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Conceptual Analysis and Conceptual Model for Medical Processes

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Abstract
Business Process Management (BPM) is an area concerned with the formalization and analysis of the activities conducted by an enterprise to produce goods and services. The importance of BPM both in research and industry motivates its use in the healthcare sector. In BPM literature, medical processes may fall into two types, structured vs. unstructured processes. Despite the dissemination of BPM technologies in healthcare has achieved a significant maturity, it remains elusive whether there are semantic differences between both types of processes. To elucidate this question, this paper conducts conceptual analysis of both structured and unstructured processes in the medical sector, using process models instances, and their corresponding process logs as objects of this conceptual analysis. The semantics (labels) of the activities, events (from both process models) and event logs are analyzed to understand the type of information represented. Such conceptual investigation then gives rise to a two-level conceptual model for medical unstructured processes.

Keywords
Medical Processes, Clinical Guidelines, Business Process Management (BPM), Log Analysis, Conceptual Analysis

1. Introduction

Business Process Management (BPM) [1] consists on the formalization and analysis of the activities conducted by an enterprise to produce goods and services to its customers. Due to its wide applicability in real settings, BPM became an active area both in research and industry. Inspired by benefits in many different sectors, BPM techniques have also been used in healthcare in the formalization and analysis of medical knowledge as business processes [2, 3].

In BPM literature, medical processes may fall into two types. A widespread spectrum of work [1] that classifies business processes according to their level of behavioral predictability and structuring characterize medical processes as either a *structured* or *unstructured processes*. Structured processes correspond to the procedures that consistently follows a predefined process model [1]. Medical administrative processes [4] like lab procedures, and documents handling falls into this type. Differently, unstructured processes are such ones with sufficient variability so no process description can be pre-defined at all [1, 4]. Treatment processes (e.g., cancer

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treatment) fall into this type due to their intrinsic unpredictable features.

Although the BPM community recognizes the differences among the medical structured and unstructured process models, in practice, such differences are shadowed by modeling both types of processes using traditional process languages, such as BPMN and DECLARE. Consequently, it remains elusive whether there are semantic differences between both types of processes. For example, why unstructured processes are unpredictable? Are there circumstances or extreme cases in which structured processes can also turn to be unpredictable? The answer to such questions are fundamental to provide a reasonable support for the management of processes in different domains, including healthcare.

To elucidate this question, this paper provides two contributions. First, it conducts conceptual analysis of both structured and unstructured processes in the medical sector. A framework (Characterizing Conceptual Modeling (CCM) framework [5]) that characterizes conceptual modeling is used to analyze instances of both types of process models expressed in BPMN, together with their corresponding process logs. The semantics (labels) of the activities and events represented in both process models is analyzed to understand the type of information represented, and matched against the log structure expressed in its Extensible Event Stream (XES) [1] definition. The goal is to evaluate whether different levels of predictability imply in different conceptualizations for processes, or the instances of the extremes are just different manifestations of the same phenomenon. Such investigation then gives rise to a two-level conceptual model for medical unstructured processes. A remarkable characteristic of our approach is to consider the analysis of information at design time (models) and runtime (logs).

This paper is structured as follows: Section 2 presents the conceptual framework used to structure the conceptual investigation of medical processes and how this framework is adapted to conduct conceptual investigation in the healthcare sector, while Section 3 conducts the actual conceptual investigation, presenting the process of conceptual investigation, together with the conceptual model for unstructured processes. Section 4 discusses the findings, while Section 5 presents related approaches. Section 6 summarizes the results and outlines future work.

2. Baseline

This section introduces a conceptual framework [5] used for analysis (Sec. 2.1), explaining how this framework is adapted for conducting analysis of medical processes (Sec. 2.2).

2.1. Reference Framework for Conceptual Analysis

Conceptual modeling emerged as a new field of study around the 1970's with the arousal of novel models to describe data structures (Entity Relationship, Relational models) and processes (Structured Analysis models). In the early 80's, the software development, database design, and knowledge representation communities recognized a convergence of the information at a more abstract level captured by the models produced within the three communities [5].

Arising from distinct communities and interests, conceptual modeling lacked a coherent characterization, making it difficult for researchers to position the type and extent of their contributions in the field. To tackle this issue, Delcambre and colleagues [5] drew a characterization for the field by defining the Characterizing Conceptual Modeling (CCM) framework.

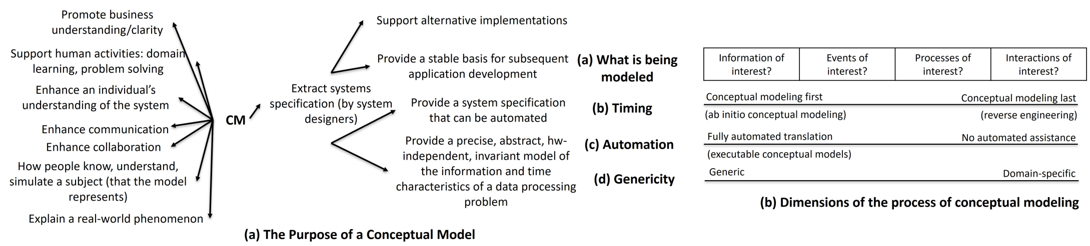


Figure 1: Characterizing Conceptual Modeling (CCM) framework [5]

In CCM, a *conceptual model* represents someone's conceptualization of a domain, being used for human communication and decision making. Contributions in the field necessarily involve some type of language, model or other representation used as a conceptual model.

Other CCM aspects can be seen in Figs. 1(a) and (b). Fig. 1(a) elaborates on the multiple *purposes* of a conceptual model. On the left side, conceptual models have a purpose for humans reading the model (*understanding/communicating a domain, phenomenon, or (future) system*), while on the right side, conceptual models have a purpose of *extracting systems specification.*

CCM also focuses on the *process of producing a concept model*, characterizing the conceptual modeling activity in terms of four dimensions (Fig. 1(b)). The process starts with the identification of which type of information is being modeled (*what is being modeled?*, information, events, processes, and/or interactions?), when the modeling happens? (*timing*), is there automated assistance? (*automation*), is the conceptual model generic or domain-specific? (*genericity*). The conceptual modeling activity can be characterized by positioning a mark in the adequate position along each dimension. This paper investigates conceptual models in Medicine in light of the elements of the CCM framework.

2.2. Conceptual Framework Adapted for Medical Business Processes

This section discusses computer support in Medicine, establishing which conceptual models are used in our conceptual characterization.

Two types of computer support exist in Medicine [6, 3]. Since late 1990s, many Knowledge Representation (KR) formalisms have been developed to represent medical knowledge in Medical Informatics, including ontologies, semantic web related formalisms, logics [7]. Medical processes have been formalized as computer interpretable clinical guidelines (CIG) using general-purpose formalisms, such as document models, decision trees, probabilistic models and task-network models [8]. Many domain-specific languages to model CIGs have also been proposed, such as Asbru, PROforma, GLIF, EON and GUIDE [9]. CIGs are executed over patient-specific clinical data stemmed from Electronic Medical Record (EMR) systems, that store patient data, thus keeping a historical record of patient's health state [3]. The integration of CIGs with EMR compose the medical Decision Support Systems (DSS) that provides recommendations for interventions in single points in time. The medical informatics community is mainly concerned with execution-related aspects, such as CIG execution, reasoning with medical knowledge, integration of CIGs with EMRs, not with conceptual models designed for humans.

More recently, advances in the BPM community proved to be fruitful in the representation of medical knowledge as business processes (sequence of care actions). In BPM lifecycle, business processes are captured using a process language like BPMN or DECLARE in the (re)-design phase. Such process model is then used as a blueprint for configuring a Process-Aware Information System (PAIS) that supports the process at execution phase [1].

In BPM, medical processes may fall into two types. In the leftmost extreme of the spectrum, the activities of a *tightly framed (or structured) process* consistently follows a predefined process model [1], thus being fully predictable and repetitive. Medical administrative processes [4] like lab procedures, and documents handling falls into this type. In the rightmost category of the spectrum, *fully unframed (or unstructured) processes* have sufficient variability so that no process description can be pre-defined at all [1, 4]. Process participants need to make runtime decisions using their knowledge to create activities on the fly. Examples of such processes are medical emergency management processes and clinical guidelines [4]. In between, process models have a varied level of predictability depending on the occurrence of exceptions and evolutions in the domain. Notice also that falling into any category of such spectrum is an inherent characteristic of the process regardless how its representation is supported by any modeling language.

In this paper, I take the BPM stance to investigate medical knowledge represented as business processes. Although the BPM community recognizes the differences among the medical structured and unstructured process models, in practice, such differences are shadowed by modeling both types of processes using traditional process languages, such as BPMN. This community also focuses on implementation issues and execution aspects of executable process models, with little attention devoted to *conceptual models* and *conceptualizations*, thus motivating the work presented in this paper. Here, I investigate structured and unstructured medical processes (*conceptual models*) in terms of the elements of the CMM framework.

3. Conceptual Analysis of Medical Business Processes

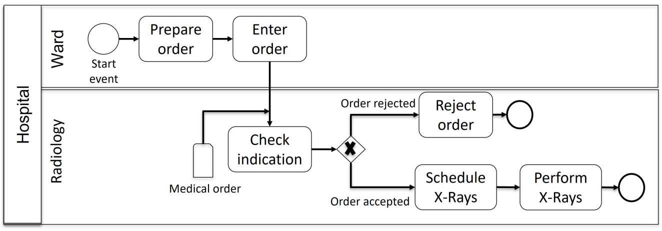
This section conducts the characterization of instances of medical structured and unstructured process in terms of the elements of the CMM framework. Sec 3.1 investigates structured processes, while Sec. 3.2 evaluates unstructured processes. Instances of both types expressed in BPMN style are extracted from literature and used in the investigation of the domain.

Conceptual models are characterized in terms of their *purposes* (Fig. 1(a)) and the *process of producing a conceptual model* into characterized in terms of the four dimensions (Fig. 1(b)). As the BPM spectrum accounts for different levels of predictability between design time and runtime (different phases in the process of producing and using the conceptual model), our investigation focuses on: (i) the *elicitation process* of structured and unstructured processes, (ii) the *nature of specifications* of both processes and (iii) the *characteristics of execution time* that may interfere in the level of predictability, including the process logs resulting from the execution of business processes.

The semantics (labels) of the activities and events represented in both process models is analyzed to understand the type of information represented. The log structure follows the standard definition of Extensible Event Stream (XES) [1]. The information represented in the process model is also matched against the information represented in the XES.

3.1. Investigating Structured Processes

Fig. 2 depicts a simplified version of a medical structured process extracted from [2]. In BPMN diagrams, rounded rectangles represent activities, circles represent (start) events, arrows indicate the flow of execution, the diamond represent a decision, lanes represent the actors executing activities and the rectangle represents a data object.



(a)

Case ID	Event ID	Timestamp	Activities	Resource
1	3565	30-12-20 10:11.02	Prepare order	Susi
	3566	31-12-20 10:10.06	Enter order	Susi
	3567	05-01-20 11:15.12	Check indication	John
	3568	06-01-20 11:11.18	Reject order	John
2	3569	07-01-20 11:14.24	Prepare order	Susi
	3570	30-12-20 10:11.32	Enter order	Susi
		...	....	...

(b)

Figure 2: (a) Process model for handling medical order adapted from [2] and (b) event log resulting from its execution

Elicitation process. At modeling time, the process analyst interviews the employees from "Ward" and "Radiology" to understand which activities they execute.

Nature of process specification. Based on these interviews, the analyst represents the business processes in terms of a number of concepts (Fig. 2(a)). *Activities* correspond to some work to be done ("Perform X-rays"). Some activities aim at executing some physical work ("Perform X-rays"), while others intend to manipulate the data and information used in the process ("Prepare order"). *Events* ("Start event") correspond to internal or external changes in the state of the world that triggers something within the business process (in this case, the "Start event" triggers the process to start). A *precedence relation* ("Prepare order" precedes "Enter order") logically expresses that some work has to be performed before other. For example, logically, the order has to be prepared before one enters it in the system. *Actors* ("Ward") capture the people or roles that perform the work. *Decisions* ("order rejected" or "order accepted") aim at routing the work to be done. Finally, *data objects* ("Medical order") represent the data and information manipulated along the process, necessary for the execution of the work. This process model elaborated on design time is used as a blueprint to configure a PAIS supporting the medical process.

Characteristics of execution time. At runtime, the PAIS suggests the activities for process performers to execute their work. For example, the PAIS suggest the "Prepare order" activity for the "Ward" that performs it by interviewing the patient and entering her details in the system ("Enter order"). The "Radiology" will then check the details of the order ("Check indication") and take a decision ("Order reject" or "Order accept"). If she rejects the order, the process ends. Notice that the PAIS executes the process in conjunction with the human actor. Data manipulated along the process (patients admitted by the unit) is inserted into the PAIS ("Enter order") so that information about the patients can be later used for organizational purposes (statistics about patient admission, follow up by other doctors, legal auditing, etc.). Fig. 2(b) depicts an event log resulting from the execution of the process model by the PAIS.

PAIS process models are *prescriptive*, i.e., if an actor skips some activity, it is considered deviation. Here, a possible deviation (exception) would arise if patient arrives in an emergency state and the "Ward" skips preparing the order, sending the patient directly to "Perform X-rays". Potentially, few cases will need skipping the order preparation and for this reason, it is said that structured processes are relatively predictable and repetitive.

Conceptual characterization using CMM framework. Among the human *purposes* (Fig. 1(a)) of the structured process model, one can see it *promotes business understanding/clarity* as it allows one to grasp the flow of work and medical resources along the process. It also *enhances an individual's understanding of the system*, as one can see the touching points of the business process that is supported by the PAIS. In terms of the support for extracting systems specification, the process models provides a *system specification that can be automated*, that is, one can configure a PAIS by deriving a workflow model from the process model.

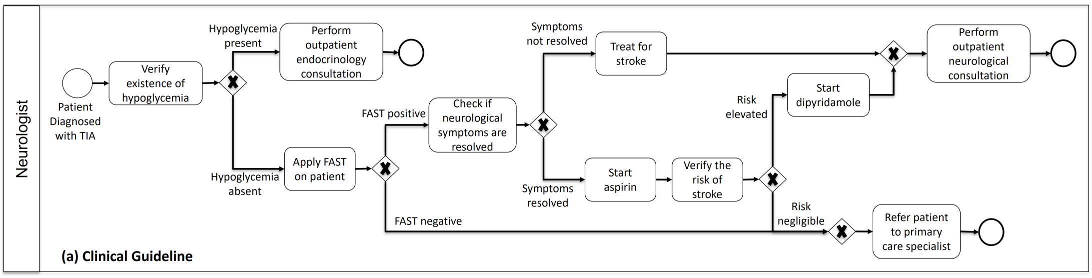
In terms of the four dimensions of the CMM (Fig. 1(b)), the information modeled (concepts) by the process model is highlighted in italics along this section (also depicted in central column of Table 1). The process model is produced before implementing it in a PAIS (*timing*), with automated assistance, holding the possibility of becoming an executable conceptual model, if fully configured as an workflow model (*automation*). Even if the structured process model focuses on healthcare, I classify it as an administrative process model (*genericity*), as it captures the flow of a medical order along process, like any other office work.

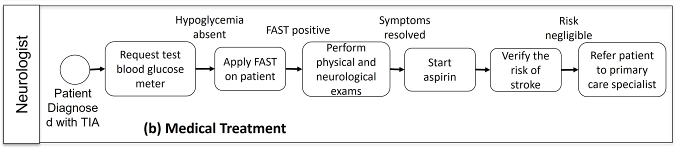
3.2. Investigating Unstructured Processes

Fig. 3(a) depicts a simplified version of a medical unstructured process extracted from [10]. This section describes the nature of such processes based on this example and on the features of a framework for assessing the quality of CGs [11, p. 141].

Elicitation process. Diagnosis and treatment processes (*clinical guidelines* (CGs)) consist of "systematically developed statements to assist practitioner and patient decisions about appropriate health care for specific clinical circumstances" [11]. CGs are developed on the basis of evidence-based studies in clinical research, rather than opinions of experts based on physiology reasoning or unstructured usage of evidences. The result of such studies is systematized as recommendations into a flowchart-like structure (in our case, BPMN in Fig. 3(a)) and textual descriptions.

Nature of process specification. An analysis of Fig. 3(a) reveals that every activity in the process model corresponds to a recommendation that support healthcare providers to develop care actions for patients. Therefore, every activity within the process model is a *recommendation* ("Verify existence of hypoglycemia") to be adapted at runtime according to a specific patient by the healthcare provider executing the CG. Furthermore, some activities correspond to some work to be done ("Start aspirin"), some work to be avoided (e.g. "Do not provide aspirin", included in the textual version of the guideline), or *goals* ("Treat for stroke"), with many *operationalizations* (care actions) accepted to achieve the goal (e.g., "execute endovascular procedure" or "surgery" to "treat stroke"). Every operationalization has a *level of evidence* that tells how much evidence exists about the efficacy of the care action, a *pre-situation* that tells when that recommendation





Case ID	Event ID	Timestamp	Activities	Resource
1	3565	30-12-20 10:11.02	Request test blood glucose	Sam
	3566	30-12-20 10:50.06	Apply FAST	Sam
	3567	30-12-20 11:15.12	Perform physical and neuro exams	Sam
	3568	30-12-20 12:00:00	Start aspirin	Sam
		...	....	...

(c)

Figure 3: Transient Ischemic Attach (TIA) Clinical Guideline (CG) extracted from [10]

is applicable and a *post-situation* that enumerates the effects (benefits, harms and costs) of a specific operationalization.

Precedence relations also exist in CGs, for example, "Verify existence of hypoglycemia" must precede "Apply FAST on patient" because the doctor has to check whether the dizziness is due to hypoglycemia or to neurological symptoms. *Decisions* ("Check if neurological symptoms are resolved") are taken in both structured and unstructured processes, but unstructured processes have an additional source of decisions that correspond to the customizations of care activities from the recommendation. Finally, *data objects* typically remain implicit in CG specifications giving that healthcare providers always manipulate patient's EMR.

Regarding the nature of CG specifications, they are recommendations built of the basis on the best state-of-art evidence of clinical practice and therefore, they are *descriptive* specifications. Technically, healthcare providers are free to customize and even to skip recommendations that do not fit the current needs of patient and environment constraints at a given moment.

Characteristics of execution time. At runtime, healthcare providers use the CG recommendations to decide the care actions to be provided to a specific patient. In terms of decision-support tools, CG engines suggest recommendations, and healthcare providers select the most suitable one [8]. The rationale for customizing each recommendation is denominated as *diagnostic-therapeutic cycle*, being composed by three phases, observation, reasoning and action phases (depicted in Fig. 4) that can be described as follows:

Observation phase. To follow the CG, the doctor analyzes the current *situation* at hand ("Patient diagnosed with TIA") to know whether the recommendation applies. If so, the doctor analyzes attributes and new *events* related to patient's health state, patient's values, preferences and environment constraints to determine the attributes that are relevant for a given recommendation. For example, the CG recommendation (Fig. 3(a)) states the doctor to "Verify the existence of hypoglycemia". The doctor requests a blood test to measure the level of sugar. The threshold for hypoglycemia depends on the age and gender the patient (extracted from

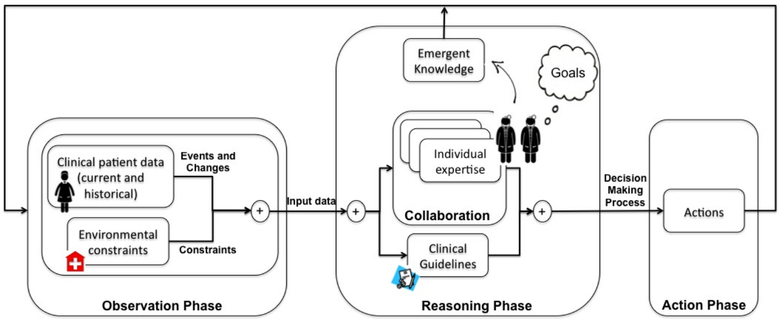


Figure 4: Generation of a medical treatment from a CG in the Diagnostic-Therapeutic Cycle

the EMR). The doctor may consider the existence or absence of some specific insulin test to determine the existence of hypoglycemia.

Reasoning phase. The information about the patient and environment gathered during observation phase is used during the reasoning phase to customize the CG *recommendation* according to the *level of evidence*. From this point, two situations are possible.

This first situation happens when CG recommendations do not exist for specific groups of patients or lack evidence. In this case, the doctor may try to adapt the observed situation with the recommendation at hand. For instance, after the patient has performed the blood test, the exam states that "level of sugar = 70mg/dL", but the CG only specifies recommendations for patients with level of sugar > 70mg/dL. For practical purposes, the doctor may find suitable to still consider the recommendation or simply deviates from it. If the healthcare provider decides to skip the CG recommendation this is not considered a deviation.

The second situation happens when there exists the CG recommendation. For example, for "Treat for stroke" recommendation, the doctor has to choose the concrete care action (*operationalization*) to treat the stroke (surgery or endovascular procedure). To choose among the alternatives, the doctor considers the *pre-situation* (patient's health's state and environment constraints), the *goal* (desired consequence) of the customization and the possible side-effects (undesired consequence, *post-situation*) of the care action. According to medical knowledge, an endovascular procedure is usually better for treating the stroke due to lower risks. However, considering that the patient under consideration is a man over 45 years old, and the doctor wants to avoid the type of anesthesia used during an endovascular procedure (doctor's goal), the surgery is selected. Typically, the procedural specification do not contain operationalizations and goal of recommendations, which may be only in the mind of healthcare providers, and sometimes in the CG textual version.

Action phase. Finally, the correspondent concrete action(s) generated by the healthcare provider in the reasoning phase are executed in the action phase. In this case, the surgery is the concrete activity executed in this phase. The set of care actions for a given patient derived from the CG is called a *medical treatment* (Fig. 3(b)). Fig. 3(c) shows an event log for the execution of the CG. Notice that a recommendation (CG level) becomes a care action (medical treatment level) and the event log tracks the occurrence of the care actions at the medical treatment.

Ideally, three integrated systems must support the execution of CGs: PAIS (that follows the process), EMR (that contain patient's specific information) and CG execution engines (DSS) (that contains CG recommendations regardless the patient, together with general domain specific knowledge, like diseases and treatments).

Conceptual characterization using CMM framework. Among the human *purposes* (Fig. 1(a)) of the unstructured process model, although *business understanding/clarity* is undoubtedly a gain, it is not the ultimate goal. Rather, having a CG process model *supports domain learning* for novice healthcare provides and helps healthcare provides in general in *problem solving* and in *enhancing communication*, by making available a consensual, evidence-based view on how to react to patient's health state in certain circumstances Finally, it also *explains a real-world phenomenon*, making clear the evolution of a certain diseases by representing the different activities that have to be performed in the course of the disease evolution. For example, in the case of the TIA guideline, the doctor has to first check for hypoglycemia, then the neurological symptoms, and finally for stroke. Contrasting with the structured model, the CG is not directly related to the *extraction of system specifications that can be automated*, mainly remaining as an artifact that only supports human activities.

In terms of the four dimensions of the CMM (Fig. 1(b)), the information modeled (concepts) by the process model is highlighted in italics along this section (also depicted in rightmost column of Table 1). The process model is produced only in the beginning of the conceptual modeling activity (*timing*), and thus, it can be automated only by process editors that support modeling, with no corresponding executable model (*automation*). The unstructured process model focuses on domain-related healthcare activities and thus, it is classified as a domain-specific model (*genericity*).

3.3. Summary of Concepts of Structured and Unstructured Medical Processes

Table 1 summarizes the findings for the investigation of the concepts of structured and unstructured medical processes. Notice that while *activities* exist in structured processes, a number of other concepts exist in unstructured processes (*recommendations*, *operationalizations*, *goals* and *situations*), which correspond to the step of using the CG recommendations for producing care actions (operationalizations) for treating patients.

Fig. 5 depicts the conceptual model of unstructured process (clinical guideline) written in UML notation. As the conceptual model of structured process corresponds to the traditional conceptualization of business processes in BPM community [1], I skip to repeat it here.

This conceptual model has been built considering the rightmost concepts from Table 1. After deriving such concepts, the relations among them have been established using the semantics of the relations in the CG from Fig. 3 and generalized when possible. For example, the conceptual model says that each *positive/negative recommendation* has a *goal* (and each *goal* belongs to a *recommendation*). This statement is true for this CG, but by analyzing other CGs, one may conclude that one recommendation aims at achieving multiple goals simultaneously. I leave such generalizations for future work. An exception is when the model considers that each *recommendation* has a *pre-situation*. The conceptual model considers that each pre-situation may have multiple recommendations to take into account the case when there is an AND gateway linking pre-situation and recommendation at the CG. Furthermore, the *treatment level* represents only the actions from the Action Phase (Fig. 4), while the activities of the Observation

Table 1
Summary of Concepts of Structured and Unstructured Processes

Source	Structured Processes	Unstructured Processes
Elicitation process	Interviews	Evidence-based studies in clinical research
Concepts for **Specification**	Activities precedence relations, events actors decisions, data objects	+/- Recommendations operationalizations goals, situations precedence relations, events, actors decisions
Execution time	Process models are prescriptive. Skipping activities is a deviation	Process models are descriptive. Freedom for activities operationalization operationalization
System	PAIS	PAIS, EMR, CG engines

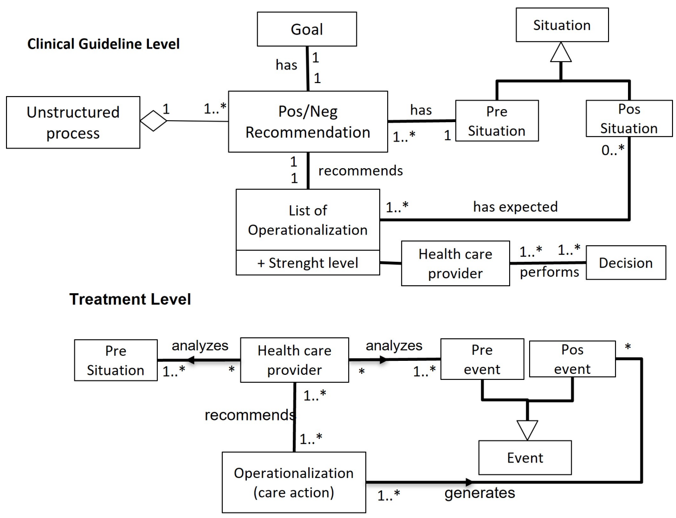


Figure 5: Conceptual Model of Unstructured Medical Process (Clinical Guideline)

and Reasoning Phases need to be also included in future work.

4. Discussion

This section discusses the *process of conceptual analysis* of medical processes, together with considerations about the discovered *conceptual model.*

The process of *conceptual analysis* aimed at investigating the conceptualization of model instances and process logs of structured and unstructured medical processes regardless any formalisms, possibly revealing semantic differences between them. To perform such analysis, the CCM framework has been used because this framework defines core concepts in conceptual modeling.

This analysis revealed that both types of specifications have different natures. Medical structured processes are generic (*genericity*), dealing with business-oriented issues like medical order management, while unstructured processes (CGs) are domain-specific, supporting domain experts in *domain learning*, *problem solving*, *enhancing communication* and *explaining a real-world phenomenon.* Both types of specifications promote *business understanding and clarity* (*purpose*), but this is certainly more important for structured processes. Being domain-specific, unstructured process do not directly support an *extraction of a system specification*, contrasting with structured processes in which it is possible to configure the specification to be automated by a PAIS.

Turning back to the questions raised at the introduction, unstructured processes are unpredictable because events related to changes in patient's health state are virtually infinite, context-dependent and cannot be foreseen at modeling time. They operate over patient's state, while structured processes operate over documents.

An analysis of the *information* contained in both types of processes revealed a two-level structure *conceptual model* (CG and medical treatment) for unstructured medical processes (CGs). To support such new conceptualization, a novel *process modeling* (Sec. 2.1) can be created to reflect the conceptual distinctions of the model. Besides the modeling language, this novel BPM system will have to cope with the issues of customizing the unstructured processes. Similarly, process discovery and conformance checking techniques in BPM process mining [1] will have to reflect the two-level structure of this new conceptualization.

5. Related Work

The problem of conceptualization and formalization of medical knowledge as medical processes is addressed by the medical informatics and BPM communities.

The medical informatics community focuses on representing knowledge of medical processes as computer interpretable guidelines (CIGs) [7], with the purpose of executing the guideline (i.e., generating the treatment) [12], with the aid of the DSS that suggests interventions in unique points of care. Their focus is on the CIG formalisms, rather than conceptualizations. Diverging from this trend, in [12], authors propose a CG conceptual model that enables automated detection of recommendations when combining multiple guidelines.

In BPM, the focus is on using existing process modeling languages (e.g., BPMN, Declare) to represent medical processes, being these medical processes clinical guidelines or pathways, administrative medical processes or medical treatments. In [13], authors define Treatment Cases (TCs) to represent guidelines, pathways and structured processes, giving them operational semantics based on BPMN, while Declare [14] has been used to capture a fracture treatment process as a declarative process specification. In [15], authors propose the CIGDec language for modelling and enacting clinical guidelines. The MobiGuide Project [16] integrates CIGs with organizational workflows by integrating the Picard CIG engine and BPM Activiti execution engine. In [17], authors analyze the knowledge structure of CGs and propose a general framework for conformance of a log of events to the formal CG specification. Ciccio et. al [4] enumerate general characteristics of unstructured processes (including guidelines as an unstructured process), and the current support of BPM systems in terms of flexibility for these characteristics. Their aim is to provide an overview of characteristics of unstructured processes, not conceptualizations. Pufahl et. al [18] identify nine challenges of process modeling in healthcare grouped into three groups (patient-related, medical-practice specific and medical resource-related challenges). For each challenge, the paper provides BPMN best practices written as process fragments that help modeling these complex healthcare aspects. Similarly, Szelagowski et. al [19] propose BPMN extensions to facilitate the representation of clinical pathways. Even though both papers identify challenges and requirements prior to propose BPMN modeling guidelines, the identified challenges and requirements focus on modeling problems sole at design time, while the focus of the present paper considers both design and runtime aspects.

In relation to the medical informatics community, the work here presented is not focused on the execution of clinical guideline, but rather in the conceptual status of medical processes in general. In BPM, current approaches represent medical processes with process languages, not distinguishing among the guideline and treatment levels. As both have different natures and are semantically different, their management has to consider such distinctions. The conceptual model here proposed clarifies the knowledge structure of medical processes. This is a benefit because it opens the possibility of integrating both types of medical processes in a unique framework for process management. This novel framework will be able to manage those processes, taking into account their semantic differences accordingly.

6. Conclusion

In this paper, I conducted conceptual domain analysis of medical structured and unstructured processes. Two benefits have been achieved with this approach. I first show the viability of conducting conceptual analysis with process model instances and their corresponding event logs. Current BPM approaches focuses on the elicitation of challenges and requirements for modeling medical processes, sole remaining at modeling time, while t This paper gives a step further by analyzing the process domain at the instance level.

The second contribution concerns a novel conceptualization for unstructured medical processes. This conceptualization clarifies the knowledge structure of unstructured processes, and may serve as guidance on which formalism to adopt depending on which reasoning technique one wants to perform with medical processes. Further, by relying on this model, a novel BPM system may be created to manage unstructured medical processes based on this two-level structure. A new process modeling language needs to be created, together with new process mining algorithms to assess the conformance of traces to treatments and guidelines.

As future work, I have three directions. First, strength the conceptual analysis of business processes using a particular ontology, such as Basic Formal Ontology (BFO) or DOLCE, also using real-event logs, extracted from information systems. The second one concerns the development of the BPM system that reflects the two-level distinction. Third, conduct similar investigation with other domains (e.g. legal, agrifood businesses) to check if the same considerations apply.

References

[1] W. M. P. van der Aalst, Business Process Management: A Comprehensive Survey, ISRN Software Engineering 2013 (2013).

[2] M. Reichert, B. Weber, Enabling Flexibility in Process-Aware Information Systems - Challenges, Methods, Technologies, Springer, 2012.

[3] R. Lenz, M. Peleg, M. Reichert, Healthcare Process Support: Achievements, Challenges, Current Research, International Journal of Knowledge-Based Organizations 2 (2012).

[4] C. Di Ciccio, A. Marrella, A. Russo, Knowledge-intensive Processes: Characteristics, Requirements and Analysis of Contemporary Approaches, Journal on Data Semantics 4 (2015) 29–57.

[5] L. Delcambre, S. Liddle, O. Pastor, V. Storey, A Reference Framework for Conceptual Modeling: Focusing on Conceptual Modeling Research, 2018. doi:10.13140/RG.2.2.33041.07521.

[6] A. Latoszek-Berendsen, H. Tange, H. J. van den Herik, A. Hasman, From Clinical Practice Guidelines to Computer-Interpretable Guidelines. A Literature Overview, Methods of Information in Medicine 49 (2010) 550–570.

[7] D. Riaño, M. Peleg, A. ten Teije, Ten Years of Knowledge Representation for Health Care (2009–2018): Topics, Trends, and Challenges, Artificial Intelligence in Medicine 100 (2019).

[8] M. Peleg, Computer-Interpretable Clinical Guidelines: A Methodological Review, Journal of Biomedical Informatics 46 (2013) 744–763.

[9] D. Isern, A. Moreno, Computer-Based Execution of Clinical Guidelines: A Review, International Journal of Medical Informatics 77 (2008) 787–808.

[10] S. Wilk, M. Michalowski, W. Michalowski, M. M. Hing, K. Farion, Reconciling Pairs of Concurrently Used Clinical Practice Guidelines Using Constraint Logic Programming, in: Proceedings of AMIA, 2011, pp. 944–953.

[11] T. Greenhalgh, How to Read a Paper: The Basics of Evidence-based Medicine, John Wiley & Sons, 2014.

[12] V. Carretta Zamborlini, M. Da Silveira, C. Pruski, R. Hoekstra, A. ten Teije, F. van Harmelen, A Conceptual Model for Detecting Interactions among Medical Recommendations in Clinical Guidelines, volume 8876 of *Proceedings of the 19th International Conference on Knowledge Engineering and Knowledge Management (EKAW 2014)*, 2014, pp. 591–606.

[13] M. Hewelt, A. Kunde, M. Weske, C. Meinel, Recommendations for Medical Treatment Processes: The PIGS Approach, volume 202 of *Lecture Notes in Business Information Processing*, Springer, 2014, pp. 16–27.

[14] W. M. P. van der Aalst, M. Pesic, H. Schonenberg, Declarative Workflows: Balancing between Flexibility and Support, Computer Science-Research and Development 23 (2009) 99–113.

[15] N. Mulyar, M. Pesic, W. Van Der Aalst, M. Peleg, Declarative and Procedural Approaches for Modelling Clinical Guidelines: Addressing Flexibility Issues, in: Business Process Management Workshops - BPM 2007 International Workshops BPI, BPD, CBP, ProHealth, RefMod, semantics4ws, Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics, 2008, pp. 335–346.

[16] A. Shabo, M. Peleg, E. Parimbelli, S. Quaglini, C. Napolitano, Interplay between Clinical

Guidelines and Organizational Workflow Systems. Experience from the MobiGuide Project, Methods of Information in Medicine 55 (2016).
[17] S. Bragaglia, F. Chesani, P. Mello, M. Montali, Conformance Verification of Clinical Guidelines in Presence of Computerized and Human-Enhanced Processes, Springer International Publishing, 2015, pp. 81–106.
[18] L. Pufahl, F. Zerbato, B. Weber, I. Weber, BPMN in Healthcare: Challenges and Best Practices, Information Systems 107 (2022) 102013.
[19] M. Szelagowski, P. Biernacki, J. Berniak-Wozny, C. R. Lipinski, Proposal of BPMN Extension with a View to Effective Modeling of Clinical Pathways, Business Process Management Journal 28 (2022) 1364–1390.