Static analysis with LiSA

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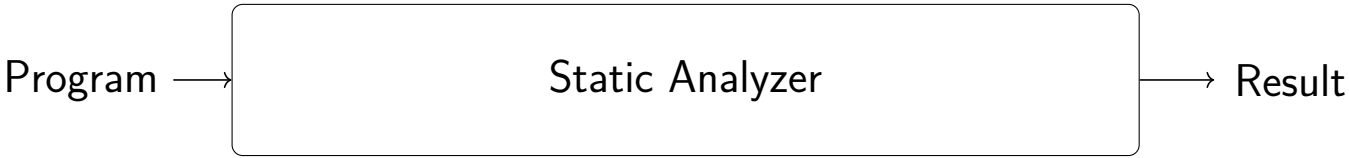
2025

From theory to practice



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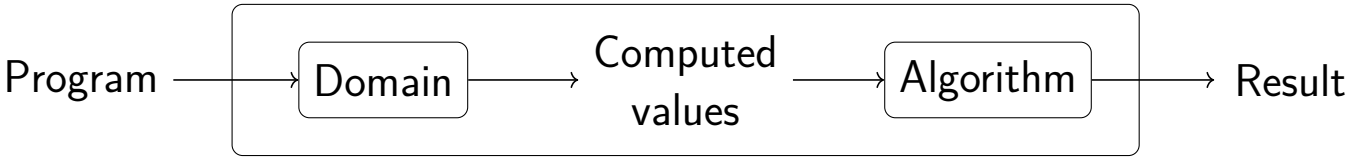

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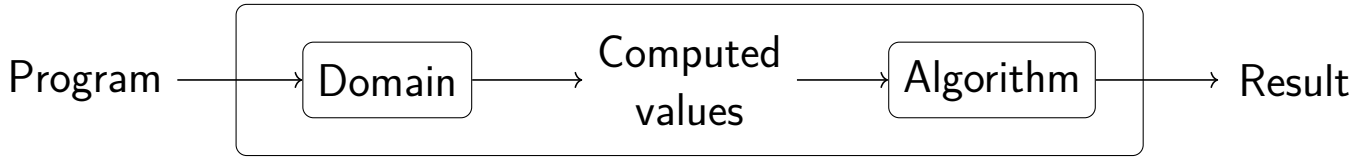
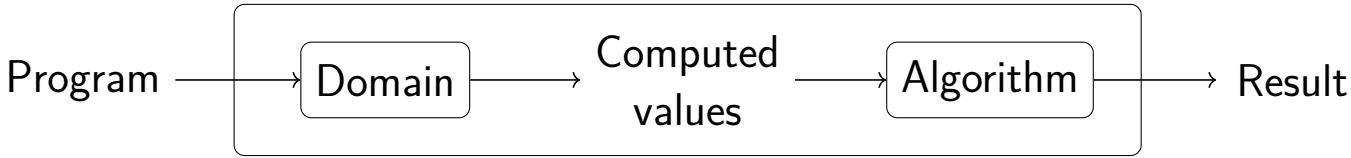


$$y = (2 * 2) - 4$$
$$z = 1 / y$$

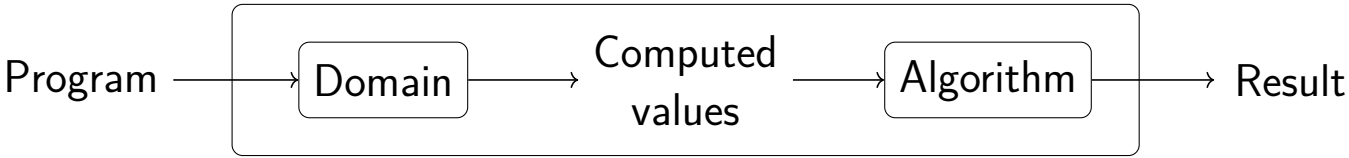
From theory to practice



$y = (2 * 2) - 4$ constant $y \mapsto 0$

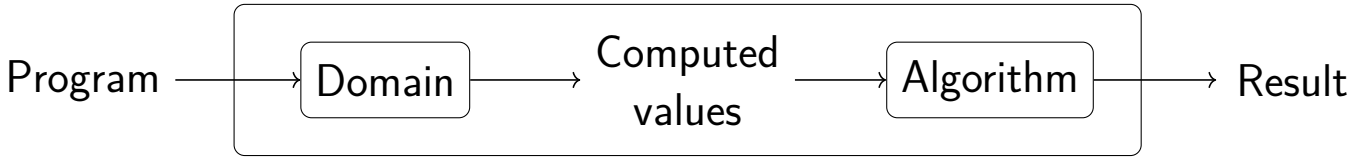
$z = 1 / y$ propagation $z \mapsto$ error

From theory to practice



$y = (2 * 2) - 4$ $z = 1 / y$	constant propagation	$y \mapsto 0$ $z \mapsto$ error	check for div by zero	message to the user

From theory to practice



y = (2 * 2) - 4 z = 1 / y	constant propagation	y ↦ 0 z ↦ error	check for div by zero	message to the user

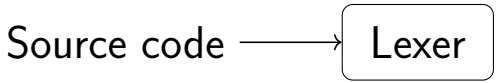
how do we parse the input code?

A (simplified) compiler/interpreter

Source code

$x = y + 2$

A (simplified) compiler/interpreter



x = y + 2

ID EQ ID
PLUS LITERAL

A (simplified) compiler/interpreter

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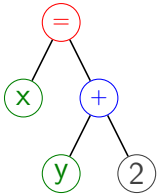

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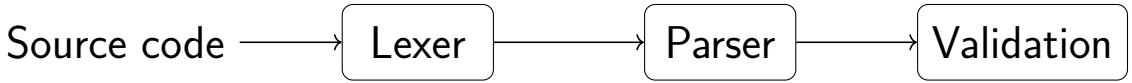

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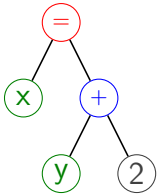

type check,
duplicate functions,
...

A (simplified) compiler/interpreter

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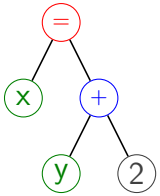

type check,
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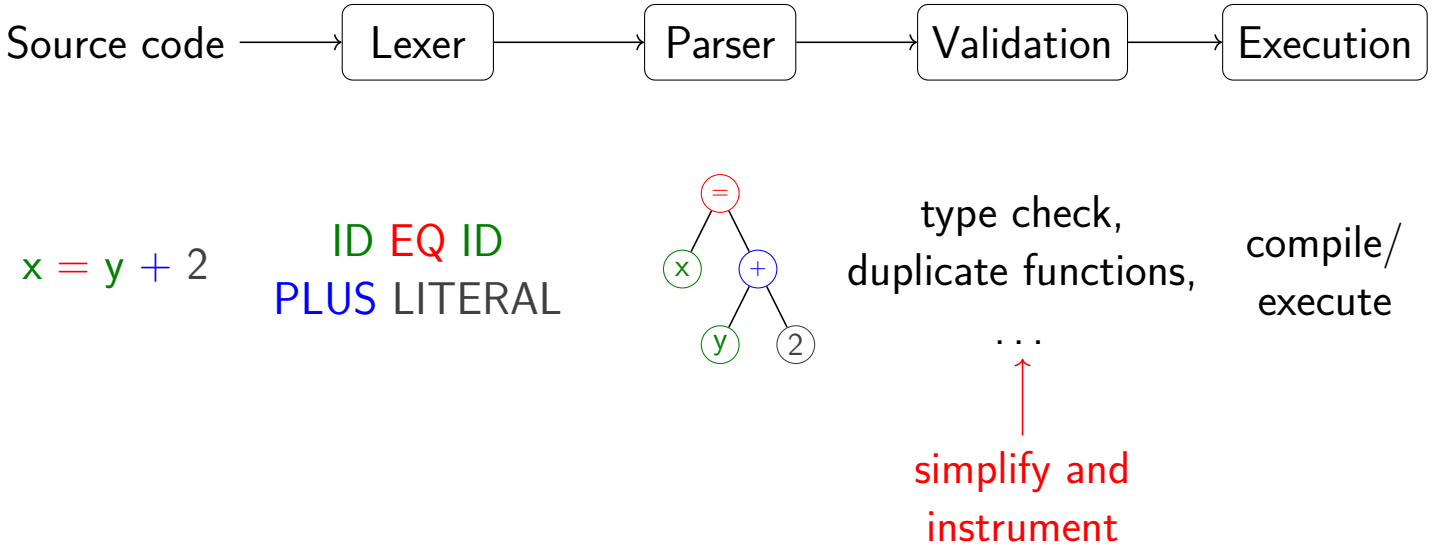
...

compile/
execute

A (simplified) compiler/interpreter



A (simplified) compiler/interpreter

$x = y + 2$

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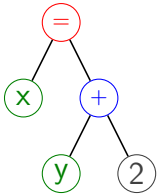


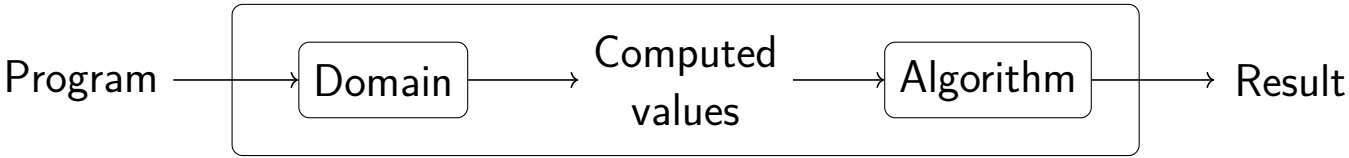
type check,
duplicate functions,
...

simplify and
instrument

compile/
execute

run domains
and algorithms

From theory to practice



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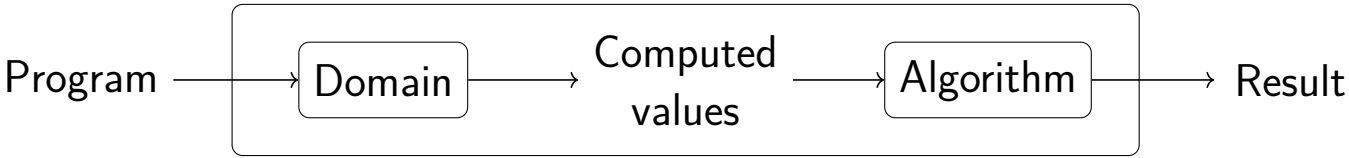
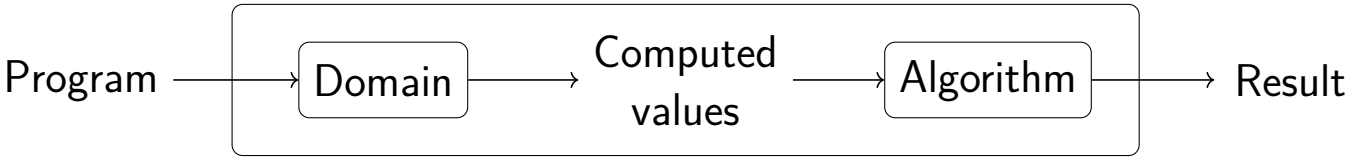
From theory to practice



y = (2 * 2) - 4	constant	$y \mapsto 0$
z = 1 / f(y)	propagation	$z \mapsto ?$

From theory to practice

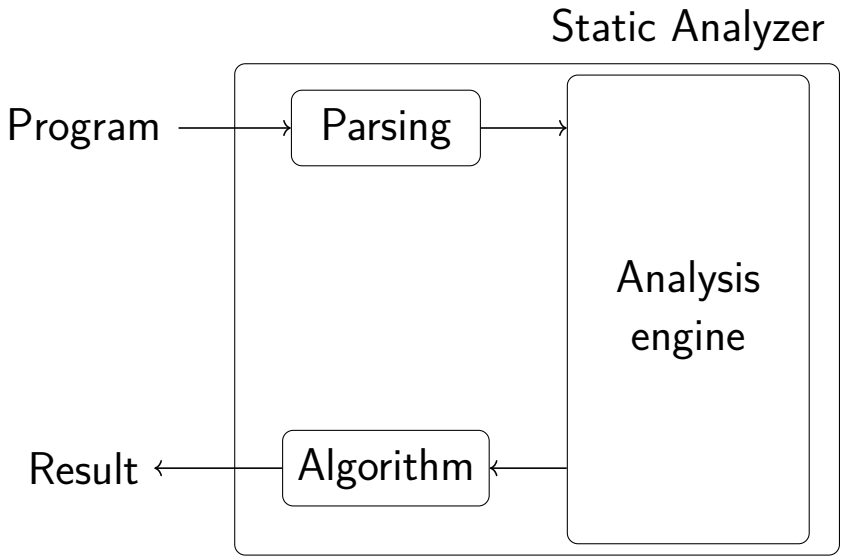


$y = (2 * 2) - 4$ constant $y \mapsto 0$

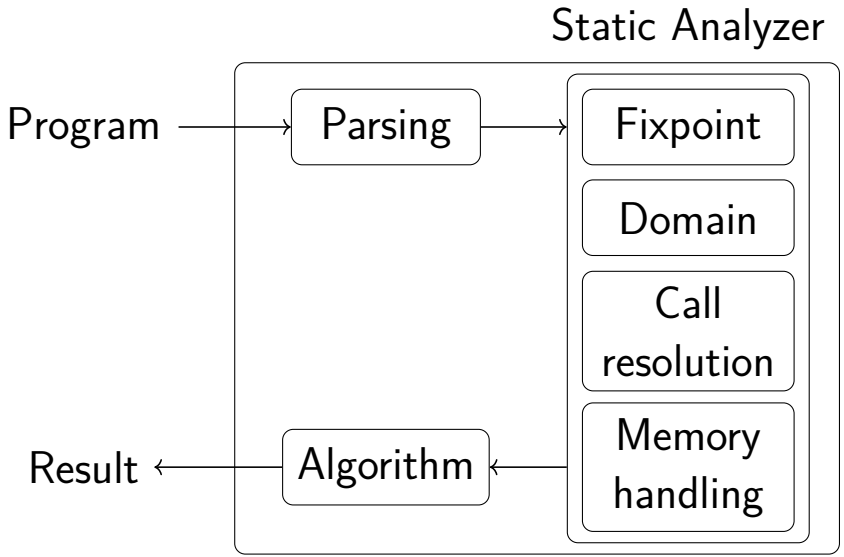
$z = 1 / f(y)$ propagation $z \mapsto ?$

need to handle some program features independently of the domain

A realistic structure



A realistic structure



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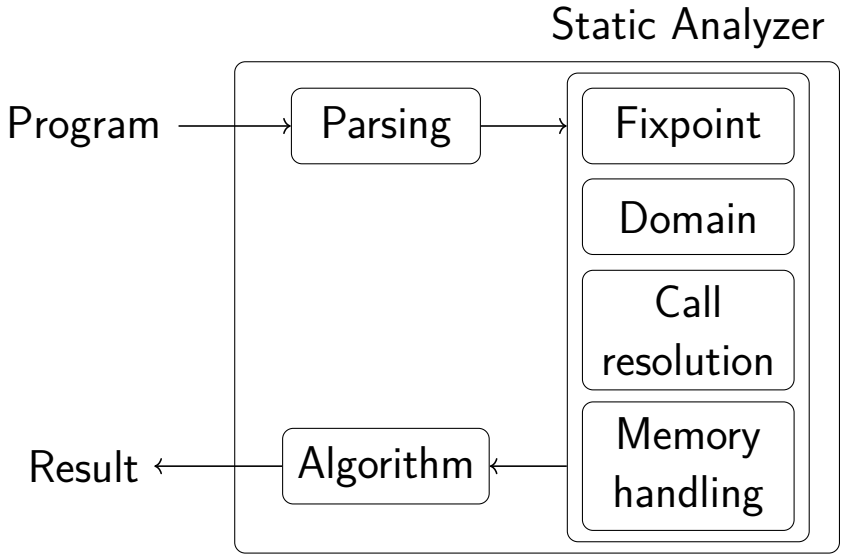


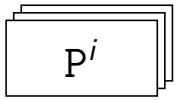
Key points:

- separate components for each task
- modular components

LiSA, a Library for Static Analysis

- Open source library written in Java
- Created and maintained by the SSV group @ UniVE
- Library for creating static analyzers based on abstract interpretation
  - For multiple programming languages
  - For a variety of different domains

LiSA Overview



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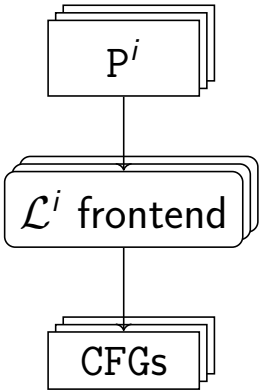


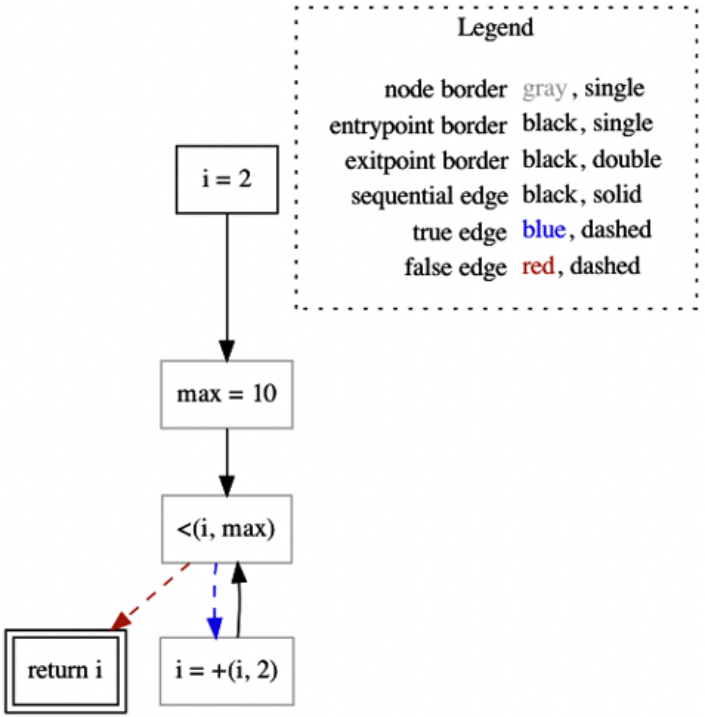
CFGs

A `CFG` is:

- Set of nodes (`Statement`)
- Set of edges linking nodes
  - `SequentialEdge`
  - `TrueEdge` (the statement at source node is assumed to hold)
  - `FalseEdge` (the statement at source node is assumed not to hold)

Example:

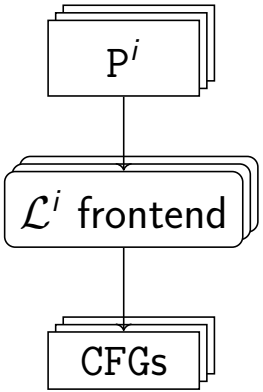
```
1 int i = 2;
2 int max = 10;
3 while (i < max)
4   i = i + 2;
5 return i;
```



Why CFGs?

- Get rid of the syntax for control flow
- Extensible: node instances are not fixed
- Received as inputs: no knowledge of source languages is kept past the frontends
- Easy to define fixpoints over graphs!
- Can be produced in isolation: each frontend produces the `CFG`s for that language, and we can analyze them together
    - For the course, we will use a frontend for an IMP language (similar to JAVA)

LiSA Overview



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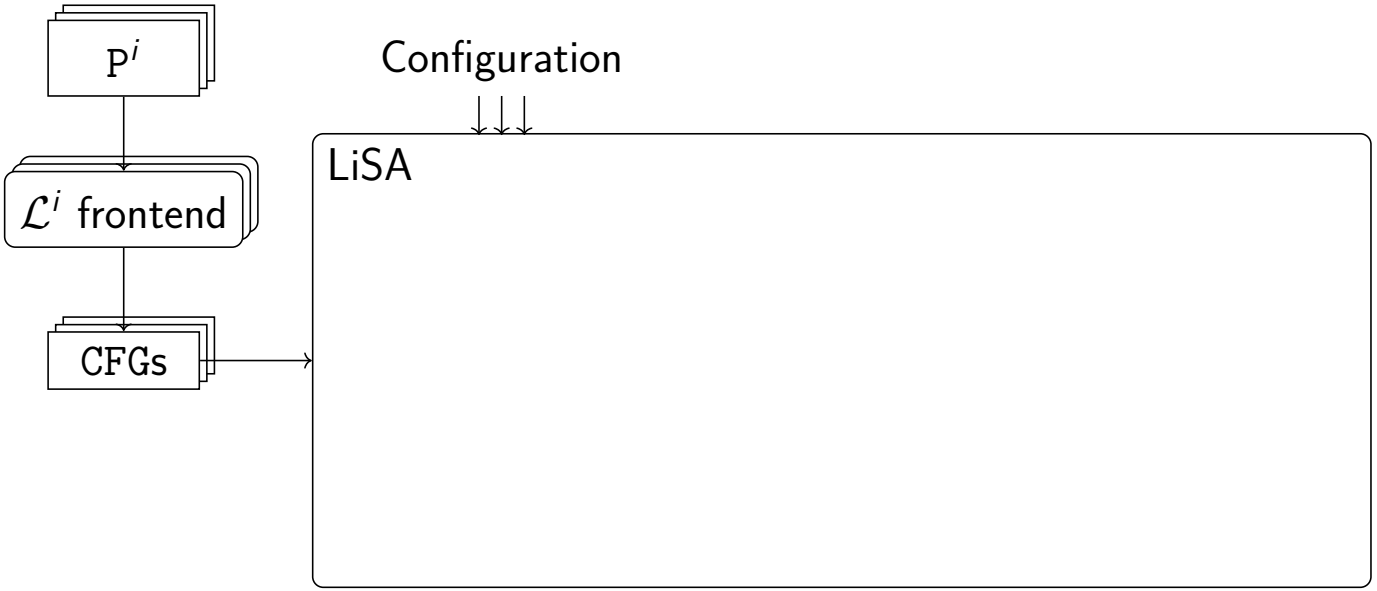

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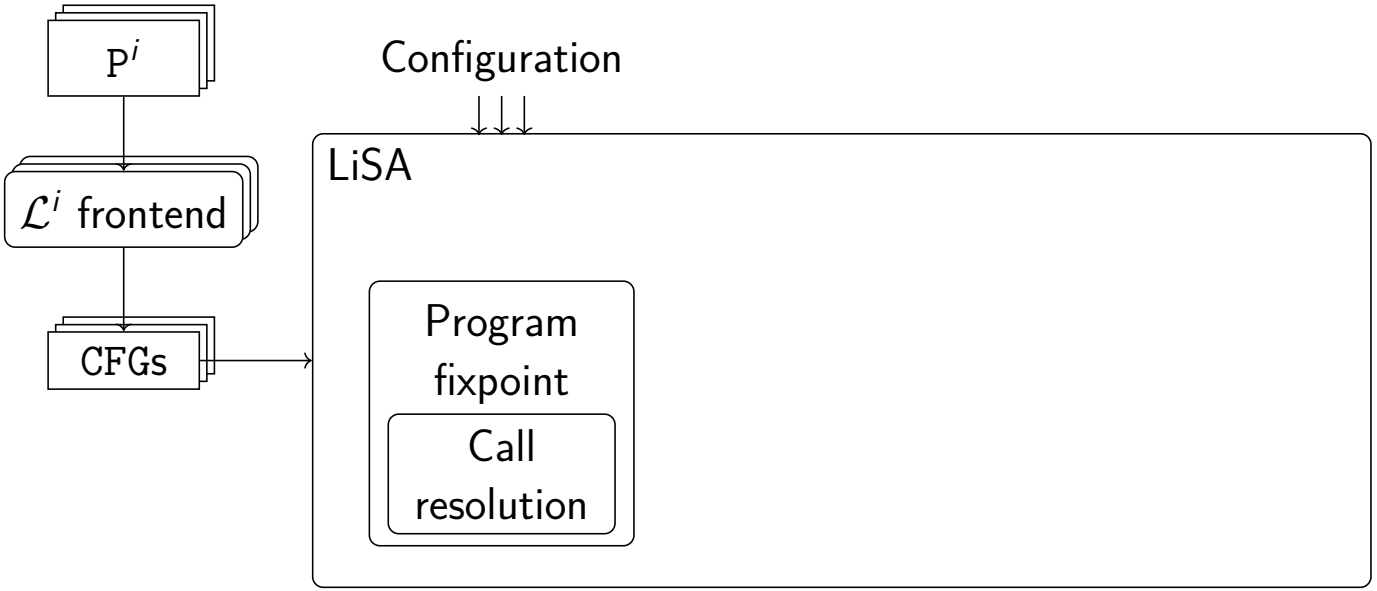

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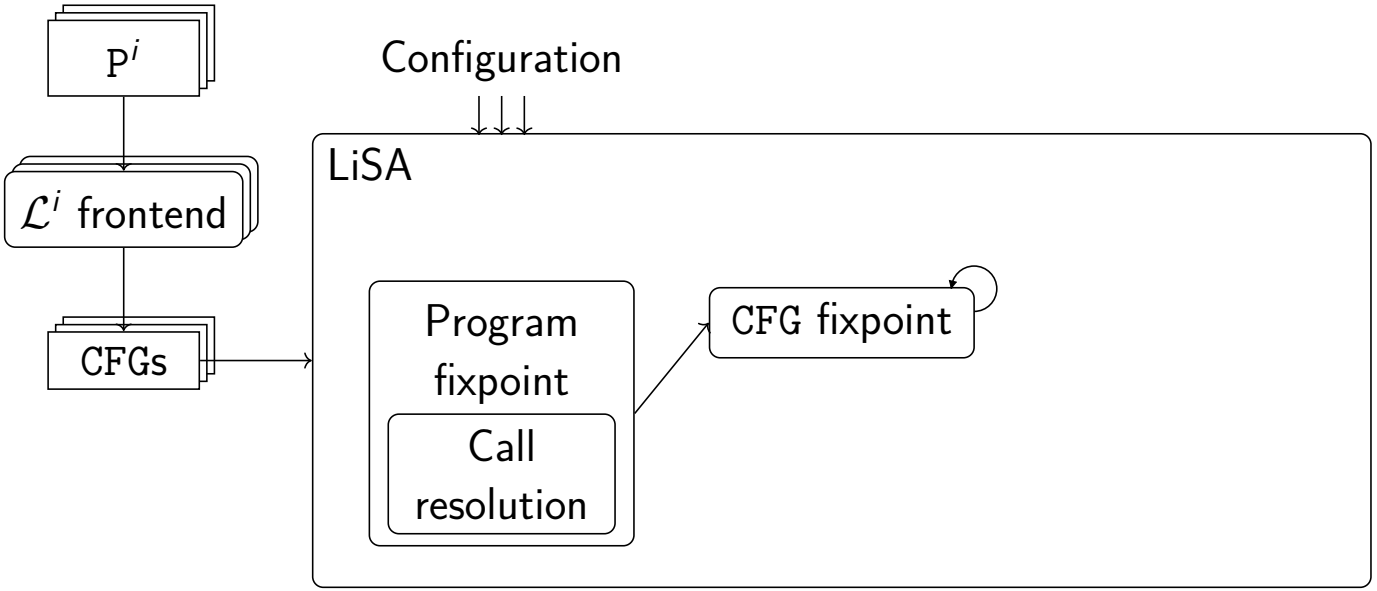

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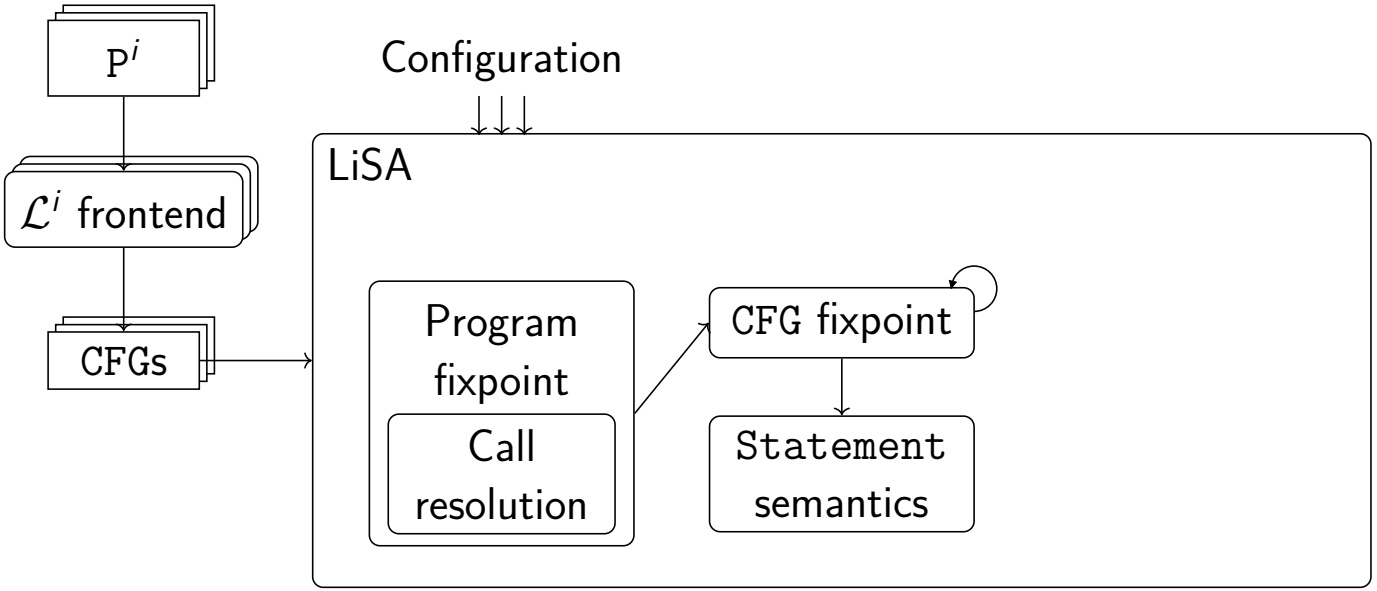


Syntax vs semantics

- `Statement` (`CFG` nodes) express the syntax of the program
- A statement can be complex: `x == null ? "unknown": x.toString()`
- Different statements can have the same meaning (semantics): `"a" + "b"` and `"a".concat("b")`
- Can we simplify?

Syntax vs semantics

- `Statement` (`CFG` nodes) express the syntax of the program
- A statement can be complex: `x == null ? "unknown": x.toString()`
- Different statements can have the same meaning (semantics): `"a" + "b"` and `"a".concat("b")`
- Can we simplify? Yes! The `SymbolicExpressions` language:
  - Each symbolic expression is an "atomic" operation (concatenation, addition, ...)
  - Domains handle `SymbolicExpressions` instead of `Statements`
  - Fixpoint uses `Statement.semantics()` to rewrite each `Statement` to `SymbolicExpression`(s) and feed them to the domain

Examples (pseudocode)

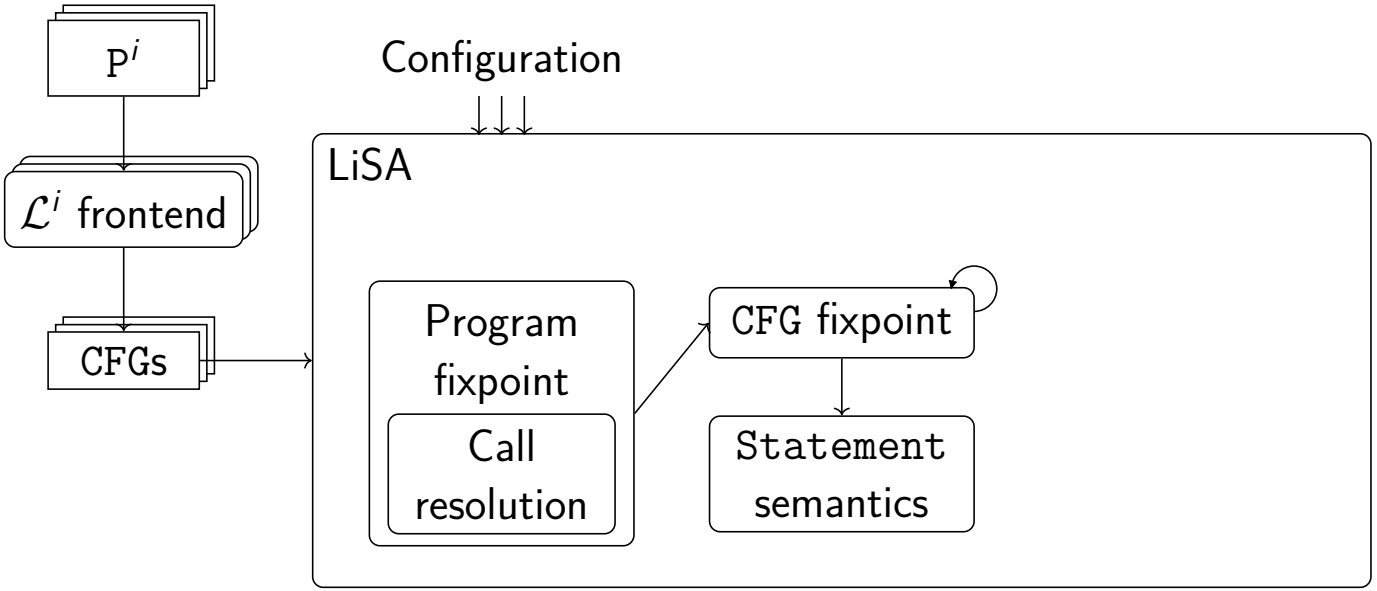
```
Addition.semantics():
  return domain.eval(new ArithmSum(left, right))
```

```
Concatenation.semantics():
  return domain.eval(new StringConcat(left, right))
```

```
Plus.semantics():
  if left is string or right is string:
    return domain.eval(new StringConcat(left, right))
  else:
    return domain.eval(new ArithmSum(left, right))
```

```
Conditional.semantics():
  if domain.isSatisfied(condition):
    return ifTrue.semantics()
  else:
    return ifFalse.semantics()
```

LiSA Overview



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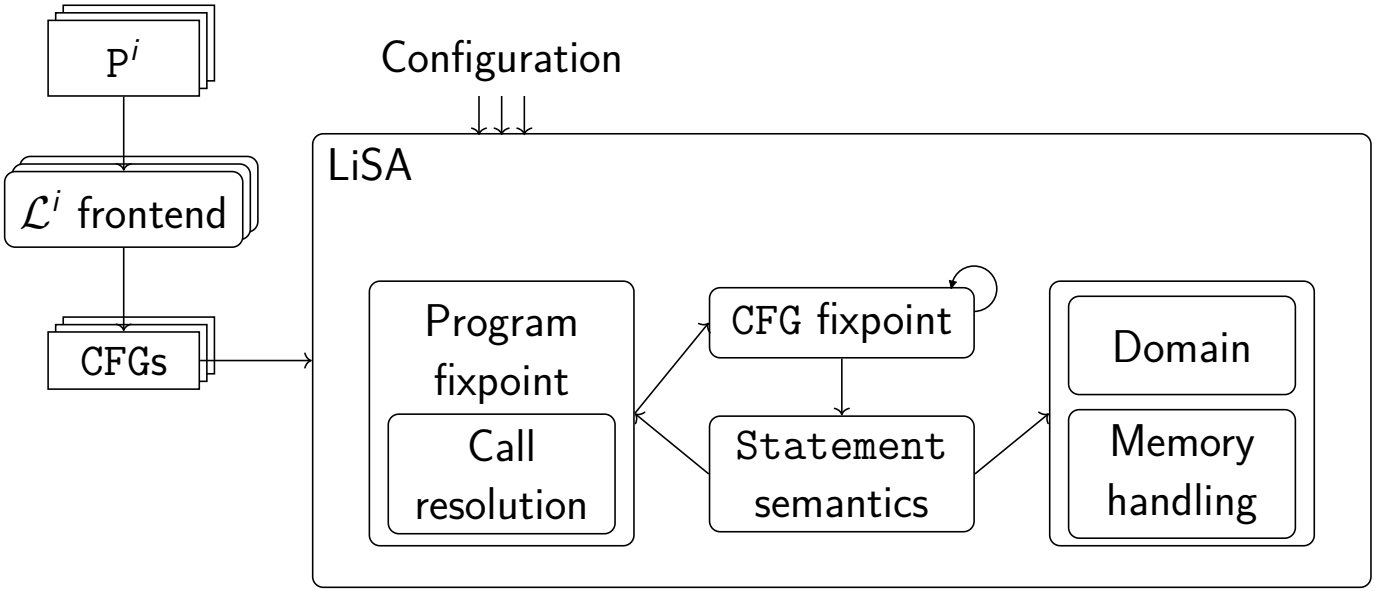

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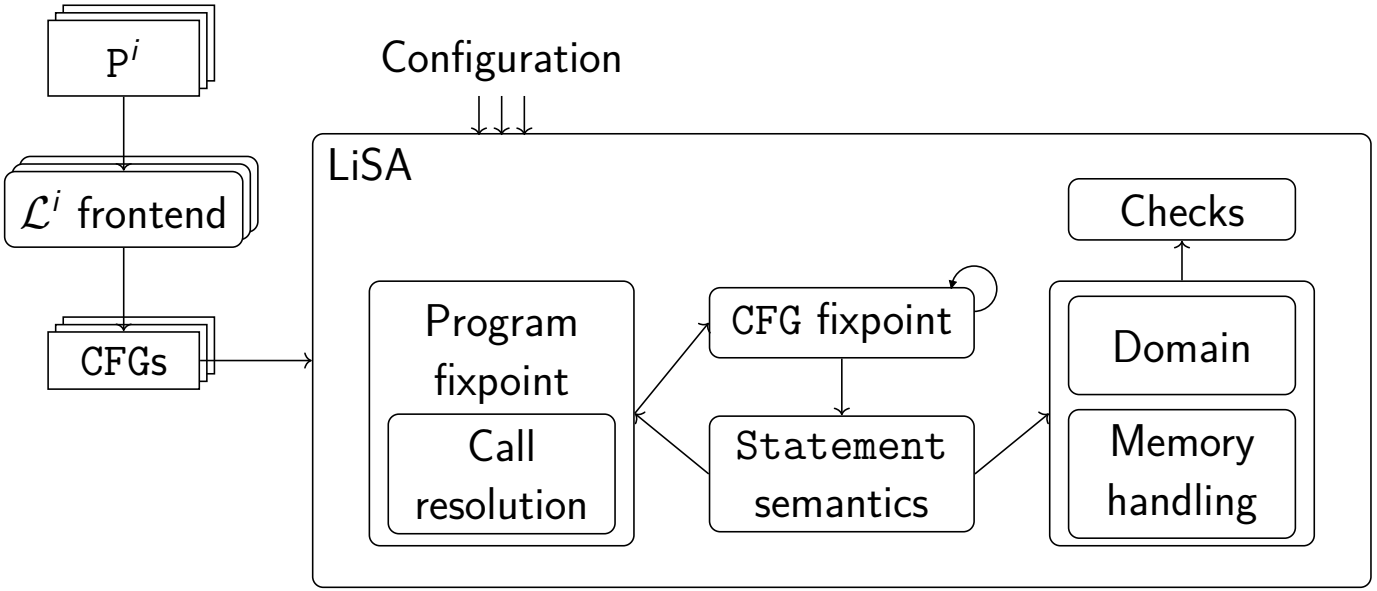

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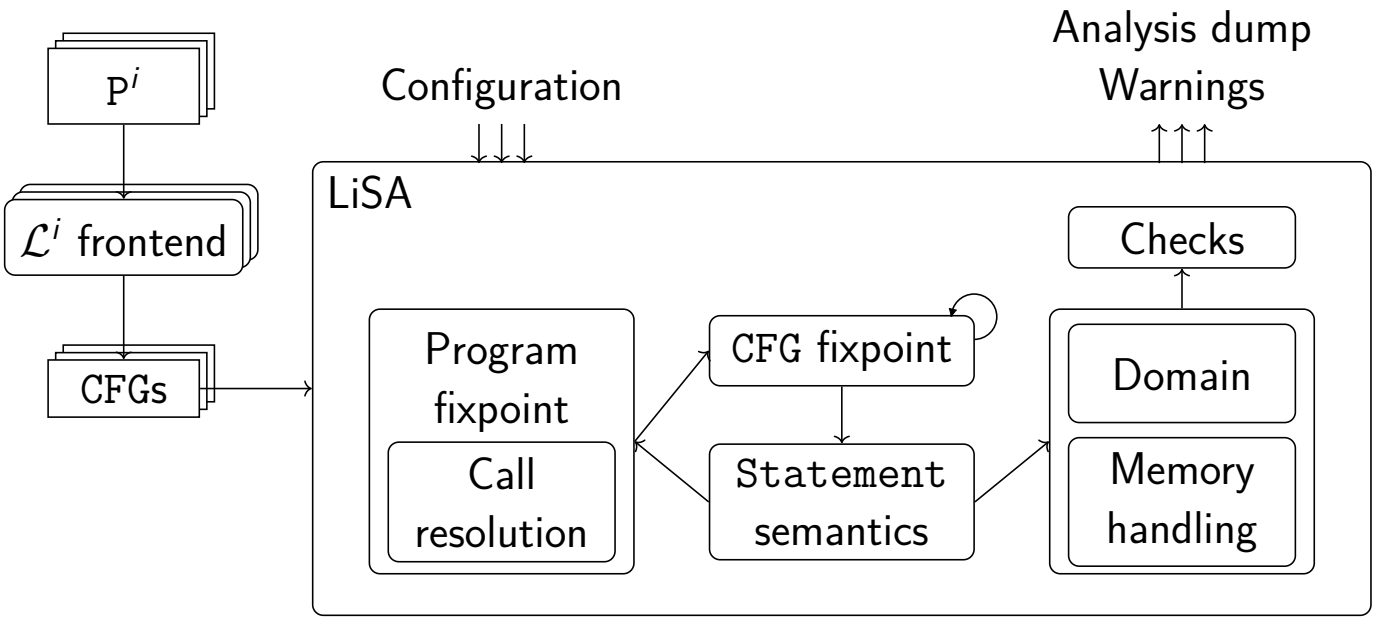

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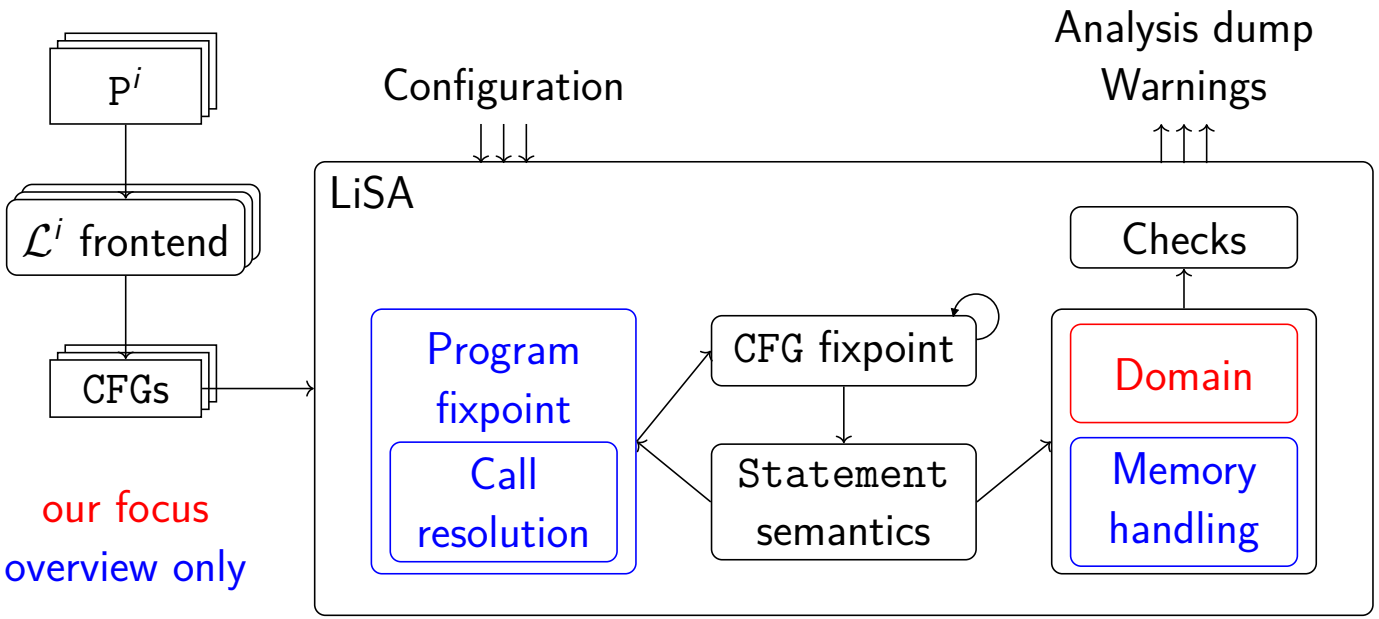

Questions?

Course project setup

Coding demo

This week's task

Download the course project and ensure that you can get it up and running

- Send me an email with your **GitHub username** to get permissions to the repo
- Create a branch named `id-lastname-firstname` and **checkout the branch**
  - e.g., `859156-zanatta-giacomo`
- Run `gradlew build` to ensure everything is working properly
- Import the project in your IDE
- Run the test class to ensure everything works properly

Links and Tips

- Repository for the tasks
- Cloning the repository:
  `git clone git@github.com:giacomozanatta/scsr-2025.git`
- Create a branch: `git checkout -b <branch name>`
- Commit your code: `git commit -am "<commit message>"`
- Push your code: `git push origin <branch name>`

Enjoy coding!

giacomo.zanatta@unive.it

https://github.com/lisa-analyzer/lisa

https://github.com/giacomozanatta/scsr-2025