EAST WEST UNIVERSITY

Department of CSE

Course Code
CSE360

Course Title
Computer Architecture

Project Title

Single-Register Assembly Language Interpreter in C

Section : 01 Semester : Spring-2025

Submitted By
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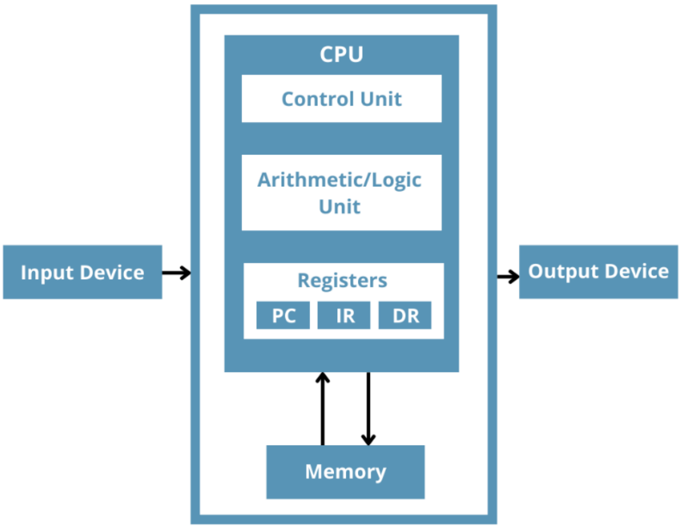
Objective

The goal of this project is to design and implement an interpreter in C for a simple assembly language. The interpreter uses a single accumulator register. The interpreter will read a text file containing one instruction per line. The assembly code format will be [Opcode Operand]. The interpretor will also support labels for branching. Finally it can execute instructions such as LOAD, STORE, ADD, SUB, and JUMP. By implementing this functionalities the interpretor can simulates a basic single-accumulator CPU. We implemented the accumulator register to hold intermediate arithmetic results and additionally a small memory array for data. For example, a statement LOAD X transfers the contents of memory at address X into the accumulator. While ADD Y adds the contents of memory Y to the accumulator. The interpreter emulates the CPU's fetch-decode-execute cycle by reading and executing instructions sequentially.

Theory

A program interpreter is a program that reads, decodes, and executes instructions one by one, rather than compiling them into machine code ahead of time. In our case, the interpreter will directly execute each assembly instruction as it is parsed. This approach contrasts with a compiler (which translates the entire program first); instead, interpreted code is processed line-by-line during runtime. Modern CPUs internally perform a similar fetch-decode-execute cycle: the program counter (PC) points to the next instruction, the instruction is fetched into an instruction register (IR), decoded, and then executed by the arithmetic/logic unit (ALU), with results typically stored in registers (especially the accumulator) or memory.



Instruction	Semantics
LOAD X	AC = M[X] (Load memory at address X into the accumulator)
STORE X	M[X] = AC (Store accumulator value into memory address X)
ADD X	AC = AC + M[X] (Add memory X to accumulator)
SUB X	AC = AC M[X] (Subtract memory X from accumulator)
JUMP L	PC = address of label L (Unconditionally branch to label L)

Design

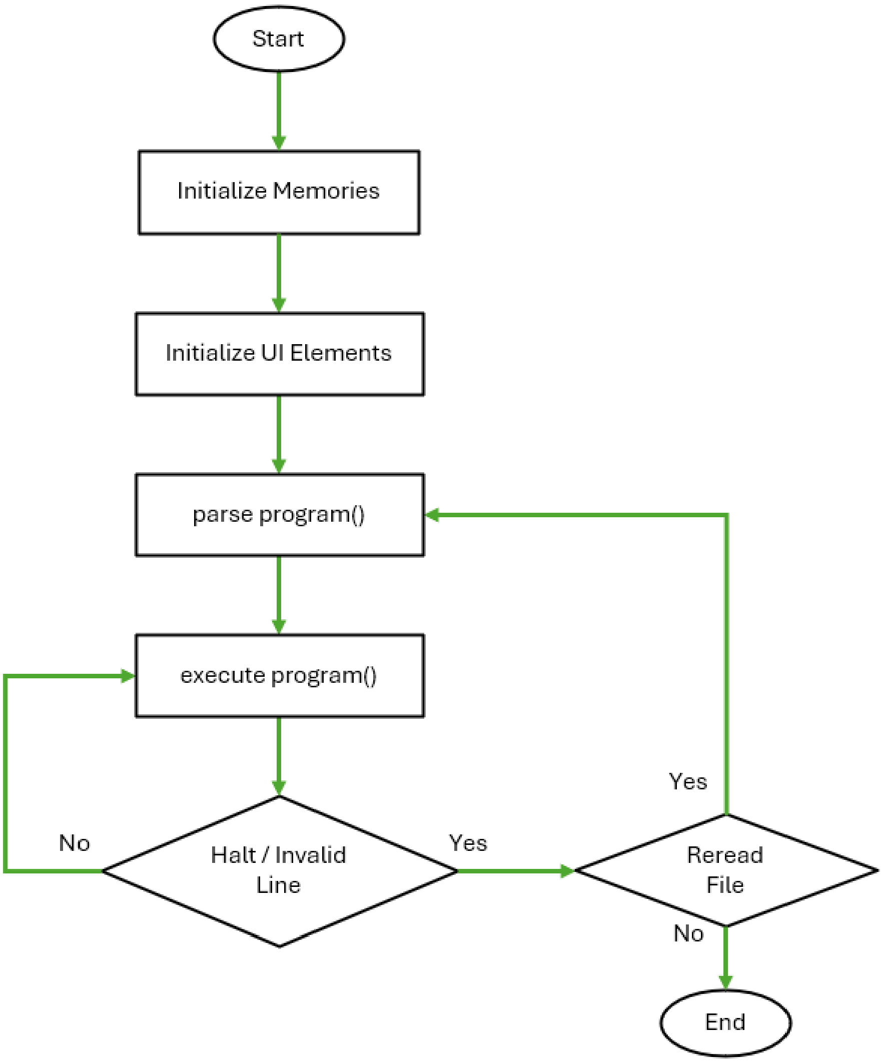
The interpreter is structured in two main phases. First parsing then execution. The program file (.asm) is read to build an internal representation of the instructions and to record the location of the labels. Then, the interpreter executes the instructions in order. The design steps are given below:

1. **Parsing Phase:**
   - Open the input text file containing assembly instructions.
   - Read each line, trimming whitespace and ignoring empty lines.
   - If a line contains a label (e.g. LOOP:), record the label name and associate it with the next instruction index. Labels are stored in a map (e.g., array or dictionary) from name to instruction number.
   - Otherwise, parse the opcode (e.g. LOAD) and operand (numeric address or label) from the line and append an instruction record to a list. We may use a struct like Instruction { OpCode op; int operand; } where operand is either a memory address or a resolved jump target.
2. **Label Resolution:**
   - After the first pass, we have a map of label names to instruction indices. In a second pass (or during initial parsing), for each JUMP L instruction we look up label L in the map and replace the operand with the numeric address of the labeled instruction. If a label is undefined, the parser signals an error.
3. **Execution Phase (Fetch-Decode-Execute Loop):**
   - Initialize AC = 0 (accumulator) and set PC = 0 (program counter starting at first instruction).
   - Enter a loop:
     - Fetch: Read the instruction at index PC.
     - Decode & Execute: Examine the opcode.
       - If LOAD X, do AC = memory[X].
       - If STORE X, do memory[X] = AC.
       - If ADD X, do AC = AC + memory[X].
       - If SUB X, do AC = AC – memory[X].
       - If JUMP L, set PC = L (resolved in parsing).
       - (If the opcode is unrecognized, report an error.)
     - Advance PC: If the instruction was not a jump, increment PC by 1. Otherwise, PC was set directly by JUMP.
     - Termination: Continue until PC reaches the end of the instruction list (or an explicit HALT if implemented).
4. **Data Structures and Memory:**
   - Use an array int memory[MAX_MEM] to simulate RAM. Memory can be initialized to 0.
   - Use an array Instruction program[MAX_INSTR] to store parsed instructions.
   - Use arrays (or a simple struct) to keep labels: e.g. char labels[MAX_LABELS][LABEL_LEN] and int label_index[MAX_LABELS].
   - Keep counters like instr_count and label_count

Below is a table summarizing each instruction's effect (from the program's design perspective):

Instruction	Effect on State
LOAD X	ACC memory[X]
STORE X	memory[X] ACC
ADD X	ACC ACC + memory[X]
SUB X	ACC ACC memory[X]
JUMP L	PC (address of label L) - Unconditional
JUMPP L	if ACC > 0 then PC ← address of label L
JUMPN L	if ACC < 0 then PC ← address of label L
JUMPZ L	if ACC == 0 then PC ← address of label L
HALT	Stop execution

5. Flowchart:



Implementation

- **Language:** C
- **Compiler:** GCC compiler
- **OS:** Linux, Windows
- **Modules:**
    - Memory setup and initialization
    - Instruction parsing and execution
    - Label resolving
    - Debug output

We implemented the interpreter in C, using standard libraries (stdio.h, stdlib.h, string.h). We also used **ncurses** library for better visualization. The code is organized into functions for parsing and execution. The key data structures are:

- An enum OpCode and struct Instruction to represent parsed instructions.
- A fixed-size memory array memory[MAX_MEM] for data.
- Arrays for label names and their corresponding instruction indices.

The program was compiled with GCC.

Source Code

```
/*
    CSE360- Project.
    Single-Register Assembly Language
Interpreter in C
        By Group-2
               Saif Khan
2022-2-60-063
               Mohammad Ashiquzzaman
Hadi   2021-3-60-143
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               Rafid Rahman
2022-2-60-040

    Run Command:
    gcc -o interpreter interpreter.c -
lncurses
    ./interpreter
*/

#include <stdio.h>
#include <stdlib.h>
#include <string.h>
#include <ctype.h>
#include <ncurses.h>
#include <unistd.h>

#define MAX_LINES 100
#define MAX_LABEL_LEN 20
#define MAX_LINE_LEN 50
#define MAX_MEM 10

typedef struct
{
  char label[MAX_LABEL_LEN];
  char opcode[10];
  char operand_str[20];
  int operand;
  int has_operand;
  int is_label_operand;
} Instruction;

Instruction program[MAX_LINES];
int memory[MAX_MEM] = {0};
int line_count = 0;
int accumulator = 0;
int log_win_height;
int acc_history[MAX_LINES] = {0};
int paused = 0;

typedef struct
{
  char label[MAX_LABEL_LEN];
  int index;
} LabelMap;
```

```
        else if
(strstr(completed_instr[i], "JUMPN"))
            color = 7;
        else if
(strstr(completed_instr[i], "JUMPZ"))
            color = 8;
        else if
(strstr(completed_instr[i], "HALT"))
            color = 9;

        wattron(log_win,
COLOR_PAIR(color));
        mvwprintw(log_win, 1 + i, 7, "%20s
| ACC: %d", completed_instr[i],
acc_history[i]);
        wattroff(log_win,
COLOR_PAIR(color));
    }

    wrefresh(mem_win);
    wrefresh(inst_win);
    wrefresh(acc_win);
    wrefresh(log_win);
}


   }
   program[line_count++] = instr;

void execute_program(WINDOW *header_win,
WINDOW *mem_win, WINDOW *inst_win, WINDOW
*acc_win, WINDOW *log_win)
{
  int running = 1;
  int paused = 0;

  nodelay(stdscr, TRUE);

  while (running)
  {
    int pc = 0;
    completed_count = 0;

    while (pc < line_count)
    {
      Instruction instr = program[pc];
      int target;

      if (log_win)
        delwin(log_win);
      log_win_height = completed_count +
2;
      if (log_win_height > LINES - 15)
        log_win_height = LINES - 15;
      log_win = newwin(log_win_height, 50,
14, 1);
```

```
LabelMap label_map[MAX_LINES];
int label_count = 0;

char
completed_instr[MAX_LINES][MAX_LINE_LEN];
int completed_count = 0;

int find_label_index(const char *label)
{
  for (int i = 0; i < label_count; i++)
  {
    if (strcmp(label_map[i].label, label)
== 0)
      return label_map[i].index;
  }
  return -1;
}

void add_label(const char *label, int
index)
{
  strcpy(label_map[label_count].label,
label);
  label_map[label_count].index = index;
  label_count++;
}

int is_number(const char *str)
{
  for (int i = 0; str[i]; i++)
  {
    if (!isdigit(str[i]))
      return 0;
  }
  return 1;
}

void parse_program()
{
  FILE *fp = fopen("program.asm", "r");
  if (!fp)
  {
    perror("Failed to open program.asm");
    exit(1);
  }

  char line[MAX_LINE_LEN];
  while (fgets(line, sizeof(line), fp) &&
line_count < MAX_LINES)
  {
    line[strcspn(line, "\r\n")] = 0;

    if (line[0] == '\0' || strspn(line, "
\t") == strlen(line))
      continue;
    if (line[0] == ';')
```

```
      draw_ui(header_win,mem_win,
inst_win, acc_win, log_win, pc);
      usleep(1000000);

      int ch = getch();
      if (ch == 'p' || ch == 'P')
      {
        paused = !paused;
        if (paused)
        {
          int y_prompt = getbegy(log_win)
+ getmaxy(log_win) + 1;
          mvprintw(y_prompt, 1, "Paused.
Press 'p' to resume.");
          refresh();
        }
      }

      while (paused)
      {
        int pause_ch = getch();
        if (pause_ch == 'p' || pause_ch ==
'P')
        {
          paused = 0;
          clear();
          refresh();
          break;
        }
        usleep(100000);
      }

char log_line[60];
snprintf(log_line, sizeof(log_line), " %-
4s %d-> %s %s","Line", pc + 1,
instr.opcode,
         instr.has_operand ?
instr.operand_str : "");


strcpy(completed_instr[completed_count],
log_line);
      acc_history[completed_count] =
accumulator;
      completed_count++;

      if (strcmp(instr.opcode, "LOAD") ==
0 && instr.has_operand)
      {
        if (instr.operand >= 0 &&
instr.operand < MAX_MEM)
          accumulator =
memory[instr.operand];
      }
      else if (strcmp(instr.opcode,
"STORE") == 0 && instr.has_operand)
```

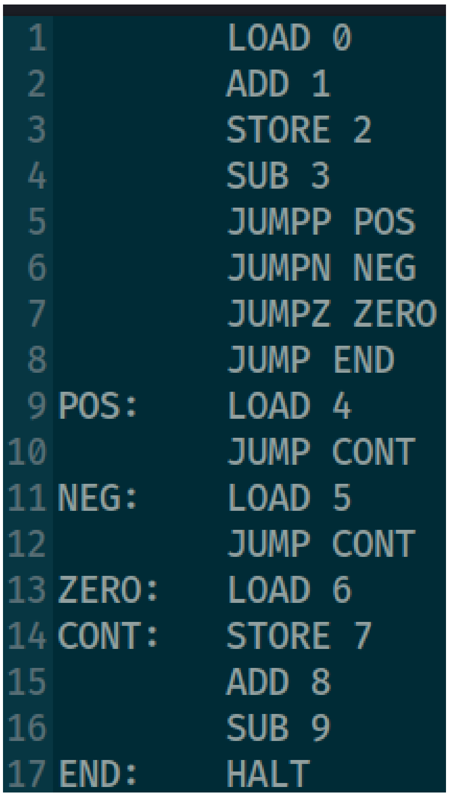
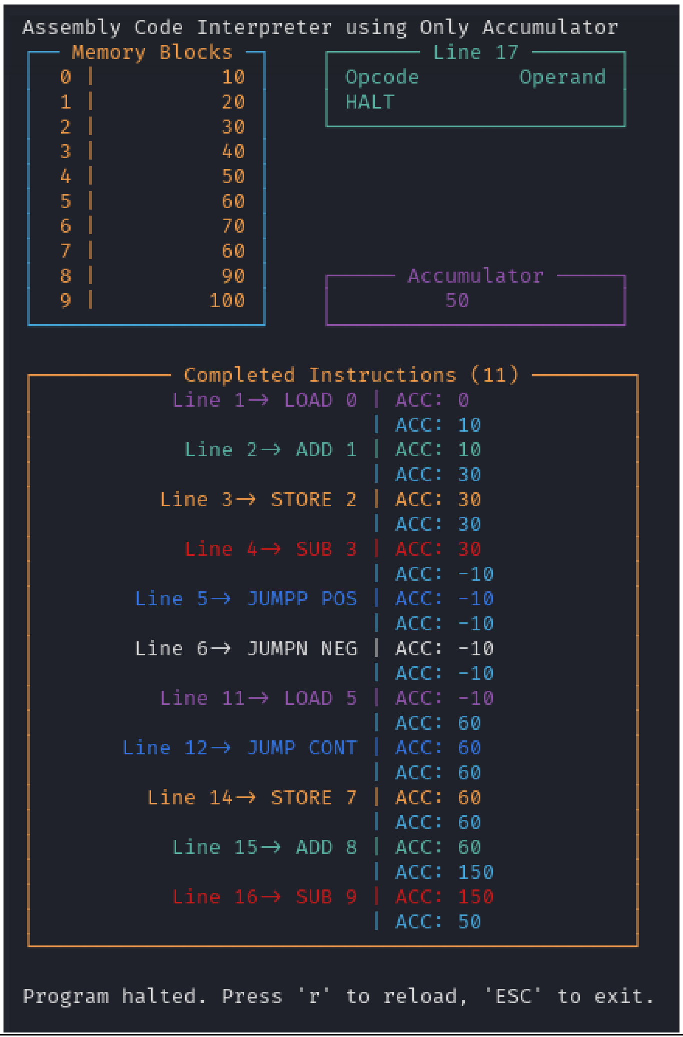
```
      continue;

    Instruction instr = {"", "", "", 0,
0, 0};
    char label[MAX_LABEL_LEN] = "";
    char opcode[10] = "";
    char operand_str[20] = "";

    if (strchr(line, ':'))
    {
      sscanf(line, "%[^:]: %s %s", label,
opcode, operand_str);
      add_label(label, line_count);
    }
    else
    {
      sscanf(line, "%s %s", opcode,
operand_str);
    }

    if (label[0] != '\0')
      strcpy(instr.label, label);
    strcpy(instr.opcode, opcode);

    if (strcmp(opcode, "HALT") != 0 &&
strlen(operand_str) > 0)
    {
      instr.has_operand = 1;
      strcpy(instr.operand_str,
operand_str);
      if (is_number(operand_str))
      {
        instr.operand =
atoi(operand_str);
        instr.is_label_operand = 0;
      }
      else
      {
        instr.is_label_operand = 1;
      }
    }

    program[line_count++] = instr;

    if (strcmp(opcode, "HALT") == 0)
      break;
  }

  fclose(fp);
}
void draw_ui(WINDOW *header_win, WINDOW
*mem_win, WINDOW *inst_win, WINDOW
*acc_win, WINDOW *log_win, int pc)
{
    werase(mem_win);
    werase(inst_win);
    werase(acc_win);
```

```
      {
        if (instr.operand >= 0 &&
instr.operand < MAX_MEM)
          memory[instr.operand] =
accumulator;
      }
      else if (strcmp(instr.opcode, "ADD")
== 0 && instr.has_operand)
      {
        if (instr.operand >= 0 &&
instr.operand < MAX_MEM)
          accumulator +=
memory[instr.operand];
      }
      else if (strcmp(instr.opcode, "SUB")
== 0 && instr.has_operand)
      {
        if (instr.operand >= 0 &&
instr.operand < MAX_MEM)
          accumulator -=
memory[instr.operand];
      }
      else if (strcmp(instr.opcode,
"JUMP") == 0 && instr.has_operand)
      {
        target = instr.is_label_operand ?
find_label_index(instr.operand_str) :
instr.operand;
        if (target >= 0 && target <
line_count)
        {
          completed_count++;
          acc_history[completed_count - 1]
= accumulator;
          pc = target;
          continue;
        }
      }
      else if (strcmp(instr.opcode,
"JUMPZ") == 0 && instr.has_operand)
      {
        if (accumulator == 0)
        {
          target = instr.is_label_operand
? find_label_index(instr.operand_str) :
instr.operand;
          if (target >= 0 && target <
line_count)
          {
            completed_count++;
            acc_history[completed_count -
1] = accumulator;
            pc = target;
            continue;
          }
        }
      }
```

```
    werase(log_win);

    mvwprintw(header_win, 0, 1, "Assembly
Code Interpreter using Only
Accumulator");
    wrefresh(header_win);

    int mem_win_height =
getmaxy(mem_win);
    int max_mem_lines = mem_win_height -
2;
    if (max_mem_lines > MAX_MEM)
        max_mem_lines = MAX_MEM;

    wattron(mem_win, COLOR_PAIR(2));
    box(mem_win, 0, 0);
    wattroff(mem_win, COLOR_PAIR(2));

    wattron(mem_win, COLOR_PAIR(1));
    mvwprintw(mem_win, 0, 3, " Memory
Blocks ");
    wattroff(mem_win, COLOR_PAIR(1));

    for (int i = 0; i < max_mem_lines;
i++)
    {
        if (program[pc].has_operand &&
program[pc].operand == i)
        {
            wattron(mem_win,
COLOR_PAIR(4));
            mvwprintw(mem_win, 1 + i, 1,
">%2d | %11d", i, memory[i]);
            wattroff(mem_win,
COLOR_PAIR(4));
        }
        else
        {
            wattron(mem_win,
COLOR_PAIR(1));
            mvwprintw(mem_win, 1 + i, 1,
" %2d | %11d", i, memory[i]);
            wattroff(mem_win,
COLOR_PAIR(1));
        }
    }

    wattron(inst_win, COLOR_PAIR(3));
    box(inst_win, 0, 0);
    wattroff(inst_win, COLOR_PAIR(3));

    wattron(inst_win, COLOR_PAIR(3));
    mvwprintw(inst_win, 0, 8, " Line %d
", pc + 1);
    mvwprintw(inst_win, 1, 2, "Opcode
Operand");
```

```
      else if (strcmp(instr.opcode,
"JUMPN") == 0 && instr.has_operand)
      {
        if (accumulator < 0)
        {
          target = instr.is_label_operand
? find_label_index(instr.operand_str) :
instr.operand;
          if (target >= 0 && target <
line_count)
          {
            completed_count++;
            acc_history[completed_count -
1] = accumulator;
            pc = target;
            continue;
          }
        }
      }
      else if (strcmp(instr.opcode,
"JUMPP") == 0 && instr.has_operand)
      {
        if (accumulator > 0)
        {
          target = instr.is_label_operand
? find_label_index(instr.operand_str) :
instr.operand;
          if (target >= 0 && target <
line_count)
          {
            completed_count++;
            acc_history[completed_count -
1] = accumulator;
            pc = target;
            continue;
          }
        }
      }
      else if (strcmp(instr.opcode,
"HALT") == 0)
      {
        break;
      }
      acc_history[completed_count] =
accumulator;
      completed_count++;
      pc++;
      clear();
      refresh();
    }
    int y_prompt = getbegy(log_win) +
getmaxy(log_win) + 1;
    mvprintw(y_prompt, 1, "Program halted.
Press 'r' to reload, 'ESC' to exit.");
    refresh();
    int ch;
    while ((ch = getch()))
    char operand_print[20] = "";
    if (program[pc].has_operand)
    {
        strncpy(operand_print,
program[pc].operand_str,
sizeof(operand_print) - 1);

operand_print[sizeof(operand_print) - 1]
= '\0';
    }

    mvwprintw(inst_win, 2, 2, "%-12s %s",
program[pc].opcode, operand_print);
    wattroff(inst_win, COLOR_PAIR(3));

    wattron(acc_win, COLOR_PAIR(5));
    box(acc_win, 0, 0);
    mvwprintw(acc_win, 0, 6, "
Accumulator ");
    mvwprintw(acc_win, 1, 2, "%10d",
accumulator);
    wattroff(acc_win, COLOR_PAIR(5));

    wattron(log_win, COLOR_PAIR(1));
    box(log_win, 0, 0);
    mvwprintw(log_win, 0, 12, " Completed
Instructions (%d) ", completed_count /
2);
    wattroff(log_win, COLOR_PAIR(1));

    int log_win_height =
getmaxy(log_win);
    int max_log_lines = log_win_height -
2;
    for (int i = 0; i < completed_count
&& i < max_log_lines; i++)
    {
        int color = 2; /
        if (strstr(completed_instr[i],
"ADD"))
            color = 3;
        else if
(strstr(completed_instr[i], "SUB"))
            color = 4;
        else if
(strstr(completed_instr[i], "LOAD"))
            color = 5;
        else if
(strstr(completed_instr[i], "STORE"))
            color = 1;
        else if
(strstr(completed_instr[i], "JUMPP") ||
strstr(completed_instr[i], "JUMP "))
            color = 6;
```

```
        {
          if (ch == 27)
          {
            running = 0;
            break;
          }
          else if (ch == 'r' || ch == 'R')
          {
            parse_program();
            break;
          }
        }
    }
}
int main()
{
  memory[0] = 10;
  memory[1] = 20;
  memory[2] = 30;
  memory[3] = 40;
  memory[4] = 50;
  memory[5] = 60;
  memory[6] = 70;
  memory[7] = 80;
  memory[8] = 90;
  memory[9] = 100;
  initscr();
  noecho();
  cbreak();
  curs_set(0);
  start_color();
  init_pair(1, COLOR_YELLOW, COLOR_BLACK);
  init_pair(2, COLOR_CYAN, COLOR_BLACK);
  init_pair(3, COLOR_GREEN, COLOR_BLACK);
  init_pair(4, COLOR_RED, COLOR_BLACK);
  init_pair(5, COLOR_MAGENTA,
COLOR_BLACK);
  init_pair(6, COLOR_BLUE, COLOR_BLACK);
  init_pair(7, COLOR_WHITE, COLOR_BLACK);
  init_pair(8, COLOR_RED, COLOR_BLACK);
  init_pair(9, COLOR_GREEN, COLOR_WHITE);
  WINDOW *header_win = newwin(1, 50, 0,
0);
  WINDOW *mem_win = newwin(12, 20, 1, 1);
  WINDOW *inst_win = newwin(4, 25, 1, 25);
  WINDOW *acc_win = newwin(3, 25, 10, 25);
  WINDOW *log_win = newwin(12, 50, 14, 1);
  parse_program();
  execute_program(header_win,mem_win,
inst_win, acc_win, log_win);
  delwin(mem_win);
  delwin(inst_win);
  delwin(acc_win);
  delwin(log_win);
  endwin();
  return 0;
}
```

Input :	**Output :**
	

```
1            LOAD 0
2            ADD 1
3            STORE 2
4            SUB 3
5            JUMPP POS
6            JUMPN NEG
7            JUMPZ ZERO
8            JUMP END
9  POS:      LOAD 4
10           JUMP CONT
11 NEG:      LOAD 5
12           JUMP CONT
13 ZERO:     LOAD 6
14 CONT:     STORE 7
15           ADD 8
16           SUB 9
17 END:      HALT
```

```
Assembly Code Interpreter using Only Accumulator
 ┌─ Memory Blocks ─┐     ┌──────── Line 17 ────────┐
 │ 0 |          10 │     │ Opcode           Operand │
 │ 1 |          20 │     │ HALT                     │
 │ 2 |          30 │     └──────────────────────────┘
 │ 3 |          40 │
 │ 4 |          50 │
 │ 5 |          60 │
 │ 6 |          70 │
 │ 7 |          60 │
 │ 8 |          90 │     ┌────── Accumulator ──────┐
 │ 9 |         100 │     │           50             │
 └─────────────────┘     └──────────────────────────┘

 ┌────────────── Completed Instructions (11) ──────────────┐
 │           Line 1→ LOAD 0 | ACC: 0                        │
 │                          | ACC: 10                       │
 │            Line 2→ ADD 1 | ACC: 10                       │
 │                          | ACC: 30                       │
 │          Line 3→ STORE 2 | ACC: 30                       │
 │                          | ACC: 30                       │
 │            Line 4→ SUB 3 | ACC: 30                       │
 │                          | ACC: -10                      │
 │        Line 5→ JUMPP POS | ACC: -10                      │
 │                          | ACC: -10                      │
 │        Line 6→ JUMPN NEG | ACC: -10                      │
 │                          | ACC: -10                      │
 │          Line 11→ LOAD 5 | ACC: -10                      │
 │                          | ACC: 60                       │
 │      Line 12→ JUMP CONT | ACC: 60                        │
 │                          | ACC: 60                       │
 │         Line 14→ STORE 7 | ACC: 60                       │
 │                          | ACC: 60                       │
 │           Line 15→ ADD 8 | ACC: 60                       │
 │                          | ACC: 150                      │
 │           Line 16→ SUB 9 | ACC: 150                      │
 │                          | ACC: 50                       │
 └──────────────────────────────────────────────────────────┘

Program halted. Press 'r' to reload, 'ESC' to exit.
```

GitHub: https://github.com/saifkhancse/Assembly-Interpreter

Debugging and Test Run

We used sample programs to verify if the interpreter is working properly. We tested cases like normal arithmetic and control flow, as well as error conditions. We inserted printf statements for debugging. Like after parsing we printed the list of instructions and their operands. We traced the accumulator value step-by-step during execution . One of the major bugs were failing to skip label lines or mismatching string names, which were caught by these prints.

As a sample run, consider the following program file example.asm:

```
        LOAD 0
        ADD 1
        STORE 2
        SUB 3
        JUMPP POS
        JUMPN NEG
        JUMPZ ZERO
        JUMP END
POS:    LOAD 4
        JUMP CONT
NEG:    LOAD 5
        JUMP CONT
ZERO:   LOAD 6
CONT:   STORE 7
        ADD 8
        SUB 9
END:    HALT
```

Before running, we manually set memory[0] to memory[9]; 10 to 100 in the code. Executing this program, the interpreter should load 5, add 3, and store 8. Indeed, the output was:

```
memory[0] = 10;
memory[1] = 20;
memory[2] = 30;
memory[3] = 40;
memory[4] = 50;
memory[5] = 60;
memory[6] = 70;
memory[7] = 80;
memory[8] = 90;
memory[9] = 100;
Expected Execution:
LOAD 0 → AC = 10
ADD 1 → AC = 30
STORE 2 → memory[2] = 30
SUB 3 → AC = -10
JUMPN NEG is triggered due to negative AC
LOAD 5 → AC = 60
JUMP CONT skips ZERO branch
STORE 7 → memory[7] = 60
ADD 8 → AC = 150
SUB 9 → AC = 50
HALT
```

Observed Output:
From the visual UI:

- **Accumulator at halt**: 50
- **Modified memory**:
  - memory[2] = 30 (after STORE 2)
  - memory[7] = 60 (after STORE 7)

The output exactly matched the expected state transitions. The branch logic also correctly followed the negative jump path (NEG) based on the accumulator condition.
This matches the expected result.

Results Analysis

Performance: The interpreter's time complexity is linear in the number of instructions. Each instruction is executed exactly once (except that JUMP may re-execute some instructions if it forms a loop). In big-O terms, the runtime is O(N) for N instructions (plus the overhead of label lookup, which is at most O(N) with a simple array). The space complexity is also O(N). As it is storing the program, plus O(M) for memory of size M. In practice, both are small since N and M are bounded by program size and our defined array lengths.

Robustness: The interpreter handles valid programs robustly: it correctly skips labels, interprets all defined opcodes, and updates state. It also detects several error conditions. For example, if a JUMP refers to an undefined label, the parser prints an error and exits (rather than crashing). If an invalid opcode is encountered, the parser likewise reports an error. Memory accesses are not checked against bounds in this simple code, so a program referring to an out-of-range address will cause undefined behavior (that could be improved). We did ensure that instructions parse correctly (using sscanf and string comparisons).

Edge Cases: - Empty or Comment Lines: Empty or Comment Lines: Our parser ignores empty lines or lines without two tokens, so blank lines or comments (beginning with ;) have no effect.

- **Label at End:** A label with no following instruction (unused) is simply recorded and not used; it causes no harm.
- **Duplicate Labels:** Duplicate label names will overwrite the first mapping silently. Which could be improved by printing an error.
- **Arithmetic Overflow:** Using the C int type, overflow behavior is wrap-around. For some applications we might detect overflow, but here we assume 32-bit wrap semantics.
- **Case Sensitivity:** Opcodes and labels are case-sensitive. Like using "load" instead of "LOAD" will not be recognized.

Overall, the interpreter performed correctly and its behavior matched as expected in all tested scenarios. There are minor limitations and handled with error messages or documented as user responsibility.

Conclusion and Future Improvements

In this project, we built a complete interpreter for a basic single-accumulator assembly language in C. We showed the theoretical concepts of CPU architecture. This report covered the design of the interpreter, parsing of labels and instructions, the fetch-decode-execute loop, and the handling of each opcode. We provided the well-commented C source code.

Limitations: The current interpreter is simplistic as per project description. In real life CPU architecture is more complex. In addition, It only supports five instructions and a single accumulator. There is, no stack or subroutine support, and no I/O instructions for user interaction. Memory is fixed-size and not bounds-checked. The user must ensure input programs are correctly formatted.

Future Enhancements: More works can be added to this project. For example:
- Add additional registers or a stack.
- Implement more instruction, such as MULTIPLY, DIVIDE.
- Provide input/output instructions for interacting with the user or files.
- Show error line numbers and error explanation.
- Implement more instruction, such as MULTIPLY, DIVIDE.
- Provide input/output instructions for interacting with the user or files.

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