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COMS W4115 – Final report
C Flat / ltc

Introduction

The C Flat language is mostly a subset of the C language. Some of the core functionalities of C has been stripped: there is no preprocessor, no structs, no strings, not even pointers. It's goal is purely educational.

Originally Nico and Dan were working on two separate languages. The two projects merged, taking some features from each, and this is the resulting language.

The ltc and C Flat language proposals are included in appendix A.

C Flat Tutorial

C Flat is easy to use for any programmer familiar with a C-like language. The main differences from C are that there is only one type: the integer, variables don't have to be declared before use (but there are no global variables), and there are exceptions.

"Hello World" (outputs 1):

```
main() {
      out(1);
}
```

Recursive Fibonacci:

```
fib(n) {
      if (n < 3) return 1;
      else return fib(n-1) + fib(n-2);
}
main() {
      out(fib(in()));
}
```

Iterative Fibonacci:

```
fib(n) {
      if (n < 1)
            throw 1;

      a = 1; // last fib #
      b = 1; // current fib #
      for (i = 3; i <= n; i++) {
            temp = b;
            b += a;
            a = temp;
      }
      return b;
}
main() {
      out(fib(in()));
}
```

Language Manual

The LRM is included in appendix B.

Project Plan

Processes

When we merged projects, we decided to start off by implementing as much of the ltc proposal as possible and adding features from the original c flat proposal at the end if we had time. The ltc proposal clearly laid out the subset of C which we would be implementing. Since we were basing the language off of an existing one, there wasn't very much planning that had to go into figuring out how the language would work as far as the users are concerned.

Our process for progressing through the project was to pick a feature that wasn't implemented and think through how exactly it should work and how it needed to be implemented. We sometimes had to compile some test C programs and look at the assembly generated or look up instructions in the Intel x86 manuals to learn exactly how something would work. Then we'd implement the feature and some tests for it. Sometimes we wrote the corresponding part of the LRM at that point and sometimes we filled it in later. This normally wouldn't be a great idea, but this language is small enough that it worked just fine.

We had an automated tester which would run a series of code snippets through the compiler, run them, and verify that the output (or lack thereof) was correct. The tester was an improved version of the tester Dan used last fall in PLT. Initially we were also running the test suite that professor Edwards supplied with microc, but we eventually migrated to only our tester. It was quicker and easier to write tests for this tester because they all go in one file. After we did any work on the compiler, we'd run a quick "make test" and be able to verify that everything still worked correctly.

Programming Style Guide

For the compiler, we stuck with the style already used in microc. More or less:

- Indentation: 2 spaces.
- Indentation level is increased when declaring a non trivial function (that is a function with at least one argument)
- When matching, each case should be on it's own line. It also increase the indentation level.
- Function names are in lower case with words separated by underscores.
- Structures: names and fields are lower case with works separated by underscores.
- Types: names lowercase, possible values first letter uppercase.
- Tester uses standard python style as outlined in PEP 8 - http://www.python.org/dev/peps/pep-0008/
- Tests: lower case variables and functions, 2 space indentation.

For example, this is a snippet from backend.ml:

```
    let rec eval_expr_to_eax fdecl = function
        Literal(l) ->
          sprintf "mov eax, %d\n" l

      | Assignop(v, o, e) ->
          let assign_binop binop =
            eval_expr_to_eax fdecl (Assignop(v, Assign, Binop(Id(v), binop, e))) in
          (match o with
              Assign        -> eval_expr_to_eax fdecl e ^
                                  sprintf "mov [ebp+%d], eax\n" (id_to_offset fdecl v)
            | Add_assign    -> assign_binop Add
            | Sub_assign    -> assign_binop Sub
            | Mult_assign   -> assign_binop Mult
            | Div_assign    -> assign_binop Div
```

Project Timeline

- October: Proposals, automated tester.
- November: Merged projects, first assembly program generated (skeleton, functions, basic operators, I/O, if, for, and while), LRM started.
- December:
  - Week 1: Nothing.
  - Week 2: Many operators, proper argument evaluation, break, continue, exceptions.
  - Week 3: Static semantic analysis, compiler completed, LRM completed.

Roles and Responsibilities

We worked together on most aspects of the project. Nico implemented a number of language features on his own and Dan got the automated tester going.

Software Development Environment

We are both running a linux OS with its standard tools.

Kate, Vim, and Nano	Source code editing
Ocaml Tool Suite	Lexer, parser, static and semantic analysis, backend, top level compiler driver
Gcc	Compiling standard library (which is C), assembling output of the C Flat compiler, linking object files
Python	Automated tester
OpenOffice	Report
Lyx	LRM
GNU Make	Project building

Project Log

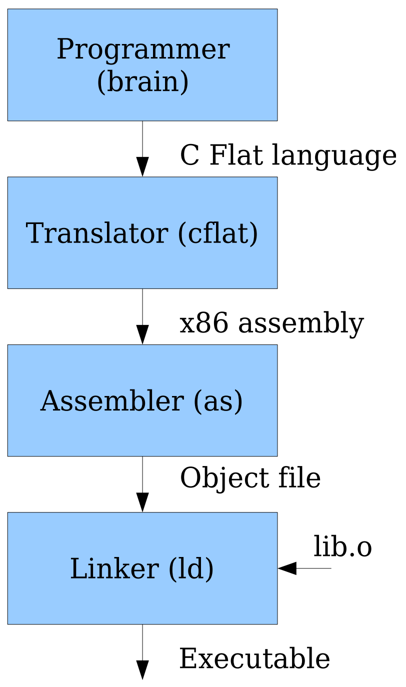
We used git as a version control system. The project history is:

```
Nicolas Viennot   2008-12-18 10:47:49 -0500          style fix
Nicolas Viennot   2008-12-18 10:45:37 -0500          style fix
Nicolas Viennot   2008-12-18 10:39:08 -0500          style fix
Nicolas Viennot   2008-12-18 10:01:23 -0500          lrm updated
Nicolas Viennot   2008-12-18 08:37:28 -0500          removed dead code
Nicolas Viennot   2008-12-18 08:34:34 -0500          not pushing esp for exception
Nicolas Viennot   2008-12-17 21:44:26 -0500          added test for shifting negative number
Nicolas Viennot   2008-12-17 18:03:25 -0500          removed the goto keyword
Nicolas Viennot   2008-12-17 16:45:58 -0500          added if/else test (2)
Nicolas Viennot   2008-12-17 16:44:52 -0500          added if/else test
Daniel Benamy     2008-12-17 16:05:22 -0500          Merge branch 'work'
Daniel Benamy     2008-12-17 16:05:00 -0500          Renamed microc to cflat.
Nicolas Viennot   2008-12-17 16:01:14 -0500          Assign is not an assignop
Daniel Benamy     2008-12-17 15:54:58 -0500          Added a couple of tests for exceptions.
Nicolas Viennot   2008-12-17 15:48:23 -0500          precedence change for < >
Daniel Benamy     2008-12-17 15:47:16 -0500          Print compiler errors to stderr.
Nicolas Viennot   2008-12-17 15:35:01 -0500          unclosed comment raise exception
Nicolas Viennot   2008-12-16 19:51:18 -0500          cleanup
Nicolas Viennot   2008-12-16 12:37:58 -0500          asm test pretty
Nicolas Viennot   2008-12-16 12:33:02 -0500          small asm change
Nicolas Viennot   2008-12-16 08:37:29 -0500          added .PHONY : test/clean in Makefile
Nicolas Viennot   2008-12-15 20:45:41 -0500          sast: checking for duplicated function, duplicated formals.
                                                     test: testing for local variable discovery and duplicates.
Nicolas Viennot   2008-12-15 20:09:35 -0500          sast: forgot a variable check
Nicolas Viennot   2008-12-15 20:07:04 -0500          cleanup
Nicolas Viennot   2008-12-15 20:03:59 -0500          sast: variables are added through the context struct
Nicolas Viennot   2008-12-15 19:44:13 -0500          cleanup
Nicolas Viennot   2008-12-15 14:42:54 -0500          cleanup
Nicolas Viennot   2008-12-15 14:14:57 -0500          removed test directory
Nicolas Viennot   2008-12-15 14:08:45 -0500          removing old tests
Nicolas Viennot   2008-12-15 14:06:09 -0500          more tests
Nicolas Viennot   2008-12-15 12:10:25 -0500          cleanup
Nicolas Viennot   2008-12-15 12:10:15 -0500          added test when mixing same function name/variable name
Nicolas Viennot   2008-12-15 12:09:25 -0500          catch exception on syntax error
Nicolas Viennot   2008-12-15 10:41:14 -0500          ast printer removed
Nicolas Viennot   2008-12-15 10:38:39 -0500          local variables are now initialized to 0
Nicolas Viennot   2008-12-15 10:07:50 -0500          SAST added, local variables doesnt need to be declared anymore
Nicolas Viennot   2008-12-14 20:38:40 -0500          "uncaught exception" message added
Nicolas Viennot   2008-12-14 14:28:08 -0500          cleanup
Nicolas Viennot   2008-12-14 14:14:41 -0500          reversing args in function call is done is assembly
Nicolas Viennot   2008-12-14 13:37:41 -0500          precedence test added
Nicolas Viennot   2008-12-14 12:26:43 -0500          operator precedence fixed
Nicolas Viennot   2008-12-14 09:40:40 -0500          cleanup
Nicolas Viennot   2008-12-14 09:13:02 -0500          sign tests added for arithmetic binops
Nicolas Viennot   2008-12-14 09:12:45 -0500          using movzx insead of mov eax, 0
Nicolas Viennot   2008-12-13 16:33:28 -0500          cleanup
Nicolas Viennot   2008-12-13 15:14:11 -0500          exception implemented
Nicolas Viennot   2008-12-13 10:03:40 -0500          basic try/catch/throw implementation
Nicolas Viennot   2008-12-13 09:12:36 -0500          Operators implemented and tested
Nicolas Viennot   2008-12-13 07:43:56 -0500          comment scanner fixed
Nicolas Viennot   2008-12-13 07:32:01 -0500          arguments of a function are evaluated from left to right
Nicolas Viennot   2008-12-13 07:00:41 -0500          cleanup
Nicolas Viennot   2008-12-12 14:49:58 -0500          all operators added, exception added (not finished !!)
Nicolas Viennot   2008-12-12 09:20:40 -0500          added multiline comments
Nicolas Viennot   2008-12-12 09:12:31 -0500          reverted out() -> outputs \n and test programs are piped to xargs
Nicolas Viennot   2008-12-12 00:08:43 -0500          Added test for double variable declarations.Whitespace fix.
Nicolas Viennot   2008-12-12 00:06:55 -0500          Added lrm.
Nicolas Viennot   2008-12-11 23:07:12 -0500          Implemented proper labels for loops.
                                                     Added break and continue keywords.
                                                     Added tests.
Nicolas Viennot   2008-12-11 23:07:00 -0500          Removed interpreter.
Nicolas Viennot   2008-12-11 22:04:34 -0500          Implemented proper labels.Implemented in().
                                                     Changed out() to not add newline and added outln() and ln().
                                                     Fixed make test.
Nicolas Viennot   2008-12-11 22:04:02 -0500          Added .gitignore.
Nicolas Viennot   2008-12-11 20:25:43 -0500          removed test from make clean
Nicolas Viennot   2008-12-02 00:35:04 -0500          new test case, cleanup
Nicolas Viennot   2008-12-02 00:21:38 -0500          new test
```

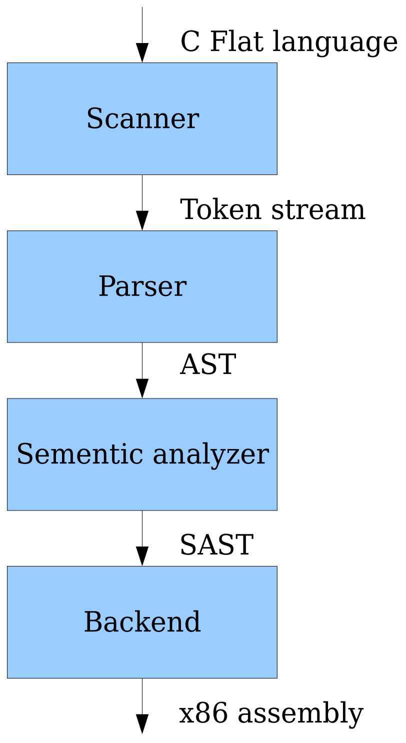
Nicolas Viennot	2008-12-02 00:18:13 -0500	global removed
Nicolas Viennot	2008-12-02 00:15:15 -0500	global tests removed
Nicolas Viennot	2008-12-02 00:12:32 -0500	okey whatever
Nicolas Viennot	2008-12-02 00:11:25 -0500	microc deleted
Daniel Benamy	2008-11-22 02:14:32 -0500	Added .gitignore.
Daniel Benamy	2008-11-22 02:11:46 -0500	Added ltc and microc. Started on a backend for microc to produce x86 assembly.
Daniel Benamy	2008-11-22 02:10:36 -0500	Put some skeleton file in cflat/, moved testing code to cflat/test, and added the very beginnings of a test file for c flat.
Daniel Benamy	2008-11-22 02:06:49 -0500	Fix crash when no executable is created.
Daniel Benamy	2008-10-16 02:49:59 -0400	Added hw1 dir.
Daniel Benamy	2008-10-16 01:24:07 -0400	Give nice error if no test file given.
Daniel Benamy	2008-10-16 00:39:13 -0400	Adding test-gcc.txt.
Daniel Benamy	2008-10-16 00:38:26 -0400	Changed test markers to ..., added support for comments before compilercommand, and cleanup.
Daniel Benamy	2008-10-16 00:24:50 -0400	Various fixes. Tester works.
Daniel Benamy	2008-10-16 00:09:09 -0400	Cleanup.
Daniel Benamy	2008-10-16 00:07:48 -0400	Importing compiler-tester.py in progress.

Architectural Design

Our translator receives a C Flat program and outputs the x86 assembly code:



The translator first tokenizes the character stream, parses it to generate an AST. Then the tree is semetically checked to produce a SAST which go through the backend to produce assembly code.



A few notes about the implementation:

- The sementic analyzer does the local variables discovery so that the backend knows in advance the stack size for local variables.
- Function calls: we follow the C convention that is: arguments are pushed in reverse order, and the caller cleans the stack. The register eax is used for return values.
- Exceptions: we use a linked list that is built on the stack. An element is added to the list when the program enters a try block. When an exception is thrown, it checks if the list is empty; if yes uncaught_exception() is called, if not it passes control to the catch block.
- Temporary values: during a complex expression evaluation, we use the stack to store temporary results.

Nico adapted the parser and the scanner from the microc code and implemented the sementic analyzer. Both Dan and Nico implemented the Backend.

Test Plan
Sample compilations

Recursive Fibonacci:

C Flat:
```
fib(n) {
        if (n < 0) throw -1;
        if (n < 3) return 1;
        else return fib(n-1) + fib(n-2);
}

main() {
        try {
                out(fib(in()));
        } catch(ex) {
                out(ex);
        }
}
```

Generated assembly:
```
.intel_syntax noprefix
.text
.globl main
.type main, @function
main:
push ebp
mov  ebp, esp
xor  eax, eax
push eax
push ecx
push edx
push ebp
push offset .L1
push dword ptr [__exception_ptr]
mov  [__exception_ptr], esp
call in
add  esp, 0
push eax
call fib
add  esp, 4
push eax
call out
add  esp, 4
mov eax, [__exception_ptr]
mov eax, [eax]
mov [__exception_ptr], eax
add  esp, 12
jmp .L2
.L1:
mov [ebp+-4], edx
mov eax, [ebp+-4]
push eax
call out
add  esp, 4
.L2:
.L0:
```

```
pop  edx
pop  ecx
mov  esp, ebp
pop  ebp
ret
.globl fib
.type fib, @function
fib:
push ebp
mov  ebp, esp
xor  eax, eax
push ecx
push edx
mov eax, [ebp+8]
push eax
mov eax, 0
pop  ecx
xchg eax, ecx
cmp eax, ecx
setl  al
movzx eax, al
test eax, eax
jz   .L4
mov eax, 1
neg   eax
mov  edx, eax
mov  ecx, [__exception_ptr]
test ecx, ecx
jnz  .L6
push edx
call __uncaught_exception
.L6:
mov eax, [__exception_ptr]
mov eax, [eax]
mov [__exception_ptr], eax
lea  esp, [ecx+12]
mov  ebp, [ecx+8]
jmp  [ecx+4]
jmp  .L5
.L4:
.L5:
mov eax, [ebp+8]
push eax
mov eax, 3
pop  ecx
xchg eax, ecx
cmp eax, ecx
setl  al
movzx eax, al
test eax, eax
jz   .L7
add  esp, 0
mov eax, 1
jmp .L3
jmp  .L8
.L7:
add  esp, 0
mov eax, [ebp+8]
```

```
push eax
mov eax, 1
pop  ecx
xchg eax, ecx
sub   eax, ecx
push eax
call fib
add  esp, 4
push eax
mov eax, [ebp+8]
push eax
mov eax, 2
pop  ecx
xchg eax, ecx
sub   eax, ecx
push eax
call fib
add  esp, 4
pop  ecx
xchg eax, ecx
add   eax, ecx
jmp .L3
.L8:
.L3:
pop  edx
pop  ecx
mov  esp, ebp
pop  ebp
ret
.ident "C Flat compiler 0.1"
```

GCD:

C Flat:

```
gcd(a, b) {
        while (a != b) {
                if (a > b) a -= b;
                else b -= a;
        }
        return a;
}

main() {
        a = in();
        b = in();
        out(gcd(a, b));
}
```

Generated assembly:

```
.intel_syntax noprefix
.text
.globl main
.type main, @function
main:
push ebp
mov  ebp, esp
xor  eax, eax
push eax
push ecx
push edx
push ebp
push offset .L1
push dword ptr [__exception_ptr]
mov  [__exception_ptr], esp
call in
add  esp, 0
push eax
call fib
add  esp, 4
push eax
call out
add  esp, 4
mov eax, [__exception_ptr]
mov eax, [eax]
mov [__exception_ptr], eax
add  esp, 12
jmp .L2
.L1:
mov [ebp+-4], edx
mov eax, [ebp+-4]
push eax
call out
add  esp, 4
.L2:
.L0:
pop  edx
pop  ecx
mov  esp, ebp
pop  ebp
```

```
ret
.globl fib
.type fib, @function
fib:
push ebp
mov  ebp, esp
xor  eax, eax
push ecx
push edx
mov eax, [ebp+8]
push eax
mov eax, 0
pop  ecx
xchg eax, ecx
cmp eax, ecx
setl  al
movzx eax, al
test eax, eax
jz   .L4
mov eax, 1
neg   eax
mov  edx, eax
mov  ecx, [__exception_ptr]
test ecx, ecx
jnz  .L6
push edx
call __uncaught_exception
.L6:
mov eax, [__exception_ptr]
mov eax, [eax]
mov [__exception_ptr], eax
lea  esp, [ecx+12]
mov  ebp, [ecx+8]
jmp  [ecx+4]
jmp  .L5
.L4:
.L5:
mov eax, [ebp+8]
push eax
mov eax, 3
pop  ecx
xchg eax, ecx
cmp eax, ecx
setl  al
movzx eax, al
test eax, eax
jz   .L7
add  esp, 0
mov eax, 1
jmp .L3
jmp  .L8
.L7:
add  esp, 0
mov eax, [ebp+8]
push eax
mov eax, 1
pop  ecx
xchg eax, ecx
```

```
sub   eax, ecx
push eax
call fib
add  esp, 4
push eax
mov eax, [ebp+8]
push eax
mov eax, 2
pop  ecx
xchg eax, ecx
sub   eax, ecx
push eax
call fib
add  esp, 4
pop  ecx
xchg eax, ecx
add   eax, ecx
jmp .L3
.L8:
.L3:
pop  edx
pop  ecx
mov  esp, ebp
pop  ebp
ret
.ident "C Flat compiler 0.1"
```

Test suite

Our tester is a small python program which parses a text file with a very simple format, runs the test cases it finds, and verifies that the correct result is produced. See appendix C for the tester code (tester.py).

Test cases

Each feature of the compiler is tested. During the developement, when we added a feature, we wrote a test case for it to validate the implementation. At least one test case is written for each specification of the LRM.
See appendix C for test cases (test-cflat.txt).

Automation

A simple “make test” rebuilds the compiler if needed and executes all test cases. Making the test process very accessible is important since we use a test-driven development

Division of Testing Work

Dan wrote the automated tester. We wrote tests as we were adding features so we wrote a number of tests together, mainly checking things in microc. Then when Nico implemented all the additional operators, exceptions, and static semantic analysis, he wrote most of the tests for those.

Lessons Learned

Dan learned that Ocaml is pretty cool. Functional programming takes getting used to, and this project was a bunch of getting-used-to-ness.

Nico learned that Ocaml is a very nice language and that compilers are not magical anymore.

We would strongly encourage future teams to do automated testing and add test cases for each feature before or at roughly the same time as the feature it's testing. In addition to serving as a verification of functionality and preventing regressions, the act of writing code in the new language helps with figuring out how things should work and can bring up odd cases that might otherwise go unnoticed.

We recommend that teams reuse our tester since it lowers the effort required to add tests to about as low as possible.

Appendix A – Language proposals

Appendix B - LRM

Appendix C - source

Makefile

```
OBJS = parser.cmo scanner.cmo backend.cmo sast.cmo cflat.cmo

CFLAGS="-m32"

cflat : $(OBJS) lib.o
	ocamlc -o cflat $(OBJS)

.PHONY: test
test : cflat tester.py test-cflat.txt
	./tester.py test-cflat.txt

scanner.ml : scanner.mll
	ocamllex scanner.mll

parser.ml parser.mli : parser.mly
	ocamlyacc parser.mly

%.cmo : %.ml
	ocamlc -c $<

%.cmi : %.mli
	ocamlc -c $<

.PHONY : clean
clean :
	rm -f cflat parser.ml parser.mli scanner.ml testall.log *.cmo *.cmi *.o
*.s test

# Generated by ocamldep *.ml *.mli
backend.cmo: ast.cmi
backend.cmx: ast.cmi
cflat.cmo: scanner.cmo sast.cmo parser.cmi backend.cmo
cflat.cmx: scanner.cmx sast.cmx parser.cmx backend.cmx
parser.cmo: ast.cmi parser.cmi
parser.cmx: ast.cmi parser.cmi
sast.cmo: ast.cmi
sast.cmx: ast.cmi
scanner.cmo: parser.cmi
scanner.cmx: parser.cmx
parser.cmi: ast.cmi
```

scanner.mll

```
{ open Parser }


let newline    = '\n' | "\r\n"
let whitespace = [' ' '\t'] | newline
let digit      = ['0'-'9']
let integer    = digit+
let alpha      = ['_' 'a'-'z' 'A'-'Z']
let alphanum   = alpha | digit
let identifier = alpha alphanum*

rule token = parse
    whitespace          { token lexbuf }
  | "//"                { comment_double_slash lexbuf }
  | "/*"                { comment_slash_star 0 lexbuf }

  (* arithmetic operators *)
  | "++"                { INC }
  | "--"                { DEC }
  | "-="                { MINUS_ASSIGN }
  | "+="                { PLUS_ASSIGN }
  | "*="                { TIMES_ASSIGN }
  | "/="                { DIVIDE_ASSIGN }
  | "%="                { MODULO_ASSIGN }
  | '-'                 { MINUS }
  | '+'                 { PLUS }
  | '*'                 { TIMES }
  | '/'                 { DIVIDE }
  | '%'                 { MODULO }

  (* must be before the "|" and "&" *)
  | "&&"                { AND }
  | "||"                { OR }

  (* bitwise operators *)
  | "<<="               { LSHIFT_ASSIGN }
  | ">>="               { RSHIFT_ASSIGN }
  | "&="                { BW_AND_ASSIGN }
  | "|="                { BW_OR_ASSIGN }
  | "^="                { BW_XOR_ASSIGN }
  | "<<"                { LSHIFT }
  | ">>"                { RSHIFT }
  | "~"                 { BW_NOT }
  | "&"                 { BW_AND }
  | "|"                 { BW_OR }
  | "^"                 { BW_XOR }

  (* logic operators *)
  (* done before
  | "&&"                { AND }
  | "||"                { OR }
  *)
  | "<="                { LEQ }
  | ">="                { GEQ }
  | "!="                { NEQ }
  | "=="                 { EQ }
  | "!"                  { NOT }
  | '<'                  { LT }
  | '>'                  { GT }

  (* punctuation *)
  | '='                  { ASSIGN }
  | '('                  { LPAREN }
  | ')'                  { RPAREN }
  | '{'                  { LBRACE }
  | '}'                  { RBRACE }
  | ';'                  { SEMI }
  | ','                  { COMMA }

  (* keywords *)
  | "for"                { FOR }
  | "while"              { WHILE }
  | "if"                 { IF }
  | "else"               { ELSE }
  | "return"             { RETURN }
  | "break"              { BREAK }
  | "continue"           { CONTINUE }
  | "try"                { TRY }
  | "catch"              { CATCH }
  | "throw"              { THROW }
  | integer as lit       { LITERAL(int_of_string lit) }
  | identifier as id     { ID(id) }

  | eof                  { EOF }
  | _ as char            { raise (Failure("illegal character " ^ Char.escaped
char)) }

and comment_slash_star level = parse
    "*/"                 { if level = 0 then token lexbuf
                           else comment_slash_star (level-1) lexbuf }
  | "/*"                 { comment_slash_star (level+1) lexbuf }
  | eof                  { raise (Failure("Comment not closed")) }
  | _                    { comment_slash_star level lexbuf }

and comment_double_slash = parse
    newline              { token lexbuf }
  | _                    { comment_double_slash lexbuf}
```

parser.mly

```
%{ open Ast %}

%token INC DEC MINUS_ASSIGN PLUS_ASSIGN TIMES_ASSIGN DIVIDE_ASSIGN MODULO_ASSIGN
%token MINUS PLUS TIMES DIVIDE MODULO
%token LSHIFT_ASSIGN RSHIFT_ASSIGN BW_AND_ASSIGN BW_OR_ASSIGN BW_XOR_ASSIGN
%token LSHIFT RSHIFT BW_NOT BW_AND BW_OR BW_XOR
%token LEQ GEQ NEQ EQ NOT AND OR LT GT
%token ASSIGN LPAREN RPAREN LBRACE RBRACE SEMI COMMA
%token FOR WHILE IF ELSE RETURN BREAK CONTINUE TRY CATCH THROW
%token <int> LITERAL
%token <string> ID
%token EOF

%nonassoc NOELSE
%nonassoc ELSE

%right BW_AND_ASSIGN BW_XOR_ASSIGN BW_OR_ASSIGN LSHIFT_ASSIGN RSHIFT_ASSIGN
       TIMES_ASSIGN DIVIDE_ASSIGN MODULO_ASSIGN PLUS_ASSIGN MINUS_ASSIGN ASSIGN
%left OR
%left AND
%left BW_OR
%left BW_XOR
%left BW_AND
%left EQ NEQ
%left GT GEQ LT LEQ
%left LSHIFT RSHIFT
%left PLUS MINUS
%left TIMES DIVIDE MODULO
%nonassoc NOT BW_NOT U_PLUS U_MINUS

%start program
%type <Ast.program> program

%%

program:
   /* nothing */ { [] }
 | program fdecl { $2 :: $1 }

fdecl:
   ID LPAREN formals_opt RPAREN LBRACE stmt_list RBRACE
     { { _fname = $1;
         _formals = $3;
         _body = List.rev $6 } }

formals_opt:
    /* nothing */ { [] }
  | formal_list   { List.rev $1 }

formal_list:
    ID                   { [$1] }
  | formal_list COMMA ID { $3 :: $1 }

stmt_list:
    /* nothing */  { [] }
  | stmt_list stmt { $2 :: $1 }

stmt:
    expr SEMI { Expr($1) }
  | SEMI { Expr(Noexpr) }
  | RETURN expr SEMI { Return($2) }
  | LBRACE stmt_list RBRACE { Block(List.rev $2) }
  | IF LPAREN expr RPAREN stmt %prec NOELSE { If($3, $5, Block([])) }
  | IF LPAREN expr RPAREN stmt ELSE stmt    { If($3, $5, $7) }
  | FOR LPAREN expr_opt SEMI expr_opt SEMI expr_opt RPAREN stmt
     { For($3, $5, $7, $9) }
  | WHILE LPAREN expr RPAREN stmt { While($3, $5) }
  | BREAK SEMI { Break }
  | CONTINUE SEMI { Continue }
  | TRY LBRACE stmt_list RBRACE CATCH LBRACE stmt_list RBRACE
    { Try_catch(Block(List.rev $3), "", Block(List.rev $7)) }
  | TRY LBRACE stmt_list RBRACE CATCH LPAREN ID RPAREN LBRACE stmt_list RBRACE
    { Try_catch(Block(List.rev $3), $7, Block(List.rev $10)) }
  | THROW expr SEMI { Throw($2) }

expr_opt:
    /* nothing */ { Noexpr }
  | expr          { $1 }

expr:
    LITERAL          { Literal($1) }
  | ID               { Id($1) }

  | expr OR       expr { Binop($1, Or,      $3) }
  | expr AND      expr { Binop($1, And,     $3) }
  | expr BW_OR    expr { Binop($1, Bw_or,   $3) }
  | expr BW_AND   expr { Binop($1, Bw_and,  $3) }
  | expr BW_XOR   expr { Binop($1, Bw_xor,  $3) }
  | expr LSHIFT   expr { Binop($1, Lshift,  $3) }
  | expr RSHIFT   expr { Binop($1, Rshift,  $3) }
  | expr PLUS     expr { Binop($1, Add,     $3) }
  | expr MINUS    expr { Binop($1, Sub,     $3) }
  | expr TIMES    expr { Binop($1, Mult,    $3) }
  | expr DIVIDE   expr { Binop($1, Div,     $3) }
  | expr MODULO   expr { Binop($1, Modulo,  $3) }
  | expr EQ       expr { Binop($1, Equal,   $3) }
  | expr NEQ      expr { Binop($1, Neq,     $3) }
  | expr LT       expr { Binop($1, Less,    $3) }
  | expr LEQ      expr { Binop($1, Leq,     $3) }
  | expr GT       expr { Binop($1, Greater, $3) }
  | expr GEQ      expr { Binop($1, Geq,     $3) }

  | NOT    expr { Unop(Not,      $2) }
  | BW_NOT expr { Unop(Bw_not,   $2) }
  | PLUS   expr %prec U_PLUS   { Unop(Plus,     $2) }
  | MINUS  expr %prec U_MINUS  { Unop(Minus,    $2) }
  | INC    ID   { Incop(Pre_inc,  $2) }
  | DEC    ID   { Incop(Pre_dec,  $2) }
  | ID     INC  { Incop(Post_inc, $1) }
  | ID     DEC  { Incop(Post_dec, $1) }

  | ID BW_AND_ASSIGN expr { Assignop($1, Bw_and_assign, $3) }
  | ID BW_OR_ASSIGN  expr { Assignop($1, Bw_or_assign,  $3) }
  | ID BW_XOR_ASSIGN expr { Assignop($1, Bw_xor_assign, $3) }
  | ID LSHIFT_ASSIGN expr { Assignop($1, Lshift_assign, $3) }
  | ID RSHIFT_ASSIGN expr { Assignop($1, Rshift_assign, $3) }
  | ID TIMES_ASSIGN  expr { Assignop($1, Mult_assign,   $3) }
  | ID DIVIDE_ASSIGN expr { Assignop($1, Div_assign,    $3) }
  | ID MODULO_ASSIGN expr { Assignop($1, Modulo_assign, $3) }
  | ID PLUS_ASSIGN   expr { Assignop($1, Add_assign,    $3) }
  | ID MINUS_ASSIGN  expr { Assignop($1, Sub_assign,    $3) }
  | ID ASSIGN expr        { Assignop($1, Assign,        $3) }

  | ID LPAREN actuals_opt RPAREN { Call($1, $3) }
  | LPAREN expr RPAREN { $2 }

actuals_opt:
    /* nothing */ { [] }
  | actuals_list  { List.rev $1 }

actuals_list:
    expr                    { [$1] }
  | actuals_list COMMA expr { $3 :: $1 }
```

ast.mli

```ocaml
type binop =
    Add | Sub | Mult | Div | Modulo
  | Or | And | Bw_or | Bw_and | Bw_xor | Lshift | Rshift
  | Equal | Neq | Less | Leq | Greater | Geq

type assignop =
    Assign | Add_assign | Sub_assign | Mult_assign | Div_assign | Modulo_assign
  | Bw_or_assign | Bw_and_assign | Bw_xor_assign | Lshift_assign | Rshift_assign

type unop =
    Not | Bw_not | Plus | Minus

type incop =
    Pre_inc | Post_inc | Pre_dec | Post_dec

type expr =
    Literal  of int
  | Id       of string
  | Unop     of unop * expr
  | Incop    of incop * string
  | Binop    of expr * binop * expr
  | Assignop of string * assignop * expr
  | Call     of string * expr list
  | Noexpr

type stmt =
    Block     of stmt list
  | Expr      of expr
  | Return    of expr
  | If        of expr * stmt * stmt
  | For       of expr * expr * expr * stmt
  | While     of expr * stmt
  | Break
  | Continue
  | Try_catch of stmt * string * stmt
  | Throw     of expr

type func_decl = {
  _fname   : string;
  _formals : string list;
  _body    : stmt list;
}

type program = func_decl list

type func_decl_detail = {
  fname   : string;
  formals : string list;
  locals  : string list;
  body    : stmt list;
}

type program_detail = func_decl_detail list
```

sast.ml

```
open Ast
open Printf

type context = {
  in_loop   : bool;
  variables : string list ref;
}

(* returns l1 - l2 *)
let rec diff_list l1 = function
    [] -> l1
  | hd2 :: tl2 ->
    let rec diff_hd2 = function
        [] -> []
      | hd1 :: tl1 ->
          if hd1 = hd2 then diff_hd2 tl1
          else hd1 :: diff_hd2 tl1 in
    diff_list (diff_hd2 l1) tl2

(* add v to the context.variables list if not in the list *)
let add_variable context v =
  let rec add_unique_v = function
      [] -> [v]
    | hd :: tl ->
        if hd = v then hd :: tl
        else hd :: add_unique_v tl in
  context.variables := add_unique_v !(context.variables)

let rec check_expr fdecl context = function
    Literal(_)           -> ()
  | Id(v)                -> add_variable context v
  | Unop(_, e)           -> check_expr fdecl context e
  | Incop(_, v)          -> add_variable context v
  | Binop(e1, _, e2)     -> check_expr fdecl context e1;
                            check_expr fdecl context e2
  | Assignop(v, _, e)    -> add_variable context v;
                            check_expr fdecl context e
  | Call(_, el)          -> List.iter (check_expr fdecl context) el
  | Noexpr               -> ()

let rec check_stmt fdecl context = function
    Block(sl)            -> List.iter (check_stmt fdecl context) sl
  | Expr(e)              -> check_expr fdecl context e
  | Return(e)            -> check_expr fdecl context e
  | If(e, s1, s2)        -> check_expr fdecl context e;
                            check_stmt fdecl context s1;
                            check_stmt fdecl context s2
  | For(e1, e2, e3, s)   ->
      let context' = { context with in_loop = true } in
                            check_expr fdecl context' e1;
                            check_expr fdecl context' e2;
                            check_expr fdecl context' e3;
                            check_stmt fdecl context' s
  | While(e, s)          -> check_stmt fdecl context (For(Noexpr, e, Noexpr, s))
  | Break                -> if not context.in_loop then
```

```
                              raise (Failure("break keyword used outside a loop"))
  | Continue             -> if not context.in_loop then
                              raise (Failure("continue keyword used outside a 
loop"))
  | Try_catch(s1, v, s2) -> check_stmt fdecl context s1;
                            add_variable context v;
                            check_stmt fdecl context s2
  | Throw(e)             -> check_expr fdecl context e

(* check a func_decl and returns a func_decl_detail *)
let check_func fdecl =
  (* first check that each formal is only declared once *)
  let rec check_formal_unique formal_list formal =
    (match formal_list with
        [] -> [formal]
      | hd :: tl ->
          if hd = formal then
             raise (Failure("formal " ^ formal ^ " is declared more than once" ^
                            " in function " ^ fdecl._fname))
          else
             hd :: check_formal_unique tl formal) in
  let _ = List.fold_left check_formal_unique [] fdecl._formals in

  let context = { in_loop = false; variables = ref [] } in
  check_stmt fdecl context (Block(fdecl._body));
  { fname = fdecl._fname;
    formals = fdecl._formals;
    locals = diff_list !(context.variables) fdecl._formals;
    body = fdecl._body }

(* check a program and returns a program_detail *)
let check_program funcs =
   (* first we check that a function is only declared once *)
    let rec check_funcs_unique fname_list fdecl =
      (match fname_list with
          [] -> [fdecl._fname]
        | hd :: tl ->
            if hd = fdecl._fname then
               raise (Failure("function " ^ fdecl._fname ^
                      " is declared more than once"))
            else
               hd :: check_funcs_unique tl fdecl) in
  let _ = List.fold_left check_funcs_unique [] funcs in

  List.map check_func funcs
```

backend.ml

```
open Ast
open Printf

type context = {
  label_count        : int ref;
  break_label        : string option;
  continue_label     : string option;
  return_label       : string option;
  function_try_level : int;
  loop_try_level     : int;
}

let get_new_label context =
  let l = !(context.label_count) in
  context.label_count := l + 1;
  ".L" ^ (string_of_int l)

let get = function
    Some(x) -> x
  | None -> ""

let rec index_of item n = function
    [] -> -1
  | hd::tl -> if hd = item then n else (index_of item (n+1) tl)

let id_to_offset fdecl id =
  let n = index_of id 0 fdecl.formals in
  if n >= 0 then
    4 * (n+2)
  else
    let n = index_of id 0 fdecl.locals in
    if n >= 0 then
      -4 * (n+1)
    else
      (* should never happen (SAST is doing its job) *)
      raise (Failure("undefined identifier " ^ id))

(*
an exception looks like this:
    struct exception {
      struct exception *next;
      void *catch_address;
      int  old_ebp;
    };
*)

let exception_context_size = 3*4

let stack_exception catch_label =
          "push ebp\n" ^
  sprintf "push offset %s\n" catch_label ^
          "push dword ptr [__exception_ptr]\n" ^
          "mov  [__exception_ptr], esp\n"

let unstack_exception n =
  sprintf "add  esp, %d\n" (exception_context_size * n)

let rec unwind_exception = function
    0 -> ""
  | n -> "mov eax, [__exception_ptr]\n" ^
         "mov eax, [eax]\n" ^
         "mov [__exception_ptr], eax\n" ^
         unwind_exception (n-1)

let rec eval_expr_to_eax fdecl = function
    Literal(l) ->
      sprintf "mov eax, %d\n" l

  | Id(s) ->
      sprintf "mov eax, [ebp+%d]\n" (id_to_offset fdecl s)

  | Unop(o, e) ->
      eval_expr_to_eax fdecl e ^
      (match o with
          Not      -> "test  eax, eax\n" ^
                      "setz  al\n" ^
                      "movzx eax, al\n"
        | Bw_not   -> "not   eax\n"
        | Plus     -> ""
        | Minus    -> "neg   eax\n")

  | Incop(o, v) ->
    let asm = function
        Pre_inc | Post_inc ->
          sprintf "inc dword ptr [ebp+%d]\n" (id_to_offset fdecl v)
      | Pre_dec | Post_dec->
          sprintf "dec dword ptr [ebp+%d]\n" (id_to_offset fdecl v) in
    (match o with
        Pre_inc  | Pre_dec  -> asm o ^ eval_expr_to_eax fdecl (Id(v))
      | Post_inc | Post_dec -> eval_expr_to_eax fdecl (Id(v)) ^ asm o)

  | Binop(e1, o, e2) ->
      eval_expr_to_eax fdecl e1 ^
      "push eax\n" ^
      eval_expr_to_eax fdecl e2 ^
      "pop  ecx\n" ^
      "xchg eax, ecx\n" ^
      (* eax contains e1, ecx contains e2 *)

      (match o with
          Equal | Neq | Less | Leq | Greater | Geq ->
            "cmp eax, ecx\n"
        | _ -> "") ^

      (match o with
          Add     -> "add   eax, ecx\n"
        | Sub     -> "sub   eax, ecx\n"
        | Mult    -> "imul  eax, ecx\n"
        | Div     -> "cdq\n" ^
                     "idiv  ecx\n"
        | Modulo  -> "cdq\n" ^
                     "idiv  ecx\n" ^
                     "mov   eax, edx\n"
        | Or      -> "or    eax, ecx\n" ^
                     "setnz al\n"
        | And     -> "test  eax, eax\n" ^
                     "setnz al\n" ^
                     "test  ecx, ecx\n" ^
                     "setnz cl\n" ^
                     "and   al, cl\n"
        | Bw_or   -> "or    eax, ecx\n"
        | Bw_and  -> "and   eax, ecx\n"
        | Bw_xor  -> "xor   eax, ecx\n"
        | Lshift  -> "sal   eax, cl\n"
        | Rshift  -> "sar   eax, cl\n"
        | Equal   -> "sete  al\n"
        | Neq     -> "setne al\n"
        | Less    -> "setl  al\n"
        | Leq     -> "setle al\n"
        | Greater -> "setg  al\n"
        | Geq     -> "setge al\n") ^

      (match o with
          Or | And | Equal | Neq | Less | Leq | Greater | Geq ->
            "movzx eax, al\n"
        | _ -> "")

  | Assignop(v, o, e) ->
      let assign_binop binop =
        eval_expr_to_eax fdecl (Assignop(v, Assign, Binop(Id(v), binop, e))) in
      (match o with
          Assign        -> eval_expr_to_eax fdecl e ^
                           sprintf "mov [ebp+%d], eax\n" (id_to_offset fdecl v)
        | Add_assign    -> assign_binop Add
        | Sub_assign    -> assign_binop Sub
        | Mult_assign   -> assign_binop Mult
        | Div_assign    -> assign_binop Div
        | Modulo_assign -> assign_binop Modulo
        | Bw_or_assign  -> assign_binop Bw_or
        | Bw_and_assign -> assign_binop Bw_and
        | Bw_xor_assign -> assign_binop Bw_xor
        | Lshift_assign -> assign_binop Lshift
        | Rshift_assign -> assign_binop Rshift)

  | Call(f, el) ->
      let push_func_args =
        let prepare_arg e =
          eval_expr_to_eax fdecl e ^
          "push eax\n" in
        String.concat "" (List.map prepare_arg el) ^
        let swap_two_args i j =
          sprintf "mov  eax, [esp+%d]\n" (4 * i) ^
          sprintf "xchg eax, [esp+%d]\n" (4 * j) ^
          sprintf "mov  [esp+%d], eax\n" (4 * i) in
        let rec reverse_all_args i j =
            if i < j then
              swap_two_args i j ^
              reverse_all_args (i+1) (j-1)
            else "" in
        reverse_all_args 0 (List.length el - 1) in
      push_func_args ^
```

```ocaml
      sprintf "call %s\n" f ^
      sprintf "add  esp, %d\n" (4 * (List.length el))

  | Noexpr -> ""

let rec string_of_stmt context fdecl = function
    Block(stmts) ->
      String.concat "" (List.map (string_of_stmt context fdecl) stmts)

  | Expr(expr) -> eval_expr_to_eax fdecl expr

  | Return(expr) ->
      unwind_exception  context.function_try_level ^
      unstack_exception context.function_try_level ^
      eval_expr_to_eax fdecl expr ^
      sprintf "jmp %s\n" (get context.return_label)

  | If(e, s1, s2) ->
      let else_label    = get_new_label context
      and exit_if_label = get_new_label context in
      eval_expr_to_eax fdecl e ^
              "test eax, eax\n" ^
      sprintf "jz   %s\n" else_label ^
      string_of_stmt context fdecl s1 ^
      sprintf "jmp  %s\n" exit_if_label ^
      sprintf "%s:\n" else_label ^
      string_of_stmt context fdecl s2 ^
      sprintf "%s:\n" exit_if_label

  | For(e1, e2, e3, s) ->
      let loop_begin_label = get_new_label context
      and loop_label       = get_new_label context
      and loop_exit_label  = get_new_label context in
      let context' = { context with continue_label = Some loop_label;
                                    break_label    = Some loop_exit_label;
                                    loop_try_level = 0 } in
      eval_expr_to_eax fdecl e1 ^
      sprintf "jmp %s\n" loop_begin_label ^
      sprintf "%s:\n" loop_label ^
      eval_expr_to_eax fdecl e3 ^
      sprintf "%s:\n" loop_begin_label ^
      (match e2 with
          Noexpr -> ""
        | _ -> eval_expr_to_eax fdecl e2 ^
                        "test eax, eax\n" ^
               sprintf "jz   %s\n" loop_exit_label) ^
      string_of_stmt context' fdecl s ^
      sprintf "jmp %s\n" loop_label ^
      sprintf "%s:\n" loop_exit_label

  | While(e, s) ->
      string_of_stmt context fdecl (For(Noexpr, e, Noexpr, s))

  | Break ->
      unwind_exception  context.loop_try_level ^
      unstack_exception context.loop_try_level ^
      sprintf "jmp %s\n" (get context.break_label)
  | Continue ->
      unwind_exception  context.loop_try_level ^
      unstack_exception context.loop_try_level ^
      sprintf "jmp %s\n" (get context.continue_label)

  | Try_catch(s1, v, s2) ->
      let catch_label      = get_new_label context
      and exit_label       = get_new_label context in
      let context' = { context with
                         function_try_level = context.function_try_level + 1;
                         loop_try_level     = context.loop_try_level + 1} in
      stack_exception catch_label ^
      string_of_stmt context' fdecl s1 ^
      unwind_exception 1 ^
      unstack_exception 1 ^
      sprintf "jmp %s\n" exit_label ^
      sprintf "%s:\n" catch_label ^
      (match v with
          "" -> ""
        | _  -> sprintf "mov [ebp+%d], edx\n" (id_to_offset fdecl v)) ^
      string_of_stmt context fdecl s2 ^
      sprintf "%s:\n" exit_label

  | Throw(e) ->
      let caught_exception = get_new_label context in
      eval_expr_to_eax fdecl e ^
              "mov  edx, eax\n" ^
              "mov  ecx, [__exception_ptr]\n" ^
              "test ecx, ecx\n" ^
      sprintf "jnz  %s\n" caught_exception ^
              "push edx\n" ^
              "call __uncaught_exception\n" ^
      sprintf "%s:\n" caught_exception ^
      unwind_exception 1 ^
              "lea  esp, [ecx+12]\n" ^ (* exception is unstacked *)
              "mov  ebp, [ecx+8]\n" ^
              "jmp  [ecx+4]\n"

let string_of_fdecl context fdecl =
  let context' = { context with return_label = Some (get_new_label context) } in
  sprintf ".globl %s\n" fdecl.fname ^
  sprintf ".type %s, @function\n" fdecl.fname ^
  sprintf "%s:\n" fdecl.fname ^
          (* creating frame *)
          "push ebp\n" ^
          "mov  ebp, esp\n" ^
          (* instead of "sub esp, 4*num_locals", we "push 0" num_locals times,
             this way, the local variables are cleared on the fly *)
          "xor  eax, eax\n" ^
  String.concat "" (List.map (fun _ -> "push eax\n") fdecl.locals) ^
          "push ecx\n" ^
          "push edx\n" ^
  string_of_stmt context' fdecl (Block(fdecl.body)) ^
  sprintf "%s:\n" (get context'.return_label) ^
          "pop  edx\n" ^
          "pop  ecx\n" ^
          "mov  esp, ebp\n" ^
          "pop  ebp\n" ^
          "ret\n"

let generate_asm funcs =
  let context = { label_count        = ref 0;
                  continue_label     = None;
                  break_label        = None;
                  return_label       = None;
                  function_try_level = 0;
                  loop_try_level     = 0 } in
  ".intel_syntax noprefix\n" ^
  ".text\n" ^
  String.concat "" (List.map (string_of_fdecl context) funcs) ^
  ".ident \"C Flat compiler 0.1\"\n"
```

cflat.ml

```
let _ =
  try
    let lexbuf = Lexing.from_channel stdin in
    let program = Parser.program Scanner.token lexbuf in
    let program_detail = Sast.check_program program in
      print_string (Backend.generate_asm program_detail); exit 0
  with
      Failure(s)          -> prerr_endline ("Error: " ^ s); exit 1
    | Parsing.Parse_error -> prerr_endline ("Syntax error"); exit 1
```

lib.c

```c
#include <stdio.h>
#include <stdlib.h>

#define asmlinkage __attribute__((regparm(0)))

asmlinkage int in(void) {
  int i;
  scanf("%d", &i);
  return i;
}

asmlinkage void out(int val) {
  printf("%d\n", val);
}

asmlinkage void __uncaught_exception(int ex) {
  printf("uncaught exception: %d\n", ex);
  exit(1);
}

void *__exception_ptr;
```

tester.py

```
#!/usr/bin/env python

import commands
import os
import sys
from popen2 import Popen4

def compile_and_run(compiler, code):
    """Returns (compile status, output).
    compile status is 'OK' or 'BAD'.
    If compile fails, output has compiler output. If compile succeeds, it has
    the output of the program run.

    """
    proc = Popen4(compiler)
    proc.tochild.write(code)
    proc.tochild.close()
    if proc.wait() != 0:
        return ('BAD', proc.fromchild.read())
    proc = Popen4('./test | xargs')
    return ('OK', proc.fromchild.read().strip())

def print_indented(message):
    for line in message.splitlines():
        print "     ", line

def run_test(compiler, code, correct_result):
    """Returns True if the test passes, otherwise False."""
    status, output = compile_and_run(compiler, code)
    if correct_result == 'BAD':
        if status == 'BAD':
            print "PASS"
            return True
        elif status == 'OK':
            print "FAIL: Bad code compiled. Code:"
            print_indented(code)
            return False
    elif correct_result == 'OK':
        if status == 'BAD':
            print "FAIL: Good code didn't compile. Code:"
            print_indented(code)
            print "Compiler output:"
            print_indented(output)
            return False
        elif status == 'OK':
            print "PASS"
            return True
    else:
        if status == 'BAD':
            print "FAIL: Good code didn't compile. Code:"
            print_indented(code)
            print "Compiler output:"
            print_indented(output)
            return False
        elif correct_result == output:
            print "PASS"
            return True
        else:
            print "FAIL: Incorrect output from execution. Code:"
            print_indented(code)
            print "Executed code output:"
            print_indented(output)
            print "Correct output:"
            print_indented(correct_result)
            return False

if len(sys.argv) < 2:
    print "You must specify a test file."
    exit(1)
test_file_name = sys.argv[1]
test_file = open(test_file_name)
print "Loading test file '%s'." % test_file_name
compiler = '#'
while compiler.startswith('#'):
    compiler = test_file.readline().strip()
print "Using compile command '%s'." % compiler
test_count = 0
pass_count = 0
code = ""
for line in test_file:
    if line == "...\n":
        code = ""
    elif line.startswith("... "):
        test_count += 1
        correct_result = line.strip("\n")[4:]
        if (run_test(compiler, code, correct_result)):
            pass_count += 1
    else:
        code += line
test_file.close()
print "%d / %d tests passed." % (pass_count, test_count)
```

test-cflat.txt

```
# The first line that doesn't start with a '#' should be the compiler command.
# It should read source code from stdin and produce an executable named
# 'test'.
bash -c '(./cflat > test.s && gcc -m32 -c test.s -o test.o && gcc -m32 test.o
lib.o -o test)'

After the compiler command, anything not within a test case (surrounded by ...)
is ignored.
The closing ... should be followed by a space and then the desired result of the
test:
* OK if the code should compile,
* BAD if the code shouldn't compile, or
* Any other single line string which the code, when run, should produce.
  Whitespace may be trimmed from the front or back.


   *** Compiling ***
...
main() {
}
... OK

...
main() {
  bad
}
... BAD


   *** Comments ***
...
main() { }
/*
... BAD

...
main() {
  out(1);
  /* out(2); /* out(3); */ // */
  /* garbage */
  out(4); // out(5); garbage
  out(6);
}
... 1 4 6

   *** Variables ***
...
f(a, b) {
  out(a);
  out(b);
}
main() {
  out(a); /* a should be initialized to 0 */
  a = 1;
  b = a;
  out(b);
  out(a+b);
  f(2, 3);
}
... 0 1 2 2 3

...
/* variable can have the same name as a function */
f(f) {
  out(f);
}
main() {
  f = 2;
  f(f);
}
... 2

...
/* local variable discovery */
dummy(a) { }
a() { v; }
b() { !v; }
c() { v++; }
d() { v+0; }
e() { 0+v; }
f() { v+=0; }
g() { v=0; }
h() { dummy(v); }
i() { { v; } }
j() { return v; }
k() { if (v); }
l() { for(v;;); }
m() { for(;v;); }
n() { for(;;v); }
o() { while (v); }
p() { try {} catch(v) {} }
q() { throw v; }
main() { }
... OK


   *** Operators correctness ***
...
main() {
  /* Unop */
  out(-3);
  out(+ - + - + - + 4);
  out(!0);
  out(!2);
  out(!!2);
  out(~10);
  out(~~10);
}
... -3 -4 1 0 1 -11 10

...
main() {
  /* increment and decrement */
  out(a++);
  out(a);
  out(a--);
  out(a);
  out(++a);
  out(a);
  out(--a);
  out(a);
  out(a+++a++);
  out(a);
  out(a--+a--);
  out(a);
}
... 0 1 1 0 1 1 0 0 1 2 3 0

...
main() {
  /* Arithmetic binops */
  out(3+1);
  out(3+-1);
  out(-2+-2);
  out(3-1);
  out(3- -1);
  out(-1- -2);
  out(3*2);
  out(-2*3);
  out(-1*-1);
  out(12/4);
  out(6/-2);
  out(-5/-5);
  out(10%4);
  out(10%-4);
  out(-10%4);
  out(-10%-4);
}
... 4 2 -4 2 4 1 6 -6 1 3 -3 1 2 2 -2 -2

...
main() {
  /* Bitwise binops */
  out(3<<2);
  out(-1<<1);
  out(12>>2);
  out(-1>>1);
  out(1|4);
  out(3&5);
  out(3^5);
}
... 12 -2 3 -1 5 1 6

...
main() {
  /* Assign binops */
  a = 0; a += 2; out(a);
  a = 0; a -= 2; out(a);
  a = 2; a *= 3; out(a);
  a = 6; a /= 2; out(a);
  a = 7; a %= 4; out(a);
  a = 3; a <<= 2; out(a);
  a = 12; a >>= 2; out(a);
  a = 1; a |= 4; out(a);
  a = 3; a &= 5; out(a);
  a = 3; a ^= 5; out(a);
}
... 2 -2 6 3 3 12 3 5 1 6

...
main() {
  /* Logic binops */
  out(-2>-1);
  out(0>-1);
  out(0>0);
  out(1>0);

  out(-2>=-1);
  out(0>=-1);
  out(0>=0);
  out(1>=0);

  out(-1<-2);
  out(-2<0);
  out(1<1);
  out(0<1);

  out(-1<=-2);
  out(-2<=0);
  out(1<=1);
  out(0<=1);

  out(1==1);
  out(1==0);
  out(1!=1);
  out(1!=0);

  out(0&&1);
  out(1&&0);
  out(1&&3);
  out(0&&0);

  out(0||0);
  out(1||0);
  out(0||1);
  out(1||3);
}
... 0 1 0 1 0 1 1 1 0 1 0 1 0 1 1 1 1 0 0 1 0 0 1 0 0 1 1 1


   *** Operator precedence ***
...
op(expr, wanted, not_wanted) {
  out((expr == wanted) && (wanted != not_wanted));
}
main() {
   /* left assoc test */
  out(2) * out(3) * out(4);
  /* precedence test */
  op(~2*3,    (~2)*3,    ~(2*3));
  op(1+2*3,   1+(2*3),   (1+2)*3);
  op(1<<2+3,  1<<(2+3),  (1<<2)+3);
  op(1<2+3,   1<(2+3),   (1<2)+3);
  op(1==2<1,  1==(2<1),  (1==2)<1);
  op(2&2==2,  2&(2==2),  (2&2)==2);
  op(1^2&3,   1^(2&2),   (1^2)&2);
  op(3|2^3,   3|(2^2),   (3|2)^2);
  op(0&&2|1,  0&&(2|1),  (0&&2)|1);
  op(1||2&&0, 1||(2&&0), (1||2)&&0);

  /* right assoc test */
  a = 1; b = 2; c = 3;
  a = b = c;
  out(a); out(b); out(c);
}
... 2 3 4 1 1 1 1 1 1 1 1 1 1 3 3 3


   *** Function test ***
...
/* should compile, number of argument are not checked */
f(a,b,c) { }
main() { f(a); }
... OK

...
/* duplicate function */
f() {}
f() {}
main() {}
... BAD

...
/* duplicate formals */
f(a,b,a) {}
main() {}
... BAD

...
/* Function call evaluation order */
f(a, b, c) { out(a); out(b); out(c); }
g(a, b, c) { }
main() {
  f(1, 2, 3);
  g(out(4), out(5), out(6));
}
... 1 2 3 4 5 6

...
/* Recursive call test */
fib(x) {
        if (x < 3) return 1;
        return fib(x-1) + fib(x-2);
}
main() {
        out(fib(10));
}
... 55

...
main() {
  f(); /* will fail at linking stage */
}
... BAD


   *** if/else ***
...
main() {
  if (1) out(1);
  else   out(2);

  if (0) out(3);
  else   out(4);

  if (0)      out(5);
  else if (1) out(6);
  else        out(7);

  if (1)
    if (0)      out(8);
    else        out(9);
  else        out(10);

  if (1)    out(11);
  if (0)    out(12);
  else      out(13);
}
... 1 4 6 9 11 13


   *** Simple loop test ***
...
main() {
  sum = 0;
  for (i = 0; i <= 10; i++)
    sum += i;
  out(sum);
}
... 55

...
func(a) {
  return a-1;
}
main() {
  a = 10;
  while(func(a))
    a = func(a);
  out(a);
}
... 1
```

```
...
/* empty condition */
main() {
  for (;;) break;
  for (;;i++) {
    if (i == 3)
      break;
    out(i);
  }
}
... 0 1 2

...
main() {
  while () { }
}
... BAD

   *** Nested for/while ***
...
main() {
  for (i = 0; i < 2; i++) {
    while (0) { }
    for (j = 0; j < 2; j++)
      out (i + j);
  }
}
... 0 1 1 2


   *** break/continue tests ***
...
main() {
  if (1) {
    break;
  }
}
... BAD

...
main() {
  continue;
}
... BAD

...
/* multi level break/continue */
main() {
  for (i = 0; i < 5; i++) {
    for (j = 0; j < 5; j++) {
      if (j == 1)
        continue;
      else if (j == 3)
        break;
      out(i);
      out(j);
    }
    if (i == 2)
```

```
      break;
  }
}
... 0 0 0 2 1 0 1 2 2 0 2 2


   *** Exceptions ***
...
/* nested try/catch across functions */
g() {
  throw 4;
}
f() {
  try {
    g();
  } catch (b) {
    out(b);
    throw b-1;
  }
}
main() {
  out(1);
  try {
    f();
    out(2);
  } catch (a) {
    out(a);
  }
  out(5);
}
... 1 4 3 5

...
/* exceptions in recursive functions caught outside */
f(x) {
  if (x == 0) {
    throw -1;
  } else {
    out(x);
    f(x-1);
  }
}
main() {
  try {
    f(3);
  } catch(e) {
    out(e);
  }
}
... 3 2 1 -1

...
/* exceptions in recursive functions caught inside */
f(x) {
  try {
    if (x == 0) {
      throw -1;
    } else {
      out(x);
      f(x-1);
    }
  } catch(e) {
    out(e);
  }
}
main() {
  f(3);
}
... 3 2 1 -1

...
/* continue/break in a loop */
main() {
  for (i=0; i < 5; i++) {
    try {
      try {
        if (i == 4)
          throw 2;
      } catch {
        break;
      }
      if (i == 2)
        continue;
    } catch { }
    out(i);
  }
  out(-1);
}
... 0 1 3 -1

...
/* return within a try */
f() {
  try {
    return 0;
  } catch {
  }
}

main() {
  try {
    f();
    throw 1;
  } catch (a) {
    out(a);
  }
  out(2);
}
... 1 2

...
/* not catching an exception */
main() {
  throw 1;
}
... uncaught exception: 1
```