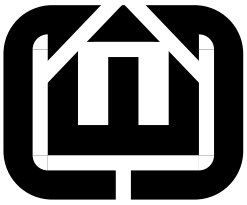
CEC GRC simulator



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Abstract

This simulates much of the GRC format. It was designed primarily for testing and is not terribly efficient.

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1 Visitor Methods

1.1 Fork

Fork schedules all its children.

2a ⟨*method declarations* 2a⟩≡ (11) 2c▷
```
Status visit(Fork &);
```

2b ⟨*method definitions* 2b⟩≡ (20b) 2d▷
```
Status GRCsim::visit(Fork &s)
{
  if (debug) cerr << cfgmap[&s] << ":fork" << '\n';
  for (vector<GRCNode *>::iterator i = s.successors.begin() ;
       i !=  s.successors.end() ; i++) schedule(*i);
  return Status();
}
```

1.2 Terminate

A Terminate node simply schedules its children.

2c ⟨*method declarations* 2a⟩+≡ (11) ◁2a 2e▷
```
Status visit(Terminate &);
```

2d ⟨*method definitions* 2b⟩+≡ (20b) ◁2b 3a▷
```
Status GRCsim::visit(Terminate &s)
{
  if (debug) cerr << cfgmap[&s] << ":term " << s.code << endl;
  schedule_child(&s);
  return Status();
}
```

1.3 Sync

The Sync node computes the maximum exit level among all its predecessors (these should be Terminate nodes by construction) and schedules its corresponding child.

2e ⟨*method declarations* 2a⟩+≡ (11) ◁2c 3b▷
```
Status visit(Sync &);
```

3a ⟨*method definitions* 2b⟩+≡ (20b) ◁2d 4▷

```
Status GRCsim::visit(Sync &s)
{
  int max_level = -1;
  assert(s.dataPredecessors.size() > 0); // grcdps should have computed them
  for ( vector<GRCNode *>::const_iterator i = s.dataPredecessors.begin() ;
        i != s.dataPredecessors.end() ; i++ ) {
    Terminate *t = dynamic_cast<Terminate*>(*i);
    assert(t);
    if (debug & debugSync)
      if (debug) cerr << cfgmap[&s] << ":sync checking "
                      << cfgmap[t] << ":term " << t->code << '\n';
    if ((sched[t]) && (t->code > max_level)) max_level = t->code;
  }

  if (debug) cerr << cfgmap[&s] << ":sync at level " << max_level << '\n';

  assert(max_level >= 0);
  assert(max_level < (int) s.successors.size());
  schedule(s.successors[max_level]);

  return Status();
}
```

1.4 Enter

The key operation for the Enter node is walking up the selection tree to find the closest exclusive node whose child this node is.

3b ⟨*method declarations* 2a⟩+≡ (11) ◁2e 5a▷

```
void setState(STNode *n);
```

4 ⟨*method definitions* 2b⟩+≡ (20b) ◁3a 5b▷

```
void GRCsim::setState(STNode *n)
{
  STexcl *exclusive = 0;

  for (;;) {
    assert(n);

    STNode *parent = n->parent;

    if (dynamic_cast<STpar*>(parent) != NULL) {
      if (debug) cerr << "parent of node " << stmap[n]
                      << " is a parallel node" << endl;
      return;
    }

    exclusive = dynamic_cast<STexcl*>(parent);
    if (exclusive != NULL) break; // found the exclusive node
    n = parent;
  }

  assert(exclusive != NULL);

  // Locate node n among the children of "parent"

  vector<STNode*>::iterator i = exclusive->children.begin();
  while (*i != n && i != exclusive->children.end()) i++;

  assert(i != exclusive->children.end());

  int childnum = i - exclusive->children.begin();

  assert(childnum >= 0);

  // Check for program termination

  if (exclusive == stroot) {
    STleaf *lf = dynamic_cast<STleaf *>(n);
    if ((lf) && (lf->isfinal())) {
      ISFinal = true;
      if (debug) cerr << "program terminated\n";
    }
  }

  state[exclusive] = childnum;
  if (debug) cerr << "   state[" << stmap[exclusive] << "] = "
                  << childnum << endl;
}
```

The visitor for the Enter node marks itself as selected using `setState` and schedules its children.

5a ⟨*method declarations* 2a⟩+≡ (11) ◁3b 5c▷
```
Status visit(Enter &);
```

5b ⟨*method definitions* 2b⟩+≡ (20b) ◁4 5d▷
```
Status GRCsim::visit(Enter &s)
{
  if (debug) cerr << cfgmap[&s] << ":enter " << stmap[s.st];
  setState(s.st);
  schedule_child(&s);
  return Status();
}
```

1.5 Suspend

5c ⟨*method declarations* 2a⟩+≡ (11) ◁5a 5e▷
```
Status visit(STSuspend &);
```

This just schedules its child.

5d ⟨*method definitions* 2b⟩+≡ (20b) ◁5b 5f▷
```
Status GRCsim::visit(STSuspend &s)
{
  if (debug) cerr << cfgmap[&s] << ":suspend " << stmap[s.st];
  schedule_child(&s);
  return Status();
}
```

1.6 Actions: Emit, Exit, Assign, Startcounter, Nop

5e ⟨*method declarations* 2a⟩+≡ (11) ◁5c 10b▷
```
Status visit(Action &);
Status visit(Emit &);
Status visit(Exit &);
Status visit(Assign &);
Status visit(StartCounter &);
Status visit(Nop &);
```

Action GRC nodes simply invoke their bodies.

5f ⟨*method definitions* 2b⟩+≡ (20b) ◁5d 6a▷
```
Status GRCsim::visit(Action &s)
{
  if (debug) cerr << cfgmap[&s];
  s.body->welcome(*this);
  schedule_child(&s);
  return Status();
}
```

Emit actions simply set their signal's status to present.

6a ⟨*method definitions* 2b⟩+≡ (20b) ◁5f 6b▷

```
Status GRCsim::visit(Emit &e)
{
  assert(e.signal);
  SignalSymbol *ss = e.signal;
  if (debug) cerr << ":emit " << ss->name << endl;
  signals[ss] = true;

  return Status();
}
```

Exit actions are similar to Emit.

6b ⟨*method definitions* 2b⟩+≡ (20b) ◁6a 6c▷

```
Status GRCsim::visit(Exit &e)
{
  assert(e.trap);
  SignalSymbol *ss = e.trap;
  if (debug) cerr << ":exit " << ss->name << endl;
  signals[ss] = true;

  return Status();
}
```

Assign statement set their variable to the value of their expression.

6c ⟨*method definitions* 2b⟩+≡ (20b) ◁6b 7a▷

```
Status GRCsim::visit(Assign &a)
{
  assert(a.variable);
  assert(a.value);
  assert(a.variable->type);

  if (a.variable->type->name != "integer" &&
      a.variable->type->name != "boolean") {
    throw IR::Error("Only integer and boolean variables supported");
  }

  var[a.variable] = intVal(a.value);

  return Status();
}
```

StartCounter actions reset their counter.

7a ⟨*method definitions* 2b⟩+≡ (20b) ◁6c 7b▷

```
Status GRCsim::visit(StartCounter &stcnt)
{
  if (debug) cerr << ":start counter\n";
  assert(stcnt.counter);
  assert(stcnt.counter->countvalue);
  counters[stcnt.counter] = intVal(stcnt.counter->countvalue);
  return Status();
}
```

NOP nodes do, not surprisingly, nothing.

7b ⟨*method definitions* 2b⟩+≡ (20b) ◁7a 7c▷

```
Status GRCsim::visit(Nop &n)
{
  if (debug) cerr << ":nop\n";
  schedule_child(&n);
  return Status();
}
```

1.7 Switch

7c ⟨*method definitions* 2b⟩+≡ (20b) ◁7b 8a▷

```
Status GRCsim::visit(Switch &s)
{
  assert(s.st);
  int act_ch = doswitch(s.st);
  assert(act_ch < (int) s.successors.size());
  GRCNode *child = s.successors[act_ch];
  if (debug) cerr << cfgmap[&s] << ":switch " << stmap[s.st]
                  << " --" << act_ch << "--> "
                  << (child ? cfgmap[child] : -1) << '\n';
  if (child) schedule(child);

  return Status();
}
```

1.8 Test

8a ⟨*method definitions* 2b⟩+≡ (20b) ◁7c 8b▷

```
Status GRCsim::visit(Test &s)
{
  assert(s.predicate);
  assert(s.successors.size()==2);
  int predvalue = intVal(s.predicate);

  GRCNode *successor = s.successors[predvalue ? 1 : 0];

  if (debug) {
    cerr << cfgmap[&s] << ":test --" << predvalue << "--> ";
    if (successor) cerr << cfgmap[successor];
    else cerr << "(none)";
    cerr << '\n';
  }

  if (successor) schedule(successor);

  return Status();
}
```

1.9 Expressions

8b ⟨*method definitions* 2b⟩+≡ (20b) ◁8a 8c▷

```
Status GRCsim::visit(Literal &s)
{
  int val;
  if ( sscanf(s.value.c_str(), "%d", &val) != 1 ) assert(0);
  return Status(val);
}
```

8c ⟨*method definitions* 2b⟩+≡ (20b) ◁8b 8d▷

```
Status GRCsim::visit(LoadSignalExpression &lse)
{
  SignalSymbol *ss = lse.signal;
  assert(ss);
  return Status(signals[ss]);
}
```

8d ⟨*method definitions* 2b⟩+≡ (20b) ◁8c 9a▷

```
Status GRCsim::visit(LoadVariableExpression &lve)
{
  VariableSymbol *vs = lve.variable;
  assert(vs);
  if (var.find(vs) == var.end())
    throw IR::Error("reading uninitialized variable " + vs->name);
  return Status(var[vs]);
}
```

9a ⟨*method definitions* 2b⟩+≡ (20b) ◁8d 9b▷

```
Status GRCsim::visit(CheckCounter &chkcnt)
{
  assert(chkcnt.counter);
  assert(chkcnt.counter->predicate);
  if (intVal(chkcnt.counter->predicate))
    counters[chkcnt.counter]--;

  return Status( counters[chkcnt.counter] == 0);
}
```

9b ⟨*method definitions* 2b⟩+≡ (20b) ◁9a 9c▷

```
Status GRCsim::visit(BinaryOp &e)
{
  assert(e.source1);
  assert(e.source2);
  int val1 = intVal(e.source1);
  int val2 = intVal(e.source2);

  int result =
    (e.op == "and") ? (val1 && val2) :
    (e.op == "or") ? (val1 || val2) :
    (e.op == "+") ? (val1 + val2) :
    (e.op == "-") ? (val1 - val2) :
    (e.op == "*") ? (val1 * val2) :
    (e.op == "/") ? (val1 / val2) :
    (e.op == "mod") ? (val1 % val2) :
    (e.op == "=") ? (val1 == val2) :
    (e.op == "<>") ? (val1 != val2) :
    (e.op == "<") ? (val1 < val2) :
    (e.op == "<=") ? (val1 <= val2) :
    (e.op == ">") ? (val1 > val2) :
    (e.op == ">=") ? (val1 >= val2) :
    0;

  return Status(result);
}
```

9c ⟨*method definitions* 2b⟩+≡ (20b) ◁9b 10a▷

```
Status GRCsim::visit(UnaryOp &e)
{

  int val = intVal(e.source);

  int result =
    (e.op == "not") ? ( !val ) :
    (e.op == "-") ? ( -val ) :
    0;

  return Status(result);
}
```

10a ⟨*method definitions* 2b⟩+≡ (20b) ◁9c 10c▷
```
Status GRCsim::visit(FunctionCall &)
{
  throw IR::Error("Function calls are not supported");
}
```

1.10 DefineSignal

A DefineSignal node resets its signal's presence. This is used to initialize local signals when they enter scope.

10b ⟨*method declarations* 2a⟩+≡ (11) ◁5e 13b▷
```
Status visit(DefineSignal &);
```

10c ⟨*method definitions* 2b⟩+≡ (20b) ◁10a 13a▷
```
Status GRCsim::visit(DefineSignal &d)
{
  assert(d.signal);
  SignalSymbol *ss = d.signal;
  assert(ss);
  if (debug) cerr << cfgmap[&d] << ":DefineSignal " << ss->name << '\n';
  signals[ss] = false;
  schedule_child(&d);
  return Status();
}
```

2 The GRCsim Class

This is the heart of the simulator. Derived from the `Visitor` class, its methods simulate each type of GRC node.

11 ⟨*GRCsim class* 11⟩≡ (20a)

```
class GRCsim: public Visitor {

  int debug;
  static const int debugDFS = 1 << 1;
  static const int debugSync = 1 << 2;
  static const int debugVectors = 1 << 3;
  int useold;

  GRCgraph *top;
  EnterGRC *entergrc;
  SymbolTable *sigs;
  STNode *stroot;
  STleaf  *boot;
  GRCNode *grcroot;

  Module *module;

  GRCNode::NumMap &cfgmap;
  STNode::NumMap &stmap;
  map<STNode*, int> state; // State information for selection tree nodes
  vector<GRCNode*> topo;
  map<GRCNode*, bool> sched;
  set<GRCNode*> dfs_notwhite, dfs_black;
  map<SignalSymbol*, bool> signals; // Status of each signal
  map<Counter*, int> counters; // Value of each counter
  map<VariableSymbol*, int> var; // Value of each variable

  std::ostream &outf;
  bool ISFinal;
  bool jump;

  public:
  GRCsim(GRCgraph *top, Module *m, GRCNode::NumMap &cm,
         STNode::NumMap &sm, int db, std::ostream &outf)
    : debug(db), top(top), sigs(m->signals),
      module(m), cfgmap(cm), stmap(sm), outf(outf) {}

  virtual ~GRCsim() {}

  void visit (GRCNode *);

  Status visit(EnterGRC &) { return Status(); }
  Status visit(ExitGRC &) { return Status(); }
  Status visit(Switch &);
```

```
  Status visit(Test &);
  Status visit(LoadSignalExpression &);
  Status visit(CheckCounter &);
  Status visit(BinaryOp &);
  Status visit(UnaryOp &);
  Status visit(LoadSignalValueExpression &) { assert(0); return Status(); }
  Status visit(FunctionCall &);
  Status visit(LoadVariableExpression &);
  Status visit(Literal &);

  Status visit(STexcl &) { return Status(); }
  Status visit(STref &) { return Status(); }
  Status visit(STpar &) { return Status(); }
  Status visit(STleaf &) { return Status(); }

  void dfs(GRCNode *n);
  void init();

  void schedule_child(GRCNode *);
  void schedule(GRCNode *);
  void clear_inputs();
  void dotick();
  void execute_max(int);
  void execute_vectors(std::istream &);
  int doswitch(STNode *n);

  ⟨method declarations 2a⟩
};
```

3 Helper Methods

3.1 schedule and schedule_child

Schedule adds the given node to the "to be executed" map. `schedule_child` schedules a node's child, if one exists.

13a ⟨*method definitions* 2b⟩+≡ (20b) ◁10c 13c▷

```
void GRCsim::schedule(GRCNode *n)
{
  if (n) sched[n] = true;
}

void GRCsim::schedule_child(GRCNode *n)
{
  assert(n);
  assert(n->successors.size() <= 1);
  if ( !n->successors.empty() )
    schedule(n->successors.front());
}
```

3.2 intVal

This evaluates what is expected to be an integer or Boolean expression and returns the result.

13b ⟨*method declarations* 2a⟩+≡ (11) ◁10b

```
int intVal(ASTNode *n)
{
  assert(n);
  Status s = n->welcome(*this);
  return s.i; // Integer-valued result
}
```

3.3 doswitch

Returns the number of the currently-active child of a Switch node in the selection tree.

13c ⟨*method definitions* 2b⟩+≡ (20b) ◁13a 14▷

```
int GRCsim::doswitch(STNode *n)
{
  if ( (dynamic_cast<STexcl*>(n)) == NULL )
    cerr << "error: testing non-excl node\n";
  if ( state.find(n) == state.end() )
    cerr << "error: testing unitialized state for node " << stmap[n] << endl;
  assert(state[n] >= 0);
  assert(state[n] < (int) n->children.size());
  return state[n];
}
```

3.4 dfs

Order the nodes in the control-flow graph.

FIXME: Not all constructive programs can be scheduled statically; some will need data-dependent dynamic scheduling.

14 ⟨*method definitions* 2b⟩+≡ (20b) ◁13c 15▷

```
void GRCsim::dfs(GRCNode *n){
  vector<GRCNode *>::iterator i;

  if (!n) return;

  if ( debug & debugDFS ) cerr << "visiting " << cfgmap[n] << "...";
  if ( dfs_notwhite.count(n) > 0 ) {
    if (debug & debugDFS ) cerr << "visited before\n";
    if (dfs_black.count(n) == 0) {
      cerr << "GRCsim: cycle detected\n";
      exit(100);
    }
    return;
  }
  dfs_notwhite.insert(n);

  if (jump) {
    if (debug & debugDFS ) cerr << "JUMP!\n";
    jump = false;
  }

  if ( debug & debugDFS ) cerr << "visiting\n";

  if ( debug & debugDFS ) cerr << "dfs children\n";
  for (i = n->successors.begin(); i != n->successors.end(); i++)
    dfs(*i);

  if (n->dataSuccessors.size()>0){
    if ( debug & debugDFS ) cerr << "dfs datadps children\n";
    for (i = n->dataSuccessors.begin();
         i != n->dataSuccessors.end(); i++){
        jump = true;
        dfs(*i);
        jump = true;
      }
  }

  assert(n);
  topo.push_back(n);
  dfs_black.insert(n);
  if ( debug & debugDFS ) cerr << "push back " << cfgmap[n] << "\n";
}
```

3.5 execute max

A simulation dispatch method. Initialize the simulation and run the program for either the given number or ticks or until the program terminates, whichever is sooner.

15 ⟨*method definitions* 2b⟩+≡ (20b) ◁14 16▷

```
void GRCsim::execute_max(int maxticks)
{
  int ntick;

  useold=0;

  init();
  ntick=0;
  ISFinal = false;

  do {
    if (debug) cerr << "######## TICK " << ntick << endl;
    char buf[5];
    sprintf(buf, "%4d ", ntick);
    outf << buf;
    ntick++;
    clear_inputs();
    dotick();
  } while ((!ISFinal) && (maxticks < 0 || (ntick <= maxticks)));
}
```

3.6 Execute Vectors

A simulation dispatch method. Initialize the simulation and run the program, taking input signals presence/absence information from a test vector file.

16 ⟨*method definitions* 2b⟩+≡ (20b) ◁15 18▷

```
void GRCsim::execute_vectors(std::istream &vf)
{
  // Enumerate the inputs to be read from the vector file

  vector<SignalSymbol*> inputs;

  for ( SymbolTable::const_iterator isym = sigs->begin() ;
        isym != sigs->end() ; isym++ ) {
    SignalSymbol *ss = dynamic_cast<SignalSymbol*>(*isym);
    assert(ss);
    if ( ss->name != "tick" && (ss->kind == SignalSymbol::Input ||
                                ss->kind == SignalSymbol::Inputoutput ) ) {
      if ( debug & debugVectors ) std::cout << ss->name << '\n';
      inputs.push_back(ss);
    }
  }

  init();

  int ntick = 0;
  ISFinal = false;
  do {
    string line;
    do {
      vf >> line;
    } while (line.size() == 0 && !vf.eof());
    if (vf.eof()) break;

    if ( line.size() < inputs.size() ) {
      cerr << "Not enough inputs (" << line.size() << '<' << inputs.size()
           << ") in test vector file\n";
      exit(-2);
    }

    clear_inputs();
    string::const_iterator j = line.begin();
    for ( vector<SignalSymbol*>::const_iterator i = inputs.begin() ;
          i != inputs.end() ; i++, j++ )
      signals[*i] = (*j) == '1';

    if (debug) cerr << "######## TICK " << ntick << endl;
    char buf[5];
    sprintf(buf, "%4d ", ntick);
    outf << buf;
    ntick++;
```

```
    dotick();
  } while (!ISFinal);
}
```

3.7 init

Initialize the simulation. Gather special nodes in the graph and run DFS to order them.

18 ⟨*method definitions* 2b⟩+≡ (20b) ◁16 19a▷

```
void GRCsim::init()
{
  entergrc = dynamic_cast<EnterGRC*>(top->control_flow_graph);
  assert(entergrc);
  grcroot = dynamic_cast<GRCNode*>(entergrc->successors.back());
  assert (grcroot);
  stroot = dynamic_cast<STexcl *>(top->selection_tree);
  assert(stroot);
  boot = dynamic_cast<STleaf* >(stroot->children.back());
  assert(boot);

  setState(boot);

  if ( debug & debugDFS ) cerr << "will dfs\n";
  jump = false;
  dfs(grcroot);
  if (debug & debugDFS ) cerr << "init ok\n";

  if (debug & debugDFS ){
    cerr << "--------topo-------:\n";
    for (vector<GRCNode*>::iterator i = topo.end()-1; i >= topo.begin(); i--)
      cerr << cfgmap[*i] << ' ';
    cerr << "\n";
  }

  // Initialize constants

  assert(module->constants);
  for ( SymbolTable::const_iterator i = module->constants->begin();
        i != module->constants->end() ; i++ ) {
    ConstantSymbol *cs = dynamic_cast<ConstantSymbol*>(*i);
    if (cs && cs->initializer) {
      assert(cs->type);
      if (cs->type->name != "integer" &&
          cs->type->name != "boolean")
        throw IR::Error("only integer and boolean constants are supported");
      var[cs] = intVal(cs->initializer);
    }
  }
}
```

3.8 Clear Inputs

Reset all the signals; set the `tick` signal to be present.

19a ⟨*method definitions* 2b⟩+≡ (20b) ◁18 19b▷

```
void GRCsim::clear_inputs()
{
  for( SymbolTable::const_iterator isym = sigs->begin() ; isym != sigs->end() ;
       isym++ ) {
    SignalSymbol *ss = dynamic_cast<SignalSymbol*>(*isym);
    if (ss) signals[ss] = (ss->name == "tick");
  }
}
```

3.9 dotick

Simulate the program for a single cycle.

19b ⟨*method definitions* 2b⟩+≡ (20b) ◁19a

```
void GRCsim::dotick()
{
  int tsz = topo.size();

  for (int i = 0 ; i < tsz ; i++) sched[topo[i]] = false;

  sched[ topo[tsz-1] ] = true;

  for ( int i = tsz - 1 ; i >= 0 ; i-- ) {
    assert(topo[i]);
    if ( sched[topo[i]] )
      topo[i]->welcome(*this);
  }

  for ( SymbolTable::const_iterator isym = sigs->begin() ;
        isym != sigs->end() ; isym++ ) {
    SignalSymbol *ss = dynamic_cast<SignalSymbol*>(*isym);
    assert(ss);
    if (debug) cerr << ss->name << " : " << signals[ss] << "\n";
    if ( ss->kind == SignalSymbol::Output )
      outf << ss->name << "=" << (signals[ss] ? '1' : '0') << " ";
    else if ( ss->kind == SignalSymbol::Inputoutput )
      outf << ss->name << "_IO_O=" << (signals[ss] ? '1' : '0') << " ";
  }
  outf << "\n";
}
```

4 Top-level files

20a ⟨*GRCsim.hpp* 20a⟩≡

```
#ifndef _GRCSIM_HPP
#  define _GRCSIM_HPP

#  include "IR.hpp"
#  include "AST.hpp"
#  include "GRCPrinter.hpp"
#  include <iostream>
#  include <stdlib.h>
#  include <stdio.h>
#  include <set>
#  include <map>

namespace AST {

using std::set;
using std::map;

⟨GRCsim class 11⟩

}
#endif
```

20b ⟨*GRCsim.cpp* 20b⟩≡

```
#include "GRCsim.hpp"

using namespace std;

namespace AST {
  ⟨method definitions 2b⟩
}
```

21 ⟨*cec-grcsim.cpp* 21⟩≡

```
#include "GRCsim.hpp"
#include <fstream>

using namespace std;

struct UsageError {};

int main(int argc, char *argv[])
{
  try {
    int debug = 0;
    int maxticks = -1;
    string testvectorfile;

    ++argv, --argc;

    while (argc > 0 && argv[0][0] == '-') {
      switch (argv[0][1]) {
      case 'd':
        if (argc == 1) throw UsageError();
        ++argv, --argc;
        debug = atoi(argv[0]);
        break;
      case 'c':
        if (argc == 1) throw UsageError();
        ++argv, --argc;
        maxticks = atoi(argv[0]);
        break;
      case 't':
        if (argc == 1) throw UsageError();
        ++argv, --argc;
        testvectorfile = argv[0];
        break;
      default:
        cerr << "Unrecognized option " << argv[0] << endl;
        throw UsageError();
      }
      ++argv, --argc;
    }

    if ( argc != 0 ) throw UsageError();

    IR::XMListream r(std::cin);
    IR::Node *n;
    r >> n;

    AST::Modules *mods = dynamic_cast<AST::Modules*>(n);
    if (!mods) throw IR::Error("Root node is not a Modules object");
```

```
    AST::Module *module = mods->modules.front();
    assert(module);

    AST::GRCgraph *gn = dynamic_cast<AST::GRCgraph*>(module->body);
    assert(gn);

    AST::GRCNode::NumMap cfgmap;
    AST::STNode::NumMap stmap;

    gn->enumerate(cfgmap, stmap);

    AST::GRCsim simulator(gn, module, cfgmap, stmap, debug, std::cout);
    if ( maxticks > 0 )
      simulator.execute_max(maxticks);
    else if (!testvectorfile.empty()) {
      std::ifstream tvf(testvectorfile.c_str());
      if (tvf.bad()) {
        cerr << "Error opening test vector file " << testvectorfile << '\n';
        exit(-2);
      }
      simulator.execute_vectors(tvf);
      tvf.close();
    } else throw UsageError();

  } catch (IR::Error &e) {
    cerr << e.s << endl;
    exit(-1);
  } catch (UsageError &) {
    cerr << "Usage: cec-grcsim [-d <level>] -c <cycles> | -t <vectorfile>\n"
      "-d <level>   Enable debugging at the given level\n"
      "-c <cycles>  Simulate with no inputs for this many cycles maximum\n"
      "-t <vectorfile> Simulate taking inputs from the given vector file\n";
    exit(-1);
  }

  return 0;
}
```