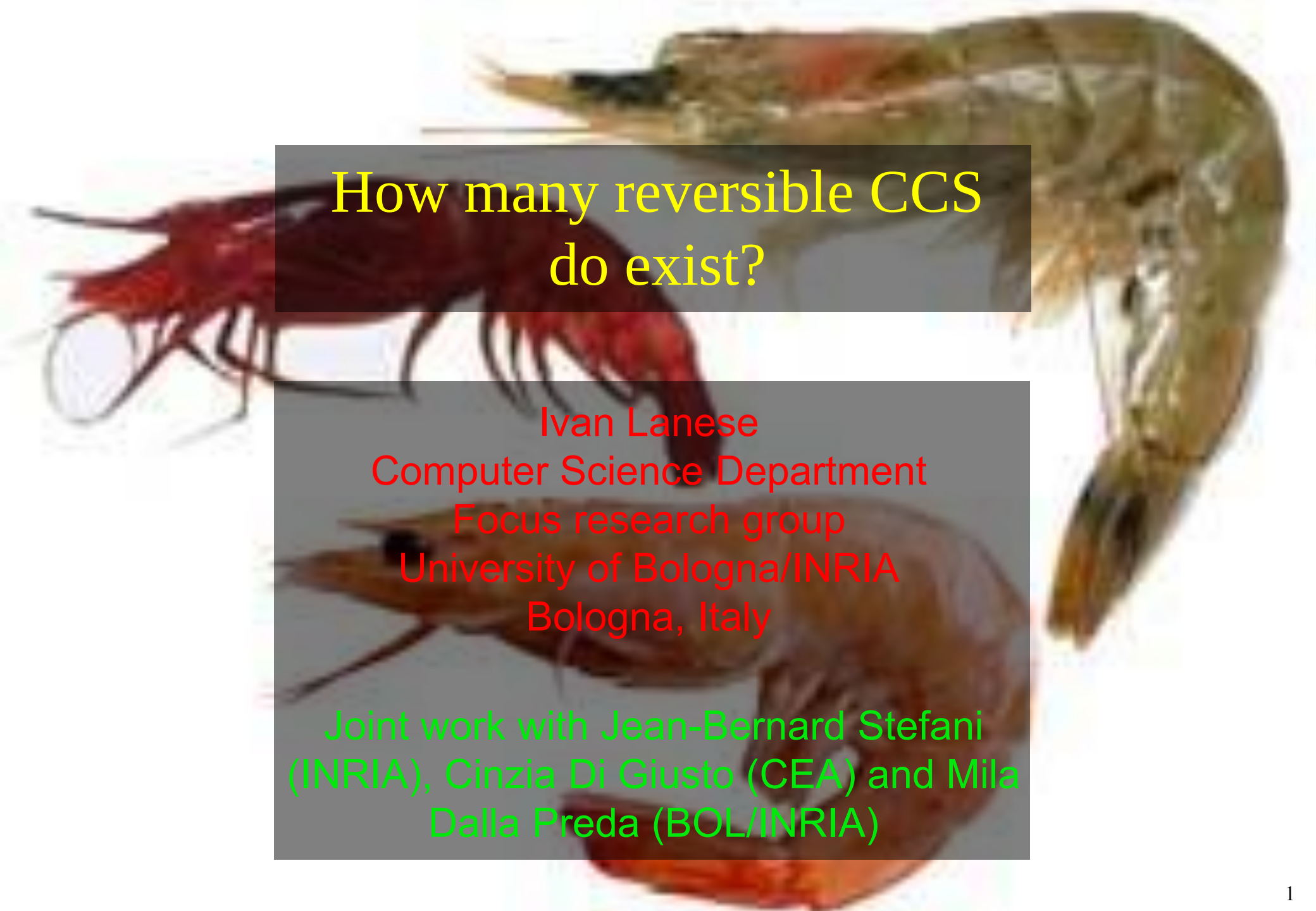

How many reversible CCS do exist?

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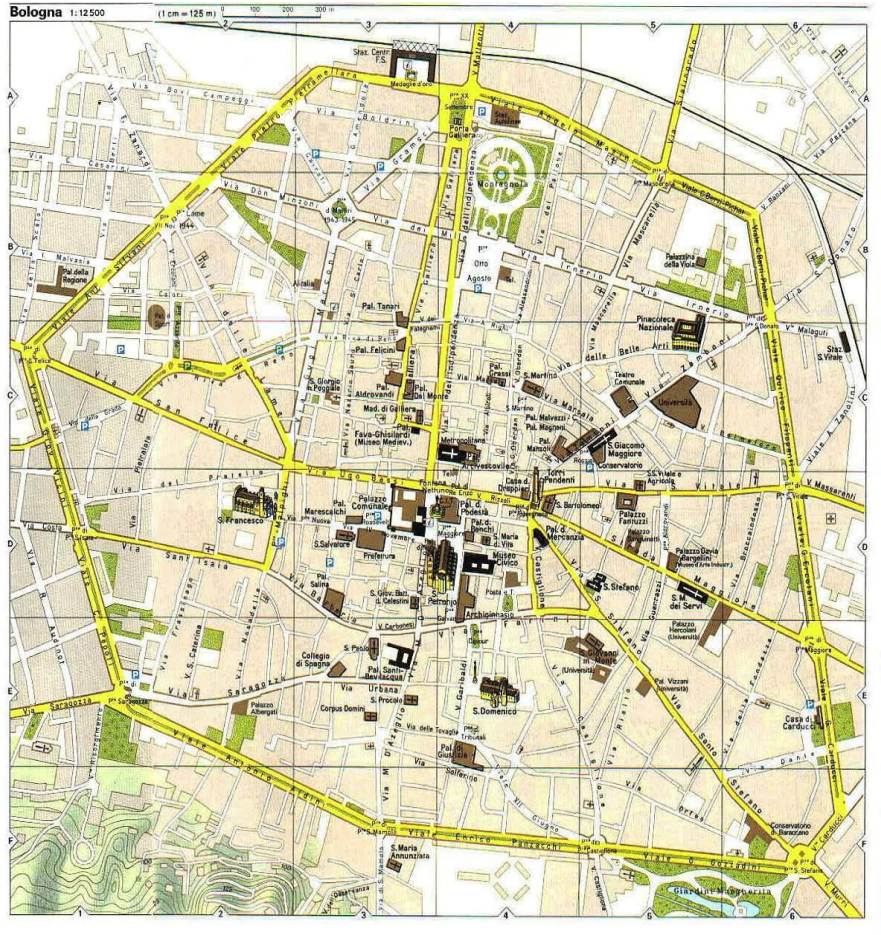
Roadmap

- Comparing reversible calculi
- Relevant properties
- What if properties do not hold?
- An abstract interpretation approach
- Conclusions



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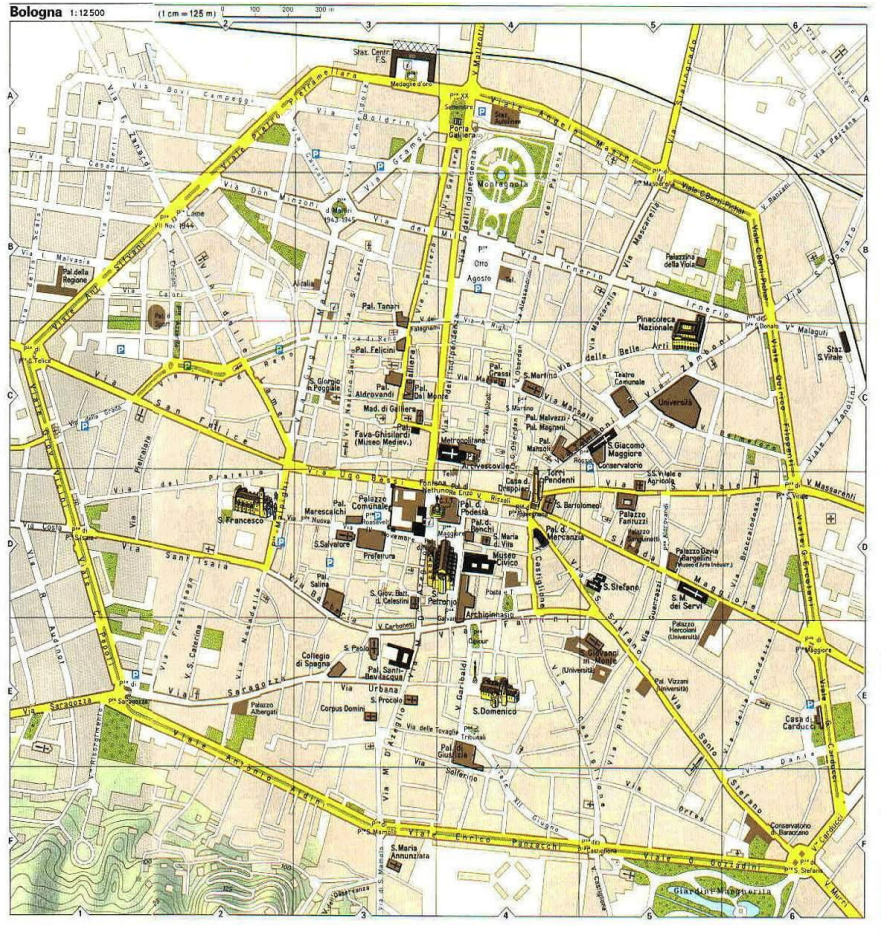

How many reversible CCS do exist?

- There are in the literature different proposals of reversible calculi
  - RCCS, ρπ, CCSk, …
- They share many properties
  - Loop lemma, causal consistency
- They use different technical solutions
  - Histories, memories, keys, …
- Can we prove equivalences among them?

A more general question

- Given a calculus, how many reversible variants of it can exist?
  - Which satisfy the properties we expect
    - » In particular, causal consistency
  - Up to differences which are only syntactic
- Which properties do we require?
  - Properties of reversibility
  - Relations with the underlying calculus

An equivalence relation

- Backward and forward barbed equivalence
  - Can be defined on different calculi
  - Does not require an LTS
  - Distinguishes between backward and forward reductions
- A symmetric relation R is a strong backward and forward barbed equivalence iff for each <P,Q> in R
  - If P→P' with a forward step then Q→Q' with a forward step and <P',Q'> in R
  - If P→P' with a backward step then Q→Q' with a backward step and <P',Q'> in R
  - If P has a barb then Q has the same barb

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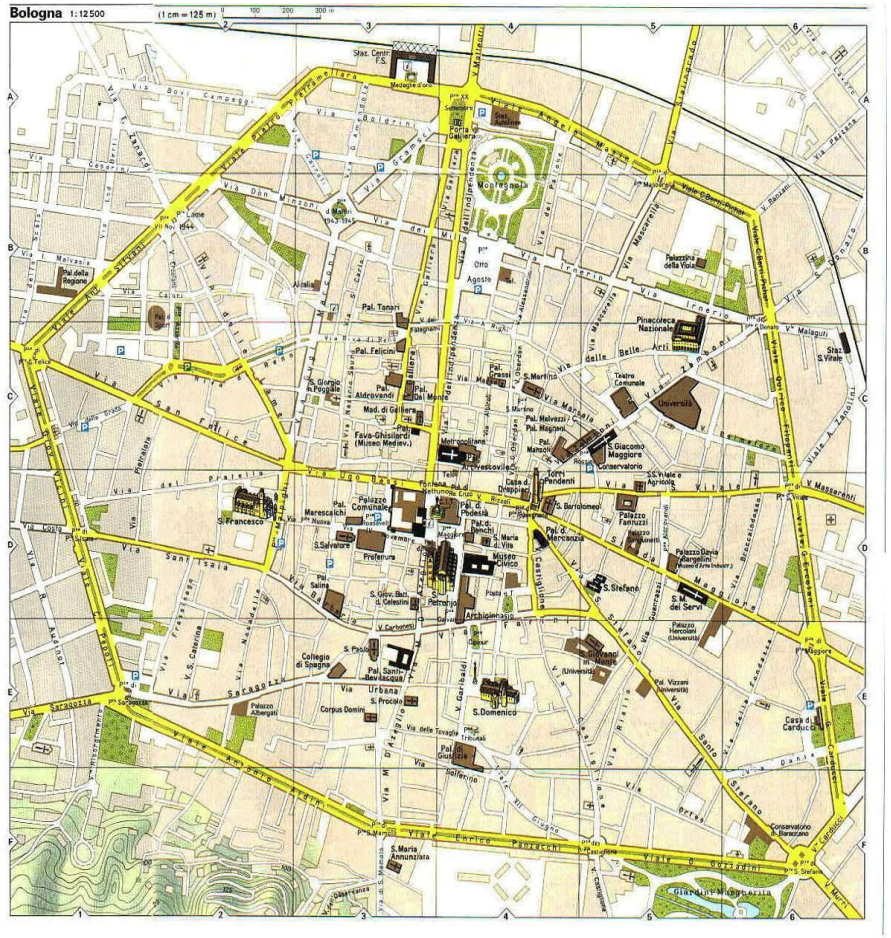

Properties of reversibility

- Property 1: loop lemma
  - Every step has an inverse
- Property 2: parabolic lemma
  - Every computation can be decomposed in a backward part followed by a forward part
- Property 3: causal consistency
  - Two computations coinitial and cofinal are causal equivalent: equivalent up to swaps of concurrent actions and simplification of inverse actions
- Property 4: finite past

Relations with the underlying calculus

- We assume a function γ mapping
  - reversible processes to the underlying processes
  - forward steps to the underlying steps
- Property 5: γ is total
- Property 6: γ is functorial
- Property 7: γ preserves and reflects barbs
- Property 8: for each underlying process there is a reversible process with no history mapped to it
- Property 9: underlying transitions can be lifted
- Property 10: γ respects concurrency

Results

- Any process originates from an ancestor with no history
  - Uniqueness is equivalent to the parabolic lemma
- Two processes with no history mapped to the same underlying process are strong backward and forward barbed equivalent
- Two reversible calculi where all the properties hold w.r.t. the same underlying calculus are strong backward and forward barbed equivalent

There is just one reversible CCS

- In RCCS, ρπ restricted to CCS processes and CCSk all the properties hold w.r.t. CCS
- From the previous theorem, they are all strong backward and forward barbed equivalent
- Direct proofs would be long and complex
- Properties can be verified quite easily, or are known to hold from the literature

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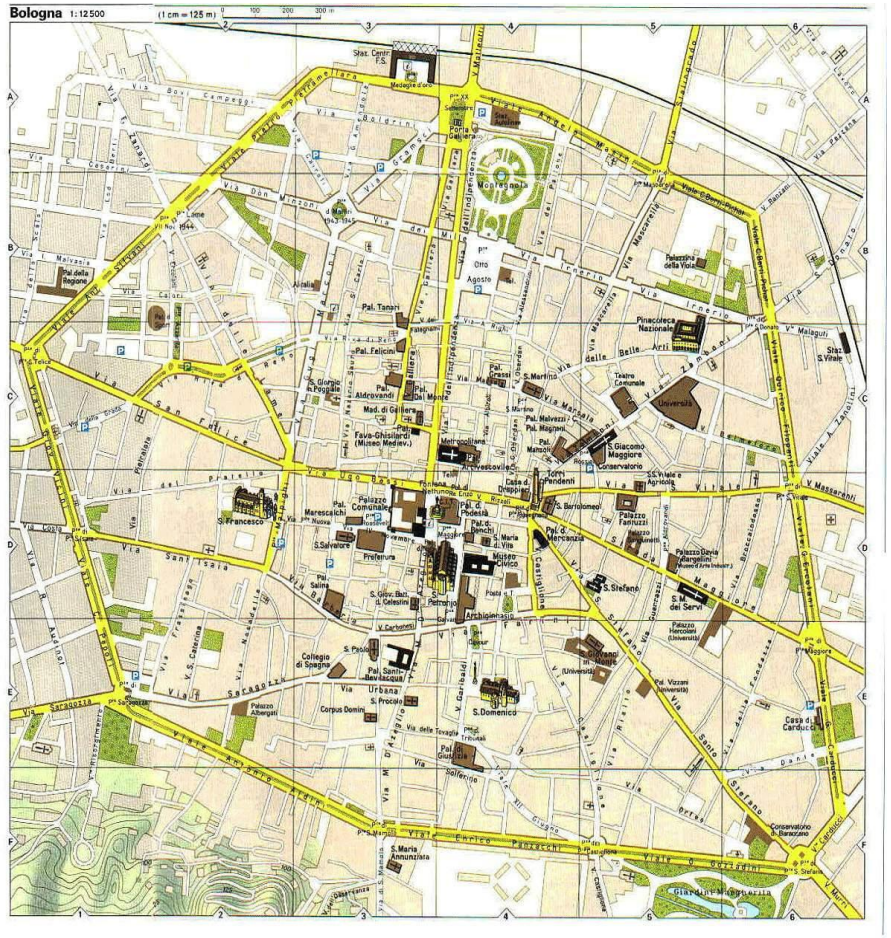

What if properties do not hold?

- Property 1: loop lemma
  - We get RCCS with irreversible actions
- Property 2: parabolic lemma
  - We get processes with many possible pasts
- Property 3: causal consistency
  - We get Laneve and Cardelli weak coherent reversible structures, where there are different ways to reverse the same step
- Property 4: finite past
  - We get RCCS with infinite pasts

What if properties do not hold?

- Property 5: γ is total
  - We get RCCS with more states
- Property 6: γ is functorial
  - We may mistake RCCS with CCS with deterministic backtracking
- Property 7: γ preserve and reflects barbs
  - We may overlook renamings

What if properties do not hold?

- Property 8: for each underlying process there is a reversible process with no history mapped to it
  - We may get the calculus with only the 0 process
- Property 9: underlying transitions can be lifted
  - We may get a calculus where less transitions are allowed
- Property 10: γ respects concurrency
  - We may mistake RCCS with CCS with deterministic backtracking

Properties in the literature

- RCCS, CCSk, ρπ and coherent reversible structures satisfy all the properties
- Reversible μOz does not satisfy properties 5 (reversibility adds some spurious steps)
- RCCS with irreversible actions does not satisfy property 1
- Weak coherent reversible structures does not satisfy property 3

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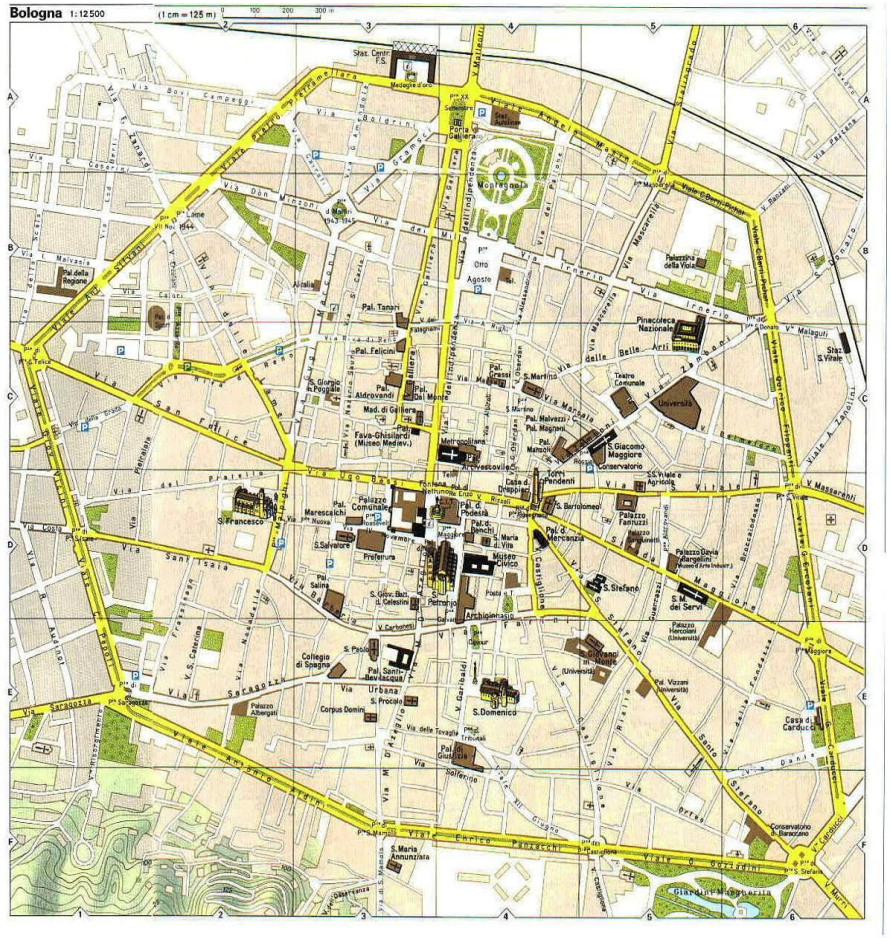

An abstract interpretation approach

- We want to use abstract interpretation to relate a reversible calculus and its underlying calculus
- Our hopes:
  - This will allow to give some structure to the set of properties
  - This will allow to relate calculi satisfying different sets of properties

The setting

- We consider a generic calculus, defined by its set of traces
- We quozient the traces according to causal equivalence
- The traces form a complete lattice (trace inclusion)
- The reversible variant of the calculus can be obtained as a refinement completion of the traces w.r.t. a function adding backward steps

Structuring the set of properties

- The properties will be distributed in:
  - The definition of the domain (e.g., causal consistency)
  - The definition of the function adding backward steps (e.g., loop lemma)
  - The notion of refinement (e.g., barb preservation)

Classifying calculi

- Abstraction/concretion will allow to classify the calculi
  - Forward only calculus will be the more abstract
  - Sequential reversibility and causal consistent reversibility will be concretions in different domains
  - What about forms of controlled reversibility?
    - » Irreversible actions can be inserted by changing the function adding reversible steps

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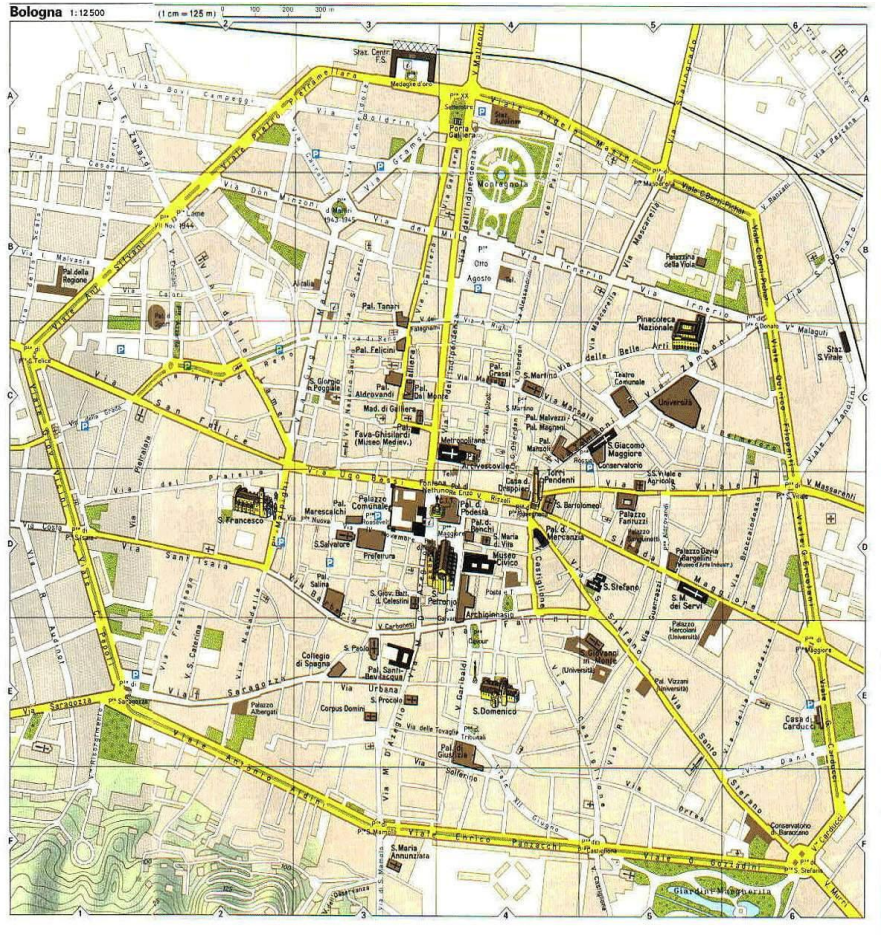

Summary

- A set of properties that we require on our reversible calculi
- A proof that there is essentially one reversible variant of a given calculus satisfying the properties
- Some intuition on how to improve the results using abstract interpretation

Future work

- Complete our analysis based on abstract interpretation
- Can category theory shed some further light?
- Can we derive results for congruences instead of equivalences?
  - Probably some property related to compositionality should be added

Finally

Thanks!

Questions?