now it compiles!

automatic repair of choreographic programs

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choreographic programming, conceptually

what are choreographies?

high-level global specifications of concurrent and distributed systems

a new programming paradigm

implementations for the local endpoints are automatically generated

- guaranteed to be deadlock-free
- guaranteed to satisfy the specification

an example

authentication choreography

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X = c.credentials --> ip.x;
    If ip.(check x)
    Then ip --> s[ok]; ip --> c[ok]; s.token --> c.t
    Else ip --> s[ko]; ip --> c[ko]; X
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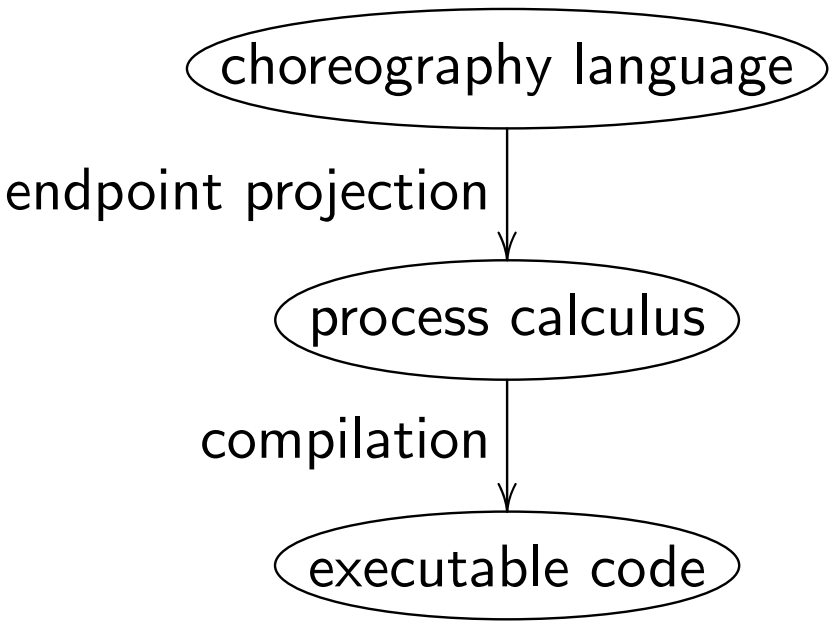
local implementations

X_c = ip!credentials; ip & {ok: s?t; ko: X_c }

X_s = ip & {ok: c!token; ko: X_s }

X_{ip} = c?x; If (check x) Then (s(+)ok; c(+)ok)
Else (s(+)ko; c(+)ko; X_{ip})

a bird's-eye view



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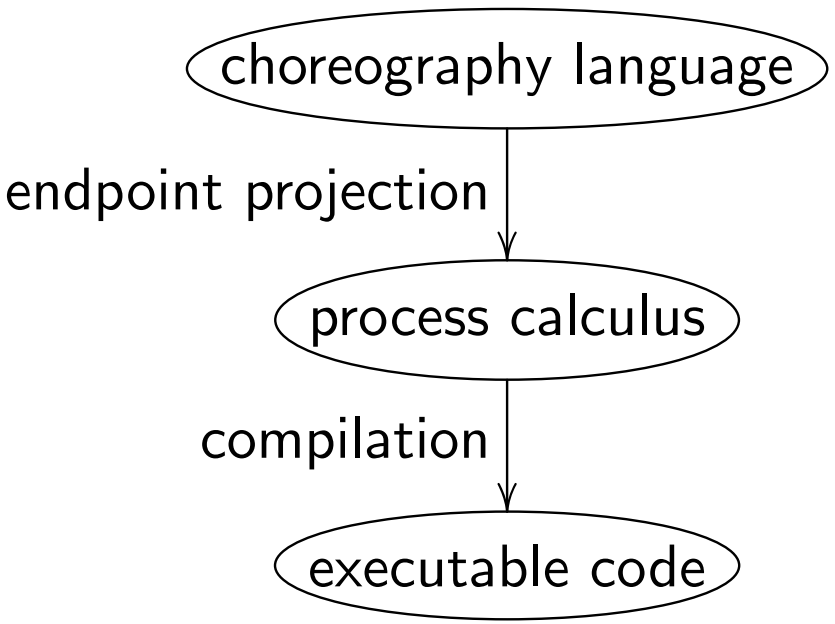

- toolchain based on formalised projection (using coq)
- practical applications motivate extensions to the choreographic theory
- in this work: make the language simpler to use

why bother formalising?

choreographies are a popular topic...

- active research field
- many relevant applications
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...but there are some hiccups

process calculus and session types plagued by wrong proofs

- complex definitions, long proofs by structural induction
- situation pointed out at itp'15
  - formalisation of a published journal article
  - most proofs were wrong (but the theorems held)
- big revision of decidability results in the last few years
  - published proofs of both A and $\neg A$ for quite a few A...

our language

a minimal choreography language

- value communication

  ```
  p.e --> q.x
  ```

- label selections (for projection)

  ```
  p --> q[l]
  ```

- conditionals

  ```
  If p.b Then Ct Else Ce
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- trailing procedure calls (for recursion)

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  X
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agnostic language

- parametric on expressions and values
- only two labels

knowledge of choice

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- choreographically, nothing wrong. . .

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- ...but impossible to implement!

knowledge of choice (cont'd)

knowledge of choice

if a participant's behaviour depends on the result of a conditional evaluated elsewhere, then it must be notified of the outcome of the evaluation

- notification uses label selections
- notifications may be indirect (e.g. a notifies b who notifies c)

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$\rightsquigarrow$ in our example, both client and server must be notified of the result of the authentication

choreography amendment

folklore

well-known facts

- selections can be inferred automatically
- adding them does not "significantly" change the protocol
- but it is useful to be able to place them manually

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"everyone knows that"

. . . does not mean that:

- it is true
- it has ever been proved

. . . likely means:

- no one proves it in detail
- no one checks proofs

our contribution

a formalisation of amendment for our choreography language

- definition of amendment in coq
- correspondence theorem
  (a.k.a. amendment does not “significantly” change the protocol)

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surprise or not?

weaker correspondence than expected

amendment by example

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amendment theorem

for every choreography C:

1. amend(C) is well-formed
2. amend(C) is projectable
3. $\langle C, \sigma \rangle \rightarrow^* \langle C', \sigma' \rangle$ iff $\langle \text{amend}(C), \sigma \rangle \rightarrow^* \langle \text{amend}(C'), \sigma' \rangle$

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the subtle problem

in a truly distributed setting we cannot enforce causal dependencies between independent actions:

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p.1 --> q.x; r.2 --> s.y
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has two different reduction paths, since the two communications can happen in any order

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out-of-order execution

semantic rules allowing to reduce *inside* a choreography (under suitable conditions)

a dangerous mix

amendment can introduce new dependencies:

original choreography

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interaction between amendment and out-of-order execution went unnoticed for a long time

- one conference publication (proofs in unpublished appendix)
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coq as a research tool

it took all of 10 minutes to find the first counterexample. . .

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the original choreography may execute actions that are blocked by amendment

$\rightsquigarrow$ we need a more relaxed correspondence

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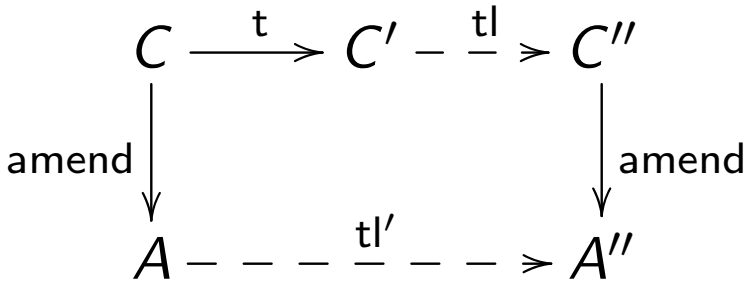
using coq for ego destruction

more iterations than we would like to admit

et voilà



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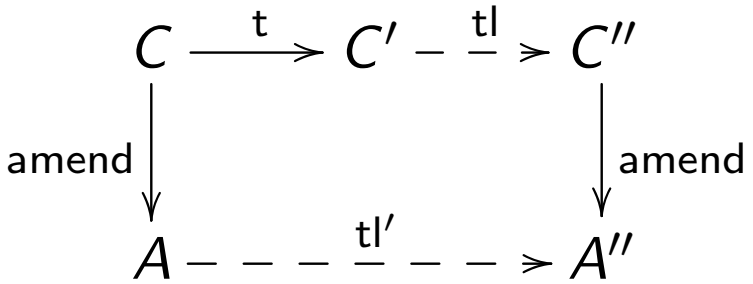

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$\rightsquigarrow$ *a posteriori*, quite intuitive

closing remarks

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future work

- more flexible projection $\rightsquigarrow$ allows for simpler amendment
- more expressive language
  more automation $\rightsquigarrow$ more interesting in practice
- applications to cybersecurity, smart contracts, . . .

thank you!