Collection and Elicitation of Business Process Compliance Patterns with Focus on Data Aspects

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Appendix (available online via http://link.springer.com)

A Horizontal Search Results

Search Date / Search String	# K.O.	# Refinement	# Selection
22.08.2017	*169*	*56*	*22*
(“business” OR (“process” OR “processes”)) (“compliance”) (“anti” OR “pattern” OR “patterns”)	14	8	3
(“business” OR (“process” OR “processes”)) (“compliance”) (“monitoring”)	33	9	2
(“business” OR (“process” OR “processes”)) (“compliance”) (“constraint” OR “constraints”)	8	7	1
(“business” OR (“process” OR “processes”)) (“compliance”) (“framework”)	40	12	5
(“business” OR (“process” OR “processes”)) (“compliance”) (“mining”)	2	0	0
(“business” OR (“process” OR “processes”)) (“compliance”) (“rule” OR “rules” OR “rule-based”)	44	16	8
(“business” OR (“process” OR “processes”)) (“compliance”) (“validation” OR “validations”)	10	0	0
(“business” OR (“process” OR “processes”)) (“compliance”) (“verification” OR “verifications”)	10	1	1
(“business” OR (“process” OR “processes”)) (“compliance”) (“violation” OR “violations”)	8	3	2
23.08.2017	*347*	*42*	*9*
(“business” OR (“process” OR “processes”)) (“constraint” OR “constraints” OR “rule” OR “rules” OR “anti” OR “pattern” OR “patterns”) (“mining”)	99	10	1
(“business” OR (“process” OR “processes”)) (“constraint” OR “constraints” OR “rule” OR “rules” OR “anti” OR “pattern” OR “patterns”) (“monitoring”)	129	7	3
(“business” OR (“process” OR “processes”)) (“constraint” OR “constraints” OR “rule” OR “rules” OR “anti” OR “pattern” OR “patterns”) (“validation” OR “validations” OR “verification” OR “verifications”)	87	20	2
(“business” OR (“process” OR “processes”)) (“constraint” OR “constraints” OR “rule” OR “rules” OR “anti” OR “pattern” OR “patterns”) (“violation” OR “violations”)	32	5	3
25.08.2017	*172*	*9*	*1*
(“business” OR (“process” OR “processes”)) (“constraint” OR “constraints” OR “rule” OR “rules” OR “anti” OR “pattern” OR “patterns”) (“mining”)	108	7	1
(“business” OR (“process” OR “processes”)) (“validation” OR “validations” OR “verification” OR “verifications”) (“runtime” OR “model-based” OR “design-time” OR “design time”)	64	2	0
06.07.2018	*110*	*2*	*2*
(“process” OR “processess”) (“data”) (“constraint” OR “constraints”)	38	2	1
(“process” OR “processes”) (“data”) (“rule” OR “rules”)	58	0	0
(“process” OR “processes”) (“data”) (“compliance”)	14	2	1
Total	**798**	**111**	**34**

The 34 selected literature documents are: Awad et al. (2009); Awad (2010); Awad and Weske (2010); Awad et al. (2011, 2015); Barnawi et al. (2016); Becker et al. (2010); Bernardi et al. (2014); Cabanillas et al. (2010); Caron et al. (2013a,b); Cheikhrouhou et al. (2014); Chesani et al. (2008, 2009); De Masellis et al. (2014); El Gammal (2012); Elgammal et al. (2016); Gomez-Lopez et al. (2013); Gong et al. (2016); Knuplesch and Reichert (2017); Kumar et al. (2010, 2015); Kumar and Barton (2017); Lam (2017); Ly et al. (2010, 2011, 2015); Ly (2016); Maggi et al. (2011); Montali et al. (2014); Thullner et al. (2011); Türetken et al.; Stuht et al. (2012); van der Aalst et al. (2017)

B Vertical Search Results

Search Date / Search String	# K.O.	# Refinement	# Selection
18.09.2017	*15*	*15*	*11*
"A framework for the systematic comparison and evaluation of compliance monitoring approaches"	1	1	0
"Business provenancea technology to increase traceability of end-to-end operations"	1	1	0
"Capturing Compliance Requirements: A Pattern-Based Approach"	1	1	1
"Data-flow anti-patterns: Discovering data-flow errors in workflows"	1	1	1
"From regulatory policies to event monitoring rules: Towards model-driven compliance automation"	1	1	1
"Making business processes compliant to standards and regulations"	1	1	1
"Modeling business rules for supervisory control of process-aware information systems"	1	1	1
"Pattern based property specification and verification for service composition"	1	1	1
"Patterns for Timed Property Specifications"	1	1	1
"Property specification patterns for finite-state verification"	1	1	1
"Root-cause analysis of design-time compliance violations on the basis of property patterns"	1	1	1
"Specification patterns for time-related properties"	1	1	1
"Understanding non-compliance"	1	1	1
"Workflow data patterns"	1	1	0
"Workflow Data Patterns: Identification, Representation and Tool Support"	1	1	0
18.06.2018	*1*	*1*	*1*
"Business Process Compliance through Reusable Units of Compliant Processes"	1	1	1
04.07.2018	*1*	*1*	*1*
"On managing business processes variants"	1	1	1
Total	**17**	**17**	**13**

The 13 selected literature documents are: Dwyer et al. (1998); Elgammal et al. (2010); Giblin et al. (2006); Gruhn and Laue (2005, 2006); Lu et al. (2009); Papazoglou (2011); Ramezani (2017); Santos et al. (2012); Schumm et al. (2010); Trčka et al. (2009); Turetken et al. (2012); Yu et al. (2006)

C Perspectives and Properties (Explicitly) Mentioned

A ✓ indicates that a perspective/property is *explicitly mentioned* in literature, whereas (✓) stands for *implicitly mentioned*. No entry represents *not mentioned*.

Source	Occurrence	Order	Control flow	Data	Resources	Time	Atomic	Composite	Anti-pattern
Awad et al. (2009)		✓	✓						
Awad (2010)	✓	✓	✓	✓	✓	✓			✓
Awad and Weske (2010)		✓	✓						✓
Awad et al. (2011)	✓	✓	✓	✓					✓
Awad et al. (2015)	✓	✓	✓		✓		✓	✓	✓
Barnawi et al. (2016)	✓	✓	✓		✓		✓	✓	✓
Becker et al. (2010)	(✓)	(✓)	✓						
Bernardi et al. (2014)	(✓)	(✓)	(✓)					(✓)	(✓)
Cabanillas et al. (2010)		(✓)	(✓)	✓					
Caron et al. (2013a)	✓	✓	✓	✓	✓	✓			
Caron et al. (2013b)	✓	✓	✓	✓	✓	✓		✓	
Cheikhrouhou et al. (2014)						✓			
Chesani et al. (2008)	✓	(✓)	✓		(✓)				
Chesani et al. (2009)	✓	(✓)	✓		(✓)				
De Masellis et al. (2014)	(✓)	(✓)	(✓)						
Dwyer et al. (1998)	✓	✓	✓					✓	
El Gammal (2012)	✓	✓	✓		✓	✓	✓	✓	
Elgammal et al. (2010)	✓	✓	✓				✓	✓	
Elgammal et al. (2016)	✓	✓	✓		✓	✓	✓	✓	
Giblin et al. (2006)						✓			
Gomez-Lopez et al. (2013)	(✓)	(✓)	(✓)						
Gong et al. (2016)	✓	✓	✓		✓	✓			
Gruhn and Laue (2005)	(✓)	(✓)	(✓)			(✓)			
Gruhn and Laue (2006)	✓	✓	✓			✓			
Knuplesch and Reichert (2017)	✓	✓	✓		✓	✓			
Kumar et al. (2010)	(✓)	(✓)	(✓)			✓			
Kumar et al. (2015)	✓	✓	✓			✓			
Kumar and Barton (2017)	✓	✓	✓			✓			
Lam (2017)	(✓)	(✓)	(✓)						(✓)
Lu et al. (2009)	(✓)	(✓)	(✓)						
Ly (2016)	✓	✓	✓						
Ly et al. (2010)	(✓)	(✓)	(✓)						
Ly et al. (2011)	(✓)	(✓)	(✓)						
Ly et al. (2015)	✓	✓	✓		✓				
Maggi et al. (2011)	(✓)	(✓)	(✓)						
Montali et al. (2014)	✓	✓	✓						✓
Papazoglou (2011)					✓	✓	✓	✓	
Ramezani (2017)	✓	✓	✓	✓	✓	✓	✓	✓	
Santos et al. (2012)		✓	✓						
Schumm et al. (2010)	(✓)	✓	✓						
Stuht et al. (2012)	(✓)	(✓)	(✓)	(✓)	(✓)				
Thullner et al. (2011)	(✓)	✓	✓			✓			
Trčka et al. (2009)				✓					✓
Türetken et al.						✓	✓	✓	
Turetken et al. (2012)	✓	✓	✓		✓	✓			
van der Aalst et al. (2017)	✓	✓	✓						
Yu et al. (2006)	✓	✓	✓						

D Regulatory Documents Selection Criteria

Source	**RegC1**	**RegC2**	**RegC3**: Current	**RegC3**: In Future
AnaCredit	Financial industry	✓		✓
DPA 2000	Data protection	✓	✓	
E-GovG	e-Government	✓	✓	✓
ELGA-VO 2015	Health care	✓	✓	✓
GTelG 2012	Health care	✓	✓	✓
Bank for International Settlements (2013)	Financial industry	✓	✓	✓
BSI Act 2009	IT security	✓	✓	✓
IMA-VO 2011	Energy sector	✓	✓	✓
Oesterreichs Energie (2018)	Energy sector	✓	✓	✓
Oesterreichs Energie (2015)	Energy sector	✓	✓	✓

E Atomic Data-Oriented Constraints Mapped to CPs

No.	Atomic Data-Oriented Constraint	CP Name
1	Data must be accurate / consistent / must have integrity	Event data multiplicity rule Logical derivation rule Event data equality rule Disjunctive event data rule Mutually exclusive event data rule Arithmetic derivation rule Logical derivation rule Event data equality rule Event data exclusion rule Time-oriented integrity rule Activity-oriented integrity rule Event-oriented integrity rule Event data value set rule Event data value range rule Event data uniqueness rule Irreflexive event data rule Event data format rule
3	Data must be available/complete	Mandatory event data rule
4	Data must be calculated using formula	Arithmetic derivation rule
5	Data must be equal/have the same values	Event data equality rule
7	Data must be in domain	Event data value set rule
8	Data must be in range	Event data value range rule
9	Data must be missing	¬ Mandatory event data rule
12	Data must be unique	Event data uniqueness rule
13	Data must be unique over time	Event data uniqueness rule
14	Data must conform to a specific format	Event data format rule
15	Data must not be changed	Time-oriented integrity rule & Activity-oriented integrity rule
16	Data must not be used	Data element never read rule
18	Data origin must be known	Mandatory event data rule
19	Data purpose must be known	Mandatory event data rule

F Unmapped CPs

Source	CP	Status	Remark
Barnawi et al. (2016)	Next Anti Patterns	Open	Insufficient description available
	Precedence isBefore	Open	Insufficient description available
	Precedes Anti Patterns	Open	Insufficient description available
	Response Anti Patterns	Open	Insufficient description available
	Response isBefore	Open	Insufficient description available
	Sequence Anti Patterns	Open	Insufficient description available
	Sequence isBefore	Open	Insufficient description available
Cabanillas et al. (2010)	Prohibited data	NA	Included in resource CPs
	Data rule violation	NA	Comprises a set of compliance problems
	Data object life cycle conformance	NA	Comprises a set of compliance problems
	Data object life cycle coverage	NA	Comprises a set of compliance problems
Gomez-Lopez et al. (2013)	$A_{EX} \wedge B_{EX} \wedge A_T < B_T$	NA	Only antecedent part of a composite CP
	$A_{EX} \wedge \neg(B_{EX} \wedge A_T < B_T)$	NA	Only antecedent part of a composite CP
	$B_{EX} \wedge \neg(A_{EX} \wedge A_T < B_T)$	NA	Only antecedent part of a composite CP
	$\rightarrow A_{EX} \wedge \neg(B_{EX} \wedge A_T < B_T)$	NA	Only antecedent part of a composite CP
	$\rightarrow B_{EX} \wedge \neg(A_{EX} \wedge A_T < B_T)$	NA	Only antecedent part of a composite CP
El Gammal (2012)	AtLeastAfter	NA	Only time restriction part of composite CP
	Every	NA	Only time restriction part of composite CP
	ExacltyAfter	NA	Only time restriction part of composite CP
	ExactDur	NA	Only time restriction part of composite CP
	ExactlyAt	NA	Only time restriction part of composite CP
	MaxDur	NA	Only time restriction part of composite CP
	MinDur	NA	Only time restriction part of composite CP
	Within	NA	Only time restriction part of composite CP
Knuplesch and Reichert (2017)	After k	NA	Only time restriction part of composite CP
	ExactlyAt k	NA	Only time restriction part of composite CP
	Exists Every k	NA	Only time restriction part of composite CP
	Exists Max/Min k	NA	Only time restriction part of composite CP
	Exists Max/Min k	NA	Only time restriction part of composite CP
	Within k	NA	Only time restriction part of composite CP
Papazoglou (2011)	AtLeastAfter k	NA	Only time restriction part of composite CP
	ExactlyAt k	NA	Only time restriction part of composite CP
	Within k	NA	Only time restriction part of composite CP
Ramezani (2017)	Between	NA	Included in Control Flow CPs
	Bounded Existence. Lower Bound	NA	Included in Control Flow CPs
	Bounded Existence. Upper Bound	NA	Included in Control Flow CPs
	Bounded Sequence	NA	Included in Control Flow CPs
	Chain Precedence	NA	Included in Control Flow CPs
	Chain Response	NA	Included in Control Flow CPs
	Cyclic Occurrence	NA	Included in Control Flow CPs
	Exclusive	NA	Included in Control Flow CPs
	Existence and Bounded Existence	NA	Included in Control Flow CPs
	Inclusive, Pre-requisite and Co-requisite	NA	Included in Control Flow CPs
	Negative Precedence or Response	NA	Included in Control Flow CPs
	Not-in-Between	NA	Included in Control Flow CPs
	Parallel. During (Activity)	NA	Included in Control Flow CPs
	Parallel. During (Sequence of Activities)	NA	Included in Control Flow CPs
	Parallel. Simultaneous	NA	Included in Control Flow CPs
	Sequence of (Multiple) Activities	NA	Included in Control Flow CPs
	Substitute	NA	Included in Control Flow CPs
Türetken et al.	AtLeastAfter k	NA	Only time restriction part of composite CP
	ExactlyAt k	NA	Only time restriction part of composite CP
	Within k	NA	Only time restriction part of composite CP
Turetken et al. (2012)	After k	NA	Only time restriction part of composite CP
	ExactlyAt k	NA	Only time restriction part of composite CP
	Within k	NA	Only time restriction part of composite CP

G CP Design for Atomic Data-Oriented Constraints

Atomic data-oriented constraint no.	6
Atomic data-oriented constraint	Data must be from a certain time span
CP name	Event data creation time span CP
CP description	The value of event data type p_1 (wrt an event of type e_1 for an activity of type a_1 with creation time $t_{creation}$) at time point t must be from absolute time span ts
Related existing CPs	*Mandatory event data rule; Time-oriented integrity rule; Data element existence rule*
Formal specification	EVENTS: Validate(value_{p_1}, $\text{t}_{\text{creation}}$) STATEMENTS: $\forall$t Happens(Validate(value_{p_1}, $\text{t}_{\text{creation}}$), t) $\rightarrow$ $\text{ts}_{\text{start}} \leqslant \text{t}_{\text{creation}} \leqslant \text{ts}_{\text{end}}$

Atomic data-oriented constraint no.	10
Atomic data-oriented constraint	Data must be of certain granularity
CP name	Event data granularity CP
CP description	The value of event data type p_1 (wrt an event of type e_1 for an activity of type a_1) at time point t must be of granularity g
Related existing CPs	*Mandatory event data rule; Event data value set rule; Event data value range rule; Event data format rule*
Formal specification	EVENTS: Validate(value_{p_1}, g) FLUENTS: IsOfGranularity(value_{p_1}, g) STATEMENTS: Happens(Validate(value_{p_1}, g), t) $\rightarrow$ HoldsAt(IsOfGranularity(value_{p_1}, g), t)

Atomic data-oriented constraint no.	11
Atomic data-oriented constraint	Data must be of specific data type
CP name	Event data type CP
CP description	The value of event data type p_1 (wrt an event of type e_1 for an activity of type a_1) at time point t must be of data type dt
Related existing CPs	*Event data format rule; Arithmetic derivation rule; Logical derivation rule*
Formal specification	EVENTS: Validate(value_{p_1}, dt) FLUENTS: IsOfDataType(value_{p_1}, dt) STATEMENTS: Happens(Validate(value_{p_1}, dt), t) $\rightarrow$ HoldsAt(IsOfDataType(value_{p_1}, dt), t)

Atomic data-oriented Constraint no.	17
Atomic data-oriented constraint	Data must be encrypted/decrypted
CP name	Event data encryption CP
CP description	The value of event data type p_1 (wrt an event of type e_1 for an activity of type a_1) at time point t must be encrypted
Related existing CPs	*Arithmetic derivation rule; Logical derivation rule; Event data format rule*
Formal specification	EVENTS: Validate(value_{p_1}) FLUENTS: IsEncrypted(value_{p_1}) STATEMENTS: Happens(Validate(value_{p_1}), t) $\rightarrow$ HoldsAt(IsEncrypted(value_{p_1}), t)