

Implementing Constraint Imperative Languages with Higher-order Functions

Martin Grabmüller

`magr@cs.tu-berlin.de`

Technische Universität Berlin
Fakultät IV – Elektrotechnik und Informatik
Franklinstr. 28/29, 10587 Berlin, Germany

Outline

- Constraint imperative programming
- The constraint imperative language Turtle
- Implementation
- Summary

Constraint Imperative Programming

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 - Statement oriented

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- Constraint imperative programming aims at combining both

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```
require x > 0 in io.put (!x); end;
```

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 - User-defined constraints

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 - Constraint solvers

Turtle – An Example

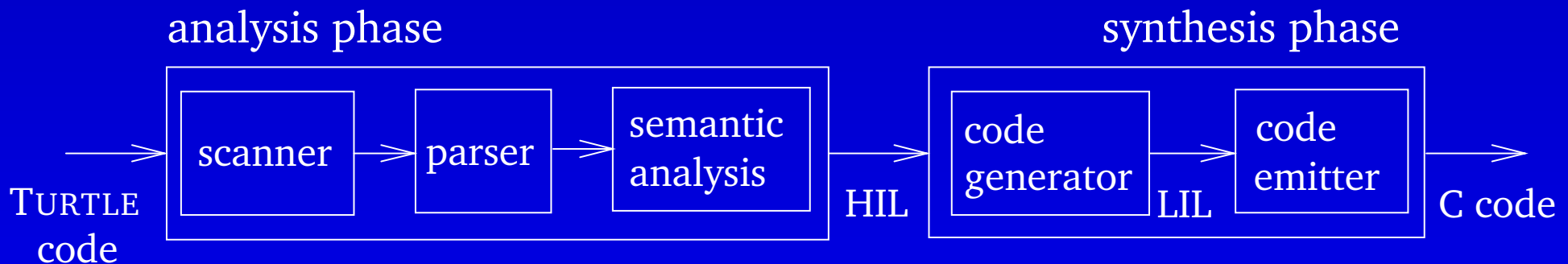
```
1  constraint all_different (l: list of !int)
2    while (tl l <> null) do
3      var ll: list of !int := tl l;
4      while (ll <> null) do
5        require hd l <> hd ll;
6        ll := tl ll;
7      end;
8      l := tl l;
9    end;
10 end;
    ...
11 var a: !int := var 0, b: !int := var 1, c: !int := var 2;
12 require all_different ([a, b, c]) in ... end;
```

Implementation

- Compiler
- Run-time system
- Library Modules

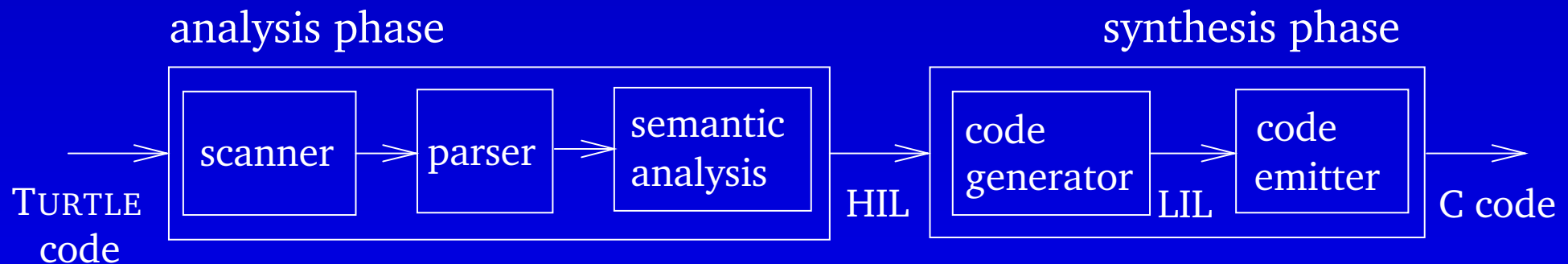
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- Compiles to ANSI C



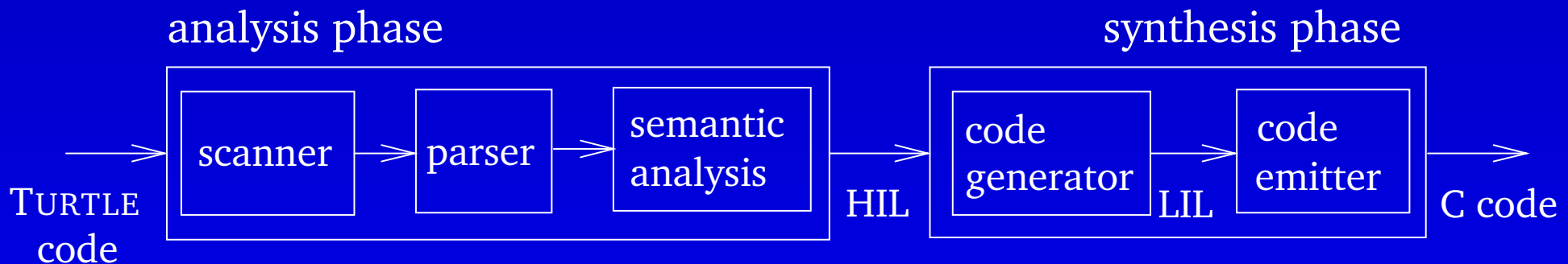
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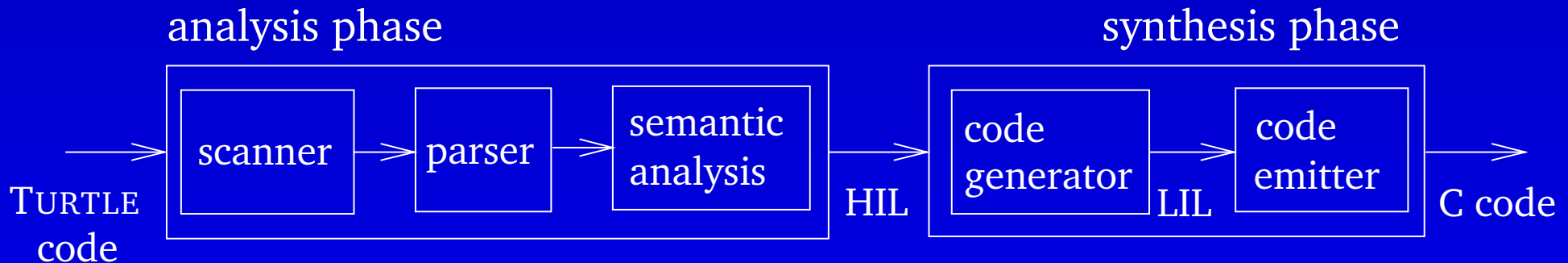
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- Static type checking with overload resolution



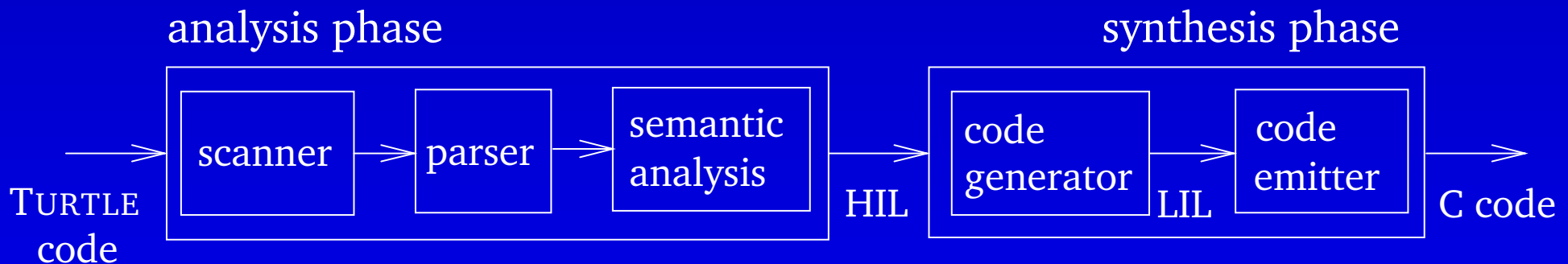
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- Static type checking with overload resolution
- Parametrized data types and modules



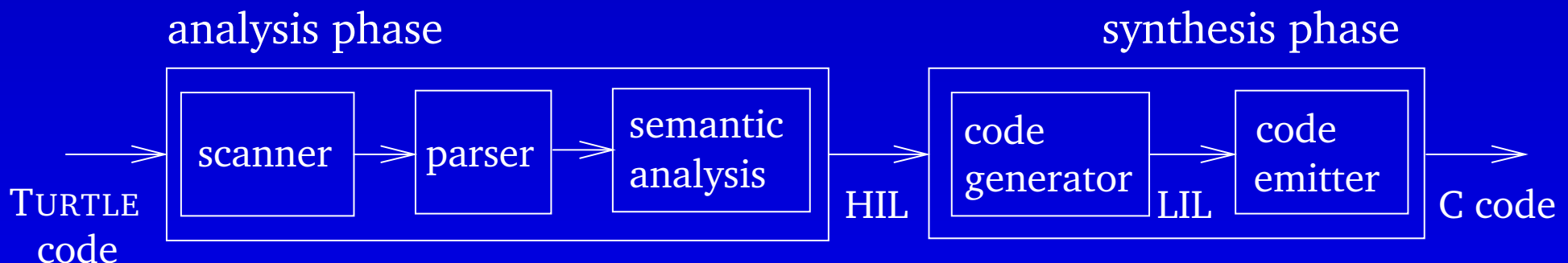
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- Algebraic data types with constructor/access function generation



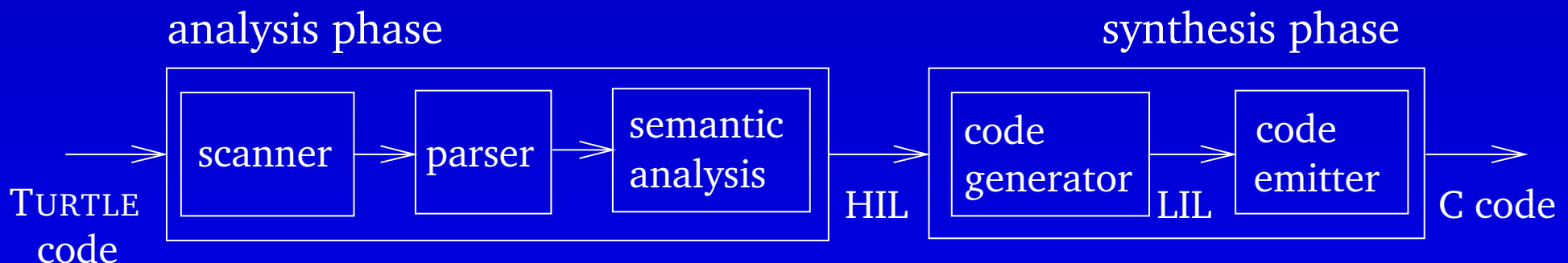
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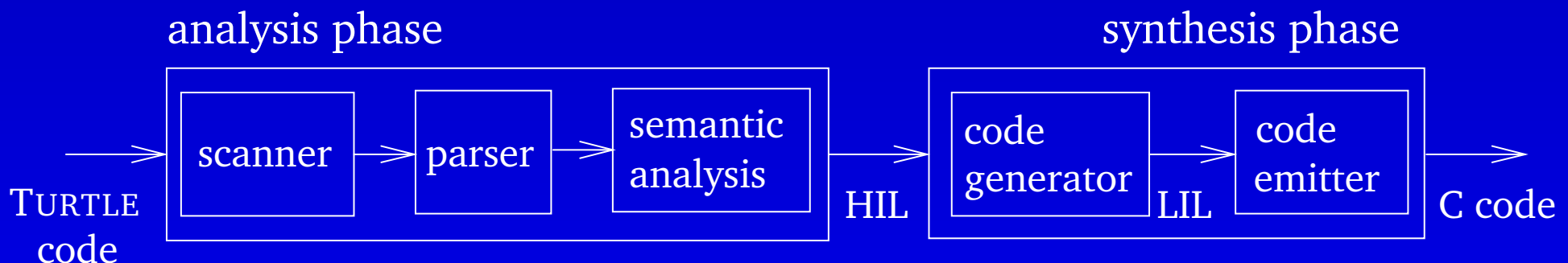
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Constraint Analysis

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var y: int ← 4;  
var x: ! int ← var 0;  
require 10 * x + 10 > 3 * y - 1;
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Constrainable variable with coefficient:

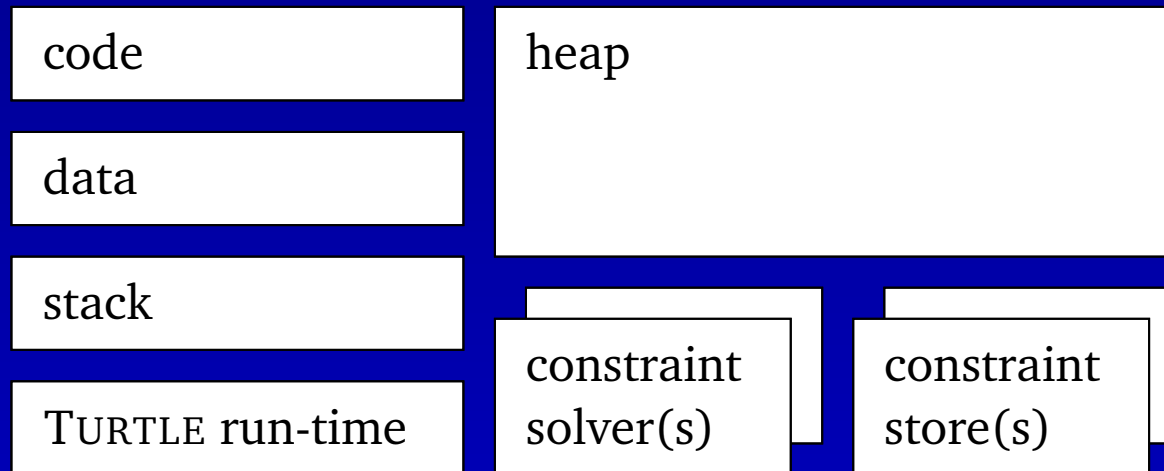
$$10*x$$

Code Generation

$$10*x > -10+3*y - 1$$

```
1  push-constant  0    // constraint strength '0'
2  push-constant  3    // constraint kind '>'
3  push-constant  1    // number of constrainable variables
4  push-variable  y    // calculate the constant term...
5  load-constant  3
6  mul
7  push
8  load-constant -11
9  add
10 push
11 push-variable  x    // load the constrainable variable object
12 push-constant  10
13 add-constraint // add the constraint to the store
```

Run-time system



- Constraint solvers
- Garbage collection
- Restricted foreign function interface

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- Imperative I/O.
- Low level library modules including interfacing with the OS, such as process management and network programming.

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 - Slow/simple proof-of-concept implementation of the constraint solvers.
 - Limited use of constraints for controlling program execution.

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<http://uebb.cs.tu-berlin.de/~magr/turtle/turtle.en.html>

Turtle: Layout Example Program

```
module layout;
import io;
fun main (args: list of string): int
  var lm, rm, gap, pw, col: !real := var 0.0;
  require lm = 2.0 and rm = 2.0 and pw = 21.0 and
    gap >= 0.5 and gap <= 2.0 and
    gap = 0.5 : medium and col <= 7.0 : strong and
    gap + lm + 2.0 * col + rm = pw in
    io.put ("lm="); io.put (!lm); io.nl ();
    ...
    io.put ("col="); io.put (!col); io.nl ();
  end;
  return 0;
end;
```