

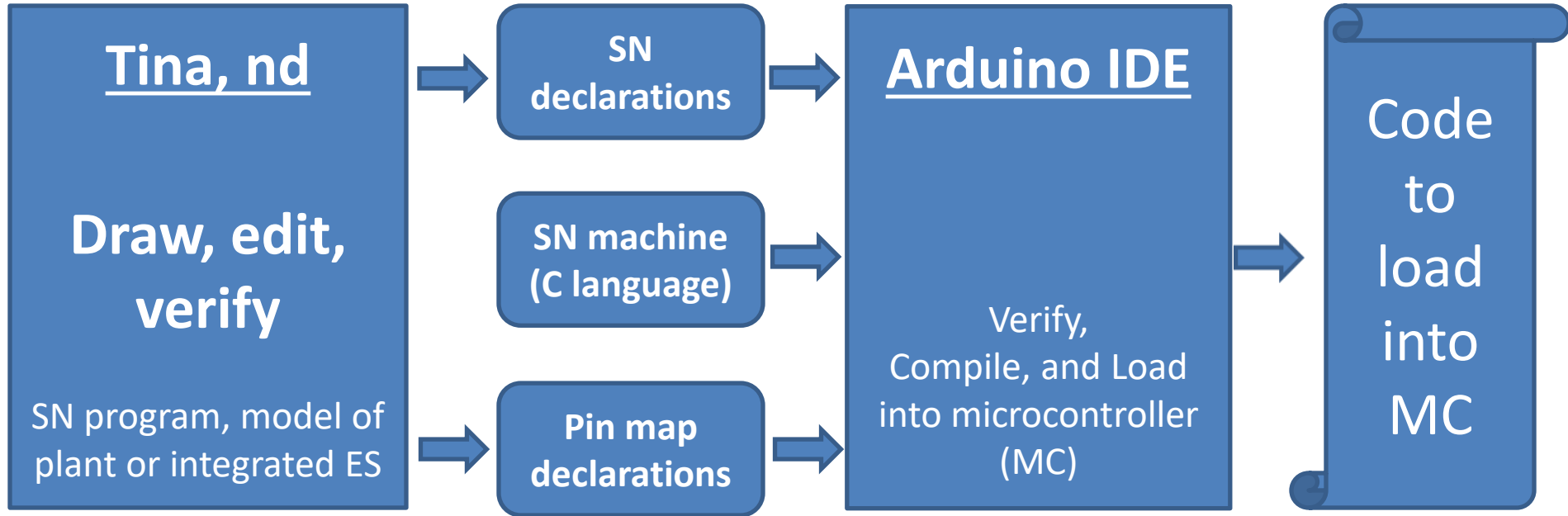
Reliable Embedded System Graphical Design in Sleptsov Net Machine

Dima Zaitsev

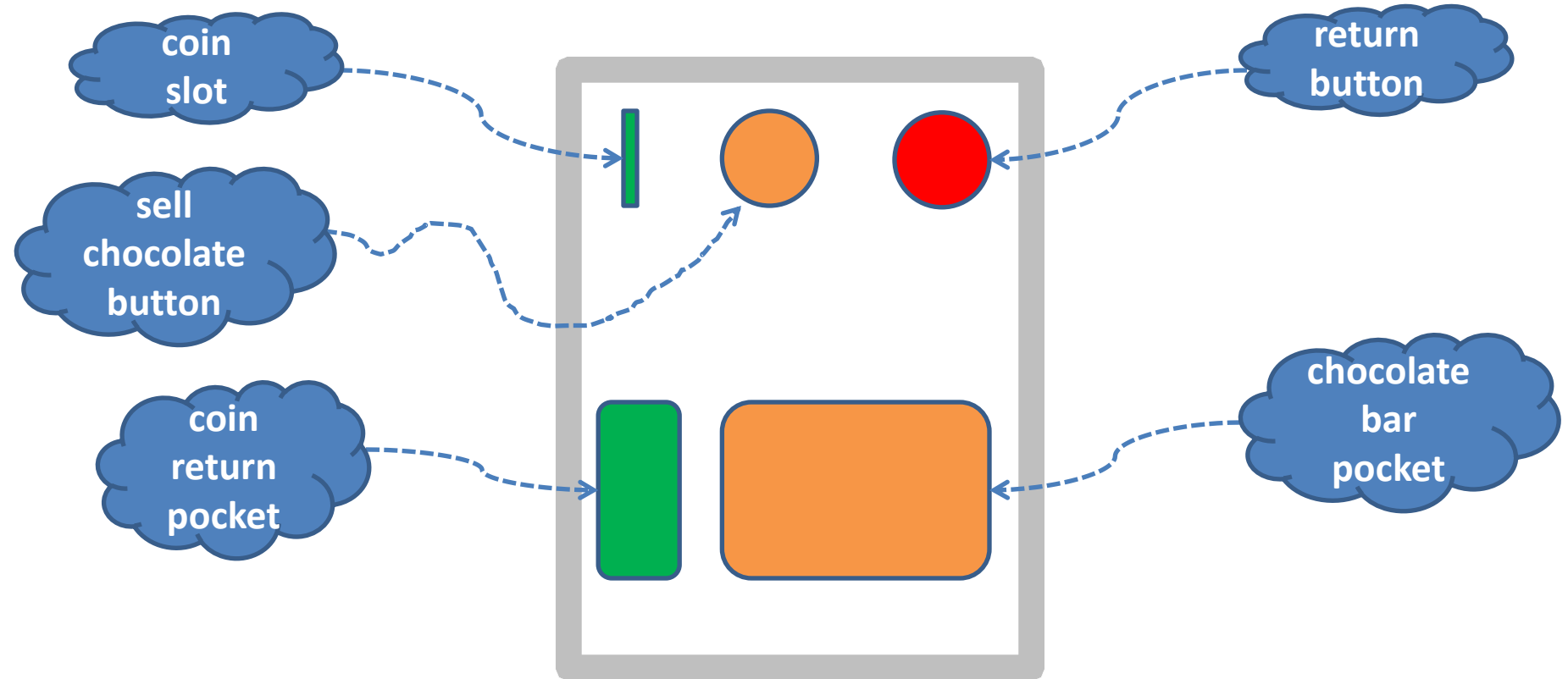
[dimazaitsev.github.io](https://github.com/dimazaitsev)

https://youtu.be/BG8_UDN7Xvk

General workflow



Vending machine example



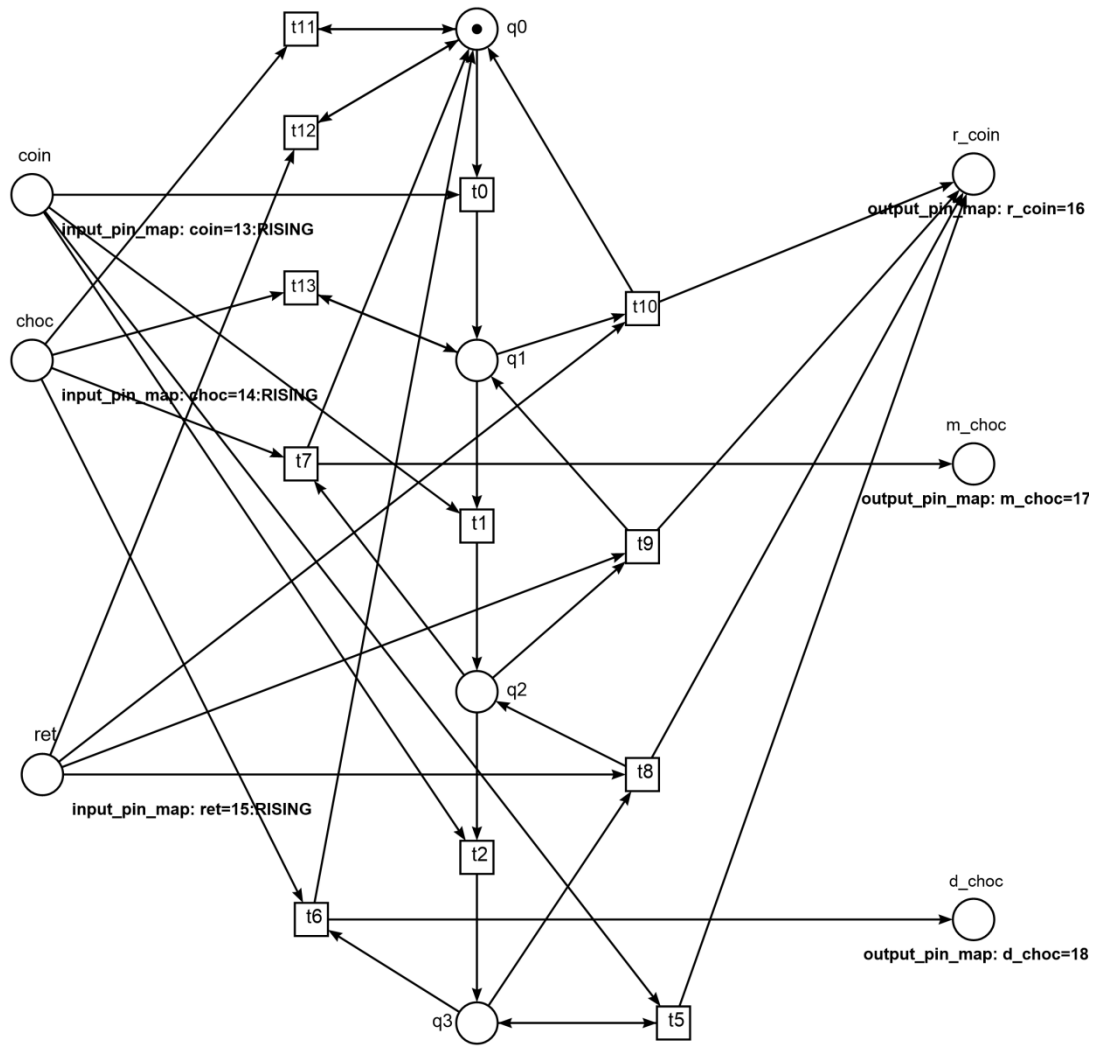
Limitations

- **Maximum to accept: 3 coins**
- **Chocolate bar price:**
 - **Milk chocolate bar: 2 coins**
 - **Dark chocolate bar: 3 coins**
- **Coin return: one-by-one**

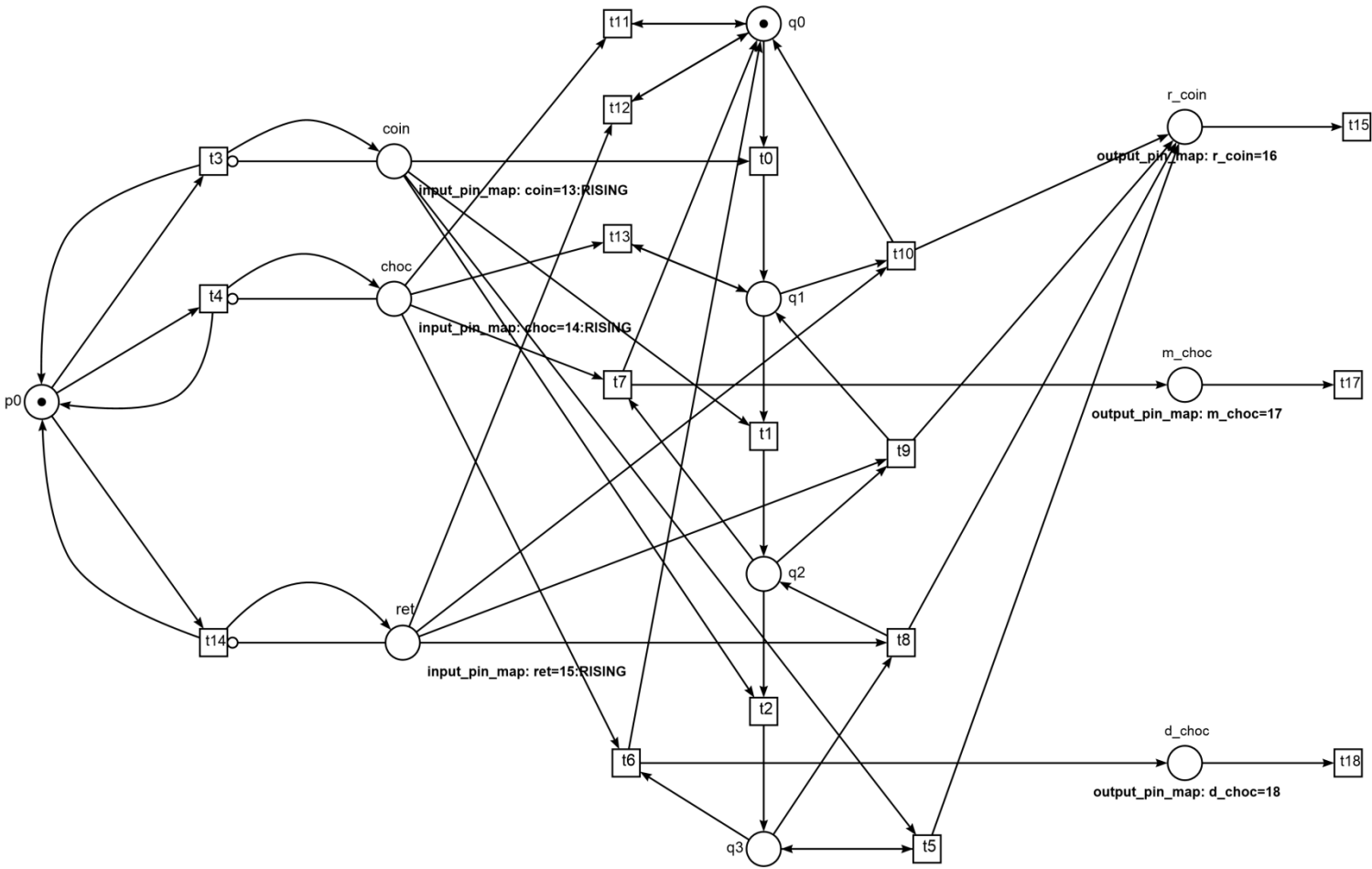
Encoding

- Inputs: **coin**, **choc**, **return**
- Outputs: **r_coin**, **m_choc**, **d_choc**
- Coins of the current purchase:
q0, q1, q2, q3

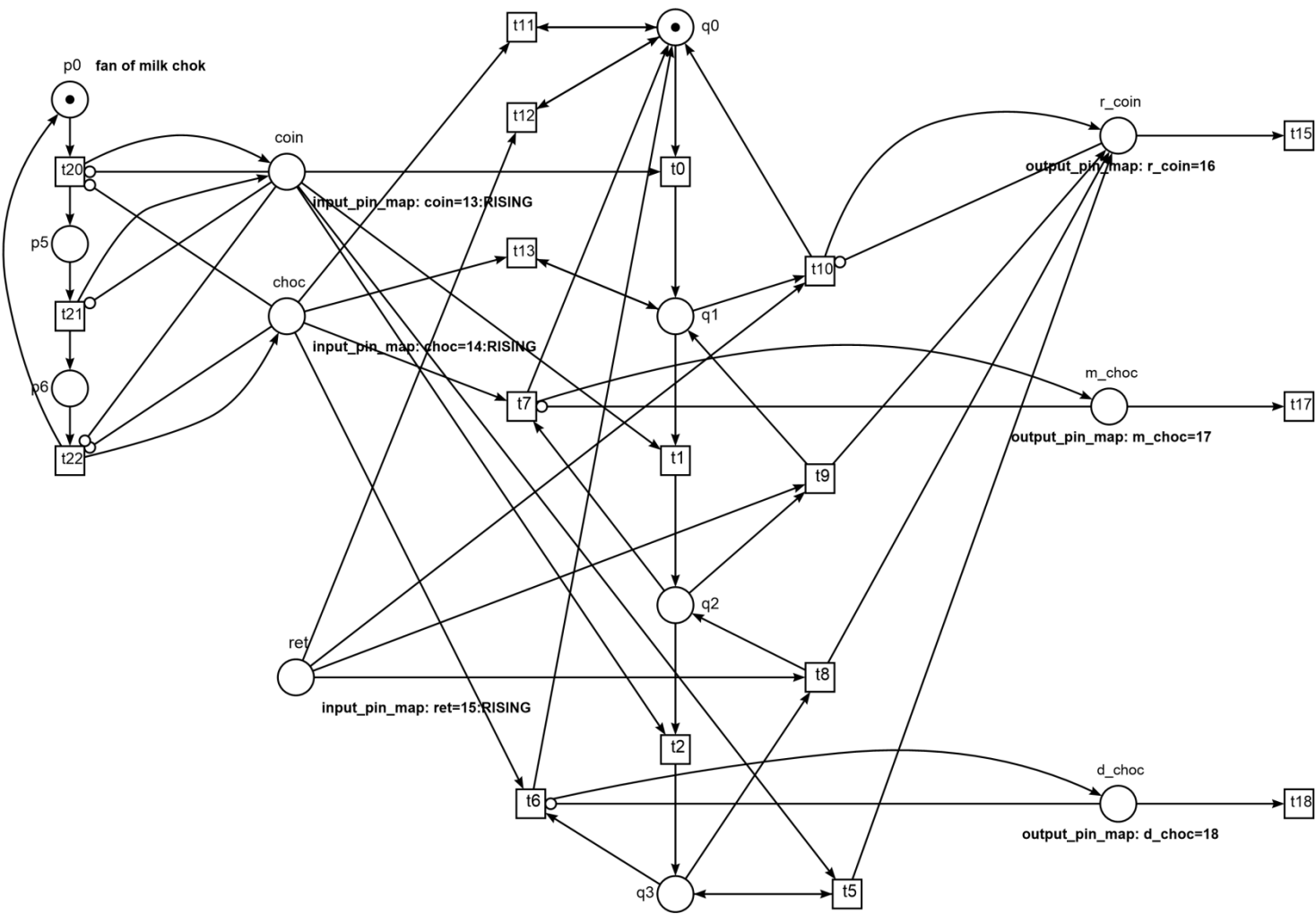
VM control SN program



VM model: SN program integrated with random user model



VM model: SN program integrated with milk choc fan user model



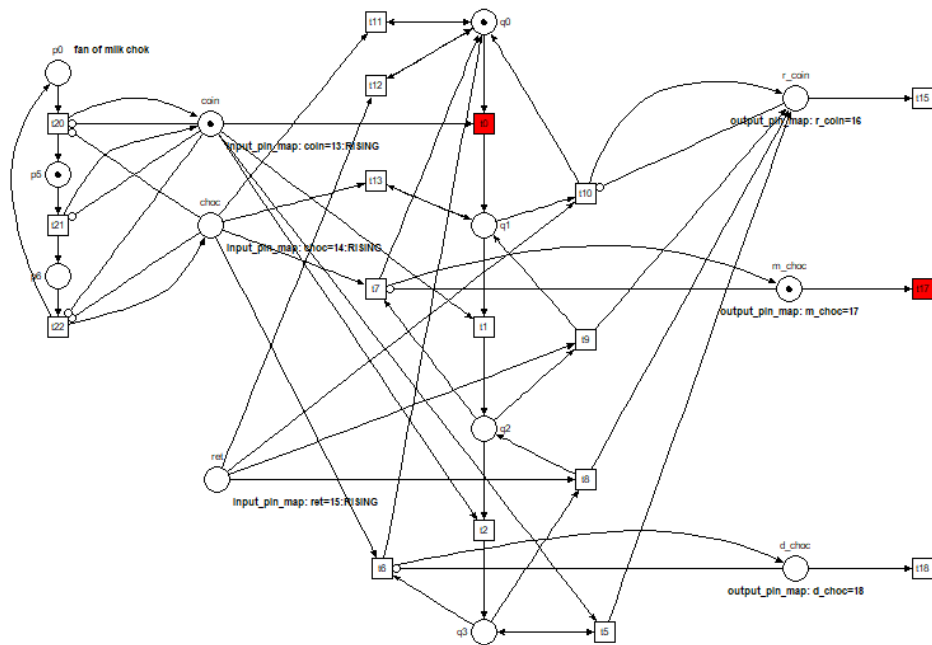
Ongoing simulation

C:\Users\dazai\Documents\soft\snm\Arduino\sn-vm-user2.ndr

File Mode Help

M |< << < > >> >|

Random



State Space (textual)

MARKINGS:

0 : p0 q0

1 : coin p5 q0

2 : p5 q1

3 : coin p6 q1

4 : p6 q2

5 : choc p0 q2

6 : m_choc p0 q0

7 : coin m_choc p5 q0

8 : m_choc p5 q1

9 : coin m_choc p6 q1

10 : m_choc p6 q2

11 : choc m_choc p0 q2

REACHABILITY GRAPH:

0 -> t20/1

1 -> t0/2

2 -> t21/3

3 -> t1/4

4 -> t22/5

5 -> t7/6

6 -> t17/0, t20/7

7 -> t0/8, t17/1

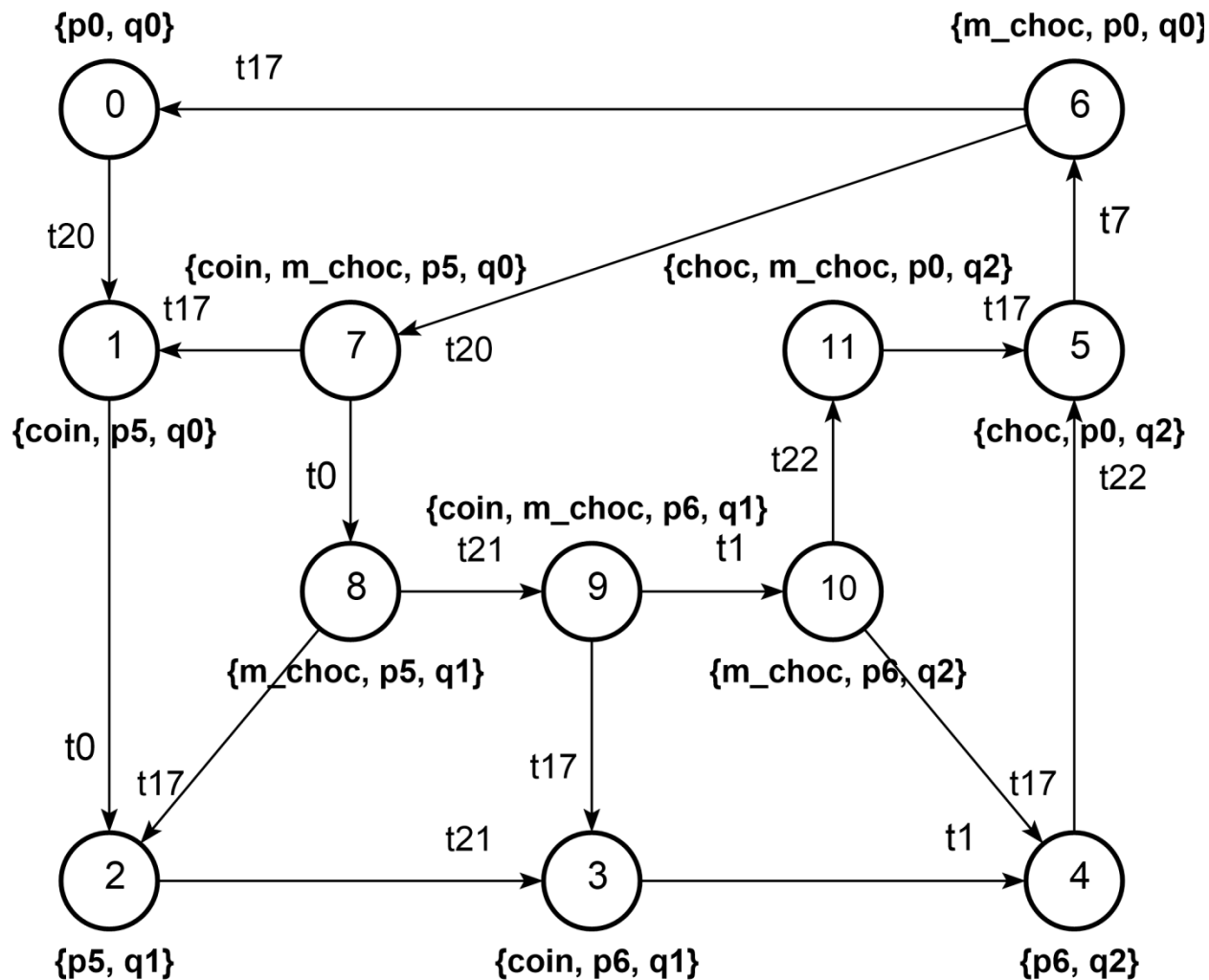
8 -> t17/2, t21/9

9 -> t1/10, t17/3

10 -> t17/4, t22/11

11 -> t17/5

State Space (graph)



State Space Analysis

REACHABILITY ANALYSIS -----

bounded

LIVENESS ANALYSIS -----

not live

reversible

0 dead marking(s), 12 live marking(s)

11 dead transition(s), 7 live transition(s)

dead transition(s): t9 t8 t6 t5 t2 t18 t15 t13 t12 t11 t10

Structural Analysis

P-SEMI-FLOWS GENERATING SET -----

q0 q1 q2 q3 (1)

p0 p5 p6 (1)

not invariant

0.000s

T-SEMI-FLOWS GENERATING SET -----

t0 t1 t17 t20 t21 t22 t7 (7)

t13 t15*2 t20 t21 t22 t5*2 (8)

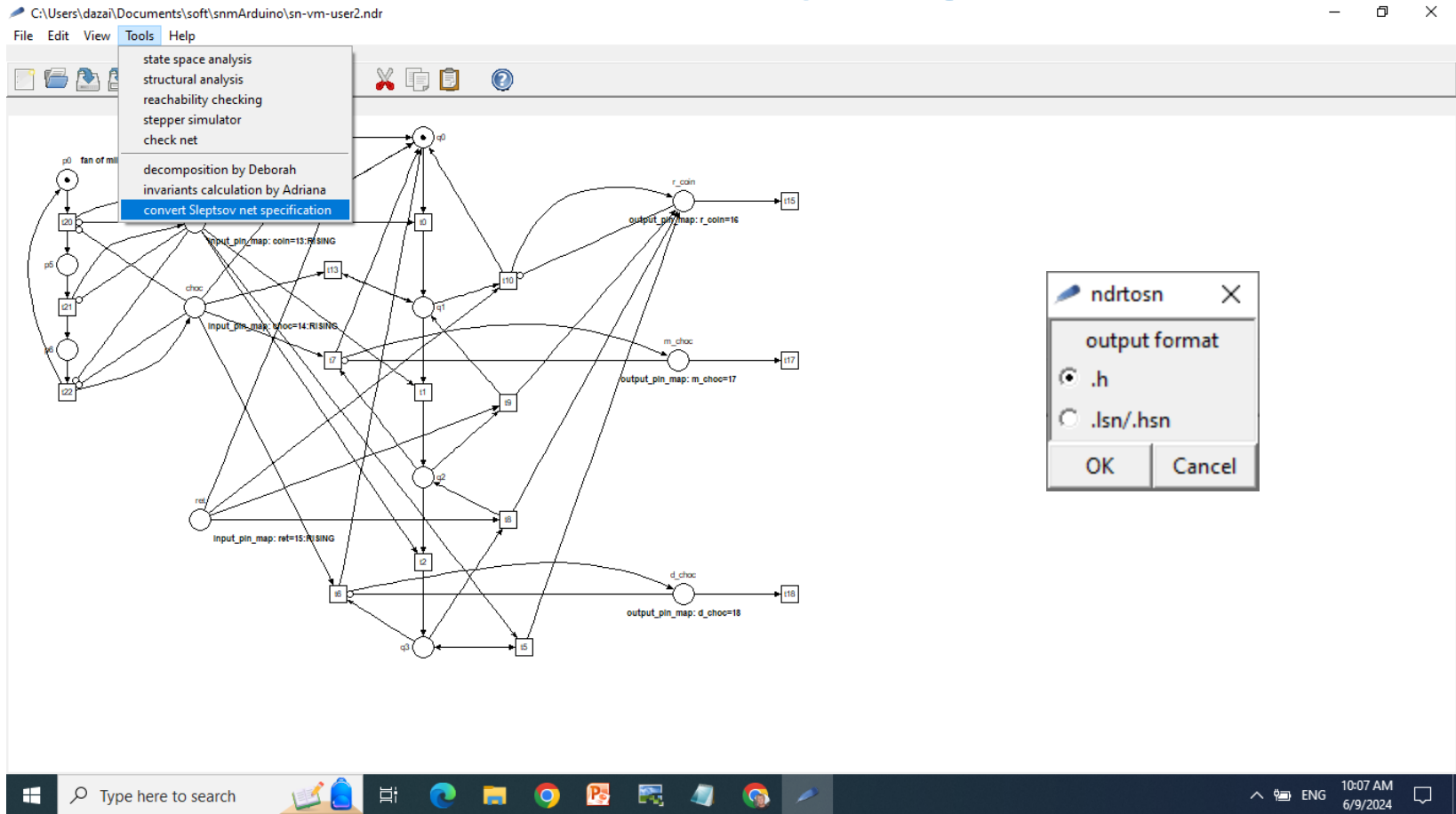
t0*2 t1*2 t13 t18*2 t2*2 t20*3 t21*3 t22*3 t6*2 (20)

t11 t15*2 t20 t21 t22 t5*2 (8)

t0*2 t1*2 t11 t18*2 t2*2 t20*3 t21*3 t22*3 t6*2 (20)

not consistent

Generate SN program



SN header: sn.h

```
// SN obtained from NDR
#define m 10
#define n 12
// incoming arcs of transitions
static int b[10][12]={
{1,0,0,0,0,0,1,0,0,1,0,0},
{0,1,0,0,0,1,0,1,0,0,0,0},
{0,0,1,1,1,0,0,0,0,0,0,0},
{0,0,0,0,0,0,0,0,1,0,1,1},
{1,1,1,0,0,0,0,0,0,0,1,0},
{0,0,0,1,0,0,0,1,1,1,0,0},
{0,0,0,0,1,1,1,0,0,0,0,1},
{0,0,0,0,0,0,0,0,0,0,0,0},
{0,0,0,0,0,0,0,0,0,0,0,0},
{0,0,0,0,0,0,0,0,0,0,0,0}};
```

```
// outgoing arcs of transitions
static int d[10][12]={
{0,0,0,1,0,1,1,0,1,1,0,0},
{1,0,0,0,1,0,0,1,0,0,0,0},
{0,1,0,0,0,0,0,0,0,0,0,1},
{0,0,1,0,0,0,0,0,0,0,1,0},
{0,0,0,0,0,0,0,0,0,0,0,0},
{0,0,0,0,0,0,0,0,0,0,0,0},
{0,0,0,0,0,0,0,0,0,0,0,0},
{0,0,0,0,1,1,0,0,0,0,1,1},
{0,0,0,1,0,0,0,0,0,0,0,0},
{0,0,0,0,0,0,0,0,1,0,0,0}};
// initial marking
static int mu[10]=
{1,0,0,0,0,0,0,0,0,0};
```

Pin map header: pin.h

```
// SN pin map
#define MI 3
#define MO 3
static int in_places[MI]=
{4,5,6};
static int in_pins[MI]=
{15,14,13};
volatile static int in_mu[MI]=
{0,0,0};
static int out_places[MO]=
{7,8,9};
static int out_pins[MO]=
{16,17,18};
void IR_Read0() { in_mu[0]=1; go=1; }
void IR_Read1() { in_mu[1]=1; go=1; }
void IR_Read2() { in_mu[2]=1; go=1; }
```

```
void Init_pins_IR()
{
    int i;
    for(i=0;i<MI;i++)
        pinMode(in_pins[i], INPUT_PULLUP);
    for(i=0;i<MO;i++){
        pinMode(out_pins[i], OUTPUT);
        digitalWrite(out_pins[i],LOW);
    }
    attachInterrupt(digitalPinToInterrupt(
in_pins[0]), IR_Read0, RISING);
    attachInterrupt(digitalPinToInterrupt(
in_pins[1]), IR_Read1, RISING);
    attachInterrupt(digitalPinToInterrupt(
in_pins[2]), IR_Read2, RISING);
}
```


SN Machine: sna.c

```
void loop() {
    while(go) {
        ReadIn();
        for(j=0;j<n;j++) y[j]=INT_MAX;
        for(i=0;i<m;i++)
            for(j=0;j<n;j++)
            {
                yij = (b[i][j]>0)? mu[i] / b[i][j] : (b[i][j]<0)? ((mu[i]>0)? 0: INT_MAX): INT_MAX;
                y[j]=zmin(y[j],yij);
            }
        jj=-1; for(j=0;j<n;j++) if(y[j]>0){jj=j; break;}
        if(jj==-1) {go=0; break;} yy=y[jj];
        for(i=0;i<m;i++) mu[i] = mu[i] - ((b[i][jj]>0)?yy*b[i][jj]:0) + yy*d[i][jj];
        WriteOut();
        k++;
    }
}
```

Arduino IDE Sketch

sna-vm | Arduino IDE 2.3.0

File Edit Sketch Tools Help

Raspberry Pi Pico



```
sna-vm.ino  sn.h  pin.h  ...
1  // SNM - Sleptsov Net Machine in Arduino IDE, debugged on Raspberry Pi Pico
2  // SN in sn.h
3  // pin map in pin.h
4  // just to run SN, pin map can be omitted
5  static int dbg=2; // debug mode if dbg>0
6  volatile static int go=1;
7
8  #include "sn.h"
9
10 #include "pin.h"
11
12 // if no pin map included, please uncomment the following plugs
13 // void Init_pins_IR(){}
14 // void ReadIn(){}
15 // void WriteOut(){}
16
17 void setup() {
18
19     // init pins
20     // init interrupts
21     Init_pins_IR();
22     if(dbg>0) {
23         Serial.begin(115200);
24         delay(1000);
25         Serial.print("SNM time in ms ");
26         Serial.println(millis());
```

Output Serial Monitor x

Message (Enter to send message to 'Raspberry Pi Pico' on 'COM4')

New Line

115200 baud

Ln 67, Col 3 Raspberry Pi Pico on COM4 1

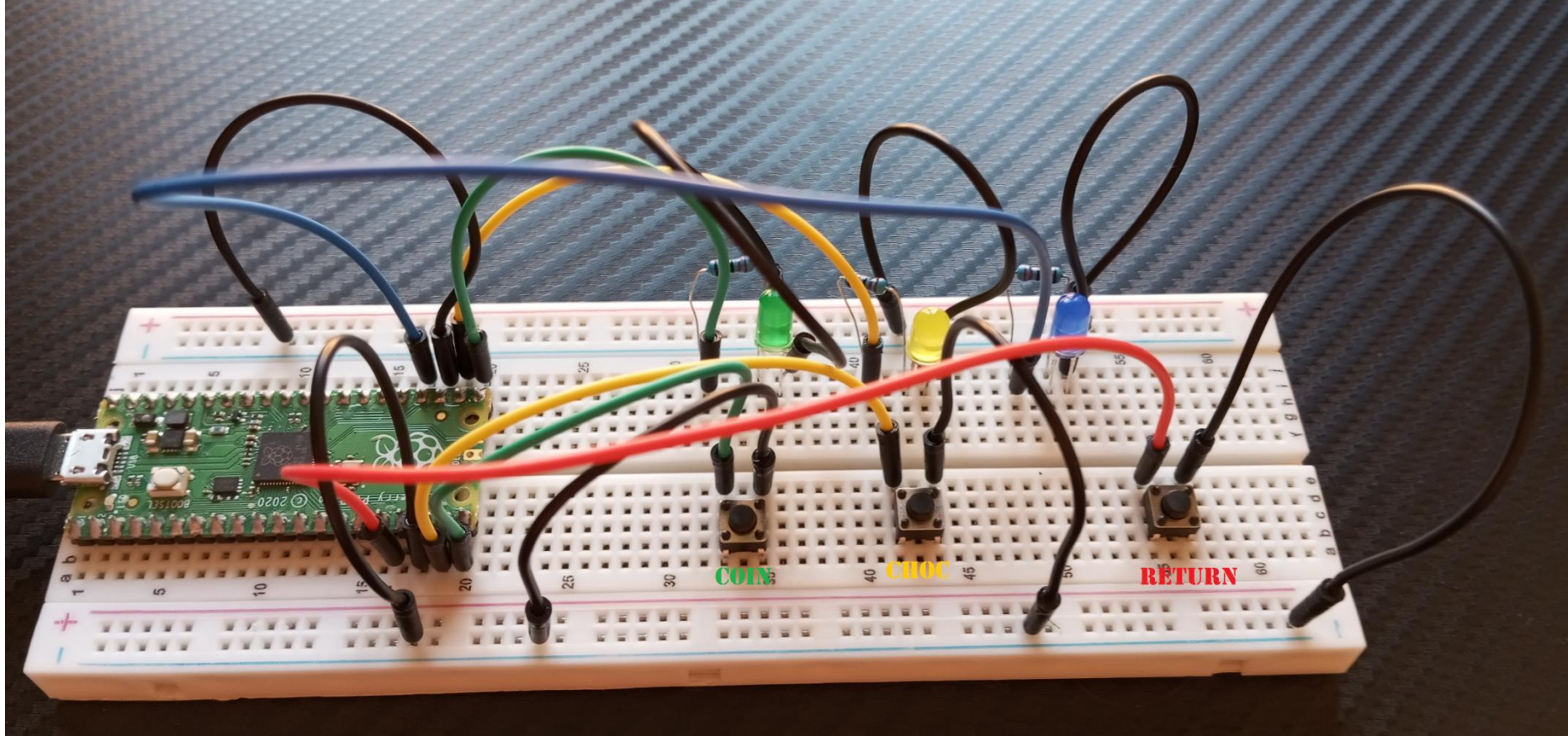


Type here to search



10:24 AM
6/9/2024




VM Prototype








Debugging Arduino IDE Sketch

sna-vm | Arduino IDE 2.3.0

File Edit Sketch Tools Help



Raspberry Pi Pico



sna-vm.ino sn.h pin.h

```
1 // SNM - Sleptsov Net Machine in Arduino IDE, debugged on Raspberry Pi Pico
2 // SN in sn.h
3 // pin map in pin.h
```

Output Serial Monitor x

New Line 115200 baud

```
SNM time in ms 1002
sn-vm step 0 time in ms 1002
1 0 0 0 0 0 0 0 0 0
y#1: 0 0 0 0 0 0 0 0 0 0
y#2: 0 0 0 0 0 0 0 0 0 0
sn-vm step 0 time in ms 9025
1 0 0 0 1 0 0 0 0 0
y#1: 1 0 0 0 0 0 0 0 0 0
y#2: 1 0 0 0 0 0 0 0 0 0
fires 0 in 1 copies
sn-vm step 1 time in ms 9026
0 1 0 0 0 0 0 0 0 0
y#1: 0 0 0 0 0 0 0 0 0 0
y#2: 0 0 0 0 0 0 0 0 0 0
sn-vm step 1 time in ms 28686
0 1 0 0 0 1 0 0 0 0
y#1: 0 0 0 0 0 0 0 0 1 0 0 0
y#2: 0 0 0 0 0 0 0 0 1 0 0 0
fires 7 in 1 copies
sn-vm step 2 time in ms 28687
0 1 0 0 0 0 0 0 0 0
y#1: 0 0 0 0 0 0 0 0 0 0
y#2: 0 0 0 0 0 0 0 0 0 0
```

Ln 67, Col 3 Raspberry Pi Pico on COM4 1

10:26 AM
6/9/2024

Conclusions

- **Reliable Embedded System Graphical Design in Sleptsov Net Machine** has been presented
- **Basic toolchain developed and tested**
- **Graphical ES design and verification in Tina**
- **Independence of definite controllers supported by Arduino IDE**
- **Tested on Raspberry Pi Pico** [dimazaitsev.github.io](https://github.com/dimazaitsev)