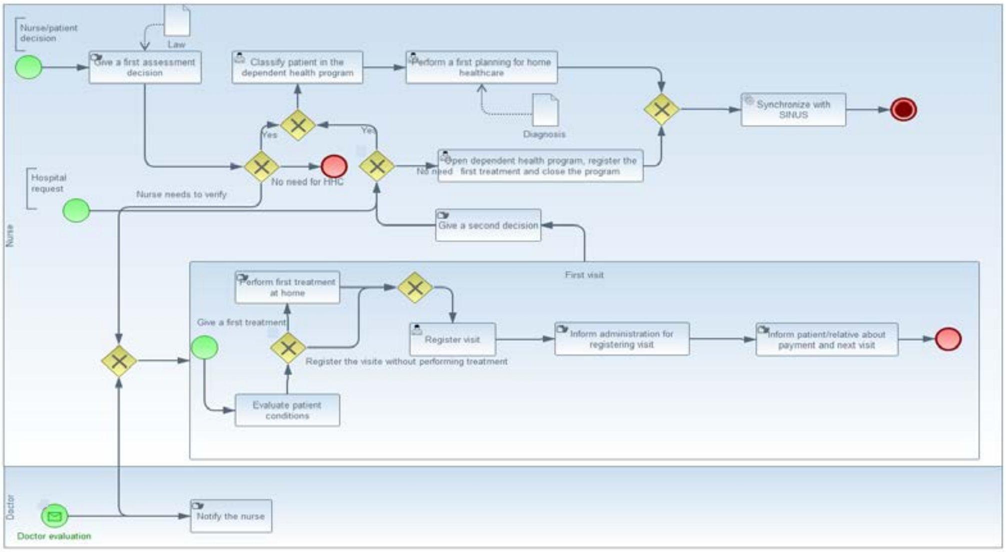
a)



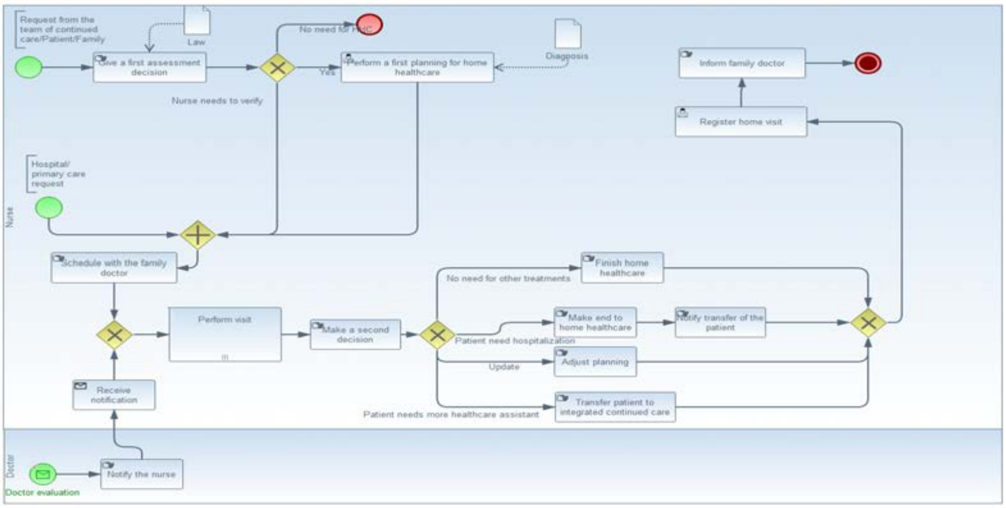
b)

Fig. 2. a) Care of Leiria region; b) Care of Lisbon region.

3.3. Organizational sub-processes



a)



b)

Fig. 3. a) Organizational of Leiria region; b) Organizational of Lisbon region.

Following the same procedure, we obtained a value of 0.62 of node matching similarity between the two models in Figure 3. The graph edit distance similarity between them is equal to 0.11, leading us to conclude that organizational home healthcare processes differ substantially between these two primary care centers.

4. Conclusion & Future works

In this paper we proposed to prove that, even taking into account the process models for organizational units of the same (regulated) organization, process variants emerge and can evolve to be quite different. For this, we elicited the process models for home healthcare between two public primary care centers. Assessing the similarity results from the 3 pairs of process models elicited, we can state that they present significant differences, to the exception of the care sub-processes. This means that the overall management and optimization of the other organizational or organizational-care sub-processes may be difficult to achieve, taking into account their similarity results.

We have already proposed an approach to align process models with significant differences in [9]. The main output of this approach is a template process model that, based on similarity results, will be composed of two types of elements: rigid and flexible. Rigid elements should be executed strictly, while flexible ones can or cannot be executed, according to the organizational unit's policies. The purpose is to enhance BPM and governance in general for this kind of organizations, and as near future work we are extending a software tool to perform similarity studies and derive the template models accordingly.

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