Introduction to the Tiger Project
and Tigrou project

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Context and Motivation

The Needs

- 20 years ago, EPITA asked for a long and challenging project.
- Should virtually be a *potpourri* of every subject from computer science courses taught in third year.

A (Miraculous) Solution

A compiler construction project.

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Compiler construction as a by-product

Complete Project

Specifications, implementation, documentation, testing, distribution.

Several iterations

6 (optionally up to 9) steps, for 3 (resp. up to 6) months.

Algorithmically challenging

Applied use of well known data structures and algorithms.

Team Management

Project conducted in group of four students.

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C++

Expressive power; uses both low- and high-level constructs; industry standard.

Object-Oriented (OO) Design and Design Pattern (DP)

Practice common OO idioms, apply DPs.

Development Tools

Autotools, Doxygen, Flex, Bison, GDB, Valgrind, Git, etc.

Understanding Computers

Compiler and languages are tightly related to computer architecture.

English

Everything is to be written in English (code, documentation, tests).

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Writing a Compiler Paradoxically!

Well, at least considered a *secondary* issue.

- Why?

  The vast majority of [Computer Science] students are unlikely to ever design a compiler [Debray, 2002].

- But... Students interested in compiler construction should be given the opportunity to work on challenging, optional assignments.
- But... Since 2002, graphics processors units have raised (GPU). A lot of work has to be done to targer such GPU.

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Introduction to the Tiger Project

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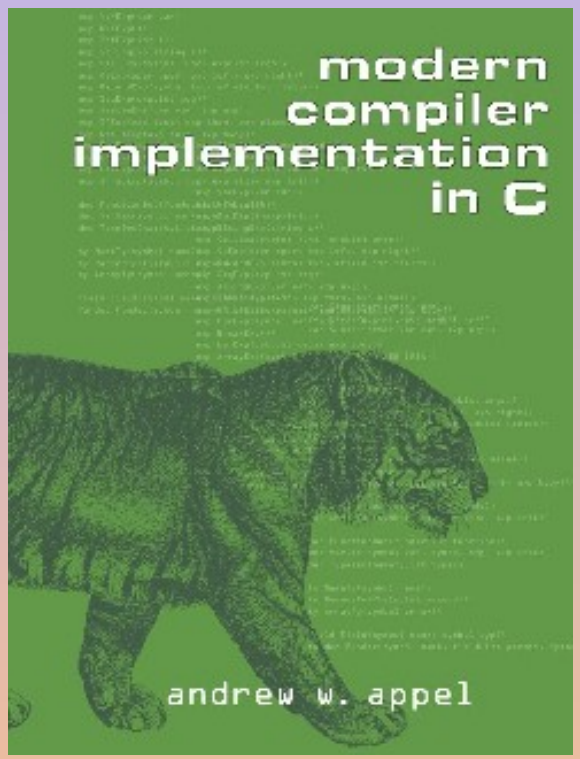
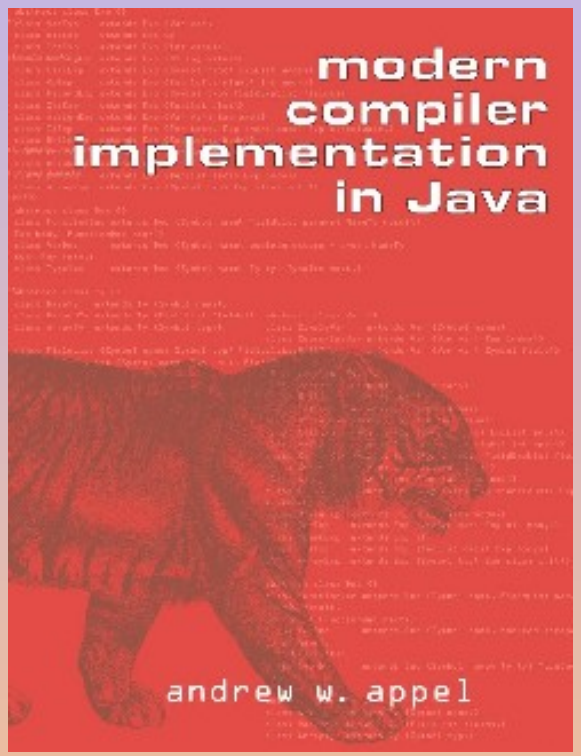
Overview of the Tiger Project

A Core-Curriculum Compiler-Construction Project

Based on Andrew Appel's Tiger language and *Modern Compiler Implementation* books [Appel, 1998].





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...and largely adapted [Demaille, 2005].

- Compiler (to be) written in C++.
- Initial Tiger language definition (a Pascal-descendant language, dressed in a clean ML-like syntax).
- Augmented with `import` statements, adjustable prelude, OO constructs, etc.
- Better defined (no implementation-defined behavior left).
- More compiler modules and features than in the initial design.
- In particular more *tools* to both help students develop and improve their compiler and make the maintenance easier to teachers and assistants.

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Project's *Modus Operandi*

- The compiler is designed as a long pipe composed of several modules.
- The project is divided in several steps, where students have to implement one (or two) module(s).
- Code with gaps.
- Work is evaluated by a program at each delivery.
- Students defend their work every two steps in front of a teaching assistant.
- Several optional assignments are given as extra modules.
- Motivated students can choose to proceed with the implementation of the back-end of the compiler.

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Figures

- 20 years of existence.
- 250/300 students per year (on average).
- Project done in groups of 4 students.
- 6 mandatory steps (compiler front-end).
- 4 optional steps (compiler back-end).
- Reference compiler: 25KLOC.
- Students are expected to write about 5500 lines (or about 7000 lines, with the optional assignments).
- 250+ pages of documentation (reference manual [Demaille and Levillain, 2007b] and project assignments [Demaille and Levillain, 2007a]).
- 3 papers in international conferences [Demaille, 2005, Demaille et al., 2008, Demaille et al., 2009].

History I

2000 Beginning of the Tiger Project: a front-end, a single teacher, no assistant.

2001 Have students learn and use the Autotools for project maintenance.

2002 Teaching Assistants involved in the project.
Interpreter for the Intermediate Representation (IR) language (HAVM).

2003 Addition of a MIPS back-end, partly from the work of motivated students.
Interpreter for the MIPS language (Nolimips).
The structures of the Abstract Syntax Tree (AST) and a visitor are generated from a description file.

History II

2005 A second teacher in the project maintenance and supervision.
First uses of some Boost libraries (Boost.Variant, Boost Graph Library (BGL), Smart Pointers).
First use of concrete-syntax program transformations (code generation) using TWEASTs

2007 Tiger becomes an Object-Oriented Language (OOL).

2009 C++ objects on the parser stack.

2011 Extension of Bison's grammar to handle named parameters.

History I

2012 Conversion of `tc` to C++11.

2015 Even more C++11/C++14, aiming at C++17.
OO is now optional.
Much simpler/faster build system.
Support form ARM backend.

2016 Support for LLVM intermediate langage.

2017 Introduce Dockerfile.
Move on C++17

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2018 Refactoring python bindings for jupyter-notebooks

2019 Rework assignments

2020 Setup Tigrou's project

Practical information

Entry Points

- Home page of the project:
  `http://tiger.lrde.epita.fr`
- Resources for the project:
  `http://www.lrde.epita.fr/~tiger`
- `news.epita.fr` newsgroup:
  `assistants.tiger`

Reference Documents

- Tiger Compiler Project Assignments:
  `http://assignments.lrde.epita.fr/`
- Tiger Compiler Reference Manual (TCRM):
  `http://www.lrde.epita.fr/~tiger/tiger.html`
  `http://www.lrde.epita.fr/~tiger/tiger.split`
  `http://www.lrde.epita.fr/~tiger/tiger.pdf`
  `http://www.lrde.epita.fr/~tiger/tiger.info`
  `http://www.lrde.epita.fr/~tiger/tiger.txt`

Lectures notes

Slides (like these ones):
`http://www.lrde.epita.fr/~tiger/lecture-notes/slides/`

Handouts (if you need to print lectures, please use these and save a tree):

1-up `http://www.lrde.epita.fr/~tiger/lecture-notes/handouts/`

4-up `http://www.lrde.epita.fr/~tiger/lecture-notes/handouts-4/`

Subdirectories:

`ccmp/` CCMP lecture notes

`tc/` TC-*n* presentations, given by the Assistants

`tyla/` TYLA lecture notes

Other Useful Resources

- Doxygen Documentation:
  `http://www.lrde.epita.fr/~tiger/tc-doc/`
- Past exams [outdated since 2016]
  `http://www.lrde.epita.fr/~tiger/exams/`
- Emacs/Vim modes
  `http://www.lrde.epita.fr/~tiger/tc/tiger.el`
  `http://www.lrde.epita.fr/~tiger/tc/tiger.vim`
- Docker for a fully working environnement
  `http://www.lrde.epita.fr/~tiger/tc/docker-sid`

Rules of the Game

Nul n'est censé ignorer la loi.

`http://www.assignements.lrde.epita.fr`

1. **No copy between groups.**
2. Tests are part of the project
   (test cases and frameworks should not be exchanged).
3. Fixing mistakes earlier is better (and less expensive).
4. Work between groups is encouraged!
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Vocabulary and Structure of a compiler

Compiler

- **A compiler** is a program that converts a source language into a target machine language.
- **A cross-compiler** is a program (running on a machine A) that converts a source language into a target machine language B (different from A).
- **A transpiler** is a program that converts a source language into a target language (same level of abstraction).

Compiler

- **Pre-processor** remove all *define*, *include* directives. Produces a *pure* code.
- **Linker** combines one or more object files and possible some library code into either some executable, or some library
- **Loader** A loader reads the executable code into memory, does some address translation and tries to run the program resulting in a running program.
- Linker and loader performs Basically the loader does the program loading; the linker does the symbol resolution; and either of them can do the relocation.
- **Static/Dynamic** Compile time / runtime

The C Compilation Model

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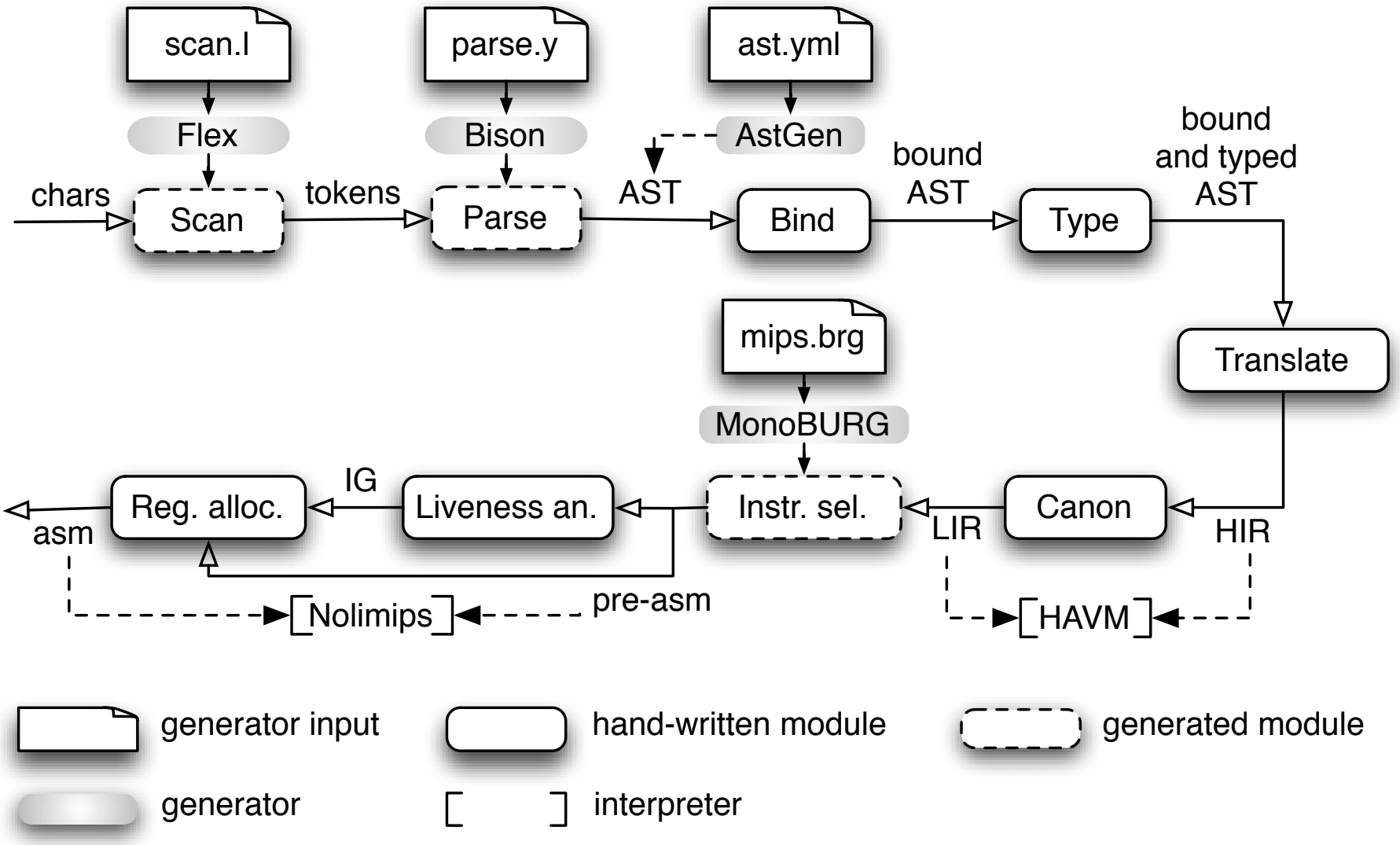
$\rightarrow$ A *pipe*.

The Tiger Compiler (and Tigrou's architecture)

tc: A Compiler as A Long Pipe



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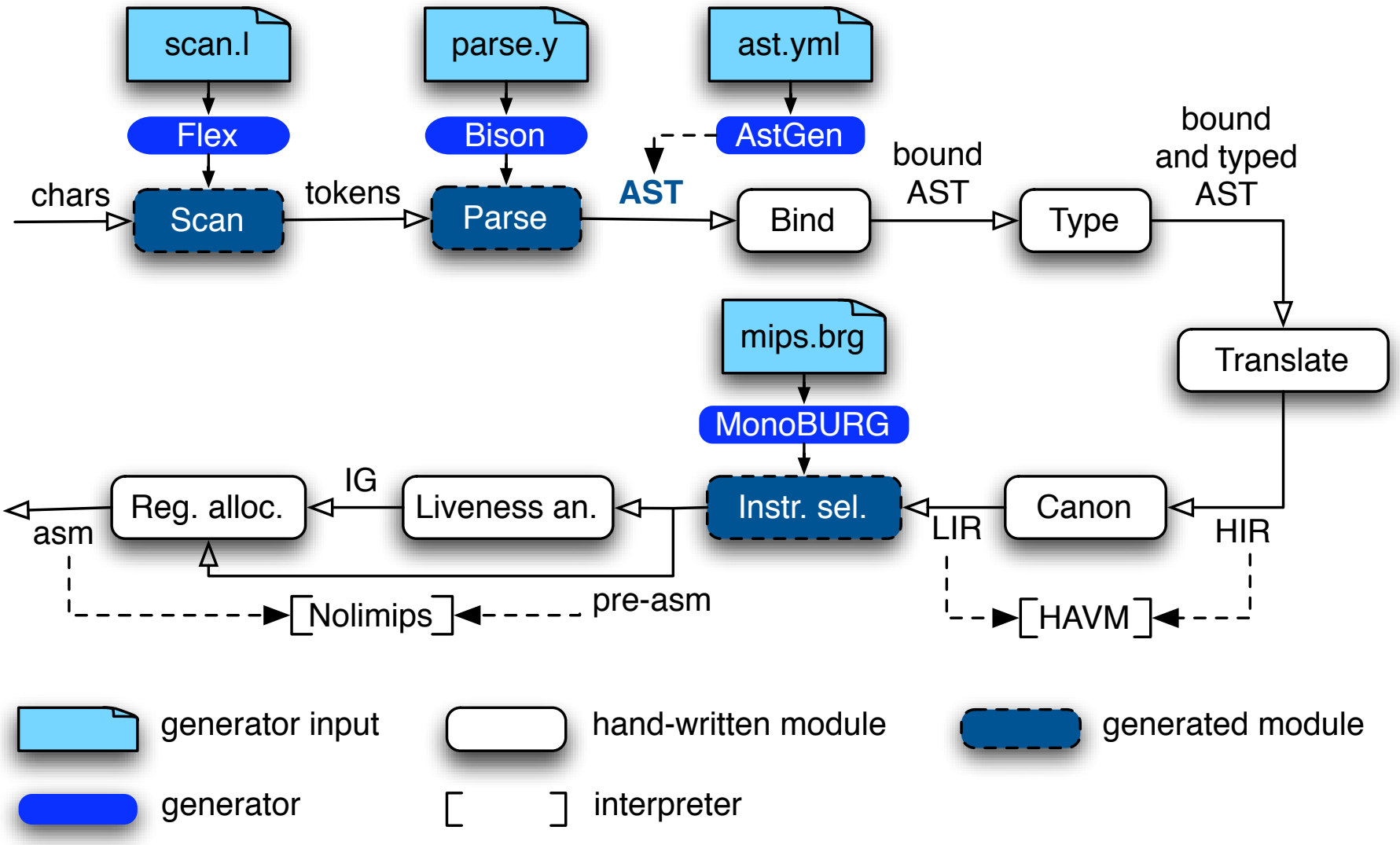

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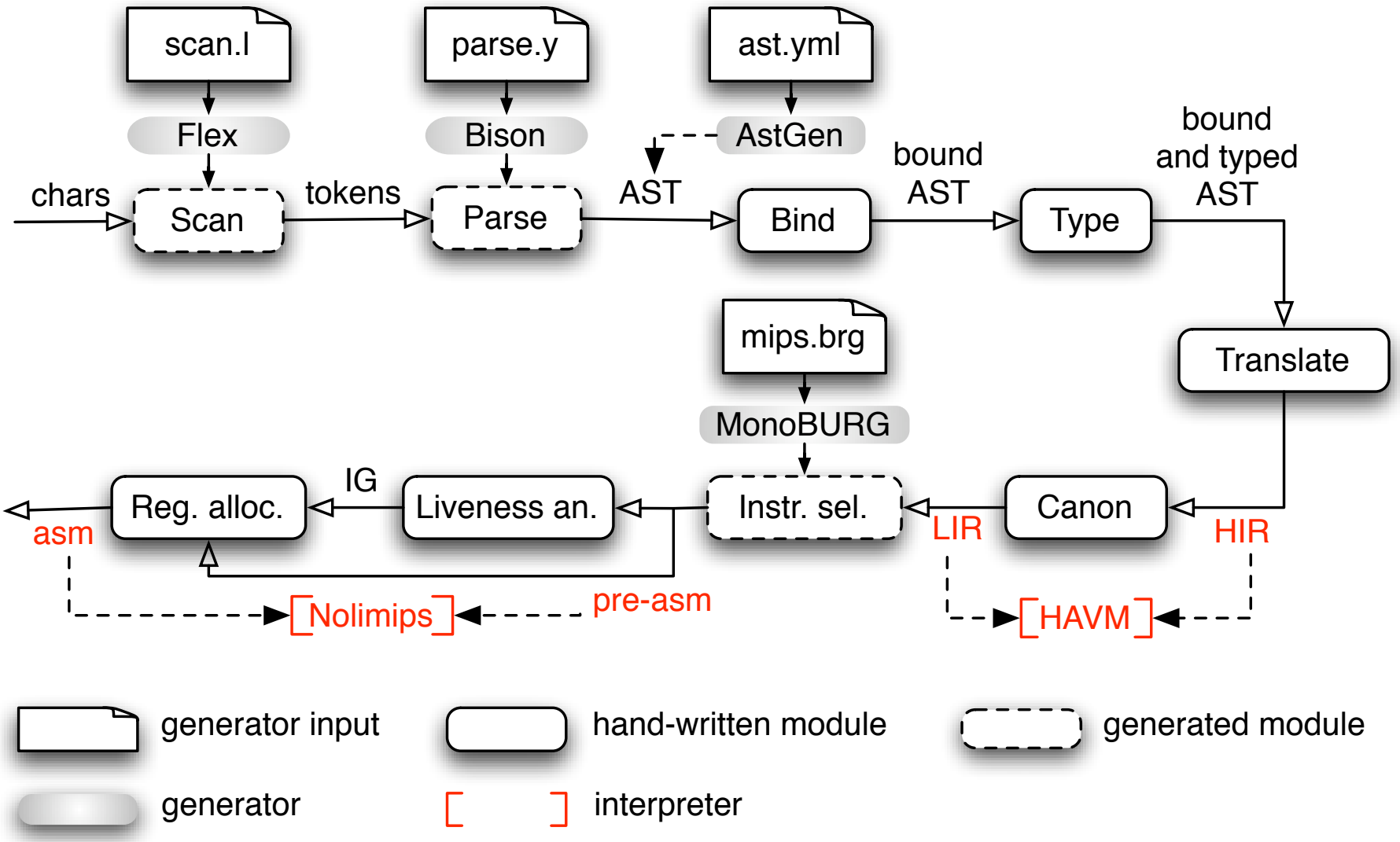

Other Compiling Strategies

- Intermediate language-based strategy: SmartEiffel, GHC
- Bytecode strategy: Java bytecode (JVM), CIL (.NET)
- Hybrid approaches: GCJ (Java bytecode or native code)
- Retargetable optimizing back ends: MLRISC, VPO (Very Portable Optimizer), and somehow C-- (Quick C--).
- Modular systems: LLVM (compiler as a library, centered on a typed IR). Contains the LLVM core libraries, Clang, LLDB, etc. Also:
  - VMKit: a substrate for virtual machines (JVM, etc.).
  - Emscripten: an LLVM-to-JavaScript compiler. Enables C/C++ to JS compilation.

Intermediate Representations (IR) are fundamental.

The Tiger Language

Two flavors

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  ...but still effective.
- Imperative language, descendant of Algol.
- Functional flavour.
  - `a := if 1 then 2 else 3`
  - `function incr(x : int) : int = x + 1`
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Your first Tiger Program

```
print("Hello World!\n")
```

Your second Tiger program

```
let
  function hello(name : string) =
    print(concat("Hello ", name))
in
  hello("You");
  print("\n")
end
```

The classic Factorial function

```
let
  /* Compute n!  */
  function fact(n : int) : int =
    if n = 0
      then 1
      else n * fact(n - 1)
in
  print_int(fact(10));
  print("\n")
end
```

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