1 目的

CPU のシミュレーションプログラム作成を通し CPU の動作を理解する.

2 実習

2.1 実習 7:一方向の連結リスト

表 1 一方向連結リストソースコード

Address	obj	code	source	code			
00	67	00	START:	LD	mem(IX+00H),	ACC	mem(IX+00H)->AC
02	6f	01		LD	mem(IX+00H),	IX	mem(IX+00H)->IX
04	fa	00		CMP	IX,	0	IX-00H
06	39	11		BZ	END:		ZF=1?
08	f5	ff		CMP	ACC,	mem[1ffH]	ACC-mem[1ffH]
0a	3a	0e		BN	P1:		NF=1?
0c	75	ff		ST	ACC,	mem[1ffH]	ACC->mem[1ffH]
0e	62	00	P1:	LD	00H	ACC	00H->ACC
10	0b			JR	START:		
11	0f		END:				

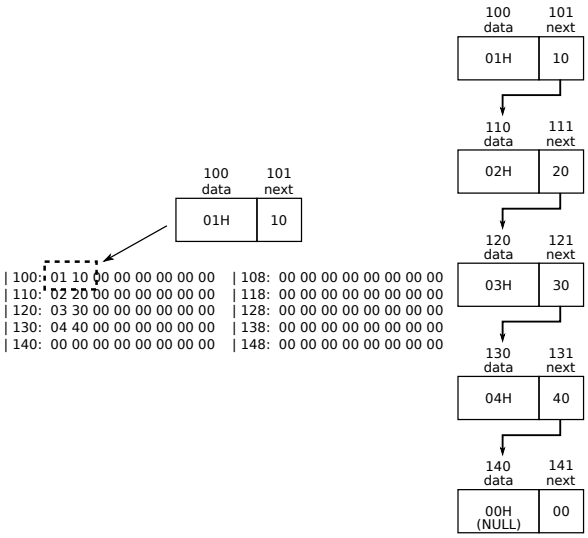

図 1 データ構造:リスト

表 1 に一方向連結リストプログラムソースコードを示す.mem[100] へ data,mem[101] へ next として考え. スタート位置は mem[100H] をスタート位置とした.

data が格納されているメモリの隣にアドレスを格納しており、アドレスを IX へ格納して次の data を参照するようになっている.data は ACC へ格納後, これまで参照した最大値が格納されているメモリ (mem[1ffH]) と比較し ACC の方が大きければ入れ替え動作を行う.

NULL は 00H とし next で参照した先が 00 の場合終了する. 表 1 に示すのデータ構造を以下に示す.

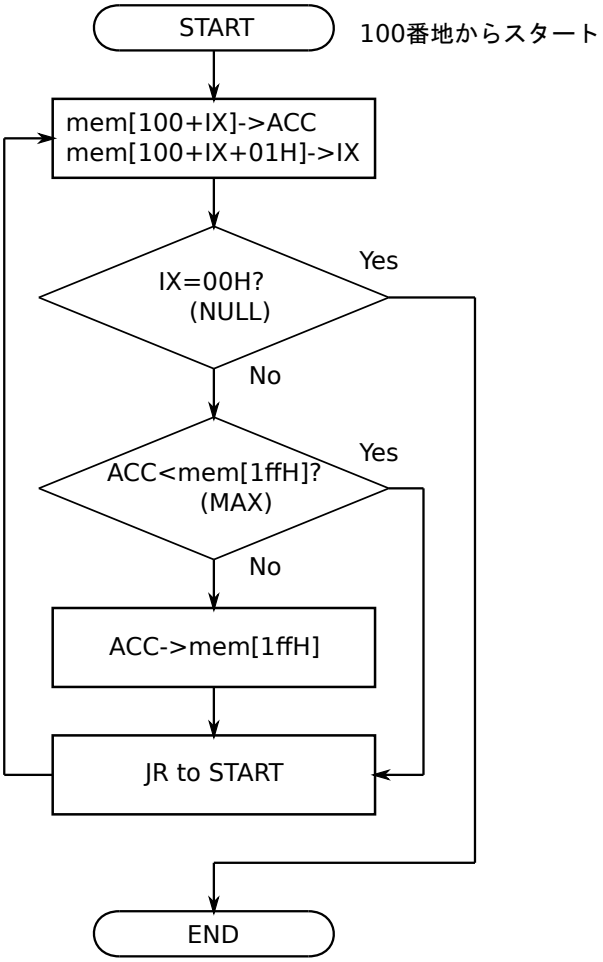

図 2　実習 7:一方向連結リストフローチャート

以下に結果を示す. 結果より mem[1ffH] へ最大値の 04H が格納され終了しているためプログラムは正しく実行されたと確認できる.

```
CPU0,PC=0x0> r 7_list.CPU0,PC=0x0> m 0
    | 000:  67 00 6f 01 fa 00 39 11    | 008:  f5 ff 3a 0e 75 ff 62 00
CPU0,PC=0x0> m 10
    | 010:  0b 0f 00 00 00 00 00 00    | 018:  00 00 00 00 00 00 00 00
CPU0,PC=0x0> m 100
    | 100:  01 10 00 00 00 00 00 00    | 108:  00 00 00 00 00 00 00 00
CPU0,PC=0x0> m 110
    | 110:  02 20 00 00 00 00 00 00    | 118:  00 00 00 00 00 00 00 00
CPU0,PC=0x0> m 120
    | 120:  03 30 00 00 00 00 00 00    | 128:  00 00 00 00 00 00 00 00
CPU0,PC=0x0> m 130
    | 130:  04 40 00 00 00 00 00 00    | 138:  00 00 00 00 00 00 00 00
CPU0,PC=0x0> m 140
    | 140:  00 00 00 00 00 00 00 00    | 148:  00 00 00 00 00 00 00 00
CPU0,PC=0x0> m 1f0
    | 1f0:  00 00 00 00 00 00 00 00    | 1f8:  00 00 00 00 00 00 00 00
CPU0,PC=0x0>c 10
```

```
CPU0,PC=0x10> m 1f0
    | 1f0:  00 00 00 00 00 00 00 00    | 1f8:  00 00 00 00 00 00 00 01
CPU0,PC=0x10> d
acc=0x00(0,0)    ix=0x10(16,16)   cf=0 vf=0 nf=0 zf=0
ibuf=0:0x00(0,0)    obuf=0:0x00(0,0)
CPU0,PC=0x10> i
CPU0,PC=0x0> c 10
CPU0,PC=0x10> m 1f0
    | 1f0:  00 00 00 00 00 00 00 00    | 1f8:  00 00 00 00 00 00 00 02
CPU0,PC=0x10> d
acc=0x00(0,0)    ix=0x20(32,32)   cf=0 vf=0 nf=0 zf=0
ibuf=0:0x00(0,0)    obuf=0:0x00(0,0)
CPU0,PC=0x10> i
CPU0,PC=0x0> c 10
CPU0,PC=0x10> m 1f0
    | 1f0:  00 00 00 00 00 00 00 00    | 1f8:  00 00 00 00 00 00 00 03
CPU0,PC=0x10> d
acc=0x00(0,0)    ix=0x30(48,48)   cf=0 vf=0 nf=0 zf=0
ibuf=0:0x00(0,0)    obuf=0:0x00(0,0)
CPU0,PC=0x10> i
CPU0,PC=0x0> c 10
CPU0,PC=0x10> m 1f0
    | 1f0:  00 00 00 00 00 00 00 00    | 1f8:  00 00 00 00 00 00 00 04
CPU0,PC=0x10> d
acc=0x00(0,0)    ix=0x40(64,64)   cf=0 vf=0 nf=0 zf=0
ibuf=0:0x00(0,0)    obuf=0:0x00(0,0)
CPU0,PC=0x10> i
CPU0,PC=0x0> c 10
Program Halted.
CPU0,PC=0x12> m 1f0
| 1f0:  00 00 00 00 00 00 00 00    | 1f8:  00 00 00 00 00 00 00 04
CPU0,PC=0x12> d
acc=0x00(0,0)    ix=0x00(0,0)   cf=0 vf=0 nf=0 zf=1
ibuf=0:0x00(0,0)    obuf=0:0x00(0,0)
CPU0,PC=0x12>
```

2.2 実習 8:データ通信プログラム

表 2　データ通信プログラム送信側

Address	obj	code	source	code			
00	62	03	START:	LD	03H(要素数),	ACC	03H->ACC
02	10			OUT			ACC->OBUF
03	3c	03	WAIT:	BNO	WAIT:		OBUF_FLG_IN=1?
05	6a	00		LD	01H,	IX	01H->IX
07	62	01		LD	01H,	ACC	01H->ACC
09	10			OUT			ACC->OBUF
0a	3c	0a	WAIT2:	BNO	WAIT2:		OBUF_FLG_IN=1?
0c	ba	01		ADD	IX,	01H	IX+01H->IX
0e	b2	01		ADD	ACC,	01H	ACC+01H->ACC
10	fa	03		CMP	IX,	03H	IX-03H
12	31	09		BNZ	WAIT2:		(NF v ZF) = 1
14	0f			HLT			

表 3　データ通信プログラム受信側

Address	obj	code	source	code			
00	34	00	WAIT:	BNI	WAIT:		IBUF$_F LG_I N = 0$?
02	1f			IN			IBUF->ACC
03	75	c0		ST	ACC,	mem[1C0H]	ACC->mem[1c0H]
05	6a	00		LD	00H	IX,	00H->IX
07	34	07	LOOP:	BNI	LOOP:		IBUF_FLG_IN=0?
09	1f			IN			IBUF->ACC
0a	b5	03		ADD	ACC,	mem[103H]	ACC+mem[103H]->ACC
0c	75	03		ST	ACC,	mem[103H]	ACC+mem[103H]->ACC
0e	ba	01		ADD	IX,	01H	IX+01H->IX
10	fd	c0		CMP	IX,	mem[1C0H]	IX+mem[1c0H]
12	31	07		BNZ	LOOP:		ZF=0?
14	0f			HLT			

表 2,3 にデータ通信プログラムソースコードを示す. 表 2 では要素数を即値を用いて通信相手の受け取りが確認できるまで WAIT でループ待機する.

```
CPU0,PC=0x0> r 8_out.txt
CPU0,PC=0x0> t
CPU1,PC=0x0> r 8_sum_calc.txt
CPU1,PC=0x0> i
CPU1,PC=0x0> i
CPU1,PC=0x0> t
CPU0,PC=0x0> i
```

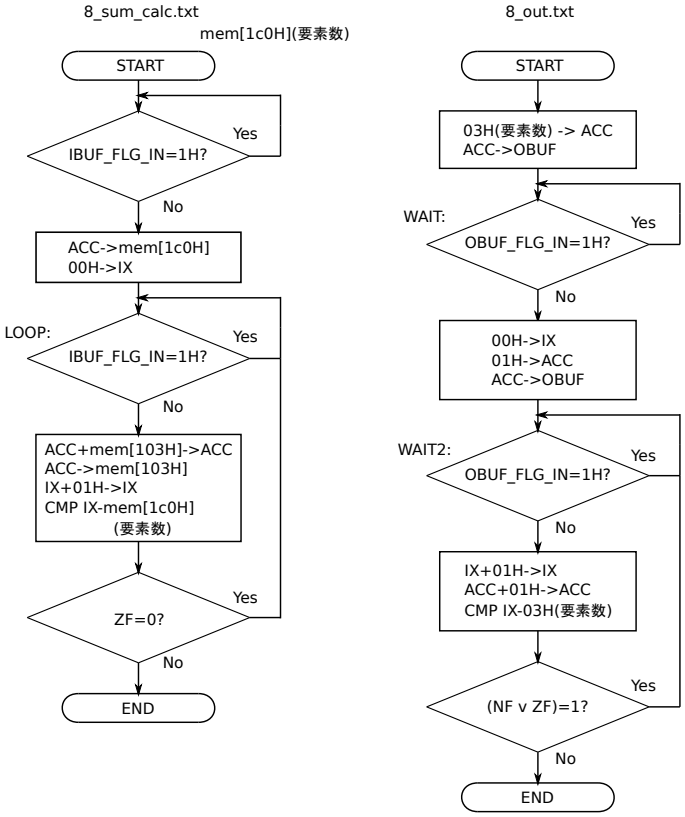

図 3　実習 8:データ通信プログラムソースコード

```
CPU0,PC=0x2> i
CPU0,PC=0x3> t
CPU1,PC=0x0> i
CPU1,PC=0x2> d
 acc=0x00(0,0)    ix=0x00(0,0)   cf=0 vf=0 nf=0 zf=0
 ibuf=1:0x03(3,3)    obuf=0:0x00(0,0)
CPU1,PC=0x2> m
    | 000:  34 00 1f 75 c0 6a 00 34    | 008:  07 1f b5 03 75 03 ba 01
    | 010:  fd c0 31 07 0f 00 00 00    | 018:  00 00 00 00 00 00 00 00
    | 020:  00 00 00 00 00 00 00 00    | 028:  00 00 00 00 00 00 00 00
    | 030:  00 00 00 00 00 00 00 00    | 038:  00 00 00 00 00 00 00 00
    | 040:  00 00 00 00 00 00 00 00    | 048:  00 00 00 00 00 00 00 00
    | 050:  00 00 00 00 00 00 00 00    | 058:  00 00 00 00 00 00 00 00
    | 060:  00 00 00 00 00 00 00 00    | 068:  00 00 00 00 00 00 00 00
    | 070:  00 00 00 00 00 00 00 00    | 078:  00 00 00 00 00 00 00 00
    | 080:  00 00 00 00 00 00 00 00    | 088:  00 00 00 00 00 00 00 00
    | 090:  00 00 00 00 00 00 00 00    | 098:  00 00 00 00 00 00 00 00
    | 0a0:  00 00 00 00 00 00 00 00    | 0a8:  00 00 00 00 00 00 00 00
    | 0b0:  00 00 00 00 00 00 00 00    | 0b8:  00 00 00 00 00 00 00 00
    | 0c0:  00 00 00 00 00 00 00 00    | 0c8:  00 00 00 00 00 00 00 00
    | 0d0:  00 00 00 00 00 00 00 00    | 0d8:  00 00 00 00 00 00 00 00
    | 0e0:  00 00 00 00 00 00 00 00    | 0e8:  00 00 00 00 00 00 00 00
    | 0f0:  00 00 00 00 00 00 00 00    | 0f8:  00 00 00 00 00 00 00 00
```

```
    | 100:  00 00 00 00 00 00 00 00    | 108:  00 00 00 00 00 00 00 00
    | 110:  00 00 00 00 00 00 00 00    | 118:  00 00 00 00 00 00 00 00
    | 120:  00 00 00 00 00 00 00 00    | 128:  00 00 00 00 00 00 00 00
    | 130:  00 00 00 00 00 00 00 00    | 138:  00 00 00 00 00 00 00 00
    | 140:  00 00 00 00 00 00 00 00    | 148:  00 00 00 00 00 00 00 00
    | 150:  00 00 00 00 00 00 00 00    | 158:  00 00 00 00 00 00 00 00
    | 160:  00 00 00 00 00 00 00 00    | 168:  00 00 00 00 00 00 00 00
    | 170:  00 00 00 00 00 00 00 00    | 178:  00 00 00 00 00 00 00 00
    | 180:  00 00 00 00 00 00 00 00    | 188:  00 00 00 00 00 00 00 00
    | 190:  00 00 00 00 00 00 00 00    | 198:  00 00 00 00 00 00 00 00
    | 1a0:  00 00 00 00 00 00 00 00    | 1a8:  00 00 00 00 00 00 00 00
    | 1b0:  00 00 00 00 00 00 00 00    | 1b8:  00 00 00 00 00 00 00 00
    | 1c0:  00 00 00 00 00 00 00 00    | 1c8:  00 00 00 00 00 00 00 00
    | 1d0:  00 00 00 00 00 00 00 00    | 1d8:  00 00 00 00 00 00 00 00
    | 1e0:  00 00 00 00 00 00 00 00    | 1e8:  00 00 00 00 00 00 00 00
    | 1f0:  00 00 00 00 00 00 00 00    | 1f8:  00 00 00 00 00 00 00 00
CPU1,PC=0x2> i
CPU1,PC=0x3> i
CPU1,PC=0x5> m
    | 000:  34 00 1f 75 c0 6a 00 34    | 008:  07 1f b5 03 75 03 ba 01
    | 010:  fd c0 31 07 0f 00 00 00    | 018:  00 00 00 00 00 00 00 00
    | 020:  00 00 00 00 00 00 00 00    | 028:  00 00 00 00 00 00 00 00
    | 030:  00 00 00 00 00 00 00 00    | 038:  00 00 00 00 00 00 00 00
    | 040:  00 00 00 00 00 00 00 00    | 048:  00 00 00 00 00 00 00 00
    | 050:  00 00 00 00 00 00 00 00    | 058:  00 00 00 00 00 00 00 00
    | 060:  00 00 00 00 00 00 00 00    | 068:  00 00 00 00 00 00 00 00
    | 070:  00 00 00 00 00 00 00 00    | 078:  00 00 00 00 00 00 00 00
    | 080:  00 00 00 00 00 00 00 00    | 088:  00 00 00 00 00 00 00 00
    | 090:  00 00 00 00 00 00 00 00    | 098:  00 00 00 00 00 00 00 00
    | 0a0:  00 00 00 00 00 00 00 00    | 0a8:  00 00 00 00 00 00 00 00
    | 0b0:  00 00 00 00 00 00 00 00    | 0b8:  00 00 00 00 00 00 00 00
    | 0c0:  00 00 00 00 00 00 00 00    | 0c8:  00 00 00 00 00 00 00 00
    | 0d0:  00 00 00 00 00 00 00 00    | 0d8:  00 00 00 00 00 00 00 00
    | 0e0:  00 00 00 00 00 00 00 00    | 0e8:  00 00 00 00 00 00 00 00
    | 0f0:  00 00 00 00 00 00 00 00    | 0f8:  00 00 00 00 00 00 00 00
    | 100:  00 00 00 00 00 00 00 00    | 108:  00 00 00 00 00 00 00 00
    | 110:  00 00 00 00 00 00 00 00    | 118:  00 00 00 00 00 00 00 00
    | 120:  00 00 00 00 00 00 00 00    | 128:  00 00 00 00 00 00 00 00
    | 130:  00 00 00 00 00 00 00 00    | 138:  00 00 00 00 00 00 00 00
    | 140:  00 00 00 00 00 00 00 00    | 148:  00 00 00 00 00 00 00 00
    | 150:  00 00 00 00 00 00 00 00    | 158:  00 00 00 00 00 00 00 00
    | 160:  00 00 00 00 00 00 00 00    | 168:  00 00 00 00 00 00 00 00
    | 170:  00 00 00 00 00 00 00 00    | 178:  00 00 00 00 00 00 00 00
    | 180:  00 00 00 00 00 00 00 00    | 188:  00 00 00 00 00 00 00 00
    | 190:  00 00 00 00 00 00 00 00    | 198:  00 00 00 00 00 00 00 00
```

```
    | 1a0:  00 00 00 00 00 00 00 00    | 1a8:  00 00 00 00 00 00 00 00
    | 1b0:  00 00 00 00 00 00 00 00    | 1b8:  00 00 00 00 00 00 00 00
    | 1c0:  03 00 00 00 00 00 00 00    | 1c8:  00 00 00 00 00 00 00 00
    | 1d0:  00 00 00 00 00 00 00 00    | 1d8:  00 00 00 00 00 00 00 00
    | 1e0:  00 00 00 00 00 00 00 00    | 1e8:  00 00 00 00 00 00 00 00
    | 1f0:  00 00 00 00 00 00 00 00    | 1f8:  00 00 00 00 00 00 00 00
CPU1,PC=0x5> i
CPU1,PC=0x7> t
CPU0,PC=0x3> i
CPU0,PC=0x5> i
CPU0,PC=0x7> i
CPU0,PC=0x9> i
CPU0,PC=0xa> i
CPU0,PC=0xa> t
CPU1,PC=0x7> i
CPU1,PC=0x9> i
CPU1,PC=0xa> i
CPU1,PC=0xc> i
CPU1,PC=0xe> i
CPU1,PC=0x10> m
    | 000:  34 00 1f 75 c0 6a 00 34    | 008:  07 1f b5 03 75 03 ba 01
    | 010:  fd c0 31 07 0f 00 00 00    | 018:  00 00 00 00 00 00 00 00
    | 020:  00 00 00 00 00 00 00 00    | 028:  00 00 00 00 00 00 00 00
    | 030:  00 00 00 00 00 00 00 00    | 038:  00 00 00 00 00 00 00 00
    | 040:  00 00 00 00 00 00 00 00    | 048:  00 00 00 00 00 00 00 00
    | 050:  00 00 00 00 00 00 00 00    | 058:  00 00 00 00 00 00 00 00
    | 060:  00 00 00 00 00 00 00 00    | 068:  00 00 00 00 00 00 00 00
    | 070:  00 00 00 00 00 00 00 00    | 078:  00 00 00 00 00 00 00 00
    | 080:  00 00 00 00 00 00 00 00    | 088:  00 00 00 00 00 00 00 00
    | 090:  00 00 00 00 00 00 00 00    | 098:  00 00 00 00 00 00 00 00
    | 0a0:  00 00 00 00 00 00 00 00    | 0a8:  00 00 00 00 00 00 00 00
    | 0b0:  00 00 00 00 00 00 00 00    | 0b8:  00 00 00 00 00 00 00 00
    | 0c0:  00 00 00 00 00 00 00 00    | 0c8:  00 00 00 00 00 00 00 00
    | 0d0:  00 00 00 00 00 00 00 00    | 0d8:  00 00 00 00 00 00 00 00
    | 0e0:  00 00 00 00 00 00 00 00    | 0e8:  00 00 00 00 00 00 00 00
    | 0f0:  00 00 00 00 00 00 00 00    | 0f8:  00 00 00 00 00 00 00 00
    | 100:  00 00 00 01 00 00 00 00    | 108:  00 00 00 00 00 00 00 00
    | 110:  00 00 00 00 00 00 00 00    | 118:  00 00 00 00 00 00 00 00
    | 120:  00 00 00 00 00 00 00 00    | 128:  00 00 00 00 00 00 00 00
    | 130:  00 00 00 00 00 00 00 00    | 138:  00 00 00 00 00 00 00 00
    | 140:  00 00 00 00 00 00 00 00    | 148:  00 00 00 00 00 00 00 00
    | 150:  00 00 00 00 00 00 00 00    | 158:  00 00 00 00 00 00 00 00
    | 160:  00 00 00 00 00 00 00 00    | 168:  00 00 00 00 00 00 00 00
    | 170:  00 00 00 00 00 00 00 00    | 178:  00 00 00 00 00 00 00 00
    | 180:  00 00 00 00 00 00 00 00    | 188:  00 00 00 00 00 00 00 00
```

```
    | 190:  00 00 00 00 00 00 00 00    | 198:  00 00 00 00 00 00 00 00
    | 1a0:  00 00 00 00 00 00 00 00    | 1a8:  00 00 00 00 00 00 00 00
    | 1b0:  00 00 00 00 00 00 00 00    | 1b8:  00 00 00 00 00 00 00 00
    | 1c0:  03 00 00 00 00 00 00 00    | 1c8:  00 00 00 00 00 00 00 00
    | 1d0:  00 00 00 00 00 00 00 00    | 1d8:  00 00 00 00 00 00 00 00
    | 1e0:  00 00 00 00 00 00 00 00    | 1e8:  00 00 00 00 00 00 00 00
    | 1f0:  00 00 00 00 00 00 00 00    | 1f8:  00 00 00 00 00 00 00 00
CPU1,PC=0x10> i
CPU1,PC=0x12> i
CPU1,PC=0x7> i
CPU1,PC=0x7> m
    | 000:  34 00 1f 75 c0 6a 00 34    | 008:  07 1f b5 03 75 03 ba 01
    | 010:  fd c0 31 07 0f 00 00 00    | 018:  00 00 00 00 00 00 00 00
    | 020:  00 00 00 00 00 00 00 00    | 028:  00 00 00 00 00 00 00 00
    | 030:  00 00 00 00 00 00 00 00    | 038:  00 00 00 00 00 00 00 00
    | 040:  00 00 00 00 00 00 00 00    | 048:  00 00 00 00 00 00 00 00
    | 050:  00 00 00 00 00 00 00 00    | 058:  00 00 00 00 00 00 00 00
    | 060:  00 00 00 00 00 00 00 00    | 068:  00 00 00 00 00 00 00 00
    | 070:  00 00 00 00 00 00 00 00    | 078:  00 00 00 00 00 00 00 00
    | 080:  00 00 00 00 00 00 00 00    | 088:  00 00 00 00 00 00 00 00
    | 090:  00 00 00 00 00 00 00 00    | 098:  00 00 00 00 00 00 00 00
    | 0a0:  00 00 00 00 00 00 00 00    | 0a8:  00 00 00 00 00 00 00 00
    | 0b0:  00 00 00 00 00 00 00 00    | 0b8:  00 00 00 00 00 00 00 00
    | 0c0:  00 00 00 00 00 00 00 00    | 0c8:  00 00 00 00 00 00 00 00
    | 0d0:  00 00 00 00 00 00 00 00    | 0d8:  00 00 00 00 00 00 00 00
    | 0e0:  00 00 00 00 00 00 00 00    | 0e8:  00 00 00 00 00 00 00 00
    | 0f0:  00 00 00 00 00 00 00 00    | 0f8:  00 00 00 00 00 00 00 00
    | 100:  00 00 00 01 00 00 00 00    | 108:  00 00 00 00 00 00 00 00
    | 110:  00 00 00 00 00 00 00 00    | 118:  00 00 00 00 00 00 00 00
    | 120:  00 00 00 00 00 00 00 00    | 128:  00 00 00 00 00 00 00 00
    | 130:  00 00 00 00 00 00 00 00    | 138:  00 00 00 00 00 00 00 00
    | 140:  00 00 00 00 00 00 00 00    | 148:  00 00 00 00 00 00 00 00
    | 150:  00 00 00 00 00 00 00 00    | 158:  00 00 00 00 00 00 00 00
    | 160:  00 00 00 00 00 00 00 00    | 168:  00 00 00 00 00 00 00 00
    | 170:  00 00 00 00 00 00 00 00    | 178:  00 00 00 00 00 00 00 00
    | 180:  00 00 00 00 00 00 00 00    | 188:  00 00 00 00 00 00 00 00
    | 190:  00 00 00 00 00 00 00 00    | 198:  00 00 00 00 00 00 00 00
    | 1a0:  00 00 00 00 00 00 00 00    | 1a8:  00 00 00 00 00 00 00 00
    | 1b0:  00 00 00 00 00 00 00 00    | 1b8:  00 00 00 00 00 00 00 00
    | 1c0:  03 00 00 00 00 00 00 00    | 1c8:  00 00 00 00 00 00 00 00
    | 1d0:  00 00 00 00 00 00 00 00    | 1d8:  00 00 00 00 00 00 00 00
    | 1e0:  00 00 00 00 00 00 00 00    | 1e8:  00 00 00 00 00 00 00 00
    | 1f0:  00 00 00 00 00 00 00 00    | 1f8:  00 00 00 00 00 00 00 00
CPU1,PC=0x7> i
CPU0,PC=0xa> i
```

```
CPU0,PC=0xc> i
CPU0,PC=0xe> i
CPU0,PC=0x10> i
CPU0,PC=0x12> i
CPU0,PC=0x9> i
CPU0,PC=0xa> i
CPU0,PC=0xa> m
    | 000:  62 03 10 3c 03 6a 00 62    | 008:  01 10 3c 0a ba 01 b2 01
    | 010:  fa 03 31 09 0f 00 00 00    | 018:  00 00 00 00 00 00 00 00
    | 020:  00 00 00 00 00 00 00 00    | 028:  00 00 00 00 00 00 00 00
    | 030:  00 00 00 00 00 00 00 00    | 038:  00 00 00 00 00 00 00 00
    | 040:  00 00 00 00 00 00 00 00    | 048:  00 00 00 00 00 00 00 00
    | 050:  00 00 00 00 00 00 00 00    | 058:  00 00 00 00 00 00 00 00
    | 060:  00 00 00 00 00 00 00 00    | 068:  00 00 00 00 00 00 00 00
    | 070:  00 00 00 00 00 00 00 00    | 078:  00 00 00 00 00 00 00 00
    | 080:  00 00 00 00 00 00 00 00    | 088:  00 00 00 00 00 00 00 00
    | 090:  00 00 00 00 00 00 00 00    | 098:  00 00 00 00 00 00 00 00
    | 0a0:  00 00 00 00 00 00 00 00    | 0a8:  00 00 00 00 00 00 00 00
    | 0b0:  00 00 00 00 00 00 00 00    | 0b8:  00 00 00 00 00 00 00 00
    | 0c0:  00 00 00 00 00 00 00 00    | 0c8:  00 00 00 00 00 00 00 00
    | 0d0:  00 00 00 00 00 00 00 00    | 0d8:  00 00 00 00 00 00 00 00
    | 0e0:  00 00 00 00 00 00 00 00    | 0e8:  00 00 00 00 00 00 00 00
    | 0f0:  00 00 00 00 00 00 00 00    | 0f8:  00 00 00 00 00 00 00 00
    | 100:  00 00 00 00 00 00 00 00    | 108:  00 00 00 00 00 00 00 00
    | 110:  00 00 00 00 00 00 00 00    | 118:  00 00 00 00 00 00 00 00
    | 120:  00 00 00 00 00 00 00 00    | 128:  00 00 00 00 00 00 00 00
    | 130:  00 00 00 00 00 00 00 00    | 138:  00 00 00 00 00 00 00 00
    | 140:  00 00 00 00 00 00 00 00    | 148:  00 00 00 00 00 00 00 00
    | 150:  00 00 00 00 00 00 00 00    | 158:  00 00 00 00 00 00 00 00
    | 160:  00 00 00 00 00 00 00 00    | 168:  00 00 00 00 00 00 00 00
    | 170:  00 00 00 00 00 00 00 00    | 178:  00 00 00 00 00 00 00 00
    | 180:  00 00 00 00 00 00 00 00    | 188:  00 00 00 00 00 00 00 00
    | 190:  00 00 00 00 00 00 00 00    | 198:  00 00 00 00 00 00 00 00
    | 1a0:  00 00 00 00 00 00 00 00    | 1a8:  00 00 00 00 00 00 00 00
    | 1b0:  00 00 00 00 00 00 00 00    | 1b8:  00 00 00 00 00 00 00 00
    | 1c0:  00 00 00 00 00 00 00 00    | 1c8:  00 00 00 00 00 00 00 00
    | 1d0:  00 00 00 00 00 00 00 00    | 1d8:  00 00 00 00 00 00 00 00
    | 1e0:  00 00 00 00 00 00 00 00    | 1e8:  00 00 00 00 00 00 00 00
    | 1f0:  00 00 00 00 00 00 00 00    | 1f8:  00 00 00 00 00 00 00 00
CPU0,PC=0xa> i
CPU1,PC=0x7> i
CPU1,PC=0x9> i
CPU1,PC=0xa> i
CPU1,PC=0xc> m
    | 000:  34 00 1f 75 c0 6a 00 34    | 008:  07 1f b5 03 75 03 ba 01
```

```
    | 010:  fd c0 31 07 0f 00 00 00    | 018:  00 00 00 00 00 00 00 00
    | 020:  00 00 00 00 00 00 00 00    | 028:  00 00 00 00 00 00 00 00
    | 030:  00 00 00 00 00 00 00 00    | 038:  00 00 00 00 00 00 00 00
    | 040:  00 00 00 00 00 00 00 00    | 048:  00 00 00 00 00 00 00 00
    | 050:  00 00 00 00 00 00 00 00    | 058:  00 00 00 00 00 00 00 00
    | 060:  00 00 00 00 00 00 00 00    | 068:  00 00 00 00 00 00 00 00
    | 070:  00 00 00 00 00 00 00 00    | 078:  00 00 00 00 00 00 00 00
    | 080:  00 00 00 00 00 00 00 00    | 088:  00 00 00 00 00 00 00 00
    | 090:  00 00 00 00 00 00 00 00    | 098:  00 00 00 00 00 00 00 00
    | 0a0:  00 00 00 00 00 00 00 00    | 0a8:  00 00 00 00 00 00 00 00
    | 0b0:  00 00 00 00 00 00 00 00    | 0b8:  00 00 00 00 00 00 00 00
    | 0c0:  00 00 00 00 00 00 00 00    | 0c8:  00 00 00 00 00 00 00 00
    | 0d0:  00 00 00 00 00 00 00 00    | 0d8:  00 00 00 00 00 00 00 00
    | 0e0:  00 00 00 00 00 00 00 00    | 0e8:  00 00 00 00 00 00 00 00
    | 0f0:  00 00 00 00 00 00 00 00    | 0f8:  00 00 00 00 00 00 00 00
    | 100:  00 00 00 01 00 00 00 00    | 108:  00 00 00 00 00 00 00 00
    | 110:  00 00 00 00 00 00 00 00    | 118:  00 00 00 00 00 00 00 00
    | 120:  00 00 00 00 00 00 00 00    | 128:  00 00 00 00 00 00 00 00
    | 130:  00 00 00 00 00 00 00 00    | 138:  00 00 00 00 00 00 00 00
    | 140:  00 00 00 00 00 00 00 00    | 148:  00 00 00 00 00 00 00 00
    | 150:  00 00 00 00 00 00 00 00    | 158:  00 00 00 00 00 00 00 00
    | 160:  00 00 00 00 00 00 00 00    | 168:  00 00 00 00 00 00 00 00
    | 170:  00 00 00 00 00 00 00 00    | 178:  00 00 00 00 00 00 00 00
    | 180:  00 00 00 00 00 00 00 00    | 188:  00 00 00 00 00 00 00 00
    | 190:  00 00 00 00 00 00 00 00    | 198:  00 00 00 00 00 00 00 00
    | 1a0:  00 00 00 00 00 00 00 00    | 1a8:  00 00 00 00 00 00 00 00
    | 1b0:  00 00 00 00 00 00 00 00    | 1b8:  00 00 00 00 00 00 00 00
    | 1c0:  03 00 00 00 00 00 00 00    | 1c8:  00 00 00 00 00 00 00 00
    | 1d0:  00 00 00 00 00 00 00 00    | 1d8:  00 00 00 00 00 00 00 00
    | 1e0:  00 00 00 00 00 00 00 00    | 1e8:  00 00 00 00 00 00 00 00
    | 1f0:  00 00 00 00 00 00 00 00    | 1f8:  00 00 00 00 00 00 00 00
CPU1,PC=0xc> i
CPU1,PC=0xe> i
CPU1,PC=0x10> i
CPU1,PC=0x12> i
CPU1,PC=0x7> i
CPU1,PC=0x7> m
    | 000:  34 00 1f 75 c0 6a 00 34    | 008:  07 1f b5 03 75 03 ba 01
    | 010:  fd c0 31 07 0f 00 00 00    | 018:  00 00 00 00 00 00 00 00
    | 020:  00 00 00 00 00 00 00 00    | 028:  00 00 00 00 00 00 00 00
    | 030:  00 00 00 00 00 00 00 00    | 038:  00 00 00 00 00 00 00 00
    | 040:  00 00 00 00 00 00 00 00    | 048:  00 00 00 00 00 00 00 00
    | 050:  00 00 00 00 00 00 00 00    | 058:  00 00 00 00 00 00 00 00
    | 060:  00 00 00 00 00 00 00 00    | 068:  00 00 00 00 00 00 00 00
    | 070:  00 00 00 00 00 00 00 00    | 078:  00 00 00 00 00 00 00 00
```

```
    | 080:  00 00 00 00 00 00 00 00    | 088:  00 00 00 00 00 00 00 00
    | 090:  00 00 00 00 00 00 00 00    | 098:  00 00 00 00 00 00 00 00
    | 0a0:  00 00 00 00 00 00 00 00    | 0a8:  00 00 00 00 00 00 00 00
    | 0b0:  00 00 00 00 00 00 00 00    | 0b8:  00 00 00 00 00 00 00 00
    | 0c0:  00 00 00 00 00 00 00 00    | 0c8:  00 00 00 00 00 00 00 00
    | 0d0:  00 00 00 00 00 00 00 00    | 0d8:  00 00 00 00 00 00 00 00
    | 0e0:  00 00 00 00 00 00 00 00    | 0e8:  00 00 00 00 00 00 00 00
    | 0f0:  00 00 00 00 00 00 00 00    | 0f8:  00 00 00 00 00 00 00 00
    | 100:  00 00 00 03 00 00 00 00    | 108:  00 00 00 00 00 00 00 00
    | 110:  00 00 00 00 00 00 00 00    | 118:  00 00 00 00 00 00 00 00
    | 120:  00 00 00 00 00 00 00 00    | 128:  00 00 00 00 00 00 00 00
    | 130:  00 00 00 00 00 00 00 00    | 138:  00 00 00 00 00 00 00 00
    | 140:  00 00 00 00 00 00 00 00    | 148:  00 00 00 00 00 00 00 00
    | 150:  00 00 00 00 00 00 00 00    | 158:  00 00 00 00 00 00 00 00
    | 160:  00 00 00 00 00 00 00 00    | 168:  00 00 00 00 00 00 00 00
    | 170:  00 00 00 00 00 00 00 00    | 178:  00 00 00 00 00 00 00 00
    | 180:  00 00 00 00 00 00 00 00    | 188:  00 00 00 00 00 00 00 00
    | 190:  00 00 00 00 00 00 00 00    | 198:  00 00 00 00 00 00 00 00
    | 1a0:  00 00 00 00 00 00 00 00    | 1a8:  00 00 00 00 00 00 00 00
    | 1b0:  00 00 00 00 00 00 00 00    | 1b8:  00 00 00 00 00 00 00 00
    | 1c0:  03 00 00 00 00 00 00 00    | 1c8:  00 00 00 00 00 00 00 00
    | 1d0:  00 00 00 00 00 00 00 00    | 1d8:  00 00 00 00 00 00 00 00
    | 1e0:  00 00 00 00 00 00 00 00    | 1e8:  00 00 00 00 00 00 00 00
    | 1f0:  00 00 00 00 00 00 00 00    | 1f8:  00 00 00 00 00 00 00 00
CPU1,PC=0x7> t
CPU0,PC=0xa> i
CPU0,PC=0xc> i
CPU0,PC=0xe> i
CPU0,PC=0x10> i
CPU0,PC=0x12> i
CPU0,PC=0x9> i
CPU0,PC=0xa> i
CPU0,PC=0xa> t
CPU1,PC=0x7> t
CPU0,PC=0xa> m
    | 000:  62 03 10 3c 03 6a 00 62    | 008:  01 10 3c 0a ba 01 b2 01
    | 010:  fa 03 31 09 0f 00 00 00    | 018:  00 00 00 00 00 00 00 00
    | 020:  00 00 00 00 00 00 00 00    | 028:  00 00 00 00 00 00 00 00
    | 030:  00 00 00 00 00 00 00 00    | 038:  00 00 00 00 00 00 00 00
    | 040:  00 00 00 00 00 00 00 00    | 048:  00 00 00 00 00 00 00 00
    | 050:  00 00 00 00 00 00 00 00    | 058:  00 00 00 00 00 00 00 00
    | 060:  00 00 00 00 00 00 00 00    | 068:  00 00 00 00 00 00 00 00
    | 070:  00 00 00 00 00 00 00 00    | 078:  00 00 00 00 00 00 00 00
    | 080:  00 00 00 00 00 00 00 00    | 088:  00 00 00 00 00 00 00 00
    | 090:  00 00 00 00 00 00 00 00    | 098:  00 00 00 00 00 00 00 00
```

```
    | 0a0:  00 00 00 00 00 00 00 00    | 0a8:  00 00 00 00 00 00 00 00
    | 0b0:  00 00 00 00 00 00 00 00    | 0b8:  00 00 00 00 00 00 00 00
    | 0c0:  00 00 00 00 00 00 00 00    | 0c8:  00 00 00 00 00 00 00 00
    | 0d0:  00 00 00 00 00 00 00 00    | 0d8:  00 00 00 00 00 00 00 00
    | 0e0:  00 00 00 00 00 00 00 00    | 0e8:  00 00 00 00 00 00 00 00
    | 0f0:  00 00 00 00 00 00 00 00    | 0f8:  00 00 00 00 00 00 00 00
    | 100:  00 00 00 00 00 00 00 00    | 108:  00 00 00 00 00 00 00 00
    | 110:  00 00 00 00 00 00 00 00    | 118:  00 00 00 00 00 00 00 00
    | 120:  00 00 00 00 00 00 00 00    | 128:  00 00 00 00 00 00 00 00
    | 130:  00 00 00 00 00 00 00 00    | 138:  00 00 00 00 00 00 00 00
    | 140:  00 00 00 00 00 00 00 00    | 148:  00 00 00 00 00 00 00 00
    | 150:  00 00 00 00 00 00 00 00    | 158:  00 00 00 00 00 00 00 00
    | 160:  00 00 00 00 00 00 00 00    | 168:  00 00 00 00 00 00 00 00
    | 170:  00 00 00 00 00 00 00 00    | 178:  00 00 00 00 00 00 00 00
    | 180:  00 00 00 00 00 00 00 00    | 188:  00 00 00 00 00 00 00 00
    | 190:  00 00 00 00 00 00 00 00    | 198:  00 00 00 00 00 00 00 00
    | 1a0:  00 00 00 00 00 00 00 00    | 1a8:  00 00 00 00 00 00 00 00
    | 1b0:  00 00 00 00 00 00 00 00    | 1b8:  00 00 00 00 00 00 00 00
    | 1c0:  00 00 00 00 00 00 00 00    | 1c8:  00 00 00 00 00 00 00 00
    | 1d0:  00 00 00 00 00 00 00 00    | 1d8:  00 00 00 00 00 00 00 00
    | 1e0:  00 00 00 00 00 00 00 00    | 1e8:  00 00 00 00 00 00 00 00
    | 1f0:  00 00 00 00 00 00 00 00    | 1f8:  00 00 00 00 00 00 00 00
CPU0,PC=0xa> t
CPU1,PC=0x7> i
CPU1,PC=0x9> i
CPU1,PC=0xa> i
CPU1,PC=0xc> i
CPU1,PC=0xe> i
CPU1,PC=0x10> i
CPU1,PC=0x12> i
CPU1,PC=0x14> i
Program Halted.
CPU1,PC=0x15> m
    | 000:  34 00 1f 75 c0 6a 00 34    | 008:  07 1f b5 03 75 03 ba 01
    | 010:  fd c0 31 07 0f 00 00 00    | 018:  00 00 00 00 00 00 00 00
    | 020:  00 00 00 00 00 00 00 00    | 028:  00 00 00 00 00 00 00 00
    | 030:  00 00 00 00 00 00 00 00    | 038:  00 00 00 00 00 00 00 00
    | 040:  00 00 00 00 00 00 00 00    | 048:  00 00 00 00 00 00 00 00
    | 050:  00 00 00 00 00 00 00 00    | 058:  00 00 00 00 00 00 00 00
    | 060:  00 00 00 00 00 00 00 00    | 068:  00 00 00 00 00 00 00 00
    | 070:  00 00 00 00 00 00 00 00    | 078:  00 00 00 00 00 00 00 00
    | 080:  00 00 00 00 00 00 00 00    | 088:  00 00 00 00 00 00 00 00
    | 090:  00 00 00 00 00 00 00 00    | 098:  00 00 00 00 00 00 00 00
    | 0a0:  00 00 00 00 00 00 00 00    | 0a8:  00 00 00 00 00 00 00 00
    | 0b0:  00 00 00 00 00 00 00 00    | 0b8:  00 00 00 00 00 00 00 00
```

```
    | 0c0:  00 00 00 00 00 00 00 00    | 0c8:  00 00 00 00 00 00 00 00
    | 0d0:  00 00 00 00 00 00 00 00    | 0d8:  00 00 00 00 00 00 00 00
    | 0e0:  00 00 00 00 00 00 00 00    | 0e8:  00 00 00 00 00 00 00 00
    | 0f0:  00 00 00 00 00 00 00 00    | 0f8:  00 00 00 00 00 00 00 00
    | 100:  00 00 00 06 00 00 00 00    | 108:  00 00 00 00 00 00 00 00
    | 110:  00 00 00 00 00 00 00 00    | 118:  00 00 00 00 00 00 00 00
    | 120:  00 00 00 00 00 00 00 00    | 128:  00 00 00 00 00 00 00 00
    | 130:  00 00 00 00 00 00 00 00    | 138:  00 00 00 00 00 00 00 00
    | 140:  00 00 00 00 00 00 00 00    | 148:  00 00 00 00 00 00 00 00
    | 150:  00 00 00 00 00 00 00 00    | 158:  00 00 00 00 00 00 00 00
    | 160:  00 00 00 00 00 00 00 00    | 168:  00 00 00 00 00 00 00 00
    | 170:  00 00 00 00 00 00 00 00    | 178:  00 00 00 00 00 00 00 00
    | 180:  00 00 00 00 00 00 00 00    | 188:  00 00 00 00 00 00 00 00
    | 190:  00 00 00 00 00 00 00 00    | 198:  00 00 00 00 00 00 00 00
    | 1a0:  00 00 00 00 00 00 00 00    | 1a8:  00 00 00 00 00 00 00 00
    | 1b0:  00 00 00 00 00 00 00 00    | 1b8:  00 00 00 00 00 00 00 00
    | 1c0:  03 00 00 00 00 00 00 00    | 1c8:  00 00 00 00 00 00 00 00
    | 1d0:  00 00 00 00 00 00 00 00    | 1d8:  00 00 00 00 00 00 00 00
    | 1e0:  00 00 00 00 00 00 00 00    | 1e8:  00 00 00 00 00 00 00 00
    | 1f0:  00 00 00 00 00 00 00 00    | 1f8:  00 00 00 00 00 00 00 00
CPU1,PC=0x15>
```

3 演習

3.1 演習 4

教育用 CPU ボードでも JR,JAL 命令を用いなくてもサブルーチンを実現することは可能だと考える. 理由としては関数に飛ぶ際にフラグ用のメモリを用意し関数 (サブルーチン) を用いる際は 1 にして条件 Branch 命令を用いて関数の動作内容が記述されている部分に PC を変更する. 事前に戻る位置の PC はどこかのメモリに記録しておき, 戻る前にフラグ用のメモリを 0 へ戻して Branch 命令を用い戻るいちを記録したメモリを参照し PC を変更させることにより実現できると考えた.

4 考察

cpu シミュレータ作成実習を通して, 各マシン命令を作成することによってフェーズ毎の動作を知ることができた. メモリを意識しながらプログラムを行うことによって C 言語のポインタに対する考えが深まった. 普段 python や c 言語などを用いるためマシン語でコーディングする際に理解しにくくミスが増えプログラミングの効率が悪く時間も多くかかってしまった, 現在利用されている言語は人間が用いる言葉に近い形で記述することができより良い形に使用される言語も変化しているのだと感じられた.

参考文献

[1] CPU 実習テキスト
[2] 教育用 CPU ボードのマニュアル