Lab6b Report

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1 Introduction

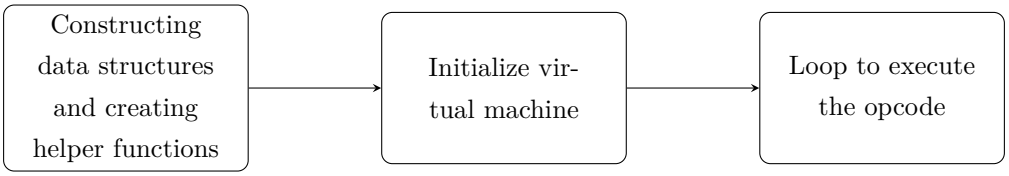
Write a program to execute LC-3 binary code. You are required to write in C or any other high level programming language.

2 Algorithm explanation

Basic idea: virtual machine. Language used : C.

2.1 Program

The flow of the procedure is as follows.



The following is the main functions.

```
int main( ){
        setup(&core);
        main_loop(&core);
        return 0;
}
```

2.2 Preparation

To build a virtual machine, we first need to create a data structure, who has a uint16_t variables to indicate Program Counter, a two-dimensional array of length 65536 and width 16 to indicate memory locations, an array of length 8 with each cell being a unint16t variable to indicate 8 register, and three int variables to indicate condition codes considering privilege mode and priority level are not required. And to easierly use opcode, we create another data structure who has wwo arrays, one of size 4 and the other of size 12. After building the data structure, construct the corresponding prototype.

In addition, we need to create the following functions before moving on to the formal program.

Algorithm 1: chartonum

Input: string need to convert, number of bits to be converted
Output: a unsigned int

```
1 while t > 0 do
2 |   temp = temp * 2 + (*str - '0');
3 |   str++;
4 |   t–;
5 end
6 return temp
```

Algorithm 2: chartosigned

Input: string need to convert, number of bits to be converted
Output: a signed int

```
1 temp = chartonum(str, t);
2 if str[t]=='1' then
3 |   temp = chartonum(str, t);
4 end
5 return temp
```

Algorithm 3: itoa

Input: number need to convert, conversion objectives, valuetype
Output: a string

```
1 char index[ ]="0123456789ABCDEF";
2 while num > 0 do
3 |   str[ i– ]=index[ unum % radix ];
4 |   unum /= radix;
5 end
6 for Each character that has been constructed do
7 |   Reverse order;
8 end
9 return temp
```

2.3 Initialization

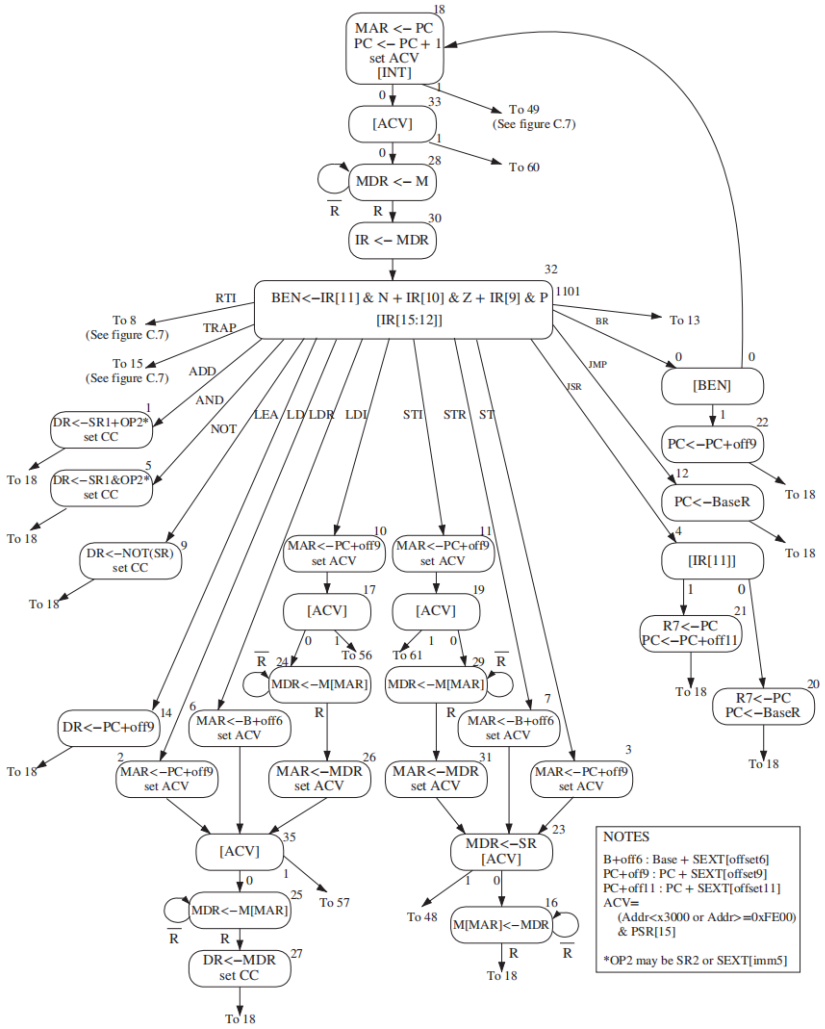
In setup, the first thing to do is to put values of all registers and memory locations to x7777. Then, read the starting address and store it to pc. Finally, read each instruction in turn and place them in turn in the position after the pc.

2.4 Loop

In the loop, we will proceed in sequence: fetch, increment and execute.

To fetch a opcode, we need use memcpy to take the code in the address pointed by pc copy to a pointer pointering to data structure. Then, increment the pc. And finally, execute the opcode according to bit[12:15].

The flow of each instruction is shown below.



3 Source code

```
\#include <stdio.h>
\#include <stdlib.h>
\#include <string.h>
\#include <stdint.h>

int chartonum(char* str, int t){
        ......
}
int chartouns(char* str, int t){
        .......
}
char* my_itoa(uint16_t num, char* str, int radix){
        .......
}
typedef struct{
    char opcode[4];
    char value[12];
} VM_INST;
typedef struct{
    uint16_t pc;
    int n;
    int z;
```

```
    int p;
    char rom[65536][16];
    uint16_t R[8];
} VM_CORE;
VM_CORE core;

void setCondition(VM_CORE *c, uint16_t value){
    if(value == 0){
        c->n = 0;  c->p = 0;  c->z = 1;
    }else if(value & (1<<15)){
        c->n = 1;  c->p = 0;  c->z = 0;
    }else{
        c->n = 0;  c->p = 1;  c->z = 0;
    }
}
void do_BR(VM_CORE *c, VM_INST* inst){
    if((inst->value[0]-'0' && c->n) ||
     (inst->value[1]-'0' && c->z) || (inst->value[2]-'0' && c->p)){
        int SEXT = chartouns((char*)inst->value + 3, 9);
        c->pc += SEXT;
    }
}
void do_ADD(VM_CORE *c, VM_INST* inst){
    int DR = chartonum((char*)inst->value, 3);
    int SR1 = chartonum((char*)inst->value + 3, 3);
    if(inst->value[6] == '1'){
        int SEXT = chartouns((char*)inst->value + 7, 5);
        c->R[DR] = c->R[SR1] + SEXT;
    }else{
        int SR2 = chartonum((char*)inst->value + 9, 3);
        c->R[DR] = c->R[SR1] + c->R[SR2];
    }
    setCondition(c, c->R[DR]);
}
void do_LD(VM_CORE *c, VM_INST* inst){
    int DR = chartonum((char*)inst->value, 3);
    int PCoffset9 = chartouns((char*)inst->value + 3, 9);
    c->R[DR] = chartonum(c->rom[c->pc + PCoffset9], 16);
    setCondition(c, c->R[DR]);
}
void do_ST(VM_CORE *c, VM_INST* inst){
    int SR = chartonum((char*)inst->value, 3);
    int PCoffset9 = chartouns((char*)inst->value + 3, 9);
    char * temp = malloc(sizeof(VM_INST) + 1);
    memset(temp, '0', 16);
    memcpy(c->rom[c->pc + PCoffset9], my_itoa(c->R[SR], temp, 2), 16);
    free(temp);
}
void do_JSR(VM_CORE *c, VM_INST* inst){
    uint16_t temp = c->pc;
    if(inst->value[0] == '1'){
        int PCoffset11 = chartouns((char*)inst->value + 1, 11);
        c->pc = c->pc + PCoffset11;
    }else{
        int BaseR = chartonum((char*)inst->value + 3, 3);
        c->pc = c->R[BaseR];
    }
    c->R[7] = temp;
}
void do_AND(VM_CORE *c, VM_INST* inst){
    int DR = chartonum((char*)inst->value, 3);
    int SR1 = chartonum((char*)inst->value + 3, 3);
```

```
    if(inst->value[6] == '1'){
        uint16_t SEXT = (uint16_t)chartouns((char*)inst->value + 7, 5);
        c->R[DR] = c->R[SR1] & SEXT;
    }else{
        int SR2 = chartonum((char*)inst->value + 9, 3);
        c->R[DR] = c->R[SR1] & c->R[SR2];
    }
    setCondition(c, c->R[DR]);
}
void do_LDR(VM_CORE *c, VM_INST* inst){
    int DR = chartonum((char*)inst->value, 3);
    int BaseR = chartonum((char*)inst->value + 3, 3);
    int offset6 = chartouns((char*)inst->value + 6, 6);
    c->R[DR] = chartonum(c->rom[c->R[BaseR] + offset6], 16);
    setCondition(c, c->R[DR]);
}
void do_STR(VM_CORE *c, VM_INST* inst){
    int SR = chartonum((char*)inst->value, 3);
    int BaseR = chartonum((char*)inst->value + 3, 3);
    int offset6 = chartouns((char*)inst->value + 6, 6);
    char * temp = malloc(sizeof(VM_INST) + 1);
    memset(temp, '0', 16);
    memcpy(c->rom[c->R[BaseR] + offset6], my_itoa(c->R[SR], temp, 2), 16);
    free(temp);
}
void do_NOT(VM_CORE *c, VM_INST* inst){
    int DR = chartonum((char*)inst->value, 3);
    int SR = chartonum((char*)inst->value + 3, 3);
    c->R[DR] = ~c->R[SR];
    setCondition(c, c->R[DR]);
}
void do_LDI(VM_CORE *c, VM_INST* inst){
    int DR = chartonum((char*)inst->value, 3);
    int PCoffset9 = chartouns((char*)inst->value + 3, 9);
    int address = chartonum(c->rom[c->pc + PCoffset9], 16);
    c->R[DR] = chartonum(c->rom[address], 16);
    setCondition(c, c->R[DR]);
}
void do_STI(VM_CORE *c, VM_INST* inst){
    int SR = chartonum((char*)inst->value, 3);
    int PCoffset9 = chartouns((char*)inst->value + 3, 9);
    char* temp = malloc(sizeof(VM_INST) + 1);
    int address = chartonum(c->rom[c->pc + PCoffset9], 16);
    memset(temp, '0', 16);
    memcpy(c->rom[address], my_itoa(c->R[SR], temp, 2), 16);
    free(temp);
}
void do_JMP(VM_CORE *c, VM_INST* inst){
    int BaseR = chartonum((char*)inst->value + 3, 3);
    c->pc = c->R[BaseR];
}
void do_LEA(VM_CORE *c, VM_INST* inst){
    int DR = chartonum((char*)inst->value, 3);
    int PCoffset9 = chartouns((char*)inst->value + 3, 9);
    c->R[DR] = (uint16_t)(c->pc + PCoffset9);
}
void do_OUT(VM_CORE *c, VM_INST* inst){
    int t = 0;
    for(t = 0; t<=7 ; t++) printf("R%d = x%04hX\n", t, c->R[t]);
}

//loop to execute
```

```
int main_loop(VM_CORE *c){
    VM_INST *inst = malloc(sizeof(VM_INST) + 1);
    ((char*)inst)[16] = '\0';
    while(1){

    // fetch the opcode
        memcpy(inst, c->rom[c->pc], sizeof(VM_INST));

    // increment the pc
        c->pc += 1;

    // execute
        switch (chartonum(inst->opcode, 4)){
            case 0:{do_BR(c, inst); break;}
            case 1:{do_ADD(c, inst); break;}
            case 2:{do_LD(c, inst); break;}
            case 3:{do_ST(c, inst); break;}
            case 4:{do_JSR(c, inst); break;}
            case 5:{do_AND(c, inst); break;}
            case 6:{do_LDR(c, inst); break;}
            case 7:{do_STR(c, inst); break;}
            case 9:{do_NOT(c, inst); break;}
            case 10:{do_LDI(c, inst); break;}
            case 11:{do_STI(c, inst); break;}
            case 12:{do_JMP(c, inst); break;}
            case 14:{do_LEA(c, inst); break;}
            case 15:{do_OUT(c, inst); return 0;}
            default:printf("Error!\n"); exit(-1);
        }
    }
}

//Initialization
void setup(VM_CORE* core){
    int t = 0;
    char temp[17] = "0111011101110111";
    for(t=0; t<65536; t++)   memcpy(core->rom[t], temp, 16);
    core->n = 0;  core->z = 0;  core->p = 0;
    core->R[0] = 30583; core->R[1] = 30583; core->R[2] = 30583; core->R[3] = 30583;
    core->R[4] = 30583; core->R[5] = 30583; core->R[6] = 30583; core->R[7] = 30583;
    t = 0;
    char c = '\0';
    char *address = malloc(sizeof(VM_INST) + 1);
    while (t!=16){
        c=getchar();
        address[t++] = c;
    }
    address[16] = '\0';
    core->pc = (uint16_t)chartonum(address, 16);
    free(address);
    t = 0;
    while ((c=getchar())!= EOF){
        if(c!=10)vcore->rom[core->pc][t++] = c;
    }
}
int main(){
    setup(&core);
    main_loop(&core);
    return 0;
}
```