# tomasulo动态调度算法模拟

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# 一、 实验目的

理解指令动态调度的原理，尤其是tomasulo动态调度算法的执行过程。

# 二、 实验环境

使用软件：Visual Studio 2019

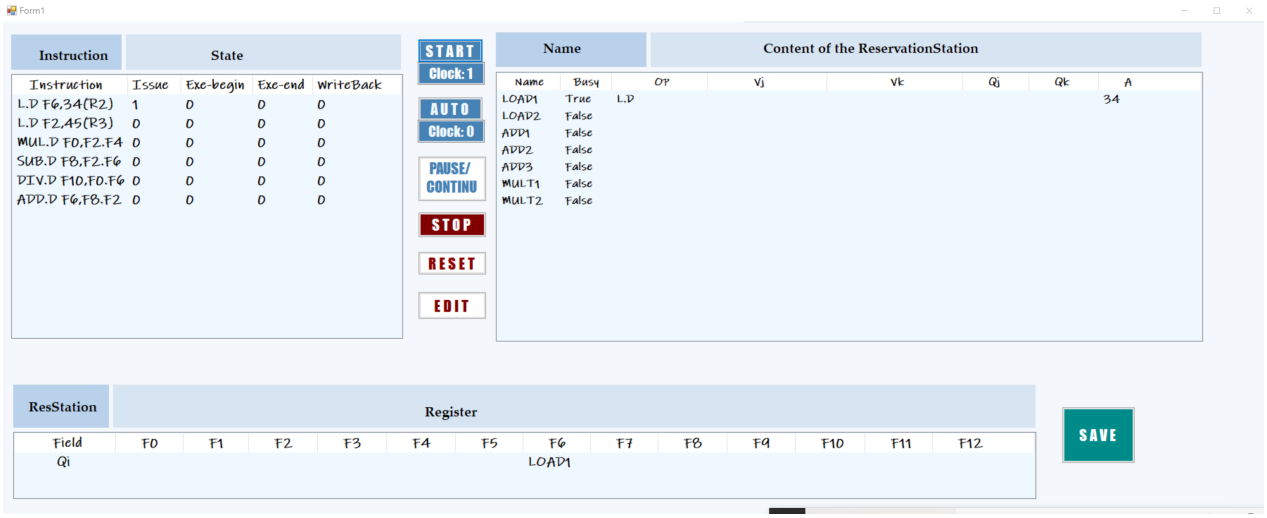
程序类型：Winform窗体应用

使用语言：C#

# 三、功能实现的说明

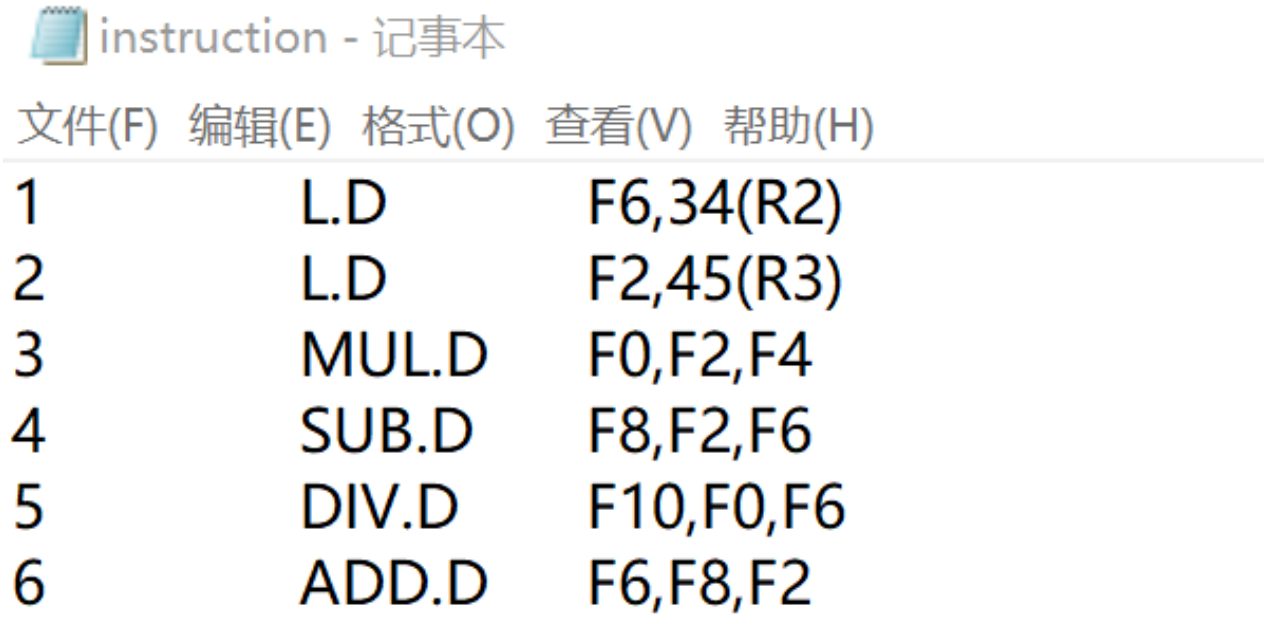
## 1.显示界面+读取

显示当前时钟、 指令状态表、保留站信息表和寄存器状态表




指令是从read_from_file()函数中，从instruction.txt文件中读入，若需要运行可执行文件，需要更改文件路径。

### （1）文件内容




### （2）思路以及源代码

直接触发，按行读取指令形成string，因为split函数不知为何在本电脑上出现问题，故选择采用最基础的判断分割方法。解析每行string，为每条指令的每个变量赋值。同时，load函数与非load函数分开讨论。

```
private void read_from_file()
        {
            int mark = 0;
            System.IO.StreamReader file = new
System.IO.StreamReader(@"\\Mac\Home\Desktop\instruction.txt");
            while ((line = file.ReadLine()) != null)
            {
                mark = 0;
                int flag = 0;
                Instruction I0 = new Instruction();
                for (int i = 0; i < line.Length-1; i++)
                {
                    if (flag == 0)
                    {
                        mark += line[i] - 48;
                        if (line[i + 1] == ' '|| line[i + 1] == '\t') flag =
1;
                        else mark = mark * 10;
                    }
                    else if (flag == 1&&line[i]!=' '&&line[i]!='\t')
                    {
                        I0.name += line[i];
                        if (line[i + 1] == ' ' || line[i + 1] == '\t')
```

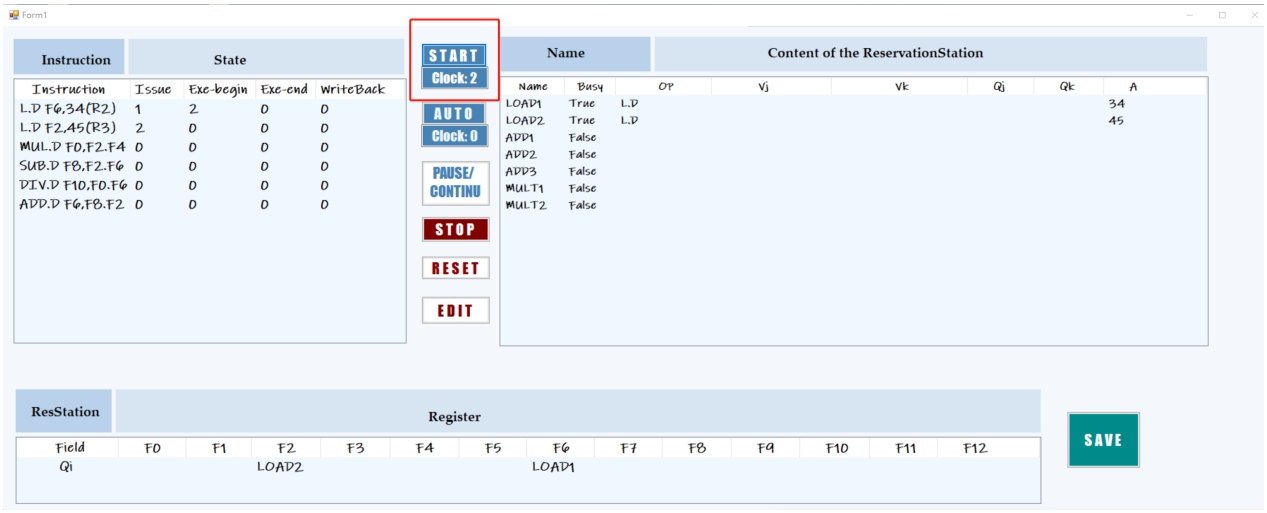
```
                    {
                        switch (I0.name)
                        {
                            case "ADD.D":
                                I0.op = AddOp;
                                break;
                            case "SUB.D":
                                I0.op = SubOp;
                                break;
                            case "MUL.D":
                                I0.op = MultOp;
                                break;
                            case "DIV.D":
                                I0.op = DivOp;
                                break;
                            case "L.D":
                                I0.op = LoadOp;
                                break;
                        }
                        flag = 2;
                        I0.name += " ";

                    }
                }
                else if (flag == 2 && line[i] != ' ' && line[i] != '\t'){
                    if (I0.name == "L.D ")
                    {
                        if (flag == 2 && char.IsDigit(line[i]))
                        {
                            I0.rd += line[i] - 48;
                            if (line[i + 1] != ',') I0.rd = I0.rd * 10;
                            else flag = 3;
                        }
                    }
                    else if (flag == 2 && char.IsDigit(line[i]))
                    {
                        I0.rd += line[i] - 48;
                        if (line[i + 1] != ',') I0.rd = I0.rd * 10;
                        else flag = 3;
                    }
                }
                else if (flag == 3 && char.IsDigit(line[i]))
                {
                    if(I0.name == "L.D ")
                    {
                        I0.imm += line[i] - 48;
                        if (line[i + 1] != '(') I0.imm = I0.imm * 10;
                        else flag = 4;
                    }
```

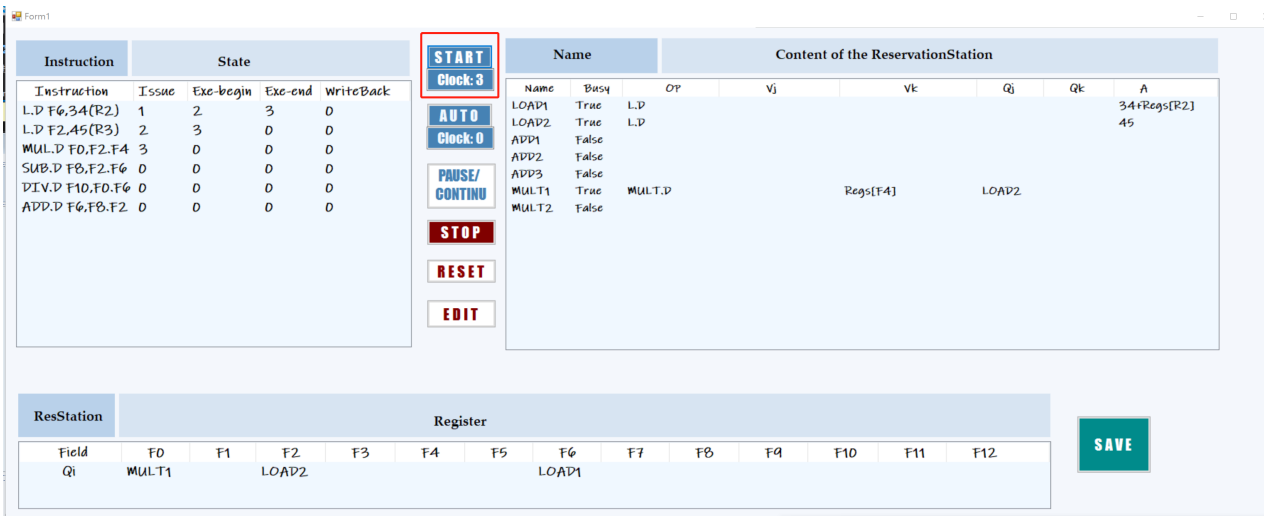
```
                    else
                    {
                        I0.rs += line[i] - 48;
                        if (line[i + 1] != ',') I0.rs = I0.rs * 10;
                        else flag = 4;
                    }
                }
                else if (flag == 4)
                {
                    if (I0.name == "L.D ")
                    {
                        if (char.IsDigit(line[i]))
                        {
                            I0.rs += line[i] - 48;
                            if (line[i + 1] != ')') I0.rs = I0.rs * 10;
                            else
                            {
                                flag = 5;
                                break;
                            }
                        }
                    }
                    else
                    {

                        if (i + 1 == line.Length - 1)
                        {
                            if (char.IsDigit(line[i]))
                            {
                                I0.rt += line[i] - 48;
                                I0.rt = I0.rt * 10;
                                I0.rt += line[i + 1] - 48;
                                break;
                            }
                            else I0.rt = line[i + 1] - 48;
                        }
                        else continue;
                    }
                }
                Inst[mark - 1] = I0;
            }
        }
        Inst_size = mark;
    }
```

## 2.START键——单步

从运行开始，用户每按一下"**START**"键，当前时钟增加1，更新四个表。

## （1）界面展示




## （2）思路以及源代码

通过Start按钮触发，每次执行RunOneCycle()函数，其可以**完成这个时钟周期的 指令流出、执行与写入操作**、并**更新四个表**（时钟表、指令状态表、保留站状态表、寄存器状态表），故完成更新。

```
        private void Button1_Click(object sender, EventArgs e)
        {
            Clock++;
            RunOneCycle();
            Update_Clock_Board();
        }

        private void RunOneCycle()
        {
          //完成这个时钟周期的 指令流出、执行与写入操作
            ISSUE(Inst, ResStation, RegisterStatus);
            EXECUTE(Inst, ResStation, RegisterStatus);
            WRITEBACK(Inst, ResStation, RegisterStatus);
            Done = false;
```

```
            if (Total_WRITEBACKS == Inst_size)
                Done = true;
            //更新四个表
            Update_Instruction_Board();
            Update_ReservationStation_Board();
            Update_Register_Board();
            //具体代码随实验报告附上
        }
```

**a.对于issue函数**

- 判断是否有空闲保留站

  已有ResStation[]数组，遍历数组判断是否有空闲保留站。通过Num_LOAD_RS、Num_ADD_RS、Num_MULT_RS在遍历时区分不同的保留站。

```
            int RsLoadStart = Num_LOAD_RS - Num_LOAD_RS;
            int RsLoadEnd = Num_LOAD_RS;
            int RSAddStart = Num_LOAD_RS;
            int RSAddEnd = Num_LOAD_RS + Num_ADD_RS;
            int RSSubStart = Num_LOAD_RS;
            int RSSubEnd = Num_LOAD_RS + Num_ADD_RS;
            int RSMulStart = Num_LOAD_RS + Num_ADD_RS;
            int RSMulEnd =  Num_LOAD_RS + Num_ADD_RS + Num_MULT_RS;
            switch (r)
            {
                case LoadOp:
                    for(int i = RsLoadStart; i < RsLoadEnd; i++)
                    {
                        if (!RESSTATION[i].busy)
                        {
                            r = i;
                            currentInst_ISSUE++;
                            RESSTATION[i].op = LoadOp;
                            rsFree = true;
                            break;
                        }
                    }
                    if (!rsFree)
                        return 1;
                    break;
                case AddOp:
                    for (int i = RSAddStart; i < RSAddEnd; i++)
                    {
                        if (!RESSTATION[i].busy)
                        {
                            r = i;
                            currentInst_ISSUE++;
```

```
                        RESSTATION[i].op = AddOp;
                        rsFree = true;
                        break;
                    }
                }
                //......MultOp/DivOp类似
```

- 若保留站空闲，则将信息更新入保留站
  - 将load和其他指令分开讨论部分
  - 对于非load指令

  Vj和Qj不可兼得，故分别讨论指令所需操作数是否准备好，若准备好

```
if (REGSTATUS[INST[currentInst_ISSUE - 1].rs].Qi == RegStatusEmpty)
```

  则更新Vj，将Qj设为OperandAvailable

```
RESSTATION[r].Vj += "Regs[F" + INST[currentInst_ISSUE - 1].rs + "]";
RESSTATION[r].Qj = OperandAvailable;
```

  否则将即将产生此操作数的保留站记录在 RESSTATION[r].Qj中，该过程由寄存器状态表（REGSTATUS[]）为媒介完成

```
RESSTATION[r].Qj = REGSTATUS[INST[currentInst_ISSUE - 1].rs].Qi;
```

  Vk、Qk同理

  - 对于load指令

  将A部分的值更改为指令中的立即数字段

```
RESSTATION[r].A += INST[currentInst_ISSUE - 1].imm.ToString() ;
```

  - 相同执行部分
    - 将保留站状态更新为true

```
RESSTATION[r].busy = true;
```

    - 将保留站此刻的指令记录下来

```
RESSTATION[r].instNum = currentInst_ISSUE - 1;
```

    - 记录下此刻的issueClock，之后可以显示在指令状态表上

```
INST[currentInst_ISSUE - 1].issueClock = Clock;
```

    - 更新寄存器状态表实现后续换名

```
REGSTATUS[INST[currentInst_ISSUE - 1].rd].Qi = r;
```

- 保证issue执行一个时钟周期

  即issue部分执行的代码在这个周期流入，至少得在下一个周期流出。因为代码书写时为

```
issue();
execute();
writeback();
```

  出现了不可避免却不存在的先后顺序。若缺少这一个变量则可能出现，issue部分使该指令流入保留站，下一行的代码execute()便使它在同一周期开始执行的错误情形。

```
 // reset ISSUE latency for RS
RESSTATION[r].ISSUE_Lat = 0;
```

**b.对于execute函数**

遍历保留站列表（RESSTATION[]）

- 非load指令经过三个判断后可执行，load指令经过两个判断后可执行
  - 判断是否有空闲

```
    if (RESSTATION[r].busy == true)
```

  - 保证issue执行一个时钟周期

```
if (RESSTATION[r].ISSUE_Lat >= ISSUE_Lat)
```

  - 非（load指令）是否两个操作数均已准备好

```
if ((RESSTATION[r].Qj == OperandAvailable &&
RESSTATION[r].Qk == OperandAvailable)||(RESSTATION[r].op == LoadOp))
```

- 开始执行
  - 记录executeBegin时钟

```
if (INST[RESSTATION[r].instNum].executeClockBegin == 0)
{
  INST[RESSTATION[r].instNum].executeClockBegin = Clock;
}
```

  - 判断是否达到该指令的延迟时间

```
RESSTATION[r].lat++;
```

- 达到后进行一系列操作

  其中，比较奇怪的

```
Register_Memory[INST[RESSTATION[r].instNum].rd] = "000";
```

是专门为寄存器内容来自存储器的寄存器设计，和后续代码有关。为了展现出Mem[34+Reg[R3]]的效果

```
switch (RESSTATION[r].op)
{
    case (AddOp):
     if (RESSTATION[r].lat == ADD_Lat)
     {
         //RESSTATION[r].result = RESSTATION[r].Vj + RESSTATION[r].Vk;
         // Result is ready to be writenback
         RESSTATION[r].resultReady = true;
         RESSTATION[r].lat = 0;
         // Set clock cycle when execution ends
         INST[RESSTATION[r].instNum].executeClockEnd = Clock;
         // reset ISSUE latency for RS
          RESSTATION[r].ISSUE_Lat = 0;
          Register_Memory[INST[RESSTATION[r].instNum].rd] = "000";
          //专门为寄存器内容来自存储器的寄存器设计，和后续代码有关。为了展现出Mem[34+Reg[R3]]的效果
      }
      ........//SubOp、MultOp、DivOp类似
     case (LoadOp):
       if (RESSTATION[r].lat == LOAD_Lat)
       {
            RESSTATION[r].resultReady = true;
            RESSTATION[r].lat = 0;
             // Set clock cycle when execution ends
            INST[RESSTATION[r].instNum].executeClockEnd = Clock;
            RESSTATION[r].A = INST[RESSTATION[r].instNum].imm.ToString() + "+Regs[R" + INST[RESSTATION[r].instNum].rs + "]";
 //专门为寄存器内容来自存储器的寄存器设计，和后续代码有关。为了展现出Mem[34+Reg[R3]]的效果
            Register_Memory[INST[RESSTATION[r].instNum].rd] = "Mem[" + RESSTATION[r].A + "]";

             // reset ISSUE latency for RS
             RESSTATION[r].ISSUE_Lat = 0;
         }
       break;
```

```
.....
```

**c.对于writeback函数**

部分判断、操作与Execute函数类似

- 遍历RegisterStatus[]，若某寄存器的Qi等于正在操作的保留站，则赋值

```
if (REGSTATUS[x].Qi == r)
{
     // Write back to Registers
     //REG[x] = RESSTATION[r].result;
      REGSTATUS[x].Qi = RegStatusEmpty;
}
```

- 通过CDB，在保留站状态表上，将等待该保留站产生结果的所有保留站名字换名为Reg[]形式，从而达成更新状态表的目的

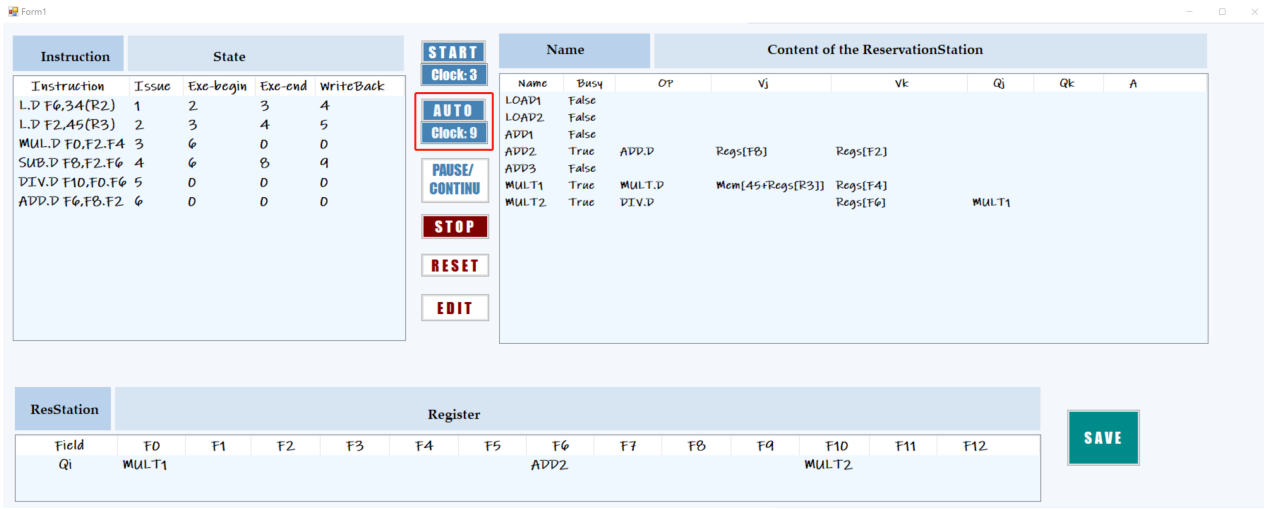
```
 for (int y = 0; y < ResStation_size; y++)
{
                            // check if any reservation stations are
                            // waiting for the given result as an operand
                            // Write back to reservation stations
                            // Given RS is not longer waiting for this
                            // operand value
    if (RESSTATION[y].Qj == r)
    {
        if (Register_Memory[INST[RESSTATION[r].instNum].rd] != "000")
RESSTATION[y].Vj = Register_Memory[INST[RESSTATION[r].instNum].rd];
        else RESSTATION[y].Vj = "Regs[F" + Inst[RESSTATION[r].instNum].rd +
"]";
        RESSTATION[y].Qj = OperandAvailable;
     }
   //....Qk同理
```

# 3.AUTO键——自动运行

## （1）自动运行

模拟程序按照每秒当前时钟增加1，并同步更新系统状态。

**a.界面展示**




**b.思路以及源代码**

通过pause_or_continue参数控制是否继续自动执行。

通过

```
System.Threading.Thread.Sleep(1000);
```

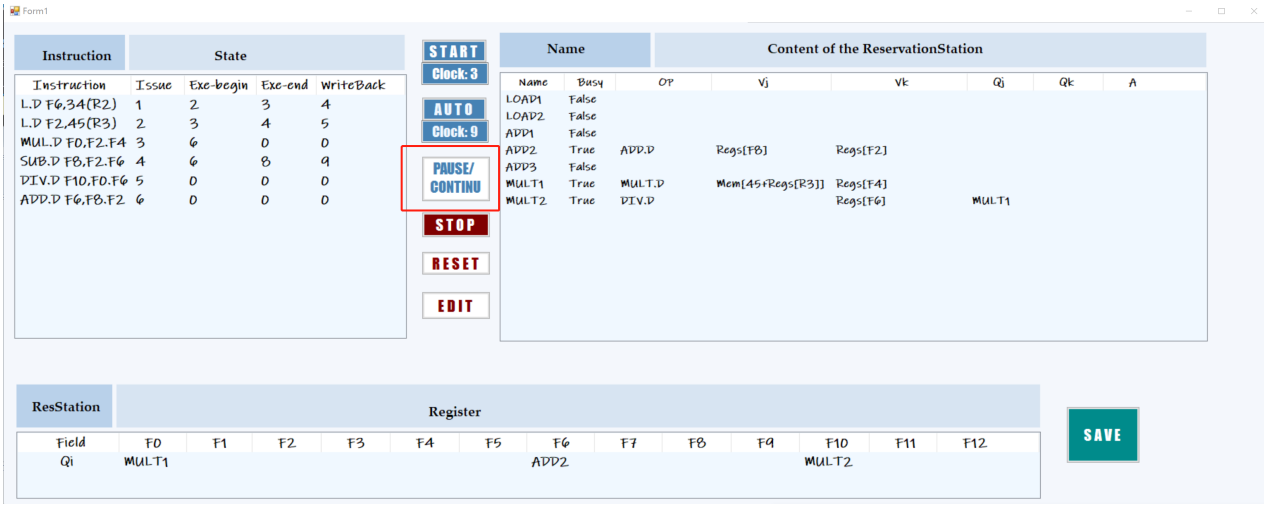
保证程序间隔一段时间自动执行一次

```
        //auto
        private void Button2_Click(object sender, EventArgs e)
        {
            run = true;
            while (run)
            {
                if (!pause_or_continue) break;
                //缺少一个执行完毕可以停下来
                // if (instructionUnit.GetCurrentInstructions().Length == 0)
break;
                //如果每个保留站都是空的，则完成
                System.Threading.Thread.Sleep(1000);
                Clock++;
                RunOneCycle();
                Update_Clock_Board1();
                //TODO:每个保留站检查是否清空
                Application.DoEvents();
                if (IsAllBufferFree()) break;
            }
        }
```

## （2）PAUSE/CONTINUE键——暂停或重新开始

为保证自动运行可操控性，增加暂停键以及重新开始键（可能有些不灵敏）。按下后程序可暂停或重新开始。

**a.界面展示**




**b.思路以及源代码**

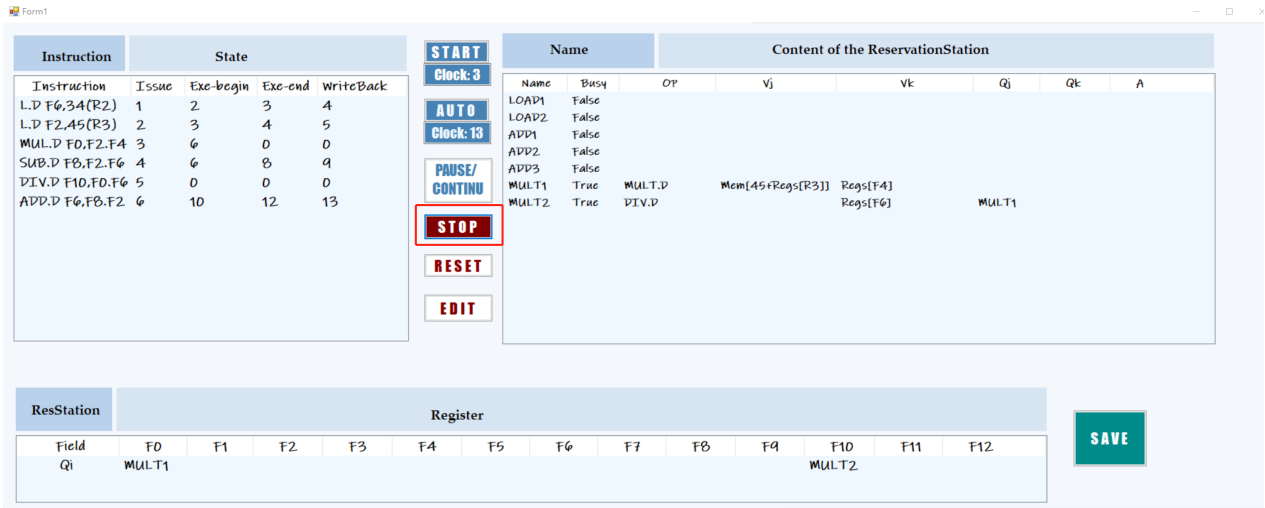
如上文所述，通过pause_or_continue参数控制是否继续自动执行。

```
        //pause
    private void Button4_Click(object sender, EventArgs e)
        {
            pause_or_continue = !pause_or_continue;
            Button2_Click(sender, e); //auto的代码
        }
```

## （3）STOP键——停止

为保证自动运行可操控性，增加停止键（可能有些不灵敏）。按下后程序停止，可退出运行。

**a.界面展示**



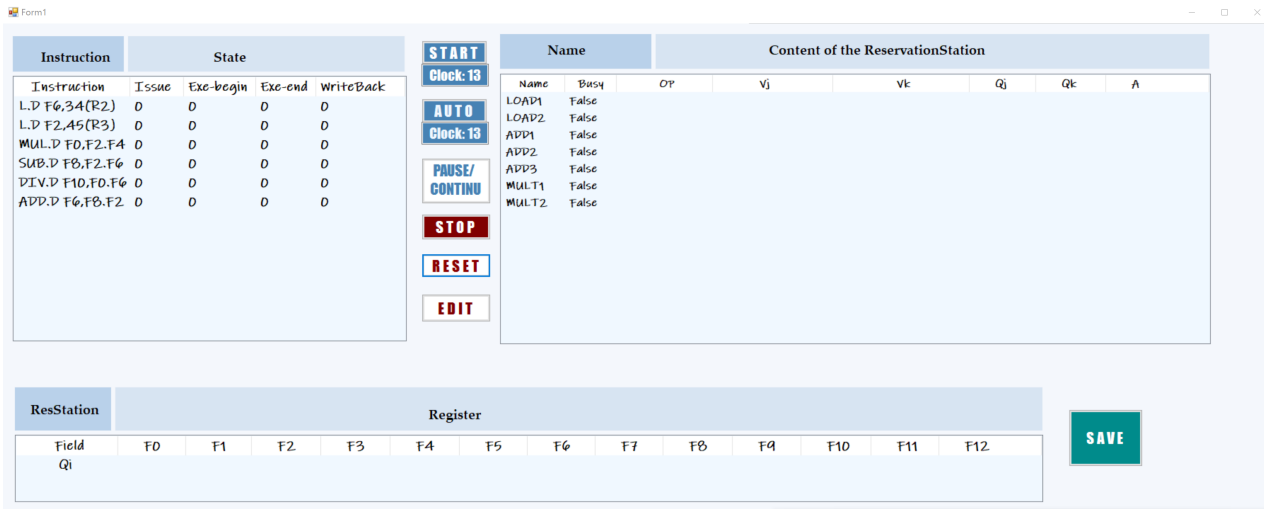

**b.思路以及源代码**

```
        private void Button3_Click(object sender, EventArgs e)
        {
            run = false;//同样与auto部分代码有关
        }
```

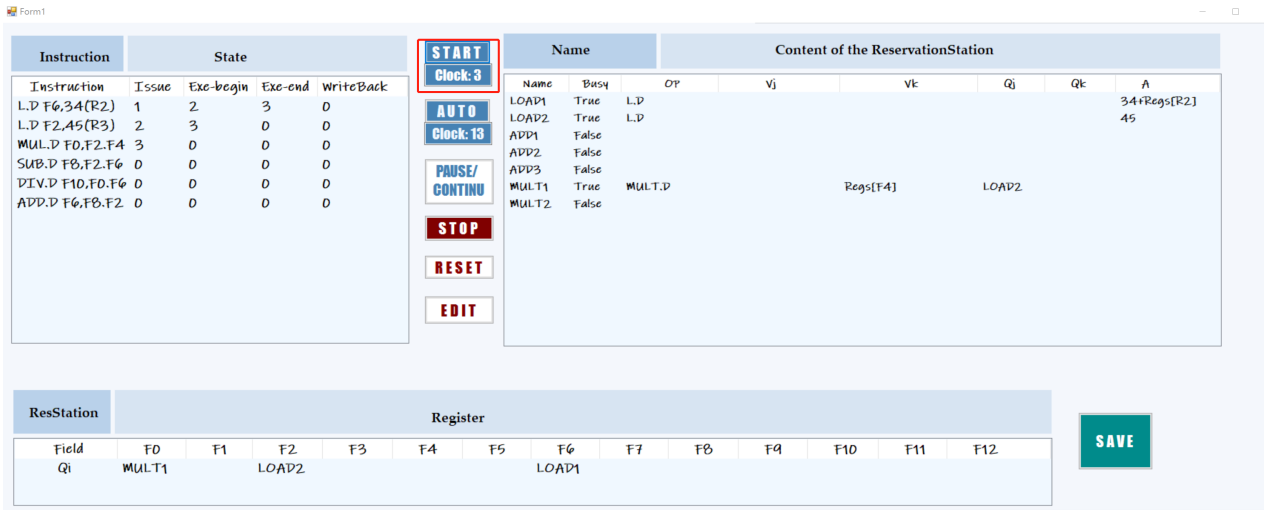
# 4.RESET键——重置

恢复到系统初始状态，当前时钟设置为0，同时指令状态表、保留站信息表和寄存器状态表设置为初始状态；

## （1）界面展示




重新点击START键一切都会从头再来。




## （2）思路以及源代码

重新加载所有变量，对已改变的全局变量进行恢复，更新所有表

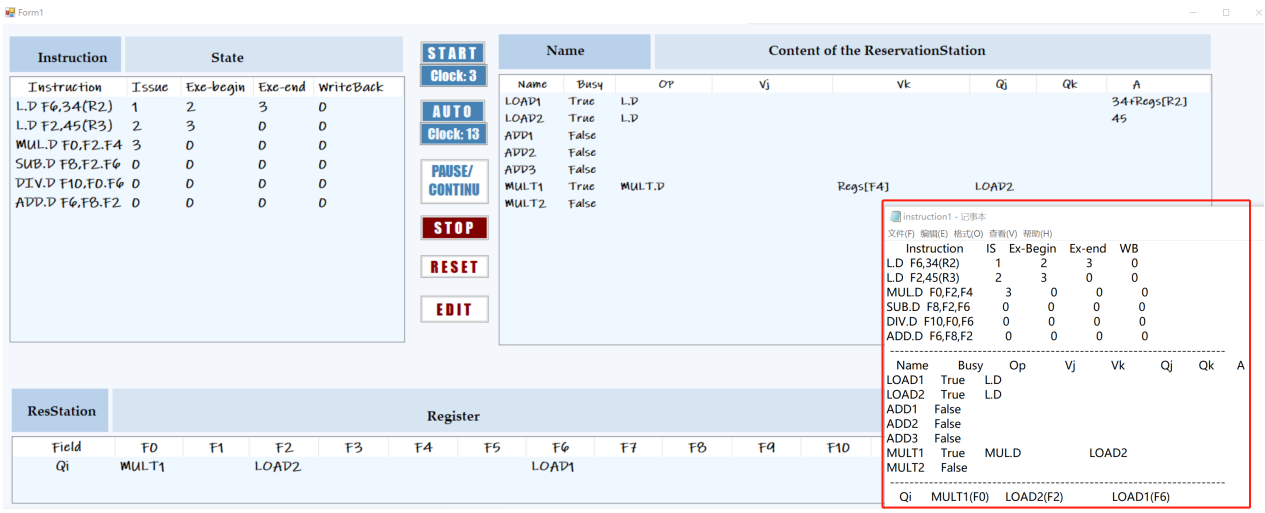
```
        //Reset
        private void Button5_Click_1(object sender, EventArgs e)
        {
          //重新initialize
```

```
            Init_Instruction();
            Init_ReservationStation();
            Init_Regiser();
            Init_Clock();
          //重新更新表
            Update_Clock_Board1();
            Update_Clock_Board();
            Update_Instruction_Board();
            Update_ReservationStation_Board();
            Update_Register_Board();


        //**** Define Architecture
            run = true;
            pause_or_continue = true;
            Clock = 0;
        // used to check if INST == WRITEBACKS to end program
            Done = true;
            Total_WRITEBACKS = 0;
        // Counter for current instruction to issue
            currentInst_ISSUE = 0;
            Register_Memory = new string[12] { "000", "000", "000", "000",
"000", "000", "000", "000", "000", "000", "000", "000" };
        }
```

## 5.SAVE键——保存

把当前状态保存在文件中，包括指令状态表、保留站信息表和寄存器状态表。若需要运行可执行文件，需要更改文件路径。

### （1）界面展示




### （2）思路以及源代码

使用System.IO.StreamWriter函数。

```
        //Save
        private void Button8_Click(object sender, EventArgs e)
        {
            using (System.IO.StreamWriter sw = new
System.IO.StreamWriter(@"\\Mac\Home\Desktop\instruction1.txt"))  //若执行文件需要
更改路径
            {
              //保存指令状态表
                sw.WriteLine("      Instruction       IS    Ex-Begin    Ex-end
   WB");
                for(int i=0;i<Inst_size;i++)
                {
                    string Instruction_output1, Instruction_output2,
Instruction_output3, Instruction_output4, Instruction_output5;
                    Instruction_output2 = Inst[i].issueClock.ToString();
                    Instruction_output3 =
Inst[i].executeClockBegin.ToString();
                    Instruction_output4 = Inst[i].executeClockEnd.ToString();
                    Instruction_output5 = Inst[i].writebackClock.ToString();
                    int j = 0;
                    int k =13 - Inst[i].issueClock.ToString().Length;
                    if (Inst[i].op == LoadOp)
                    {
                        Instruction_output1 = Inst[i].name + " F" + Inst[i].rd
+ "," + Inst[i].imm + "(R" + Inst[i].rs + ") ";
                        j = 25 - Instruction_output1.Length;
                    }
                    else
                    {
                        Instruction_output1 = Inst[i].name + " F" + Inst[i].rd
+ ",F" + Inst[i].rs + ",F" + Inst[i].rt;
                        j = 25 - Instruction_output1.Length;
                    }
                    sw.WriteLine(Instruction_output1 +
string.Empty.PadRight(j, ' ') + Instruction_output2 + string.Empty.PadRight(k,
' ')+
                        Instruction_output3 + string.Empty.PadRight(k, ' ') +
Instruction_output4 + string.Empty.PadRight(k, ' ') + Instruction_output5);
                }
                sw.WriteLine(" ----------------------------------------------
");


              //保存保留站状态表
                sw.WriteLine("   Name    " + "     Busy    " + "     Op      "
+ "      Vj      " + "      Vk       " + "    Qj    " + "     Qk    " + "   A
   ");
                for(int i = 0; i < ResStation_size; i++)
                {
```

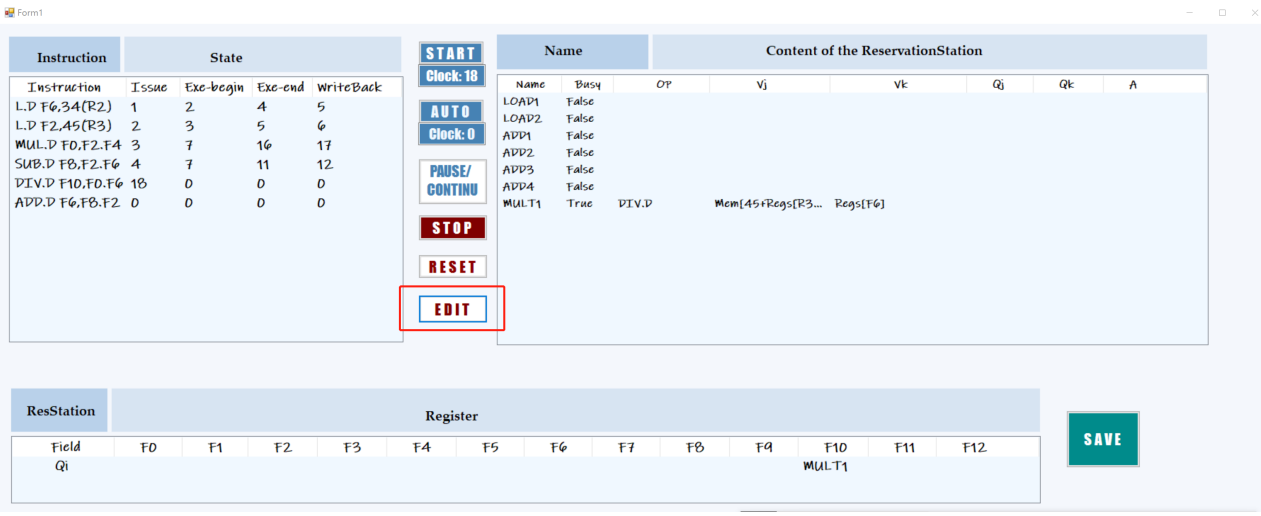
```
                    string str1 = " ";
                    string str2, str3, str4;

                    if (ResStation[i].busy)
                    {
                        switch (ResStation[i].op)
                        {
                            case 0:
                                str1 = "ADD.D";
                                break;
                            case 1:
                                str1 = "SUB.D";
                                break;
                            case 2:
                                str1 = "MUL.D";
                                break;
                            case 3:
                                str1 = "DIV.D";
                                break;
                            case 4:
                                str1 = "L.D";
                                break;
                            default:
                                break;
                        }
                        if (ResStation[i].Qj == OperandAvailable)
                            str2 = ResStation[i].Vj.ToString();
                        else str2 = "        ";
                        if (ResStation[i].Qk == OperandAvailable)
                            str3 = ResStation[i].Vk.ToString();
                        else str3 = "        ";
                    }
                    else
                    {
                        str1 = "          ";
                        str2 = "           ";
                        str3 = "           ";
                    }

                    if (ResStation[i].Qj == OperandInit) str4 = "
";
                    else if (ResStation[i].Qj == OperandAvailable) str4 = "
    ";
                    else str3 = ResStation[ResStation[i].Qj].name;

                    if (ResStation[i].Qk == OperandInit) str4 = "           ";
                    else if (ResStation[i].Qk == OperandAvailable) str4 = "
       ";
                    else str4 = ResStation[ResStation[i].Qk].name;
```

```
                    sw.WriteLine(ResStation[i].name + "      " +
ResStation[i].busy.ToString() +  "      "+ str1 + "        " + str2 + "       "
+  str3 + "      " + str4);


                }
              //保存寄存器状态表
                sw.WriteLine(" ----------------------------------------------
---- ");
                string final = " ";
                for (int i = 0; i < RegisterStatus_size; i++)
                {
                    if (RegisterStatus[i].Qi == RegStatusEmpty) final += "
";
                    else final += ResStation[RegisterStatus[i].Qi].name + "(F"
+ i + ")";
                }
                sw.WriteLine("    Qi      " + final);
            }

        }
```

## 6.EDIT键——设置

设置上面的配置信息，包括功能部件的延迟和功能部件的个数。由于时间原因并没有完善容错性，导致只能在所有textbox均填写完成才不会出错。填写完成后点击OK便更改完成，点击BACK返回到当前界面。

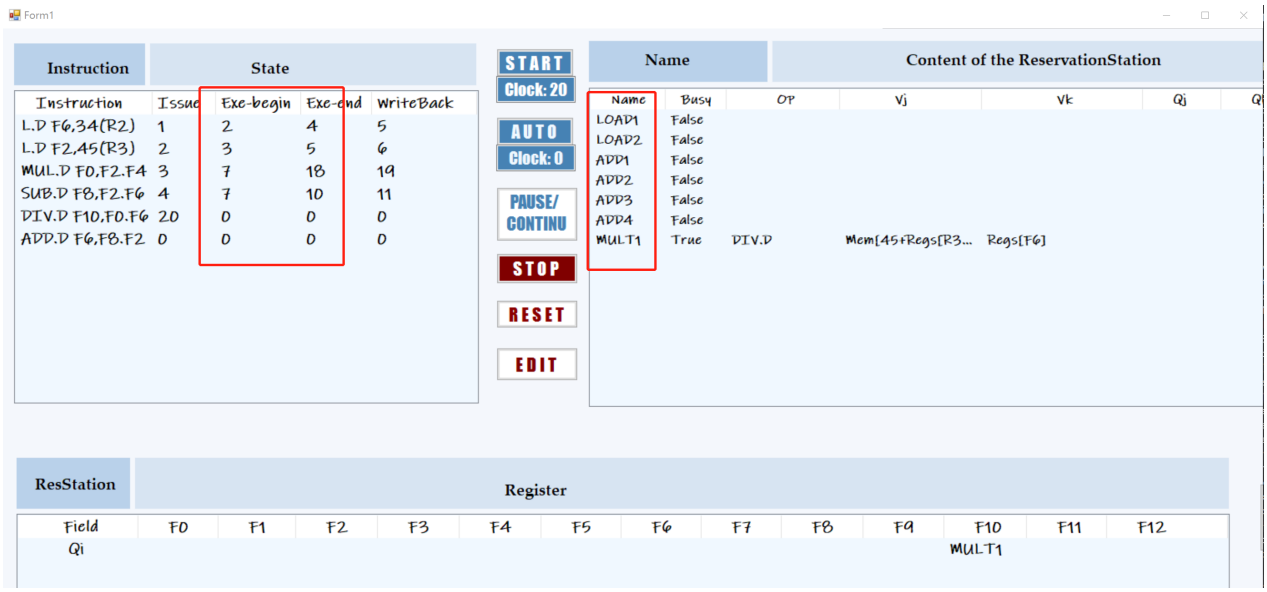
### （1）界面展示




↓注释：只能在所有textbox均填写完成才不会出错



↓返回Form1界面后，保留站数目、指令的延迟数均发生相应改变




## （2）思路以及源代码

- 通过Form2中的输入将改变的变量传入Form1中

```
        //在Form2.cs中
        private void Button2_Click(object sender, EventArgs e)
        {
            Num_LOAD_RS = int.Parse(textBox1.Text);
            Num_ADD_RS = int.Parse(textBox2.Text);
            Num_MULT_RS = int.Parse(textBox3.Text);
            Num_LOAD_lat = int.Parse(textBox4.Text);
            Num_ADD_lat = int.Parse(textBox5.Text);
            Num_MULT_lat = int.Parse(textBox6.Text);
            Num_DIV_lat = int.Parse(textBox7.Text);
            parent.SetResStation(Num_LOAD_RS, Num_ADD_RS, Num_MULT_RS,
Num_LOAD_lat, Num_ADD_lat, Num_MULT_lat, Num_DIV_lat);
        }
```

- Form1接受变量

```
            Num_LOAD_RS = num_load;
            Num_ADD_RS = num_add;
            Num_MULT_RS = num_mult;
            LOAD_Lat = load_lat;
            ADD_Lat = add_lat;
            MULT_Lat = mult_lat;
            DIV_Lat = div_lat;
```

- Form1重新初始化保留站（以Load为例）

```
//update the reservationStation
for (int i = 0; i < Num_LOAD_RS; i++)
{
   ReservationStation LOAD = new ReservationStation(LoadOp, OperandInit,
"LOAD" + (i + 1).ToString());
   ResStation[i] = LOAD;
}
```

- 初始化其他所有变量，并更新所有表

# 四、思路以及源代码

见附件

# 五、参考文献

使用部分思想：*github.com/milleraj66/ECE585_TomasuloAlgorithm*