Modeling the Resource Perspective of Business Process Compliance Rules with the Extended Compliance Rule Graph*

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Abstract. Process-aware information systems must ensure compliance of the business processes they implement with global compliance rules related to security constraints, domain-specific guidelines, standards, and laws. Usually, respective compliance rules cover multiple process perspectives; i.e., they not only deal with the control flow perspective that restricts the sequence in which the process activities shall be executed, but also refer to other process perspectives like data, time, and resource. Although there are various approaches for specifying compliance rules (e.g., based on temporal logic and narrative patterns), only few languages allow for the visual modeling of compliance rules. In turn, existing visual languages focus on the control flow perspective, but treat the other process perspectives as second class citizens. To remedy this drawback, this paper presents an approach for the visual modeling of business process compliance rules, including the resource perspective. The suitability of this approach is evaluated in a case study that was performed by business analysts in the healthcare domain.

1 Introduction

During the last decades many frameworks were proposed that aim to ensure the correctness of business process models. While early works focused on structural and behavioral model correctness (e.g., absence of deadlocks and livelocks) [1, 2], the semantic correctness of process models with imposed compliance rules (i.e., business process compliance) has been subject to recent work [3, 4, 5]. Compliance rules formally capture security constraints, domain-specific guidelines, corporate standards, and laws in a machine-readable manner. Besides control flow (i.e. sequence of activities), the resource perspective on business processes constitutes another fundamental aspect of business process compliance and respective rules (e.g. separation and binding of duties) [6, 7, 8].

For example, consider the compliance rules from Table 1. These refer to a woman's hospital [9, 10, 11, 12]. In particular, they highlight the need for covering

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C1	An X-ray examination for an inpatient must be ordered by a *ward physician*. In this context, the *same physician* must fill in an order form [9].
C2	An X-ray checkup in the *radiology department* must be performed by a *radiologist*. Prior to this, the informed consent of the patient must be checked by a *medical technical assistant (MTA)* of the *radiology department* [9].
C3	Diagnoses must be made by *ward physicians* after receiving the X-ray diagnosis and the X-ray images from the *secretary* of the *radiology department* [9].
C4	The central patient *admission* should admit a patient at the latest one week after she was referred to the hospital by a *gynecologist* [10].
C5	At least one day before a surgery takes place, blood bottles must be ordered by a *ward physician* of the *surgery ward* [10].
C6	Before a *physician* requests an informed consent (IC), the *same physician* must inform the patient about risks [9, 10, 11, 12].

Table 1. Healthcare compliance rules

the resource perspective in the context of business process compliance rules. On one hand, compliance rule C1 considers the resource perspective by requiring a performer with role *physician* assigned to the respective ward. On the other, C1 requires that both tasks (i.e., *order X-ray* and *fill order form*) are performed by the same person (i.e., binding of duties). C6 constitutes another example of such a binding of duties rule. In turn, the resource perspective related to compliance rule C2 requires performers having different roles, but being assigned to the same organizational unit. By contrast, C3 and C4 relate tasks to performers with different roles and organizational units. Altogether, the rules from Table 1 emphasize the high relevance of the resource perspective in business process compliance rules.

While there exist pattern-based approaches [13, 14] for modeling compliance rules that also cover the resource perspective, the latter has been neglected in the design of visual languages for modeling compliance rules so far. To remedy this drawback, this paper provides an approach for the visual modeling of compliance rules that covers the resource perspective as well. In particular, we will show how the resource perspective can be captured with the extended Compliance Rule Graph (eCRG) language. Further, we evaluate the applicability and expressiveness of the eCRG language in respect to the resource perspective in the context of a case study. In the latter we analyze various processes and related compliance rules from a woman's hospital.

Note that we have already introduced the fundamentals of the eCRG language in previous work [15]. However, [15] only briefly deals with the resource perspective of the eCRG as one out of multiple perspectives. By contrast, this paper provides the first detailed presentation of those eCRG elements covering the resource perspective. The remainder of this paper is structured as follows: Section 2 introduces fundamentals required for understanding this work. Section 3 discusses the eCRG based modeling of the resource perspective of business process compliance rules along examples. In particular, we first introduce a scenario referring to the organizational model of a woman's hospital. Second, we present the specific elements of the eCRG language for covering the resource perspective. Third, these eCRG elements are applied to model the rules from Table 1. Finally, results from a case study (i.e. evaluation) we conducted in the healthcare domain are discussed. Related work is presented in Section 4, while Section 5 concludes the paper.

2 Backgrounds

This paper introduces the resource perspective of the extended Compliance Rule Graph (eCRG) modeling language. Since the eCRG language is based on the Compliance Rule Graph (CRG) language, we first introduce CRG and then present the fundamentals of the eCRG language.

2.1 Compliance Rule Graph

The Compliance Rule Graph (CRG) language allows for the visual modeling of compliance rules focusing on the control flow perspective (i.e. sequence flow) of business processes [16, 17, 18]. More precisely, a CRG constitutes an acyclic graph that consists of an *antecedence pattern* and one or several related *consequence patterns*. Both patterns are modeled using *occurrence* and *absence nodes*, which either express the occurrence or absence of events (e.g. related to the execution of a particular task). Edges between such nodes indicate control flow dependencies.

As illustrated in Fig. 1, a trace is considered as compliant with a CRG iff for each match of the antecedence pattern there is at least one corresponding match of every consequence pattern. Furthermore, a trace is considered as trivially compliant iff there is no match of the antecedence pattern. For example, the CRG from Fig. 2 expresses that for each B not preceded by an A, a D must occur, which is not preceded by any C that, in turn, precedes the respective B.

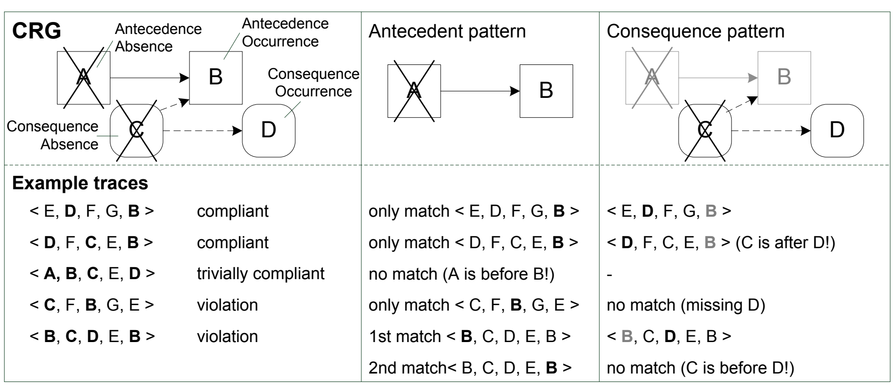


Fig. 1. CRG example and semantics [15]

2.2 Extended Compliance Rule Graph

The CRG language focuses on the **control flow perspective** of compliance rules, but factors out other perspectives. In [15], we introduced the extended Compliance Rule Graph (eCRG) as a visual language for modeling compliance rules that not only covers the control flow perspective, but provides integraed support for the resource, data, and time perspectives as well.

To enable such a support of multiple perspectives, the eCRG language allows for *attachments* in addition to nodes and connectors (i.e. edges). Respective *attachments* represent constraints of the nodes or edges they are linked to. Furthermore, an eCRG may contain instance nodes referring to particular objects, which exist independently from the respective rule (e.g. Mr. Smith, postnatal ward, physician). Note that instance nodes are neither part of the antecedence nor the consequence pattern. Fig. 2 provides an overview of eCRG elements.

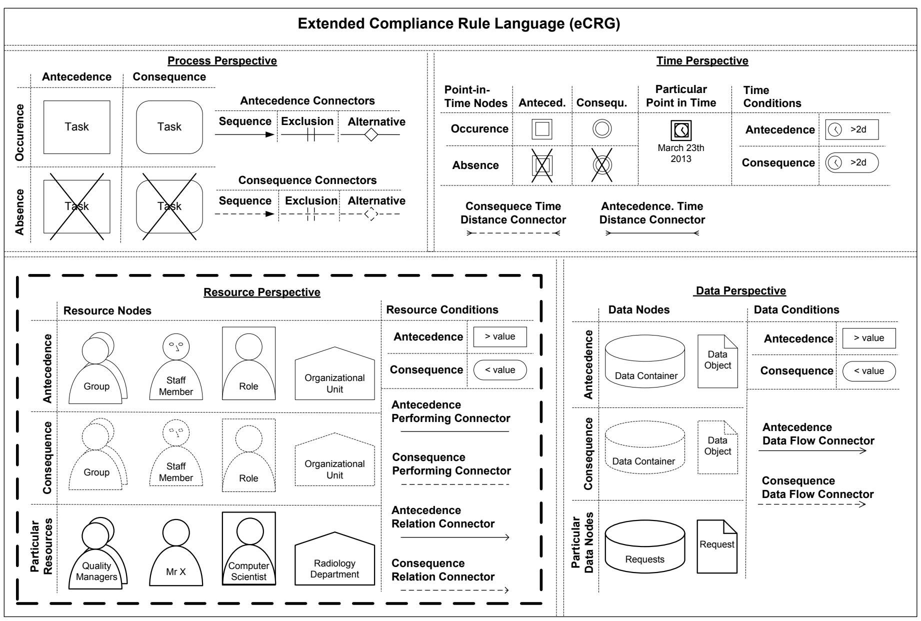


Fig. 2. Elements of the eCRG language

Control flow perspective. Modeling the control flow perspective of compliance rules is supported through four kinds of *task nodes*, i.e., antecedence occurrence, antecedence absence, consequence occurrence, and consequence absence task nodes. Based on these nodes it can be expressed whether or not particular tasks shall be executed. In addition, two kinds of *sequence flow connectors* are provided that allow constraining the execution sequence of tasks. Note that the absence of a sequence flow indicates parallel flow. Furthermore, *exclusive connectors* express mutual exclusion of the tasks they refer to. Finally, *alternative connectors* express that at least one of the connected tasks must occur [15].

Time perspective. The eCRG language offers the following elements for modeling the time perspective: *Point-in-time nodes*, *time condition attachments*, and *time distance connectors* (cf. Fig. 2). Like task nodes, *point-in-time nodes* can be either antecedence occurrence, antecedence absence, consequence occurrence, or consequence absence nodes. Furthermore, a particular date or point in time (e.g. 26th October 2014) can be expressed using instance nodes. *Time conditions* may be attached to task nodes and sequence flow connectors to constrain the duration of a task or the time distance between *task nodes* and *point-in-time nodes*. Finally, *time distance connectors* allow constraining the time distance without implying a particular sequence.

Data perspective. *Data container nodes* and *data object nodes* support the modeling of the data perspective in eCRGs. Furthermore, *data flow connectors* and *data conditions* are provided. *Data container nodes* refer to process data elements or global data stores. By contrast, *data object nodes* refer to particular data values and data object instances. Both kinds of data nodes may be part of the antecedence or consequence pattern, or represent a particular data container and data object respectively. *Data flow connectors* define which process tasks read or write which data objects or data containers. To constrain data containers, data objects and data flow, *data conditions* may be attached. Finally, *data relation connectors* may either be used to compare different data objects or to constrain the value of data containers at particular points in time.

Resource perspective. For modeling the resource perspective of compliance rules *resource nodes* are provided, i.e., staff member, role, group, and organizational unit nodes. Similar to task nodes, *resource nodes* may be part of the antecedence or consequence pattern. Alternatively, they may represent a particular resource instance (e.g. Mr. Smith, postnatal ward, physician). To specify dependencies among resources, *resource relation connectors* are provided. In turn, *resource conditions* constrain a particular resource node. Finally, the *performing relation* indicates the performer of a task node. This paper focuses on the resource perspective of process compliance rules. Respective elements are therefore described in more detail in Section 3.

3 The Resource Perspective of Compliance Rules

After having introduced the fundamentals of the eCRG and CRG languages, we discuss how the resource perspective of business process compliance rules can be modeled when using eCRG. For this purpose, we first provide an examplary application scenario from a woman's hospital. This scenario is then used to illustrate the resource perspective of the eCRG language.

3.1 Scenario

This section illustrates the resource perspective along a healthcare scenario, which refers to clinical processes from the woman's hospital. Fig. 3 illustrates our resource meta-model. It comprises the entity types *organizational unit*, *group*, *staff member*, and *role* as well as the relation types between them. However, our approach is not restricted to the entity and relation types from Fig. 3. For example, our scenario refers to additional relation types and properties (e.g. relation type *supervisor*, property '*is surgery ward*') as well.

Fig. 4 shows the organizational units relevant in the context of our scenario. On one hand, these units are subordinated ones of the *university hospital* including the *woman's hospital* with its wards (e.g. *postnatal ward 1/2*) and other units (e.g. *admission*) as well as the *radiology department*. On the other hand, Fig. 4 further refers to external medical practices of a *gynecologist* and a *general practitioner*.

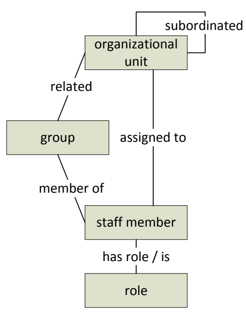


Fig. 3. Meta-model

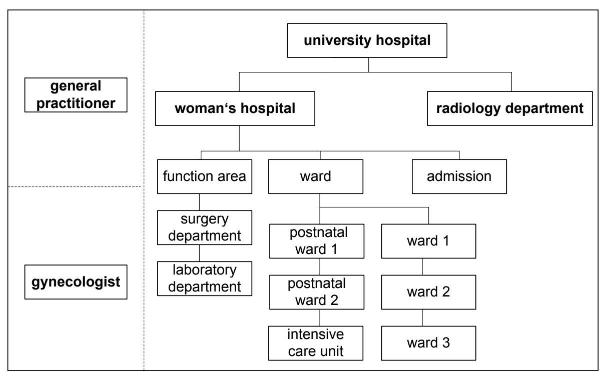


Fig. 4. Organizational units

Fig. 5 provides the assignment relation (cf. Fig. 3) of an anonymized extract of the staff database relevant in our scenario. The roles of the respective actors are shown in Fig. 6. For example, *Mrs. A*, *Mr. B*, and *Mr. C* are assigned to the *radiology department*, while *Mrs. E* is assigned to *wards 1* and *2* (cf. Fig. 5). In turn, *Mr. B* and *Mrs. E* are both physicians, while *Mrs. A* has role *MTA* (i.e., medical technical assistant).

To complement our scenario, Fig. 7 specifies the relation *supervisor*. For instance, *Mr. B* is supervisor of *Mrs. A*. In turn, Fig. 8 provides two attributes of the aforementioned wards; i.e., capacities and information on whether or not the ward is a *surgery ward*.

Finally, Fig. 9 shows a possible execution log of a healthcare process from our scenario [9].

assigned	gynecologist	general practitioner	university hospital									
			woman's hospital									radiology department
			admission	function area		ward						
				surgery department	laboratory department	postnatal ward 1	postnatal ward 2	intensive care unit	ward 1	ward 2	ward 3	
⋮												
Mrs. A												X
Mr. B												X
Mr. C												X
⋮												
Mr. D			X									
⋮												
Mrs. E									X	X		
Mr. F						X	X					
Mrs. G									X	X		
Mr. H									X		X	
⋮												
Mr. I		X										
⋮												

Fig. 5. Staff members and relation assignment

3.2 Resource Perspective in Detail

As outlined in Sect. 2, the resource perspective of the eCRG language provides elements referring to *organizational units*, *groups*, *roles*, and *staff members*. In

has role / is	...	physician	nurse	secretary	MTA	...
⋮						
Mrs. A					X	
Mrs. B		X				
Mr. C				X		
⋮						
Mr. D		X				
⋮						
Mrs. E		X				
Mr. F		X				
Mr. G			X			
Mr. H			X			
⋮						
Mr. I		X				
⋮						

Fig. 6. Staff members and their roles

is supervisor of	…	Mrs. A	Mr. B	Mr. C	…
⋮					
Mrs. A					
Mr. B		X	X	X	
Mr. C					
⋮					

is supervisor of	…	Mrs. E	Mr. F	Mrs. G	Mr. H	…
⋮						
Mrs. E				X	X	
Mr. F						
Mrs. G						
Mr. H						
⋮						

Fig. 7. Relation supervisor

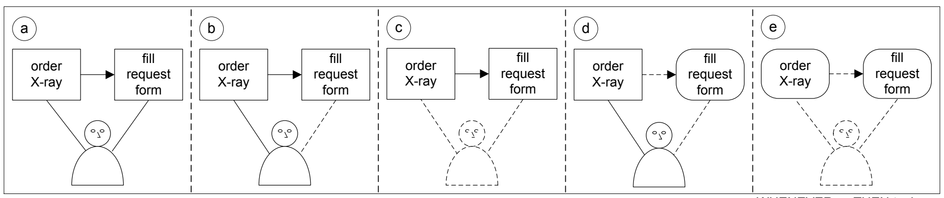
	ward					
attributes	postnatal ward 1	postnatal ward 2	intensive care unit	ward 1	ward 2	ward 3
⋮						
is surgery ward			X	X		
capcity	20	20	15	30	30	20
⋮						

Fig. 8. Ward attributes

step	date	time	activity	performer	data/documents
1	05.02.2009	09:20	examine patient	Mrs. E	
2	05.02.2009	09:40	order X-ray	Mrs. E	
3	05.02.2009	09:45	fill request form	Mrs. E	request form
4	05.02.2009	09:50	inform patient	Mrs. E	
5	05.02.2009	09:55	answer questions	Mrs. E	
6	05.02.2009	09:58	request IC	Mrs. E	signed IC
7	05.02.2009	10:10	transfer patient	Mrs. G	
8	05.02.2009	10:12	transmit IC	Mr. H	signed IC
9	05.02.2009	10:45	check IC	Mrs. A	signed IC
10	05.02.2009	10:50	prepare patient	Mrs. A	
11	05.02.2009	11:05	perfom X-ray	Mr. B	X-ray image
12	05.02.2009	11:20	transfer patient	Mrs. G	
13	05.02.2009	11:35	document result	Mr. C	X-ray diagnosis
14	05.02.2009	11:45	transmit X-ray image & X-ray diagnosis	Mr. C	X-ray image & diagnosis
15	05.02.2009	14:10	make diagnosis	Mrs. E	X-ray image & diagnosis
16	05.02.2009	14:15	prescribe therapy	Mrs. E	
17	05.02.2009	14:40	document diagnosis and therapy	Mr H	

Fig. 9. Execution log of radiology process

turn, these may either be part of the antecedence pattern (solid) or consequence pattern (dashed), or be a particular instance (bold) (cf. Fig 2). The *performing relation connector* allows using these elements in order to specify the performers of both antecedence and consequence task nodes in detail. Accordingly, the performing relation connector can either be antecedence (solid) or consequence (dashed). Fig. 10 illustrates the application of the performing relation connector and its semantics in detail. In Fig. 10a, the antecedence performing relation is used to connect antecedence tasks with an antecedence staff member. In turn, Fig. 10b shows a consequence performing relation connecting an antecedence task with an antecedence staff member. In Fig. 10c, two consequence performing relations are used to connect both antecedence tasks with a consequence staff member. Note that the eCRGs from Figs. 10b and 10c have the same meaning. Fig. 10d shows how a consequence task can be connected to an antecedence task by using a consequence performing relation, while Fig. 10e shows how the consequence performing relation connects two consequence tasks with the same consequence staff member. Note that antecedence performing relation connectors must not be connected to any element of the consequence pattern.



(a) WHENEVER task ***order X-ray*** occurs before task ***fill request form***, and both tasks are performed by the ***same staff member***, THEN ...

(b) WHENEVER task ***order X-ray*** occurs before task ***fill request form*** THEN ***fill request*** must be performed by the **same *actor***, who ***performed order X-ray.***

(c) WHENEVER task ***order X-ray*** occurs before task ***fill request form*** THEN both tasks must be performed by the ***same staff member.***

(d) WHENEVER task ***order X-ray*** occurs THEN task ***fill request form*** must occur afterwards and be performed by the ***performer of order X-ray.***

(e) WHENEVER ... THEN task ***order X-ray*** must occur before task ***fill request form*** and both tasks must be performed by the ***same staff member.***

Fig. 10. Performing relation

As indicated by the examples from Table 1, compliance rules refer to relations between different elements of the resource perspective. The *resource relation connector* can specify relations between resources in the antecedence as well as the consequence pattern. Accordingly, each resource relation connector is either part of the antecedence pattern (solid) or the consequence pattern (dashed). The corresponding resource relation can be expressed by attaching rectangles in case of antecedence relation connectors and ovals in case of consequence relation connectors. Fig. 11 shows the use of the resource relation connector and its semantics in more detail. Fig. 11a uses antecedence resource relations to connect antecedence staff members with an antecedence organizational unit. In turn, Fig. 11b illustrates an antecedence and a consequence resource relation both connecting an antecedence staff member with an antecedence organizational unit. Fig. 11c comprises a consequence resource relation that connects antecedence and consequence staff members, while an antecedence relation connects the same antecedence staff member with resource *physician*. In turn, Fig. 11d applys a consequence relation connector to refer from the staff member to resource *physician*. Finally, Figs. 11e and 11f show how the performing relation can implicitly incorporate the assignment relation and the role relation of our meta-model in some special cases (cf. Fig. 3). Note that antecedence resource relation connectors can only connect elements of the antecedence pattern, but must not be connected to any consequence resource.

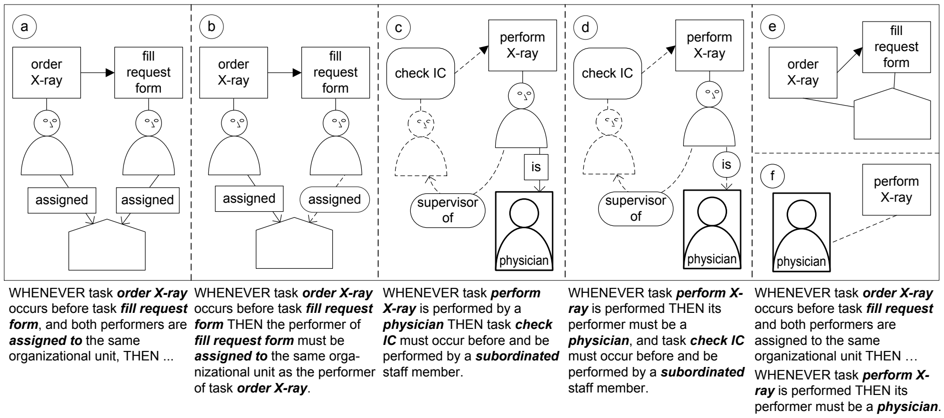


Fig. 11. Resource relations

Finally, resource conditions may be attached to the elements of the resource perspective. Resource conditions may either be part of the antecedence (rectangle) or consequence pattern (oval). Their semantics is illustrated in Fig. 12. In particular, Fig. 12a shows the use of an antecedence condition constraining an antecedence organizational unit. In turn, Fig. 12b applies a consequence condition to the same antecedence organizational unit, while in Fig. 12c a consequence organizational unit is used. Despite this difference, Figs. 12b and 12c have the same meaning. The meaning of Fig. 12d changes, when turning the antecedence organizational unit into a consequence organizational unit. Note that antecedence resource conditions may only be attached to antecedence resource nodes, but not to elements of the consequence pattern.

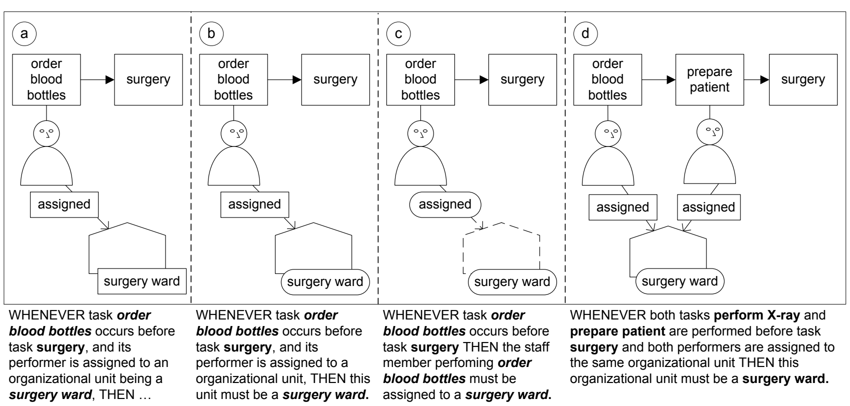


Fig. 12. Resource conditions

A simple formal specification of the eCRG language, including the resource perspective, is provided in [19].

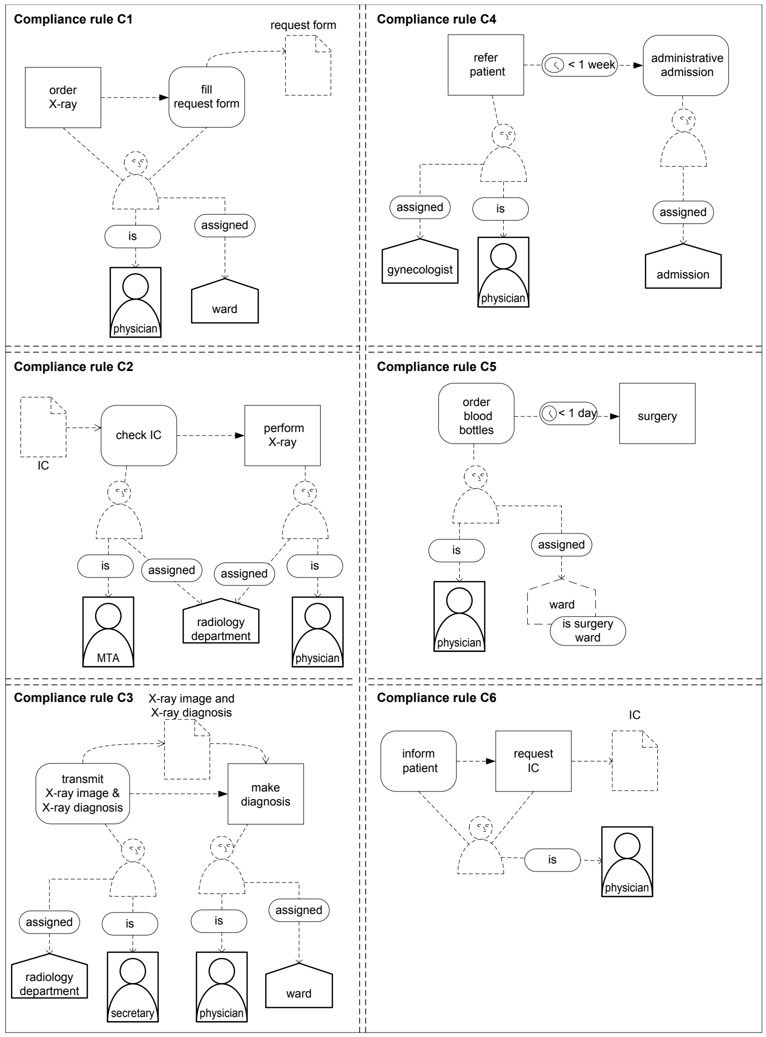


Fig. 13. Healthcare compliance rules

In Fig. 13, the six compliance rules from Table 1 are visualized using the eCRG language, including its elements for capturing the resource perspective. Note that the execution log from Fig. 9 complies with each of these eCRGs. Trivially, the log complies with rules C4 and C5, since it does not contain any of the tasks *refer patient* and *surgery*; i.e., there is no match of the antecedence patterns of rules C4 and C5. In turn, there exist matches for the antecedence patterns of rules C1, C2, C3, and C6 as well as the corresponding consequence patterns. Step 2 (i.e. *order X-ray*) matches with the antecedence pattern of C1, while the following Step 3 matches with the consequence pattern of C1 since it refers to task *fill request form* and is performed by the same staff member *Mrs. E*. As required by the consequence pattern, *Mrs. E* has role *physician* and is assigned to organizational unit *ward*. The antecedence pattern of C2 matches with Step 11 (i.e. *perform X-ray*). As specified in the consequence pattern of C2, the performer of Step 11 (i.e. *Mr. B*) is assigned to the *radiology department*. Further, this performer has role *physician*. The consequence pattern is completed by Step 9 (i.e. *check IC*), which is performed by *Mrs. A* with role *medical technical assistant (MTA)*. Furthermore, *Mrs. A* is assigned to unit *radiology department*. Step 15 (i.e. *make diagnosis*) triggers C3; i.e., it matches with the antecedence pattern of C3. As required by the consequence pattern of C3, the performer (i.e. *Mrs. E*) of Step 15 has role *physician* and is assigned to the unit *ward*. Furthermore, Step 15 is preceded by Step 14 (i.e. *transmit X-ray image & X-ray diagnosis*), which is performed by *Mr. C*. The latter is a secretary of the *radiology department*. Finally, the antecedence pattern of C6 matches with Step 6 (i.e. *request IC*). Step 4 (i.e. *inform patient*) satisfies the corresponding consequence pattern. Hence it is performed by the same staff member (i.e. *Mrs. E*), who also possesses role *physician*.

3.3 Evaluation

To evaluate the suitability of the eCRG language with respect to the modeling of the resource perspective, we conducted a case study in the healthcare domain. In particular, business analysts (i.e., non-IT-specialists) analyzed six process model collections stemming from the woman's hospital [11, 12, 10, 9]. Altogether, they identified 30 compliance rules and modeled them using the eCRG language. Out of these 30 compliance rules, 17 rules refer to the resource perspective. For these 17 compliance rules, the business analysts were able to capture the resource perspective with eCRG; i.e., the eCRG language allowed them to capture all relevant aspects of the resource perspective. Besides this, they revealed drawbacks regarding the modeling of the control flow and time perspectives. In particular, the business analysts emphasized the missing support for periodic time events and the missing ability to refine tasks. Table 2 summarizes study results.

Perspective	Status
Control flow perspective	black box character of Tasks
Data perspective	✓
Resource perspective	✓
Time perspective	periodical points in time

Table 2. Evaluation of the eCRG language

4 Related Work

Modeling issues related to the resource perspective of business processes are addressed in [20]. In turn, [21, 22, 23, 24, 25, 26] discuss the interaction, time, and data perspectives of business processes.

The integration of business process compliance throughout the entire process lifecycle is investigated in [7, 18, 27]; [28] examines compliance issues in the context of cross-organizational processes developing a logic-based formalism for describing both the semantics of normative specifications and compliance checking procedures. In turn, [29] introduces a semantic layer that interprets process instances according to an independently designed set of internal controls.

To verify whether compliance rules are fulfilled by process models at design time, many approaches apply *model checking* [4, 5, 30, 31, 32]; some of them address the data and time perspectives as well. [13] uses *alignments* to detect compliance violations in process logs. Other approaches for verifying compliance apply the notion of *semantic congruence* [33], use *petri-nets* [34], or rely on *mixed-integer programming* [35]. In turn, [36, 37, 38] deal with the compliance of interaction models and cross-organizational process collaborations. Finally, there exist visual approaches for compliance rule modeling [4, 16, 31, 39, 40]. As opposed to eCRG, they focus on the control flow and - partly - the data perspective, but factor out the resource perspective.

5 Summary and Outlook

While compliance rule modeling has been addressed by a plethora of approaches, the visual modeling of the data, time, and resource perspectives has not been sufficiently addressed yet [6, 13, 14]. To remedy this drawback, this paper introduces an extension of the compliance rule graph (CRG) language [16, 17, 18] in order to cover the resource perspective in visual compliance rules as well. Each language element has been presented in detail and illustrated along an example. In turn, all examples were gathered in a healthcare case study that was performed by business analysts. This case study further contributes to evaluate our approach, proving its suitability for modeling the resource perspective of business process compliance rules.

To enable tool support for both the modeling and verification of compliance rules, the semantics of the introduced visual compliance rule language has been formalized in a technical report [19].

In a next step, we will consider the feedback we gathered in the case study in order to enhance the visual compliance rule language. Furthermore, we are developing techniques for verifying the compliance of business processes with imposed multi-perspective compliance rules during runtime. However, our overall aim is to ensure multi-perspective compliance for all phases of the process life cycle, including *a priori* compliance checking at design time as well as *a posteriori* compliance checking after process execution. Finally, we will consider compliance checking in the context of process changes.

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