Checking the Realizability of BPMN 2.0 Choreographies

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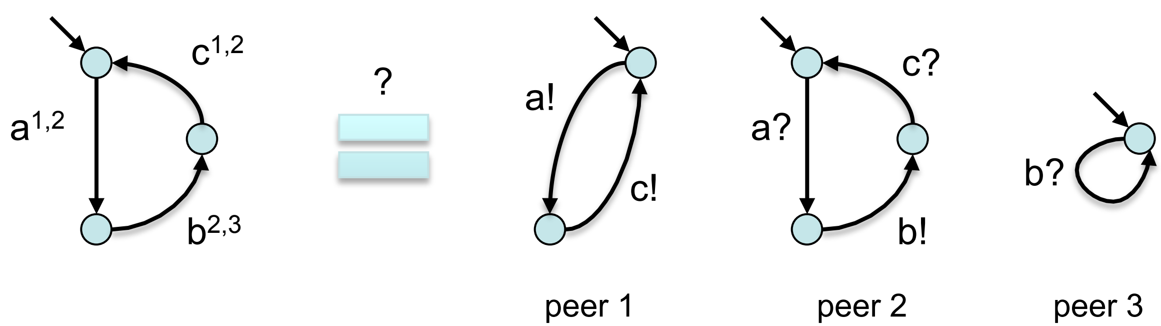
Realizability of Choreographies

- Interactions among a set of services involved in a new system can be described from a global point of view using choreography specification languages
- Given a choreography specification, local implementations, namely peers, can be automatically generated via projection
- However, peers do not always implement the choreography: this problem is known as realizability



Contributions

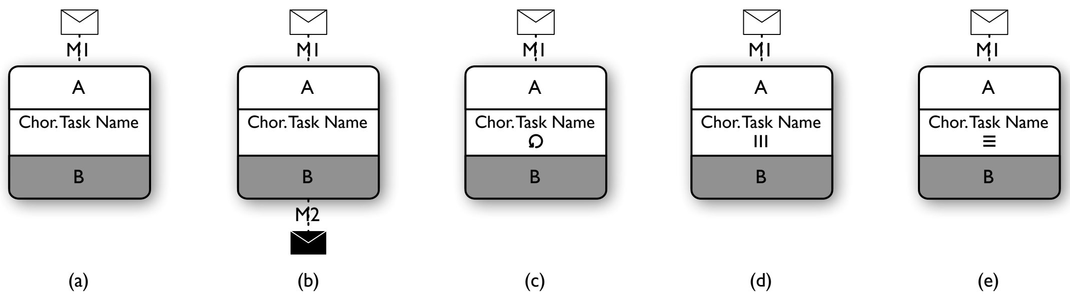
- We propose an encoding of BPMN 2.0 choreographies into the LNT specification language
- We chose LNT because:
  - It provides a good level of expressiveness for describing BPMN constructs
  - It is equipped with CADP which offers state-of-the-art tools for state space exploration and verification
- This encoding allows us to:
  - Automate service peer generation
  - Verify choreography specifications using CADP
  - Check the realizability for both synchronous and asynchronous communication

Outline

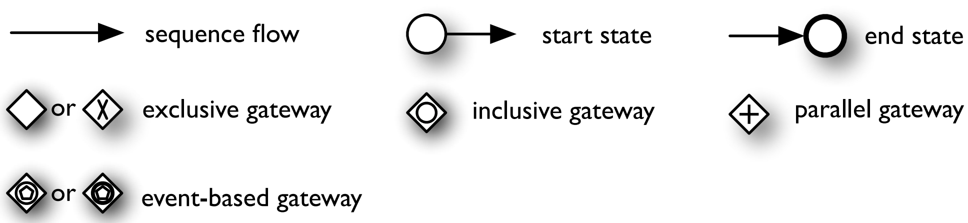
1. Preliminaries: BPMN 2.0, LNT, and CADP
2. Encoding into LNT
3. Verification and Realizability
4. Tool Support
5. Concluding Remarks

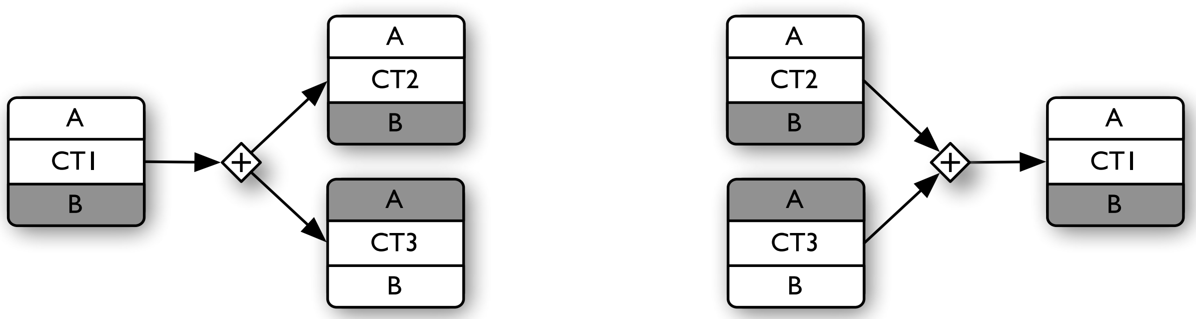
BPMN 2.0 Choreographies

- Choreography tasks and loop types



- Control flows and gateways



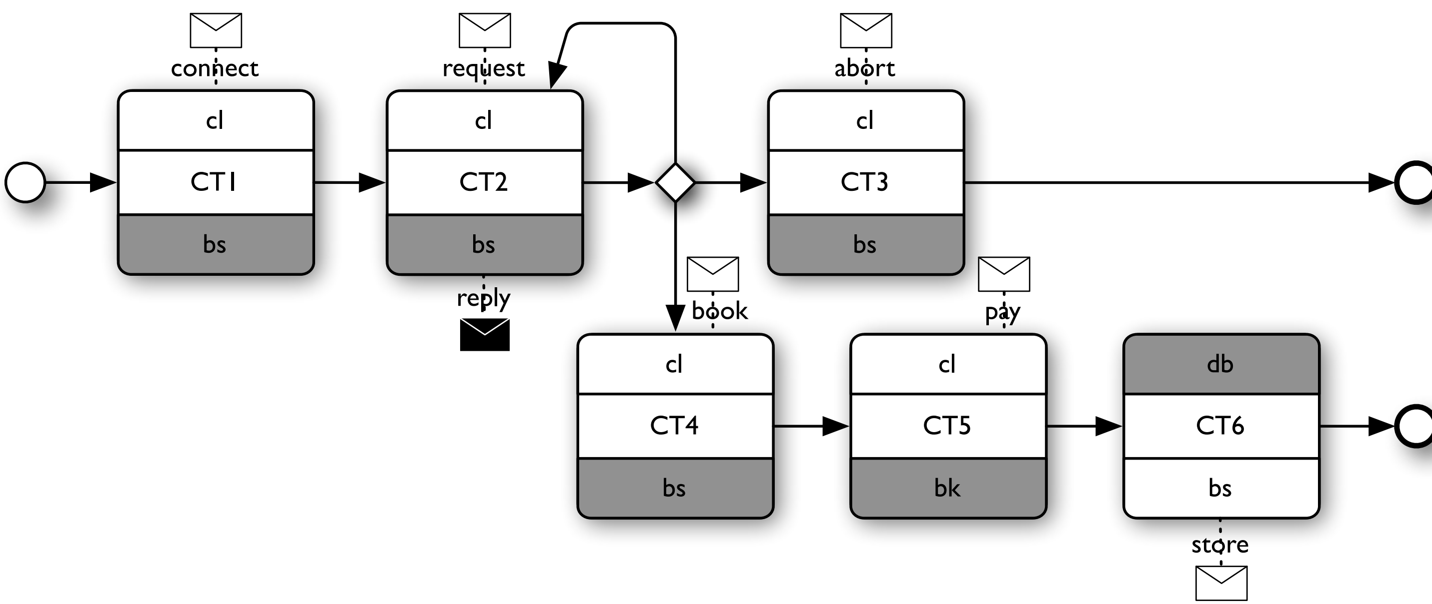


diverging pattern (diverging parallel gateway)

converging pattern (converging parallel gateway)

Running Example

An e-booking system involving four peers: a booking system (bs), a database (db), an online bank service (bk), and a client (cl)



Peers are described using Labelled Transition Systems (LTSs)

LNT

- LOTOS NT (LNT) is a value-passing process algebra with user-friendly syntax and operational semantics

- LNT is an imperative-like language where you can specify data types, functions (pattern matching and recursion), and processes

- Excerpt of the LNT process grammar:

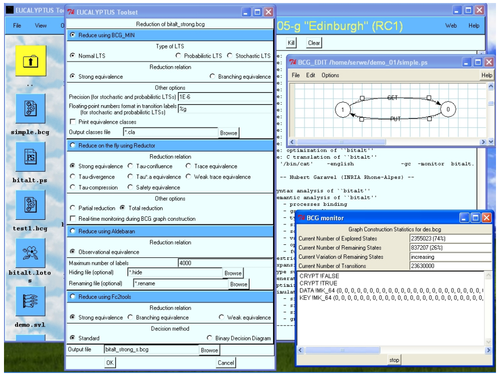
B ::= **stop** | G(!E, ?X) **where** E' | **if** E **then** B1 **else** B2 **end if**
| x:=E | **hide** G **in** B **end hide** | P [G1,...,Gm] (E1,...,En)
| **select** B1 **[]** … **[]** Bn **end select** | B1 **;** B2
| **par** G **in** B1 **||** … **||** Bn **end par**

- Verification using CADP through an automated translation to LOTOS

Construction and Analysis of Distributed Processes (CADP)

- Design of asynchronous systems
  - Concurrent processes
  - Message-passing communication
  - Nondeterministic behaviours

CADP
(INRIA/CONVECS)



- Formal approach rooted in concurrency theory: process calculi, Labeled Transition Systems, bisimulations, branching temporal logics

- Many verification techniques: simulation, model and equivalence checking, compositional verification, test case generation, performance evaluation, etc.

- Numerous real-world applications: avionics, embedded systems, hardware design, middleware and software architectures, etc.

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Encoding BPMN into LNT (1/3)

- Translation of BPMN via state machines
  - Sequence flow

```
process s1[…]
    s2[…]
end process
```

  - Message sending

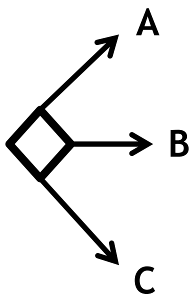
```
process s1[…]
    msg1; s2[…]
end process
```

  - Message receiving
    - Synchronous communication
    - Asynchronous communication via FIFO message buffers

```
process s1[…]
    msg1_REC; s2[…]
end process
```

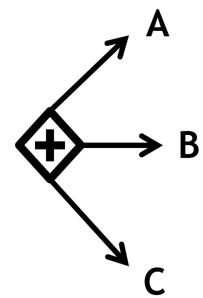
Encoding BPMN into LNT (2/3)

– Exclusive gateway



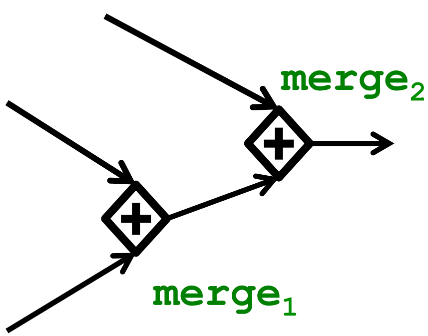

```
select
     option_A[…]
  [] option_B[…]
  [] option_C[…]
end select
```

– Parallel gateway




```
par
     option_A[…]
  || option_B[…]
  || option_C[…]
end par
```

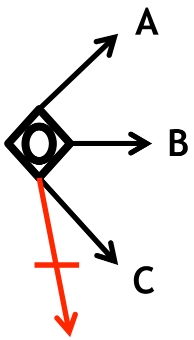
– Parallel merge (multiple merges)




```
hide sync1, sync2 in
par
   sync1, sync2 -> option_A[…,sync1,sync2]
|| sync1, sync2 -> option_B[…,sync1,sync2]
|| sync2        -> option_C[…,sync2]
end par
```

Encoding BPMN into LNT (3/3)

– Inclusive gateway



Inclusive Merging:

- Analogous to parallel merge
- Default case needs no synchronization

```
select
   option_A[…]||((option_B[…][] null) || (option_C[…][] null))
 []option_B[…]||((option_A[…][] null) || (option_C[…][] null))
 []option_C[…]||((option_A[…][] null) || (option_B[…][] null))
 []default[…]
end select
```

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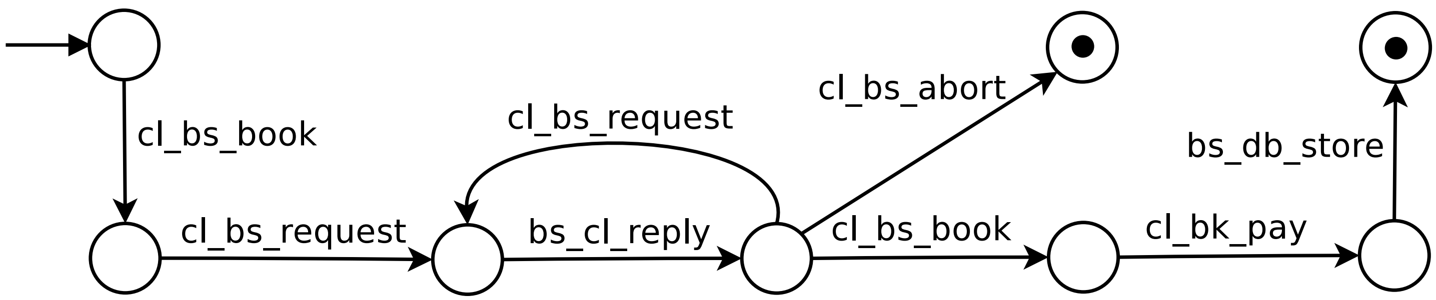
Compilation and Verification

- LTS models can be generated using CADP exploration tools, and verified using the Evaluator model-checker
- E-booking system: LTS obtained by hiding "sync_" messages, and minimizing the resulting LTS

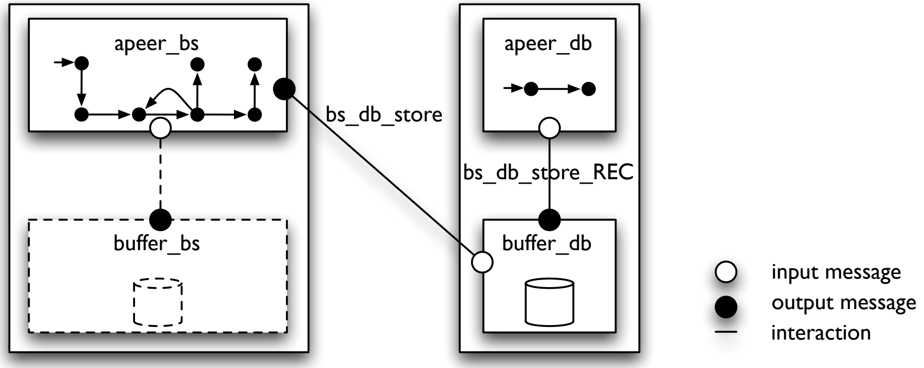


- We can check that a client can make a booking or abort only if a request has been issued (safety property):

```
[ (not 'CL_BS_REQUEST')* .
        ('CL_BS_BOOK' or 'CL_BS_ABORT') ] false
```

Realizability Checking

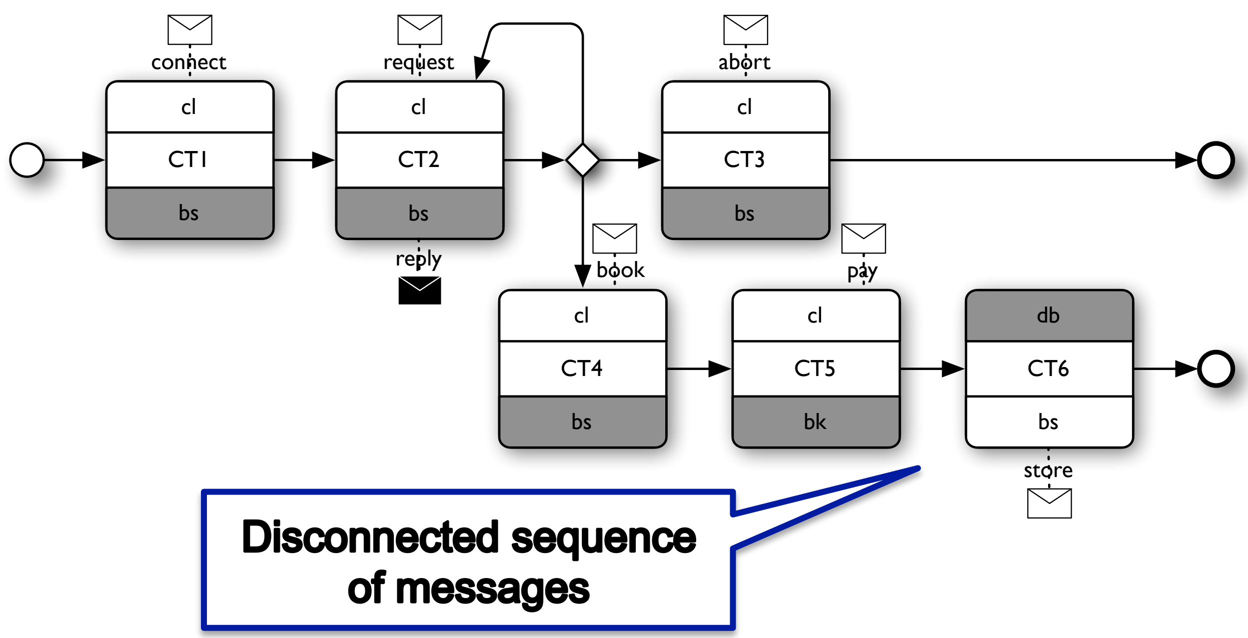
- Realizability is computed by comparing the BPMN LTS with the system composed of interacting peers using behavioural equivalences
- If these two systems are equivalent, the choreography is realizable
- In case of asynchronous communication, we generate LNT code to implement bounded FIFO buffers, and associate a buffer to each peer



- For asynchronous communication, undecidability is avoided by imposing buffer bounds or by using recent synchronizability results [BasuBultan-WWW11]

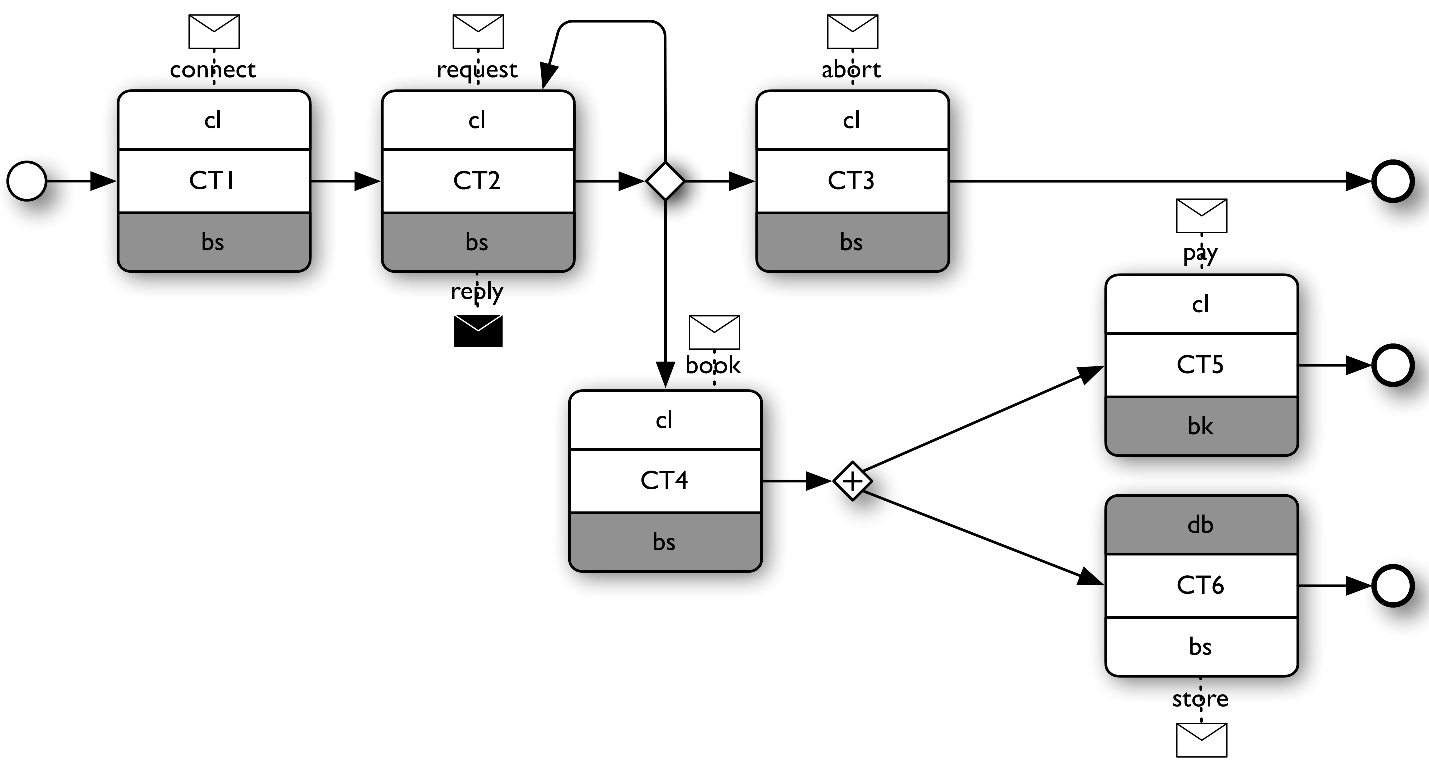
E-booking System Realizability

- Our running example is not realizable for both communication models (synchronous and asynchronous)
- The trace consisting of messages cl_bs_connect, cl_bs_request, bs_cl_reply, cl_bs_book appears in both systems, but bs_db_store is then in the distributed system, and not in the choreography LTS



E-booking System, Revisited

We use a diverging parallel gateway instead and realizability checks return positive results for both communication models



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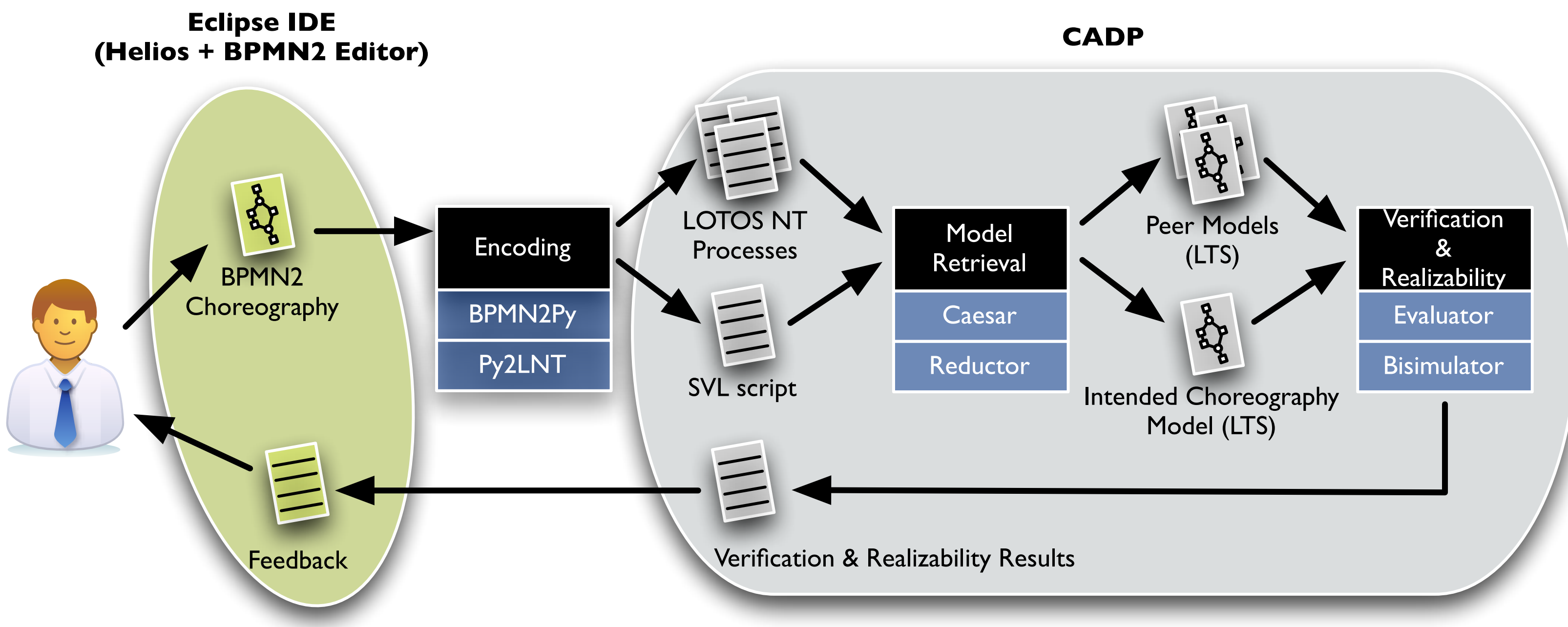
Tool Support



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Concluding Remarks

- We have presented an encoding of BPMN 2.0 choreographies into LNT, which makes the formal analysis of BPMN possible using CADP verification tools

- As far as perspectives are concerned, we would like to:
  - Extend the subset of BPMN choreographies accepted by our approach with hierarchical structuring aspects (sub- choreography)
  - Integrate looser realizability notions to our framework (pre-order, partial order, etc.)
  - Use recent compositional aggregation techniques [CrouzenLang-FASE11] to reduce intermediate state spaces size and computation times
  - Enforce realizability proposing *smart projection* techniques
  - Apply our approach to a real-size case study in the e-governance domain