Towards the Merging of Multiple Clinical Protocols and Guidelines via Ontology-Driven Modeling

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Abstract. Decision support systems based on computerized Clinical Protocols (CP) and Clinical Practice Guidelines (CPG) fall short when dealing with patient co-morbidites, as this demands the concurrent merging of multiple CP/CPG. We present an ontology-based approach for the merging of CPG and CP at two levels–i.e. knowledge modeling level and knowledge execution level. We have developed specialized ontological modeling constructs to facilitate merging of CPG and CP. We demonstrate the merging of multiple location-specific CP and disease-specific CPG.

1 Introduction

Clinical Protocols (CP) and Clinical Practice Guidelines (CPG) are evidence-based knowledge artifacts that are designed to streamline institution-specific processes and disease-specific recommendation, respectively. There are a number of initiatives to computerize these paper based resources to utilize them for decision support and care planning in clinical setting at the point of care [1]. Notwithstanding the various successes in the computerization of these healthcare knowledge artifacts, the reality is that at execution time each CPG/CP need to be executed as an independent entity because there are no conceptual and executional provisions to link multiple CPG/CP to handle co-morbidities.

In this paper we pursue the problem of *merging* multiple CP and CPG at both the knowledge and execution levels. We take a semantic web approach that entails the use of ontologies to model the knowledge within CP and CPG [2]. Next, we attempt the merging of ontologically-modeled CP and CPG along common concepts, locations and decision-points using specialized ontology mapping constructs and merging points. In this regard, we will present two ontology-driven merging exercises: (a) The merging of location-specific CP for prostate cancer management to realize a unified prostate cancer management CP; and (b) The merging of disease-specific CPG to handle co-morbidities.

2 Approaches for Merging Multiple CPG and CP

To handle co-morbid conditions using computerized computerized CPG/CP, our approach is to systematically *merge* the computerized CPG/CP of the co-morbid diseases to generate a 'broad' evidence-based knowledge resource. Merged

CPG/CP will allow to optimize the care process in terms of (a) avoiding duplication of intervention tasks, resources and diagnostic tests; (b) re-using results of common activities; (c) ensuring that different clinical activities, across active CPG/CP, are clinically compatible and their simultaneous application does not comprise patient safety; and (d) standardizing care across multiple institutions. We argue that, from a knowledge management perspective, the challenge is to develop mechanisms to 'merge' [3] multiple CPG/CP at both the knowledge modeling and knowledge execution levels. We have identified two CPG/CP merging scenarios and explore them in this paper:

1. *Merging at Knowledge Modeling Level*: In this scenario, multiple CPG/CP are merged to develop a unified 'co-morbid knowledge model' that encompasses (a) the individual knowledge of the candidate CPG/CP; and (b) the defined semantic and pragmatic relationships between the candidate CPG/CP. Here, the knowledge modeler merges the candidate CPG/CP by establishing a conceptual mapping between common concepts (such as tasks, resources, professionals, results and so on) across different CPG/CP. The merged CPG/CP model represents each CPG/CP as a combination of both unique/specialized and common/generic concepts, thus ensuring that each modeled CPG/CP maintains its unique identity and yet at the same time is part of a broader knowledge model. Knowledge level merging is particularly suitable for (a) combining a disease-specific CP for different institutions to develop a generic CP model; and (b) for combining CPG/CP of co-morbid diseases by including specialized knowledge about how to integrate them in different situations.
2. *Merging at the Knowledge Execution Level*: In this scenario, multiple CPG/CP are merged in a dynamic manner to create an *adaptable* CPG/CP that modulates with respect to the patient conditions and prospective sequence of care processes. CPG/CP merging in this case involves establishing linguistic, terminological and conceptual correspondences between the active CPG/CP models in a look-forward manner during the execution of the CPG/CP. Here, an a priori unified model is not created, rather CPG/CP merging takes place as and when needed based on pre-defined merging criterion and rules during the execution of the CPG/CP for a specific patient. A validation exercise, which can be both manual or rule-based, ensures that the merged CPG/CP is clinically pragmatic for the patient. Execution-level merging is typically suitable for merging CPG/CP based on common tasks across co-morbidities diseases. For CPG/CP modeled as ontologies, ontology alignment and reconciliation techniques [4] can be used to merge them.

In our work, we pursue the merging of CPG and CP by (a) representing the healthcare knowledge encapsulated within the CPG and CP as ontologies [5] [6], and (b) applying specialized ontology mapping/alignment constructs to merge multiple CPG/CP along common concepts or tasks.

3 Merging at the Knowledge Modeling Level

The idea is to merge multiple CPG/CP in terms of a unified knowledge model that identifies common elements and accounts for disease or institution-specific variations. We have developed two concepts, termed as *branching nodes* and *merging nodes* to pursue merging at the knowledge level. The *branching node* allows a CPG/CP to branch off the unified model in case the next task/information/constraint is unique. In our ontological knowledge modeling approach, this is achieved by the modeling construct, *Class Intersection*, that models a unique instance that combines two classes. Below we show 'institution-specific' class intersections denoting an intersection between the INSTITUTION class with some other aspect to represent an instance that is unique to an Institution.

- INSTITUTION-TASK-INTERSECTION represents an intersection between classes INSTITUTION and TASK to signify a unique individual, such as a unique TaskA that is only performed at InstitutionB.
- INSTITUTION-TREATMENT-INTERSECTION represents a unique TreatmentX that is offered in only in a specific Institution.
- INSTITUTION-FOLLOWUP-INTERSECTION represents a unique FOLLOWUP offered at a specific Institution.
- INSTITUTION-CLINICIAN-INTERSECTION represents the clinician performing a specific TASK, TREATMENT or FOLLOWUP at an Institution.
- INSTITUTION-INTERVAL-INTERSECTION represents the interval duration for a specific event at a particular Institution.
- INSTITUTION-FREQUENCY-INTERSECTION represents the frequency of a specific activity at a particular Institution.

In a unified CP/CPG model, when a CP branches off on a unique path then the *merging node* serves as a point to synchronize the multiple branches to realize a unified CPG/CPG if: (a) no further activities are left in the branch; or (b) the next task is common with other branches. There are two types of merging nodes: (a) The *Merge-Wait node* waits for all the incoming branching to the node to be satisfied before the execution moves forward; and (b) The *Merge-Proceed* node simply merges the branch to the unified model and continues the execution without waiting for the completion of the other branches. In figure 1, we illustrate both the branching and merging nodes. Note that after the task 'RecieptOfBiopsyReportByUrologist' the three institutions perform unique tasks (modeled as Institution-Task Intersections) and therefore three separate institution-speciifc branches are spawned, each having unique individuals for *hasTask* and *isFollowedByConsultation* relations. Later, the task 'Consult-4' serves as a merging node to realize a unified CP [7].

4 Merging at the Knowledge Execution Level

In conceptual terms, execution level merging involves the alignment of the knowledge models representing the CPG and CP. In our case, we use separate

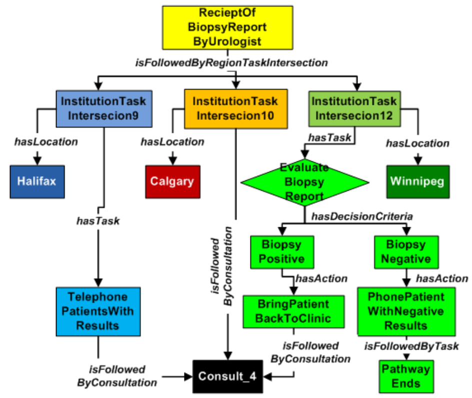

Fig. 1. Branching and Merging of Clinical Pathways

ontologies to model both CPG [5] and CP[6], therefore merging is pursed as an ontology alignment exercise [4] based on the presence of common plans/steps that exist across multiple active CP/CPG. Merging at the execution level is complex and involves a temporal aspect to maintain a state graph that encapsulates the tasks completed and the forthcoming tasks. CPG/CP merging is, therefore, based on the commonality of the forthcoming tasks and the reusability of results of previous tasks. The outcome of this exercise is (a) a comprehensive decision model, encompassing multiple CPG/CP; (b) optimization of resources by reducing repetitive tests/actions, and (c) efficient execution of common tasks. The dynamic merging of multiple CPG/CP, whilst maintaining clinical pragmatics, is quite challenging because (i) recommendations that are common across multiple CPG are not necessarily administered at the same time, and (ii) certain parts of the merging CPG may later result in contradictions or adverse effects. In our work, we pursue three CPG merging scenarios.

Scenario 1: Both guidelines recommend a common step at the same time. Both CPG merge at the common step and then branch off to their respective paths when the common step is completed (shown in figure 2a).

Scenario 2: In case the common step is not executed at the same time by two CPG, then CPG merging is still possible if the CPG in front (in terms of its execution order) can wait before executing the common step–i.e. the *ability-to-wait* constraint for the common step can be satisfied. To model this merging scenario, for each ACTION-STEP we have specified the following attributes: (a) *expected-duration* to represent the average execution time for a step; and (b) *logic-to-calculate-acceptable-wait* to specify the criteria to calculate the maximum acceptable wait time before starting the step (shown in figure 2b).

Scenario 3: Two CPG can be merged if they can re-use the results of a common step. To ensure that the result is not outdated, we have specified an attribute *acceptable-duration-of-results-if-available* that will ensure that the trailing CPG is using a valid result.

Fig. 2. (a) Merging two concurrent CPG when the common step is to be executed at the same time; (b) Two CPG with a common step but at two different times. One CPG waits for the other to reach to the common step so that they can merge

5 Concluding Remarks

In this paper we have discussed our ontology based approach to model the merging of multiple CPG and CP. The merged knowledge was subjected to two kinds of evaluation: (a) representational adequacy and efficiency to ensure that the ontological models [2], both for the original and merged knowledge, is able to capture the concerned concepts. The key feature of our approach is that it provides execution semantics whilst maintaining clinical pragmatics (based on the available knowledge). We argue that by investigating the overlaps between CPG and CP we will be able to (a) develop more sustainable knowledge models that can handle broad additions and updates; (b) generalize the knowledge across different regions; and (c) identify specialized tasks at each location and for individual diseases [8].

References

1. Peleg, M., Tu, S., Bury, J., Ciccarese, P., Fox, J., Greenes, R.A., Hall, R., Johnson, P.D., N., J., Kuma, A.: Comparing computer-interpretable guideline models: A case-study approach. Journal of American Medical Informatics Association **10** (2003) 52–68
2. Bodenreider, O.: Biomedical ontologies in action: role in knowledge management, data integration and decision support. Yearbook Medical Informatics (2008) 67–79
3. Sascha, M., Stefan, J.: Process-oriented knowledge support in a clinical research setting. In: Proceedings of 12th IEEE Symposium on Computer-Based Medical Systems, IEEE Press (2007)
4. Euzenat, J., Shvaiko, P.: Ontology matching. Springer-Verlag, Heidelberg (DE) (2007)
5. Abidi, S.S.R., Shayegani, S.: Modeling the form and function of clinical practice guidelines: An ontological model to computerize clinical practice guidelines. In: Knowledge Management for Healthcare Processes Workshop at ECAI 2008, Patras
6. Hurley, K., Abidi, S.S.R.: Ontology engineering to model clinical pathways: Towards the computerization and execution of clinical pathways. In: 20th IEEE Symposium on Computer-Based Medical Systems, Maribor, Slovenia, IEEE Press (June 20-22 2008)
7. Abidi, S., Abidi, S.S.R., Hussain, S., Butler, L.: Ontology-based modeling and merging of institution-specific prostate cancer clinical pathways. In: Knowledge Management for Healthcare Processes Workshop at ECAI 2008, Patras
8. Lenz, O., Reichert, M.: It support for healthcare processes: Premises, challenges, perspectives. Data and Knowledge Engineering **61** (2007) 39–58