CMDL: A Class-based Machine Description Language

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The CoGenT Project

- Co-generation of Compiler and Simulator Tools
- Uses a single set of specifications to produce:
  - Compiler back-end components
    - Register allocators
    - Code generators
    - Instruction schedulers
  - System tools
    - Assemblers / Disassemblers
    - Debuggers
  - Simulators
    - Functional/Instruction-accurate
    - Cycle-based

Why CoGenT?

- Hand-crafting compiler and simulator components is:
  - Time-consuming
  - Error-prone
- Current available simulators are:
  - Difficult to modify
  - Difficult to port
  - Difficult to instrument
  - Difficult to optimize

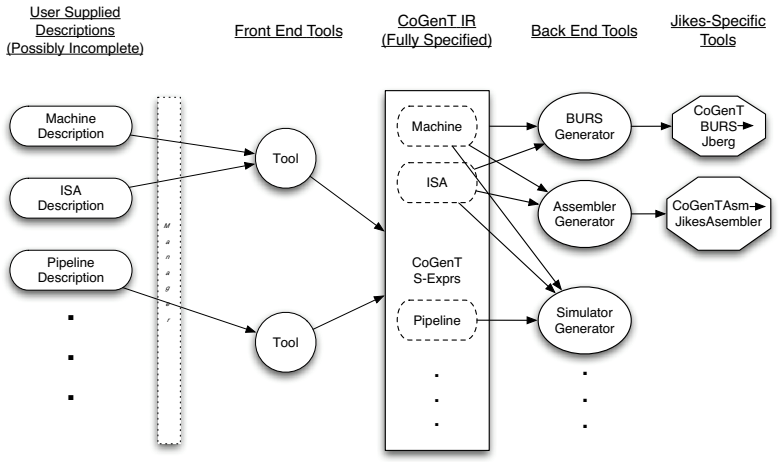
Why a common machine description?

- Compiler research requires fast & accurate simulators
- Architecture research requires optimized compiler backends
- Generate both from a common machine description
- Common language:
  - Eliminates redundancy
  - Simplifies MD compiler
  - Assures syncronization of simulator and compiler
- Previous work solves only some of these problems

CoGenT High Level Architecture

- Two Representations
  - Description language (CMDL)
  - Fully specified, tree-based IR
- Front-end tools
  - Receive partially specified input from users
  - Generate complete IR descriptions
- Back-end tools
  - Receive complete descriptions
  - Generate system tools and code

CoGenT Structure



The CoGenT Language - CMDL

- Specification language for:
  - Instruction set syntax
  - Instruction set semantics
  - Machine store descriptions
- C/Java-inspired syntax
- Elements of other machine description languages
- Allows partial descriptions (details filled in by tools)
- Allows class heirarchies to aid description

Bits: The only principal type

- Everything is bits
- Single bits are valid
- Bit Arrays are also allowed
  - Defined by length
  - Multidimensional arrays are supported
- References provide named sub-regions
- Type modifiers express abstract qualities

Type Modifiers and Declarations

- Current Modifiers:
  - Signedness: unsigned/signed
  - Endianness: big/little
  - Mutability: overlay/field
- Handling conflicts
- Type declarations using `type ... =`

Examples

- These type identifiers are equivalent:
  - Posix: `uint32_t`
  - CoGenT: `big unsigned bit[32]`
- These type declarations are equivalent:
  - `typedef uint32_t unsigned int`
  - `type uint32 = big unsigned bit[32]`
- References:

```
uint32 foo;
bit hi @ foo[0];
bit lo @ foo[31];
```


Endianness

- Endianness specifies meaning of indexing
- Example: `bit[2] foo = 0b10;`
  - Big Endian `foo[0]` = 1
  - Little Endian `foo[1]` = 1
- Bits reordered through assignment
- Indexing converted through coercion

Subranges

- Named ranges on types (rather than instances)
- Example:

```
big unsigned bit[32] ieee32fp;
subrange sign = bit @ ieee32fp[0];
subrange exponent =
unsigned big bit[8] @ ieee32fp[1];
```

- No recursive subranges
- Different signedness and endianess allowed

Classes

- Data + Methods
- Simple single inheritance
- No references
- Restricted form of inclusion
- Useful for specifying orthogonal instruction sets

Constraints

- CoGenT classes allow constraints on members
- For parsing, a constraint specifies an expected value
- For emitting, a constraint specifies a ‘magic’ constant

Instruction Definition Example

Our friend, the PowerPC add immediate (`addi`) instruction

- All PPC instructions have 6-bit opcode field
- `addi` is a D-Form instruction

Example, continued

```
class ppc {
  unsigned big bit[32] ppc_inst;
  unsigned big bit[6] OPCD @ ppc_inst[0]; }

class d-form extends ppc {
  unsigned bit bit[5] RA @ ppc_inst[11]; }

class addi extends d-form {
  unsigned big bit[5] RT @ ppc_inst[6];
  unsigned big bit[16] SI @ ppc_inst[16]; }
```

Semantics

- Instructions also have semantics
- Semantics are class methods
- Use C-style operators
- Additional, useful operators added (sign-extend, etc.)

Mixins

- Allows overloading without actually overloading
- Convenient for orthogonal instruction groups
- For instance, `getaddr()`

```
mixin getAddrByWord requires (disp) {
 getaddr(disp) { return (bit[32])disp<<2; }
}
mixin getAddrByByte requires (disp) {
 getaddr(disp) { return (bit[32])disp; }
}
```


Status + Goals

- Base language spec. stable (we even have a manual!)
- Prototype parser implementation nearly complete
- Front-end analysis in progress
- Microarchitecture description spec in progress
- *http://ali-www.cs.umass.edu/cogent/index.htm*