Cerberus: Automated Synthesis of Enforcement Mechanisms for Security-sensitive Business Processes

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SECENTIS

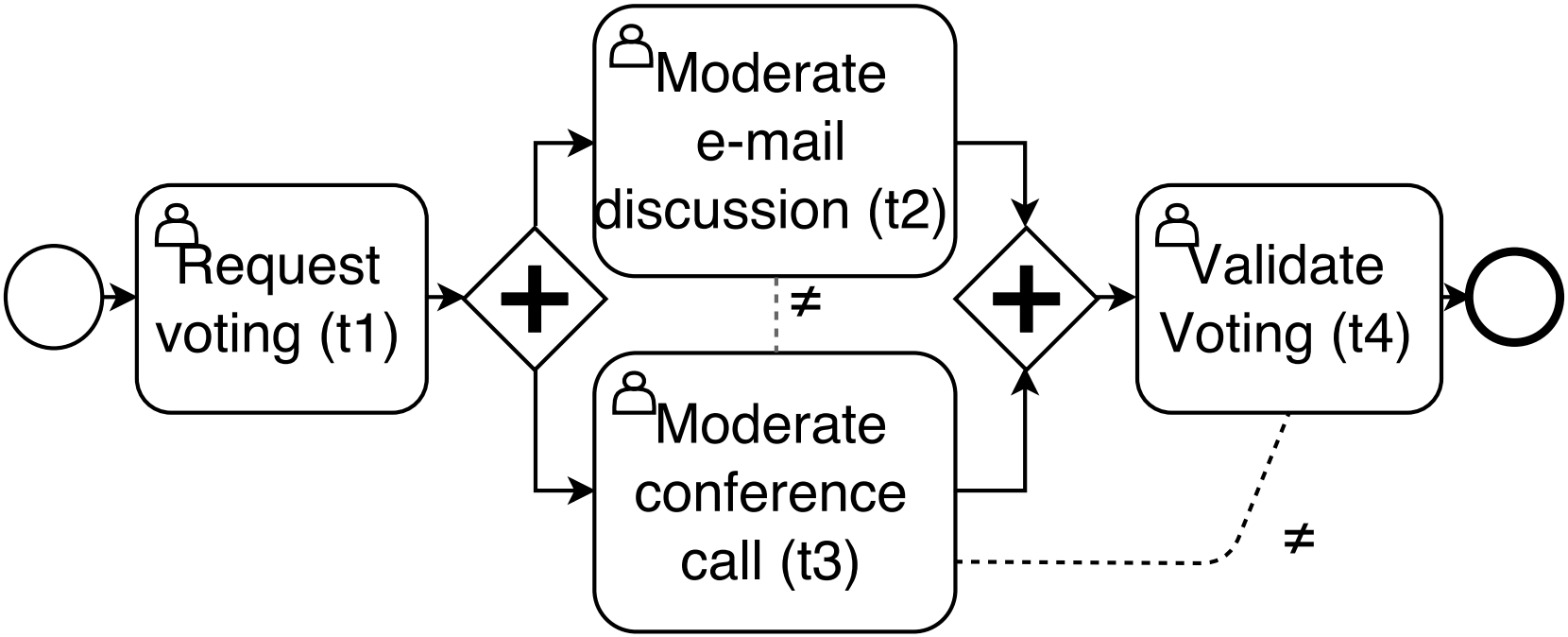
A European Industrial Doctorate on Security and Trust

Outline

Context

- A security-sensitive business process is a structured collection of tasks with:
  - Authorization policy: which users are entitled to execute which tasks
  - Authorization constraints: e.g., some tasks must be performed by the same/different users
- Policy and constraints are crucial to comply with regulations and prevent frauds, but business continuity must not be endangered:
  - It must be possible to complete the process while satisfying the policy and constraints.

Example



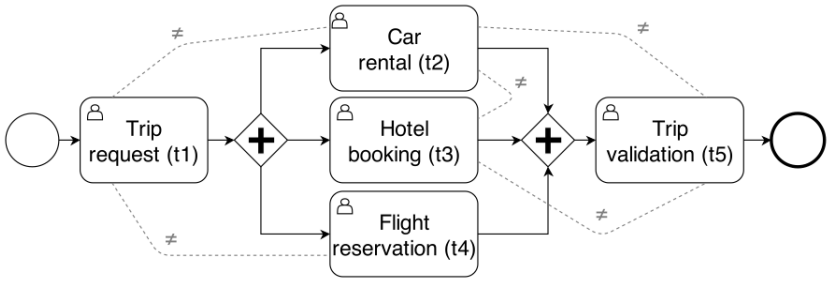
Authorization policy	
t1	A, B, C
t2	A, B, C
t3	A, B
t4	A

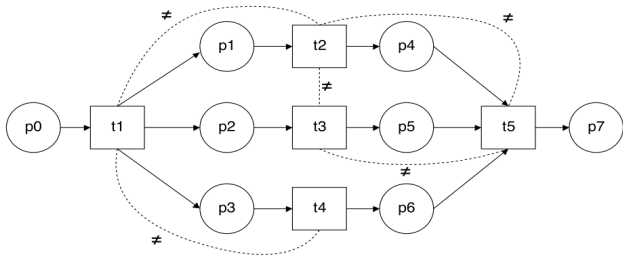
Satisfying runs: t1(C),t2(A),t3(B),t4(A) or
t1(A), t3(B), t2(C), t4(A)

Avoid: t1(A), t2(B), ...

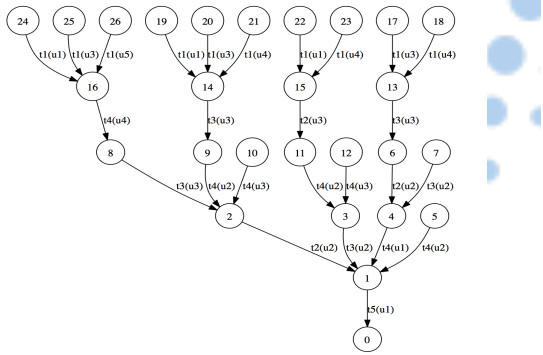
Solution

- Cerberus synthesizes, at design-time, monitors capable of answering, at run-time, user requests to execute tasks
  - request is granted if user is authorized (policy), no constraint is violated and the execution can still terminate (there are users who can perform the next tasks)
- Synthesized monitors are parametric in the authorization policy
  - can be combined at run-time with authorization policies dedicated to different instances of the process.





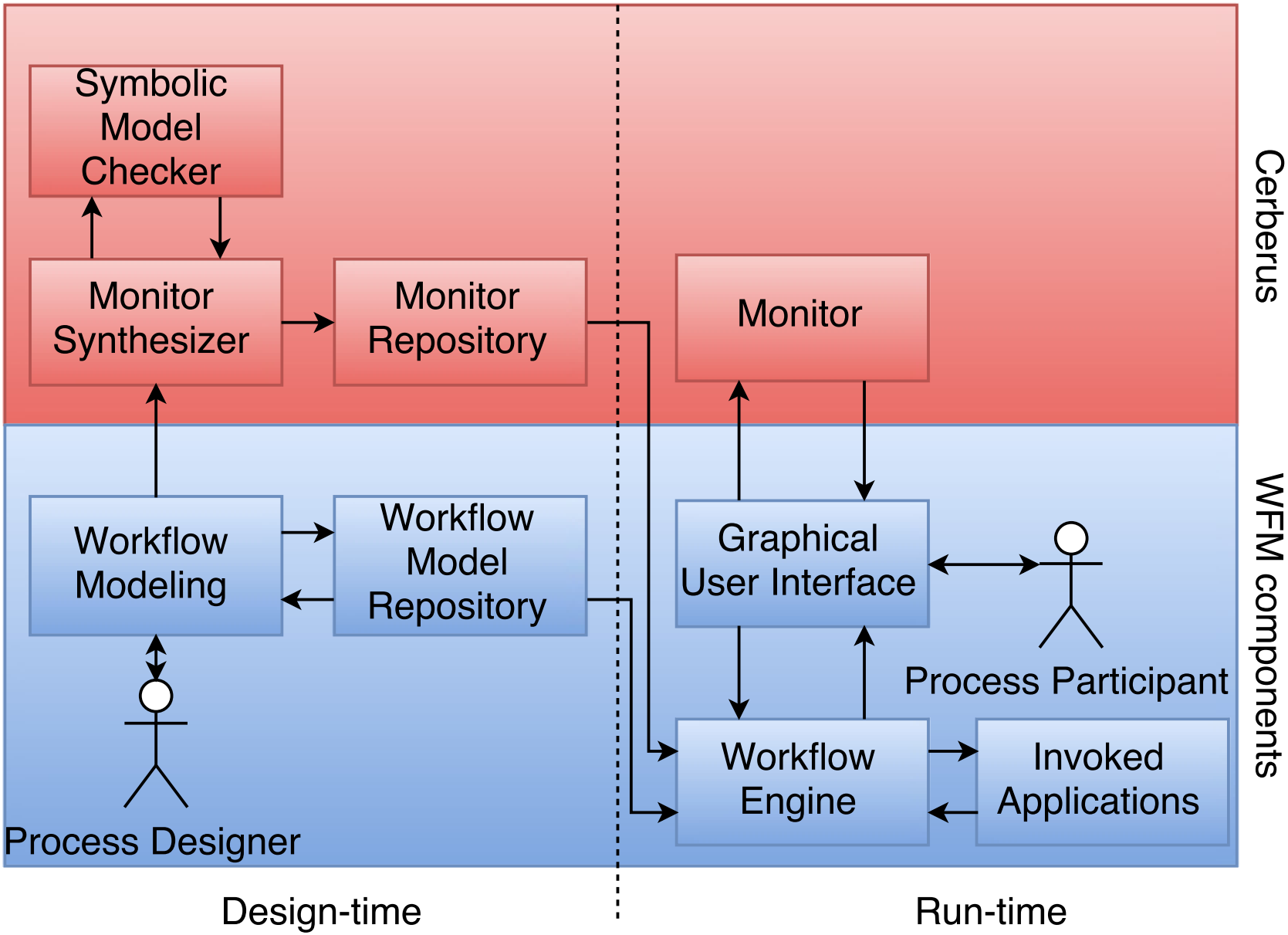
event	enabled		action	
	CF	Auth	CF	Auth
$t1(u)$	$p0 \wedge \neg d_{t1}$	$a_{t1}(u)$	$p0, p1, p2, p3, d_{t1} := F, T, T, T, T$	$h_{t1}(u) := T$
$t2(u)$	$p1 \wedge \neg d_{t2}$	$a_{t2}(u) \wedge \neg\, h_{t3}(u) \wedge \neg\, h_{t1}(u)$	$p1, p4, d_{t2} := F, T, T$	$h_{t2}(u) := T$
$t3(u)$	$p2 \wedge \neg d_{t3}$	$a_{t3}(u) \wedge \neg h_{t2}(u)$	$p2, p5, d_{t3} := F, T, T$	$h_{t3}(u) := T$
$t4(u)$	$p3 \wedge \neg d_{t4}$	$a_{t4}(u) \wedge \neg h_{t1}(u)$	$p3, p6, d_{t4} := F, T, T$	$h_{t4}(u) := T$
$t5(u)$	$p4 \wedge p5 \wedge p6 \wedge \neg d_{t5}$	$a_{t5}(u) \wedge \neg\, h_{t3}(u) \wedge \neg\, h_{t2}(u)$	$p4, p5, p6, p7, d_{t5} := F, F, F, T, T$	$h_{t5}(u) := T$



	CF	Auth				*can_do*	
#	Token in	h_{t1}	h_{t2}	h_{t3}	h_{t4}	h_{t5}	(u, t)	Resp.
0	$p0$	-	-	-	-	-	$(a, t1)$	deny
1	$p0$	-	-	-	-	-	$(b, t1)$	grant
2	$p1, p2, p3$	b	-	-	-	-	$(b, t2)$	deny
3	$p1, p2, p3$	b	-	-	-	-	$(a, t2)$	grant
4	$p4, p2, p3$	b	a	-	-	-	$(c, t3)$	grant
5	$p4, p5, p3$	b	a	c	-	-	$(a, t4)$	grant
6	$p4, p5, p6$	b	a	c	a	-	$(b, t5)$	grant
7	$p7$	b	a	c	a	b	-	-

Integration

- Cerberus can be integrated in many workflow management systems
  - It is transparent to process designers, and does not require any knowledge beyond usual BP modeling
  - Monitors can be synthesized in Datalog and SQL
- We integrated it into SAP HANA Operational Intelligence
  - BPMN modeling IDE based on eclipse
  - Enactment platform on top of an in-memory database (BPMN models translated to SQL)

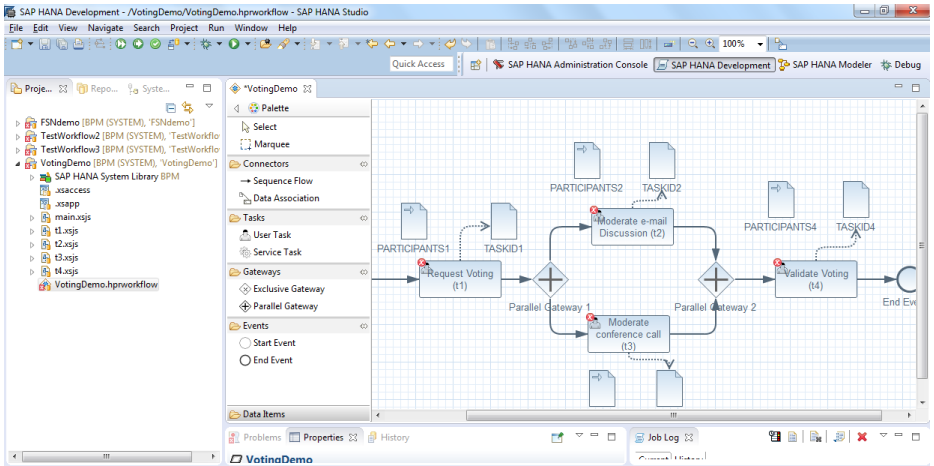

Symbolic Model Checker
Monitor Synthesizer
Monitor Repository
Monitor
Cerberus
Workflow Modeling
Workflow Model Repository
Graphical User Interface
Process Participant
Workflow Engine
Invoked Applications
Process Designer
WFM components
Design-time
Run-time

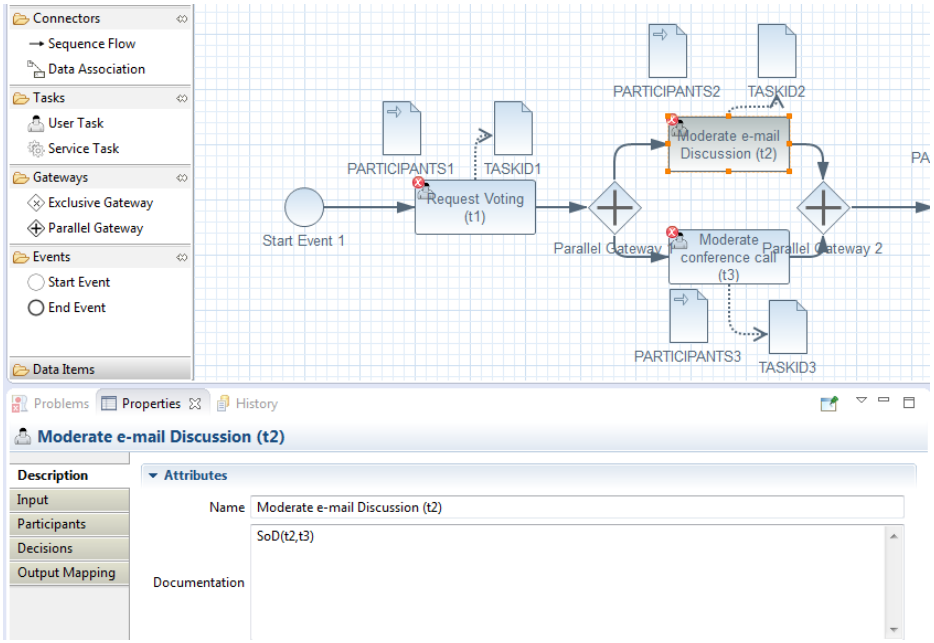
Outline

Three steps:

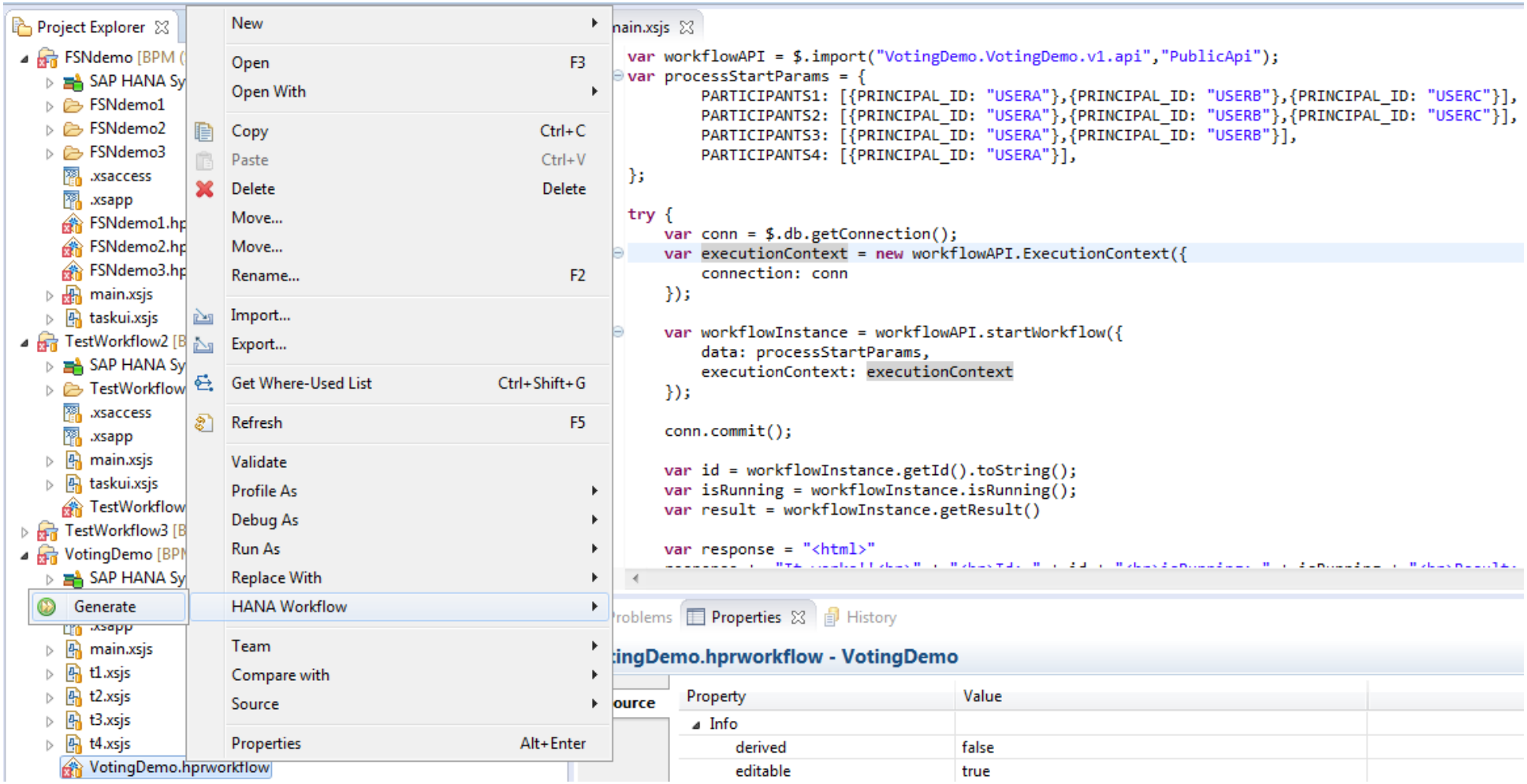
- Design-time
- Deployment (monitor synthesis)
- Run-time

Design-time: BPMN modeling and constraint specification





Monitor synthesis:



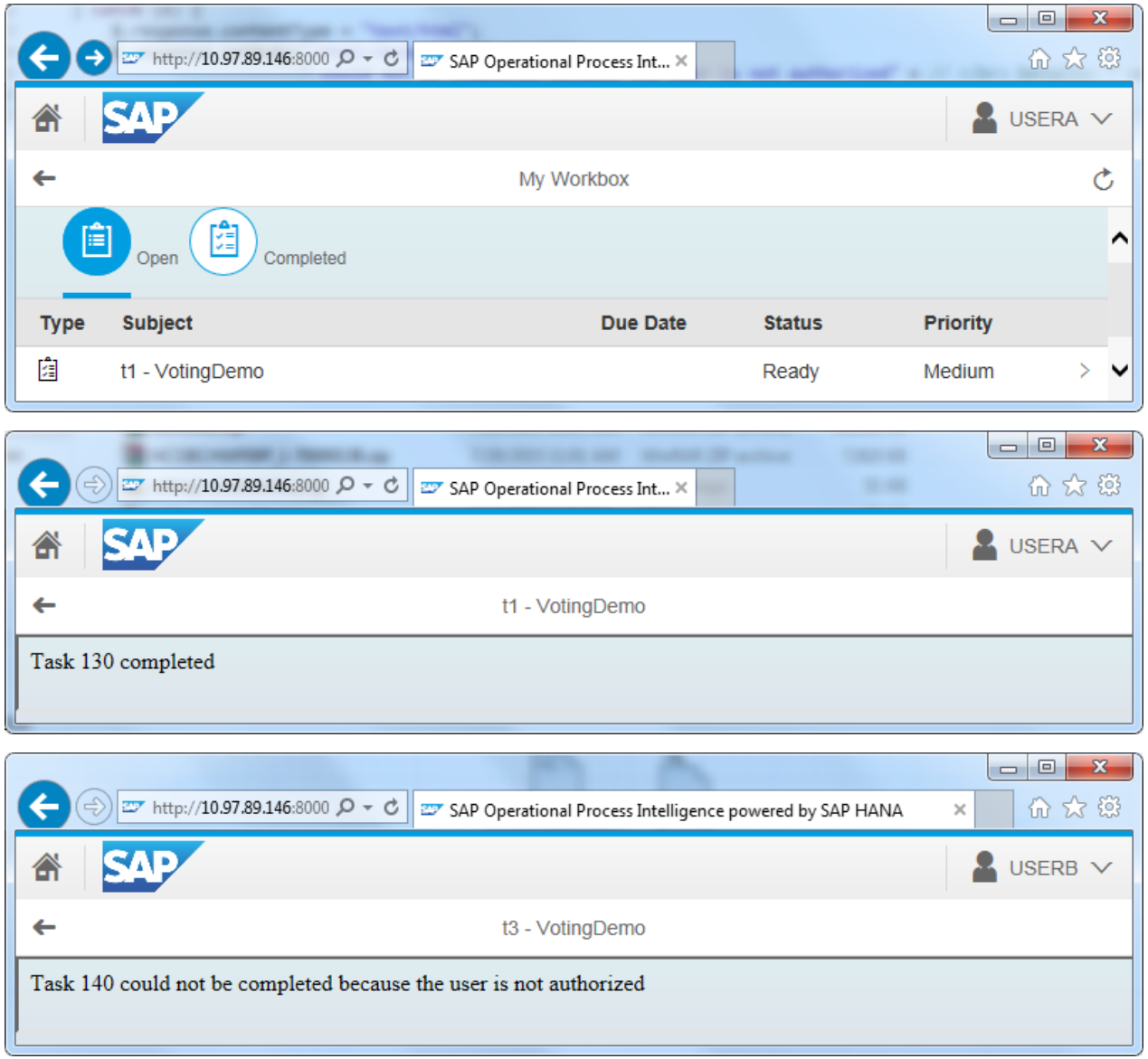
Stored monitor:

VotingDemo_VotingDemo

Details

```
131
132   --monitor auhtorization check for UserTask_2
133   ELSEIF TASK_ID_IN = m_task_id_UserTask_2 THEN
134     var_out =
135     SELECT
136       CASE WHEN T.STATUS='READY' AND (A.ROLE_TYPE='PARTICIPANT' OR A.ROLE_TYPE='OWNER') THEN 1 ELSE 0 END AS "CAN_COMPLETE",
137       T.TASK_ID
138       FROM "TASKMGT"."sap.bc.taskmgt.task::TASK" AS T INNER JOIN "TASKMGT"."sap.bc.taskmgt.task::ASSIGNMENT" AS A ON T.TASK_ID = A.TASK_ID
139       WHERE (T.CATEGORY = 'TASK' OR T.CATEGORY = 'CHECKLIST')
140       AND A.PRINCIPAL_ID IN
141       (
142       --monitor query
143       SELECT DISTINCT Z1."USER_NAME" FROM "SYS"."USERS" AS Z1 WHERE  doneUserTask_2 = 0 AND doneUserTask_4 = 0 AND doneUserTask_1 = 1 AND d
144       UNION
145       SELECT DISTINCT Z2."USER_NAME" FROM "SYS"."USERS" AS Z1, "SYS"."USERS" AS Z2 WHERE  doneUserTask_2 = 0 AND doneUserTask_4 = 0 AND don
146       UNION
147       SELECT DISTINCT Z1."USER_NAME" FROM "SYS"."USERS" AS Z1, "SYS"."USERS" AS Z2 WHERE  doneUserTask_2 = 0 AND doneUserTask_3 = 0 AND don
148       UNION
149       SELECT DISTINCT Z3."USER_NAME" FROM "SYS"."USERS" AS Z1, "SYS"."USERS" AS Z2, "SYS"."USERS" AS Z3 WHERE  doneUserTask_2 = 0 AND doneU
150       UNION
151       SELECT DISTINCT Z2."USER_NAME" FROM "SYS"."USERS" AS Z1, "SYS"."USERS" AS Z2 WHERE  doneUserTask_2 = 0 AND doneUserTask_4 = 0 AND don
152       UNION
153       SELECT DISTINCT Z1."USER_NAME" FROM "SYS"."USERS" AS Z1 WHERE  doneUserTask_2 = 0 AND doneUserTask_4 = 0 AND doneUserTask_1 = 1 AND d
154       --end of monitor query
155       ) AND A.PRINCIPAL_ID = SESSION_USER;
156
157   --monitor auhtorization check for UserTask_3
158   ELSEIF TASK_ID_IN = m_task_id_UserTask_3 THEN
159     var_out =
160     SELECT
161       CASE WHEN T.STATUS='READY' AND (A.ROLE_TYPE='PARTICIPANT' OR A.ROLE_TYPE='OWNER') THEN 1 ELSE 0 END AS "CAN_COMPLETE",
162       T.TASK_ID
163       FROM "TASKMGT"."sap.bc.taskmgt.task::TASK" AS T INNER JOIN "TASKMGT"."sap.bc.taskmgt.task::ASSIGNMENT" AS A ON T.TASK_ID = A.TASK_ID
164       WHERE (T.CATEGORY = 'TASK' OR T.CATEGORY = 'CHECKLIST')
165       AND A.PRINCIPAL_ID IN
166       (
167       --monitor query
168       SELECT DISTINCT Z2."USER_NAME" FROM "SYS"."USERS" AS Z1, "SYS"."USERS" AS Z2 WHERE  doneUserTask_3 = 0 AND doneUserTask_4 = 0 AND don
```

Run-time:


http://10.97.89.146:8000
SAP Operational Process Int...
USERA
My Workbox
Open
Completed
Type
Subject
Due Date
Status
Priority
t1 - VotingDemo
Ready
Medium
http://10.97.89.146:8000
SAP Operational Process Int...
USERA
t1 - VotingDemo
Task 130 completed
http://10.97.89.146:8000
SAP Operational Process Intelligence powered by SAP HANA
USERB
t3 - VotingDemo
Task 140 could not be completed because the user is not authorized

Outline

Conclusion

- We have other papers describing in more details the techniques used in the tool:
  - "Automated Synthesis of Run-time Monitors to Enforce Authorization Policies in Business Processes" in ASIACCS 2015
  - "Modularity for Security-Sensitive Workflows" in arXiv
  - "Assisting the Deployment of Security-Sensitive Workflows by Finding Execution Scenarios" in DBSec 2015
- The tool is under development and there is a pilot project for internal use in SAP (payment approval workflows)
- Not yet available for public use

Thank you!

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