Dynamic Choreographies
Safe Runtime Updates of Distributed Applications

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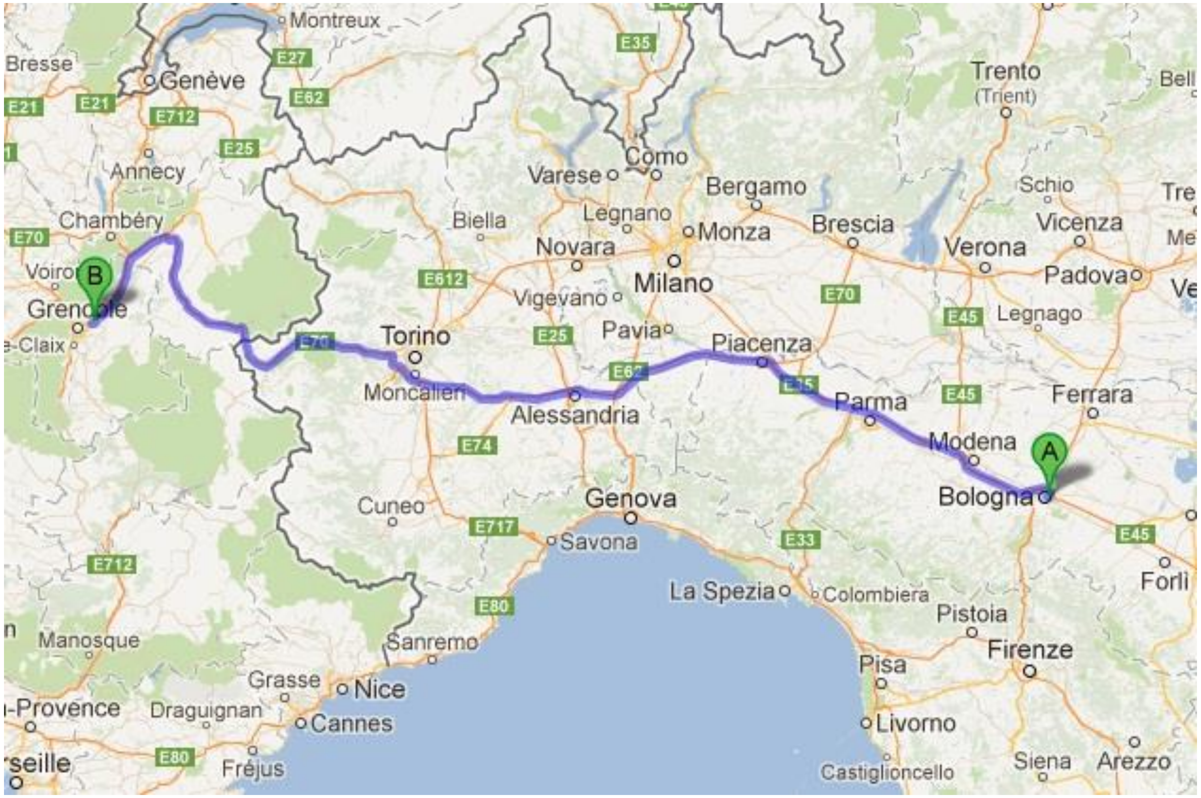
Map of the talk

- Choreographic programming
- Dynamic updates
- Results
- Conclusion



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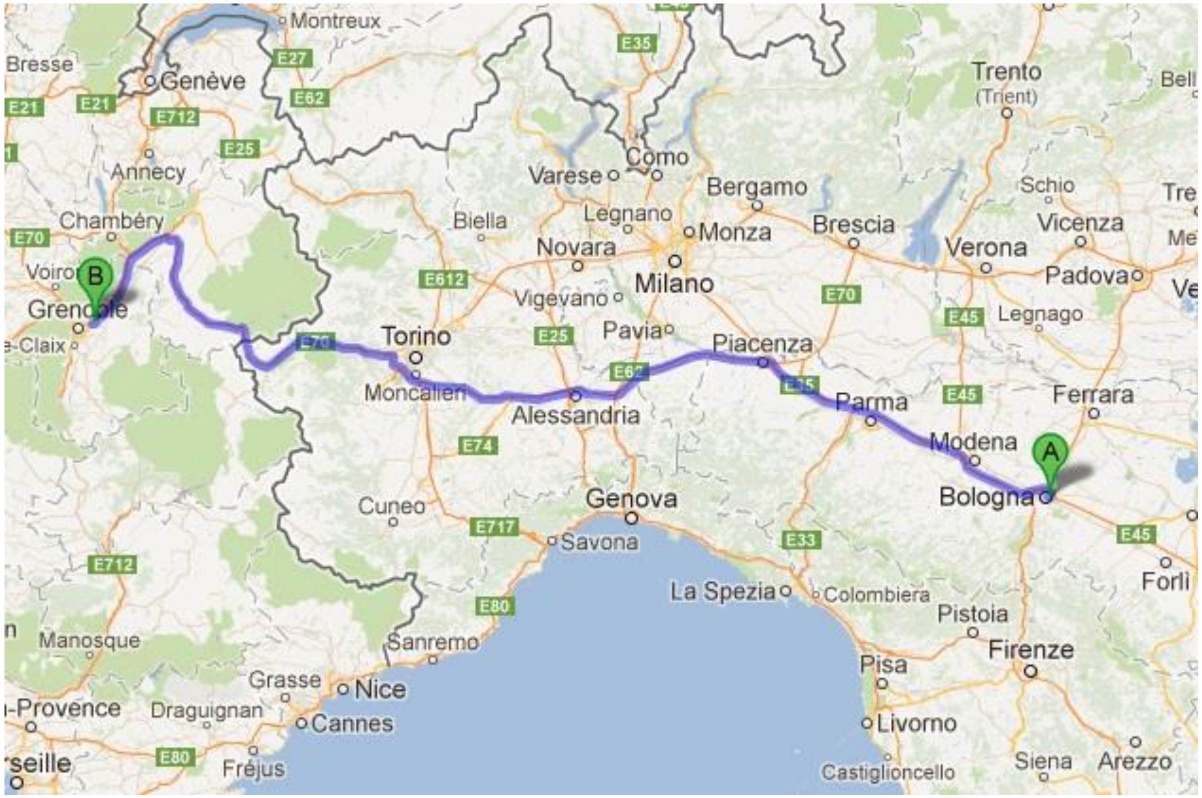

Choreographic programming: aim

- Distributed applications are normally programmed using send and receive primitives
  - Difficult and error-prone
  - Deadlocks, races, ...
- Choreographic programming aims at solving these problems by raising the level of abstraction

Choreographic programming: basics

- The basic building block is an interaction, i.e. a communication between two participants
  - Not a send or a receive
- Interactions can be composed using standard constructs: sequences, conditionals, cycles,...
- One choreographic program describes a whole distributed application
  - Not a single participant

Choreographic syntax

- $\mathcal{I} ::= \; o\!:r(e) \rightarrow s(x)$

  $x@r = e$

  1

  $\mathcal{I} \, ; \mathcal{I}'$

  $\mathcal{I} \,|\, \mathcal{I}'$

  if $b@r$ $\{\mathcal{I}\}$ else $\{\mathcal{I}'\}$

  while $b@r$ $\{\mathcal{I}\}$

- For multiparty session types addicts
  choreographic programs ≈ global types + data + conditions

A sample choreographic program

- $prodName@buyer$ = getInput();
  $priceReq\colon buyer(prodName) \rightarrow seller(pName)$;
  $price@seller$ = getPrice($pName$);
  $offer\colon seller(price) \rightarrow buyer(pr)$;
  …

Advantages of choreographic programming

- Clear view of the global behavior
- No deadlocks and races since send and receive are paired into interactions

How to execute choreographic programs?

- Most constructs involve many participants
- What each participant should do?
- We want to compile the choreographic program into a local code for each participant
- We define a projection function to this end
- When executed, the derived participants should interact as specified in the choreographic program
  - Correctness of the compilation
  - No deadlocks and no races

The target language

- P ::= $o{:}\, e$ to r
  $o{:}\, x$ from r
  $x = e$
  1
  $\mathrm{P}; \mathrm{P}'$
  $\mathrm{P} | \mathrm{P}'$
  if b $\{\mathrm{P}\}$ else $\{\mathrm{P}'\}$
  while b $\{\mathrm{P}\}$
- A distributed application is composed by named participants executing Ps

Projection: basic idea

- An interaction $o_1 : r_1(5) \rightarrow s_1(x)$ becomes
  - A send $o_1 : 5$ to s_1 on r_1
  - A receive $o_1 : x$ from r_1 on s_1
  - A skip 1 on all the other participants
- Assignments $x@r = e$ are executed by the role r
- Other constructs are projected homomorphically

- Very simple…
- …but it does not work

Projection: problems and solutions

- Participants are independent

$$o_1: r_1(5) \to s_1(x); o_2: r_2(7) \to s_2(y)$$

- Interaction on o_2 should happen after interaction on o_1
  - No participant can force this
- Participants' execution may depend on other participants

$$\text{if } x@r_1 \{o: r_2(5) \to s(x)\} \text{ else } \{o: r_2(7) \to s(x)\}$$

- Participant r_2 should send 5 or 7 according to a local decision of r_1
- These problems are solved by
  - adding auxiliary communications beyond the ones specified
  - restricting the allowed compositions (connectedness)

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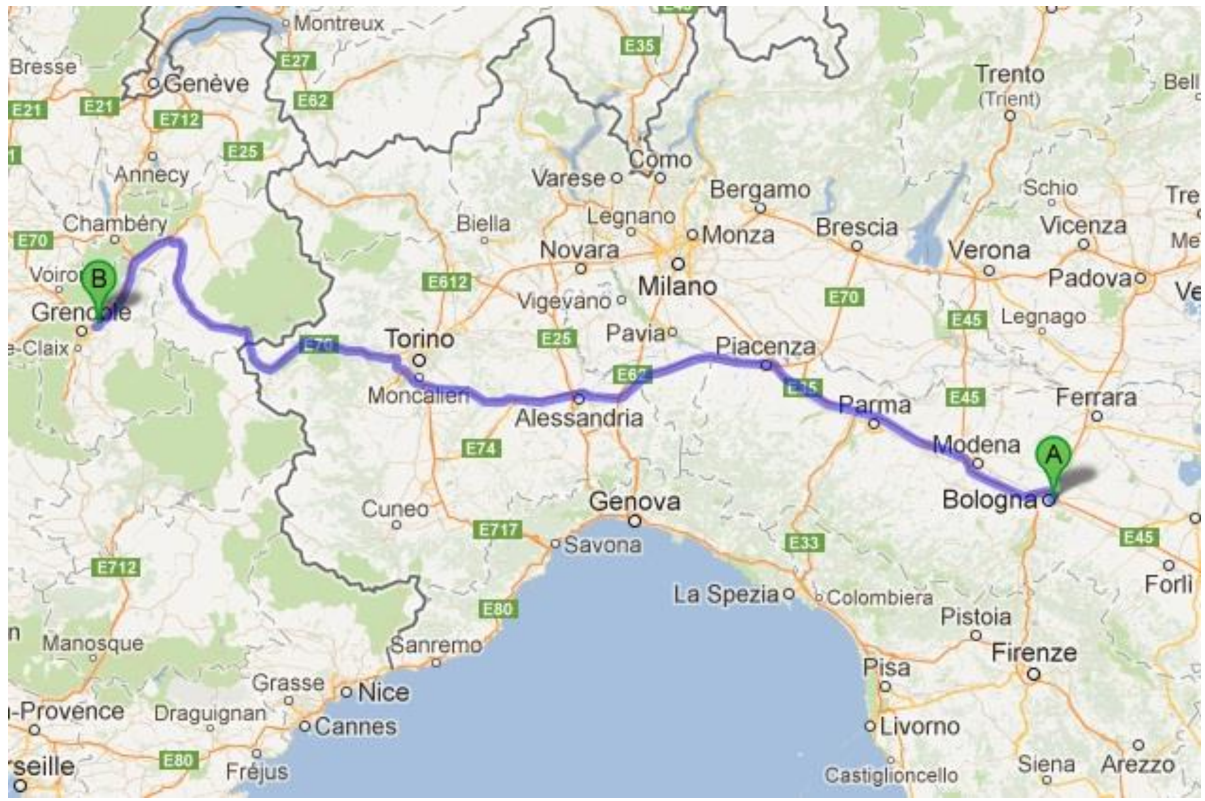


Dynamic updates

- We want to change the code of running applications, by integrating new pieces of code coming from outside
- Those pieces of code are called updates
- The set of updates
  - is not known when the application is designed, programmed or even started
  - may change at any moment and without notice
- Many possible uses
  - Deal with emergency behavior
  - Deal with changing business rules or environment conditions
  - Specialise the application to user preferences

Our approach, syntactically

- Pair a running application with a set of updates
  - Each update is a choreographic program
  - The set of updates may change at any time
- At the choreographic level, the update may replace a part of the application
  - Which part?
- Extend choreographic programs with scopes
  - scope $@r \{\mathcal{I}\}$
  - Before starting, the scope may be replaced by an update

Our approach, semantically

- A scope can either execute, or be replaced by an update

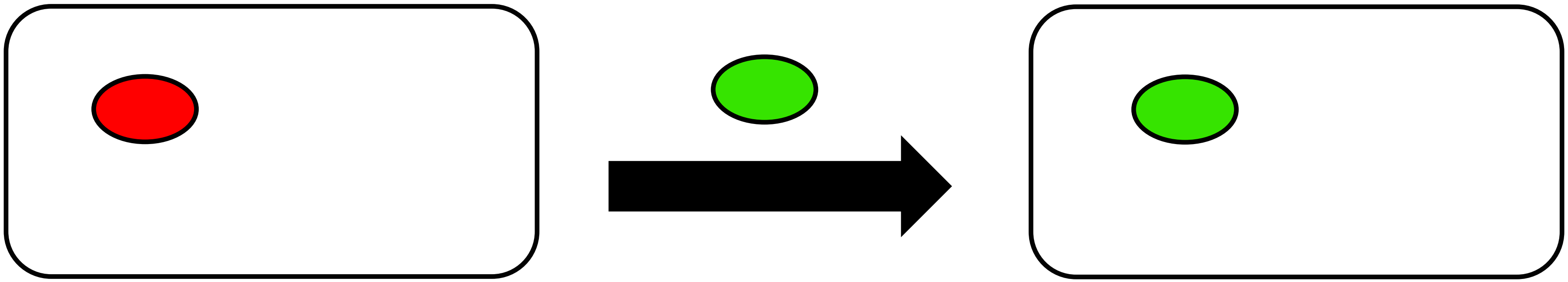
$$\langle \Sigma, \mathbf{I}, scope\ @r\ \{\mathcal{I}\} \rangle \xrightarrow{\text{no-up}} \langle \Sigma, \mathbf{I}, \mathcal{I} \rangle$$

$$\frac{roles(\mathcal{I}') \subseteq roles(\mathcal{I}) \quad \mathcal{I}' \in \mathbf{I} \quad \mathcal{I}'\, connected}{\langle \Sigma, \mathbf{I}, scope\ @r\ \{\mathcal{I}\} \rangle \xrightarrow{\mathcal{I}'} \langle \Sigma, \mathbf{I}, \mathcal{I}' \rangle}$$

- Updates can change at any time

$$\langle \Sigma, \mathbf{I}, \mathcal{I} \rangle \xrightarrow{\mathbf{I}'} \langle \Sigma, \mathbf{I}', \mathcal{I} \rangle$$

Our approach, graphically



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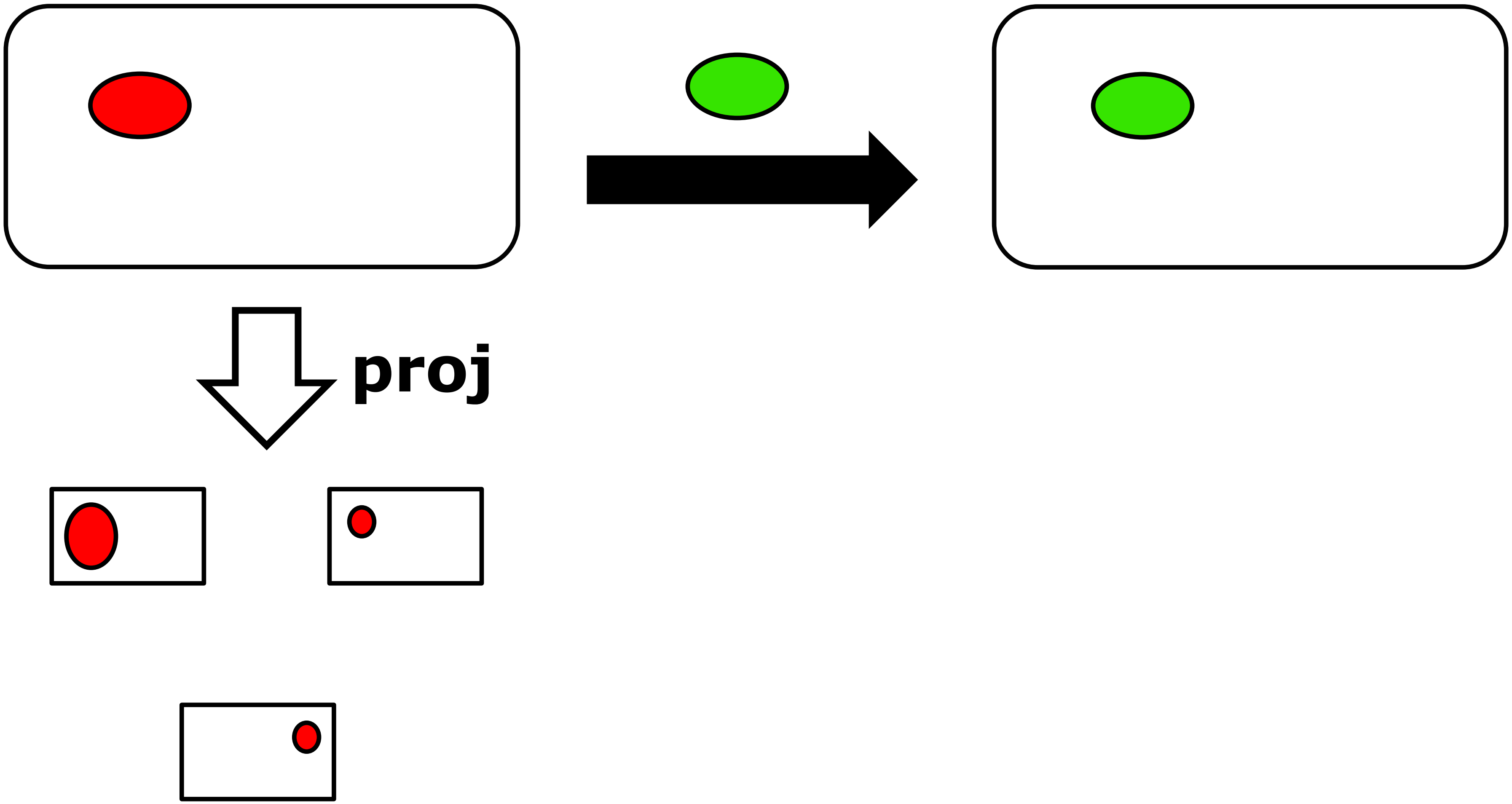

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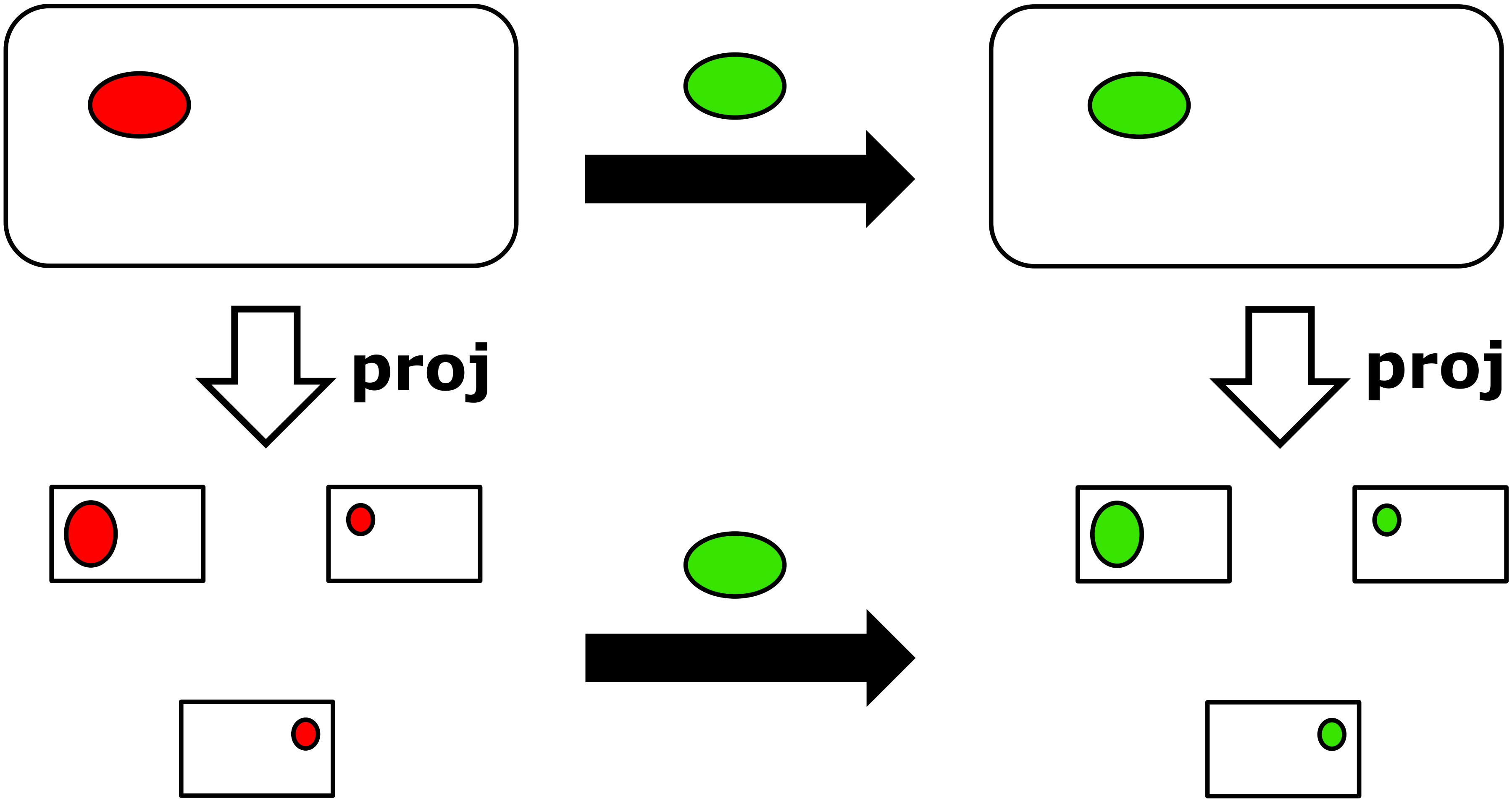

A sample update

- $cardReq\colon seller() \rightarrow buyer();$

  $cardSend\colon buyer(cardId) \rightarrow seller(buyerId);$

  $\text{if}\big(\text{isValid}(buyerId)\big)@seller$

  $\quad \{price@seller = \text{getPrice}(pName) * 0.9;\}$

  else

  $\quad \{price@seller = \text{getPrice}(pName);\}$

  $offer\colon seller(price) \rightarrow buyer(pr);$

Making the choreographic program updatable

- $prodName@buyer = \text{getInput}();$

  $priceReq: buyer(prodName) \rightarrow seller(pName);$

  $price@seller = \text{getPrice}(pName);$

  $offer: seller(price) \rightarrow buyer(pr);$

  …

Making the choreographic program updatable

- $prodName@buyer$ = getInput();
  $priceReq: buyer(prodName) \to seller(pName)$;
  scope $@seller$ {
    $price@seller$ = getPrice($pName$);
    $offer: seller(price) \to buyer(pr)$;
  }
  …

Dynamic updates: challenges

- All the participants should agree on
  - whether to update a scope or not
  - in case, which update to apply
- All the participants need to retrieve (their part of) the update
  - Not easy, since updates may disappear
- No participant should start executing a scope that needs to be updated

Dynamic updates: our approach

- For each scope a single participant coordinates its execution
  - Decides whether to update it or not, and which update to apply
  - Gets the update, and sends to the other participants their part
- The other participants wait for the decision before executing the scope
- We add scopes (and higher-order communications) to the target language, with the semantics above

Compositionality issue

- Applying an update at the choreographic level results in a new choreographic program, composed by
  - The unchanged part of the old choreographic program
  - The update
- Even if the two parts are connected, the result may not be connected
- Auxiliary communications are added to ensure connectedness

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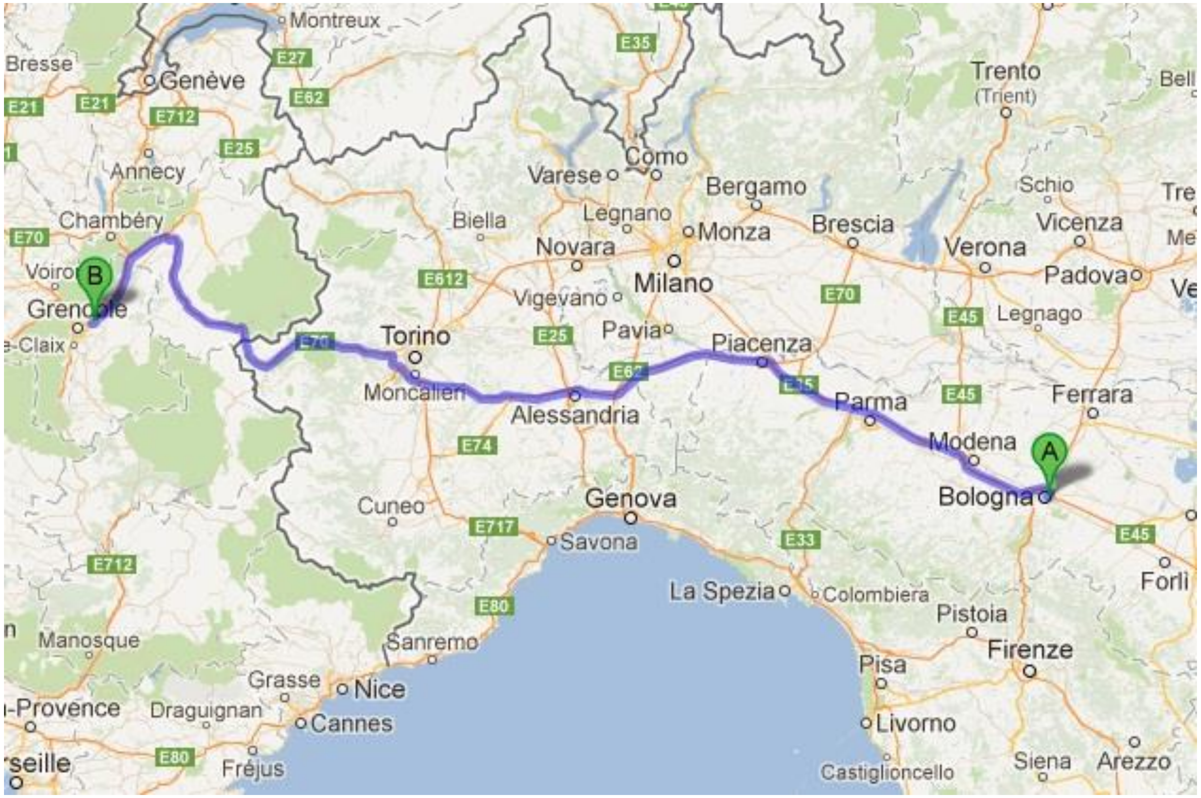

Results

- A choreographic program and its projection behave the same
  - They have the same set of traces (up to auxiliary actions)
  - Under all possible, dynamically changing, sets of updates
- The projected application is deadlock free and race free by construction

- These results are strong given that we are considering an application which is
  - distributed
  - updatable

Implementation

- Our result is quite abstract, and can be instantiated in different ways
- AIOCJ is one such way [SLE 2014]
- A framework for safe rule-based adaptation of distributed applications
- Updates are embedded into adaptation rules specifying when and where to apply them
- Scopes include some more information driving the application of adaptation rules
- Projection produces service-oriented code
- http://www.cs.unibo.it/projects/jolie/aiocj.html

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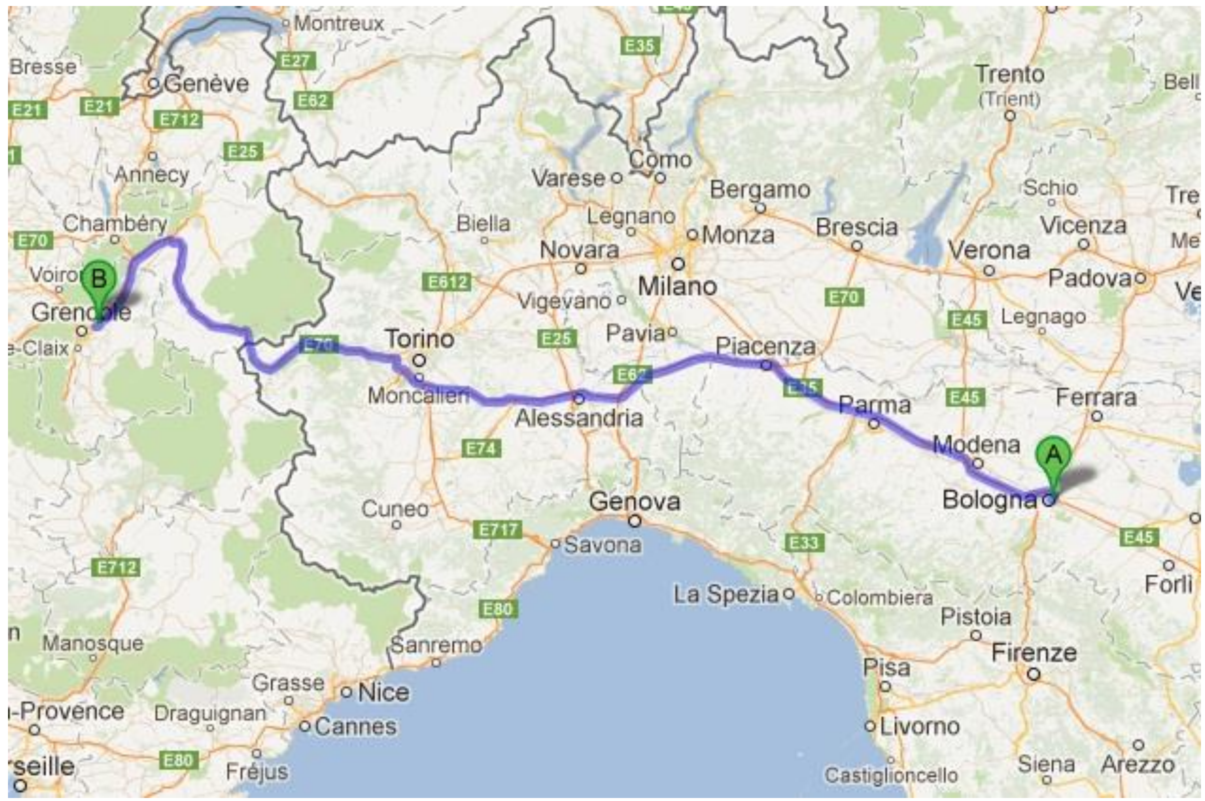

Conclusion

- A choreographic approach to dynamic updates
- The derived distributed application follows the behavior defined by the choreographic program
- We ensures deadlock freedom and race freedom in a challenging setting
- We instantiated the theoretical framework to adaptable service-oriented applications

Future work

- Extend the approach to asynchronous communication
- How to cope with multiple interleaved sessions?
- How to improve the performance?
  - Drop redundant auxiliary communications
- Can we instantiate our approach on existing frameworks for adaptation?
  - E.g., dynamic aspect-oriented programming
  - To inject correctness guarentees

End of talk

Thanks!

Questions?