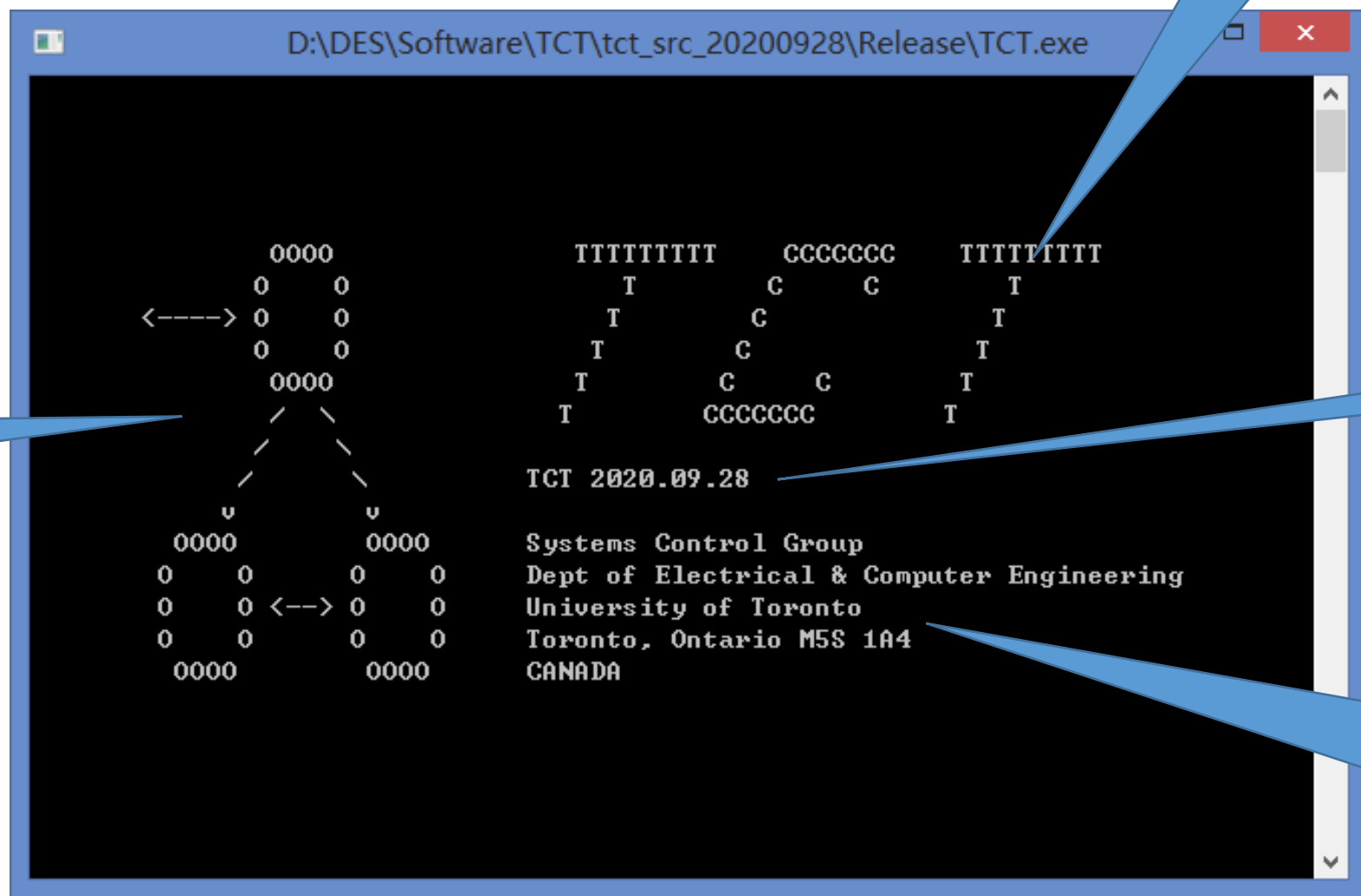# Introduction to TCT

Renyuan Zhang

Northwestern Polytechnical University

2022.04.21

Welcom page of TCT
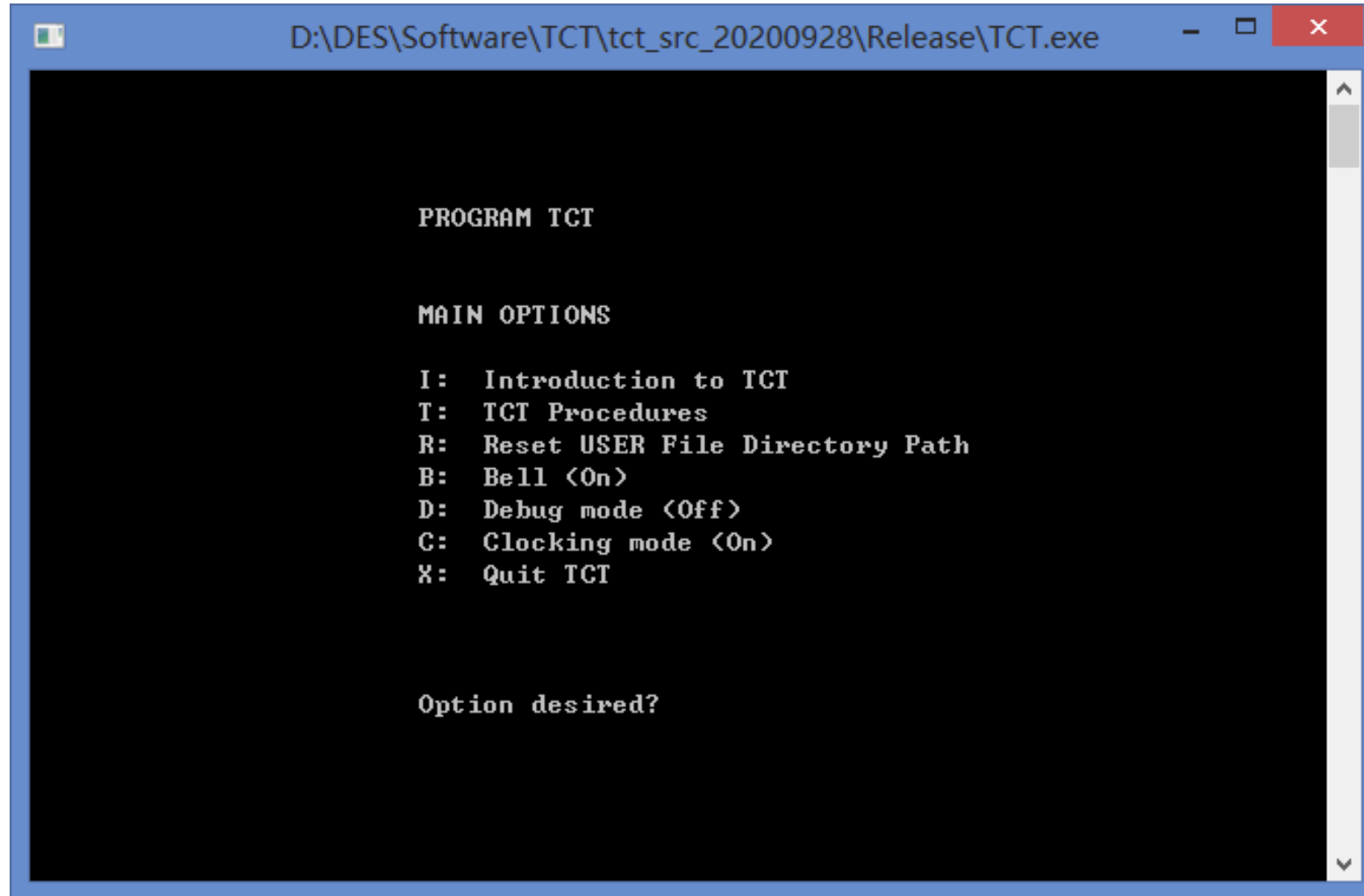

Name of TCT

Transition graph of a DES generator

Date of update

Created and developed by members (including me) of Prof. Wonham's group

Main menu of TCT

TCT procedures

Section 1:
TCT procedures

- Procedures for creating/showing/displaying a DES
- Procedures for implementing general operations on DES
- Procedures for (monolithic/partial-observation/hierarichal/distributed) supervisory control

(1) Create\Show\Display a DES

- DES = create(DES)

- DES2 = edit(DES1)

- ScreenDisplay = show(DES1)

- GIF = CE(DES)

- LabeledTransitionGraph = DE(GIF)

DES MACH1
2022.04.09/16:32
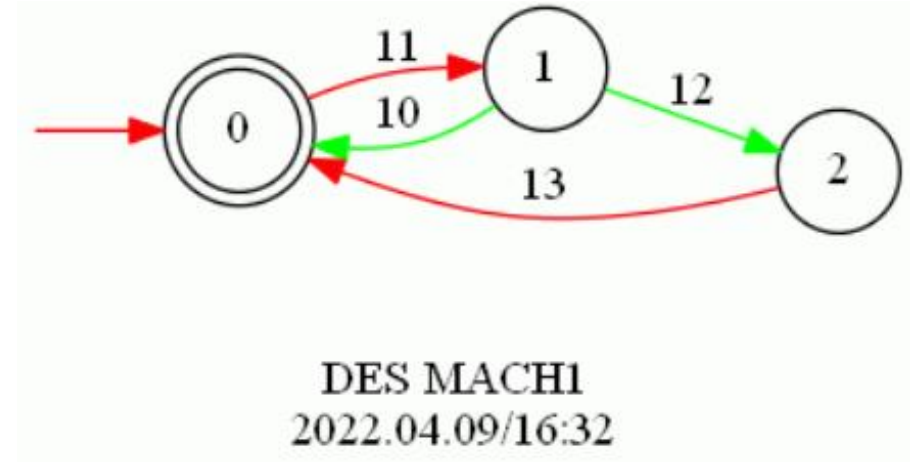
(2) General Operations on DES

- DES2 = selfloop(DES1,[SELF-LOOPED EVENTS])

- DES2 = trim(DES1)

- DES2 = minstate(DES1)

- DES2 = complement(DES1, [AUXILIARY-EVENTS])

- DES2 = allevents(DES1)

(2) General Operations on DES

- DES2 = BFS(DES1)

- DES2 = force(DES1, [FORCIBLE EVENTS], [PREEMPTABLE EVENTS], [TIMEOUT EVENT

- DES2 = project(DES1, [NULL/IMAGE EVENTS])

- DES2 = uncertmod(DES1,[NULL/IMAGE EVENTS])

- DES2 = relabel(DES1, [OLD-NEW EVENT LABEL PAIRS])

(2) General Operations on DES

- DES = meet(DES1,DES2,. . . ,DESk)

- DES = sync(DES1,DES2,. . . ,DESk)

- true/false = isomorph(DES1, DES2)

- true/false = nonconflict(DES1,DES2)

- DES3 = mutex(DES1,DES2, [EXCLUDED-STATE-PAIRS])

(3) Procedures for (Monolithic) Supervisory Control

- DES3 = supcon(DES1,DES2)

  is a trim generator for the supremal controllable sublanguage of the marked legal language generated by DES2 with respect to the plant DES1. DES3 provides a proper supervisor for DES1.

- DAT2 = condat(DES1,DES2)

  returns control data DAT2 for the supervisor DES2 of the controlled system DES1.

- DES3 = supreduce(DES1,DES2,DAT2)

  is a reduced supervisor for plant DES1 which is control-equivalent to DES2, where DES2 and control data DAT2 were previously computed using **supcon** and **condat**. Also returned is an estimated lower bound slb for the state size of a strictly state-minimal reduced supervisor.

(3) Procedures for (Partial-Observation) Supervisory Control

- DES2 = sup<s>qc(DES1,[NULL/IMAGE EVENTS])

- true/false = (s)observ(DES1,DES2,[NULL/IMAGE EVENTS])

- (DES3,DES4) = natobs(DES1,DES2)

- DES3 = supnorm(DES1,DES2, [NULL/IMAGE EVENTS])

- DES3 = supscop(DES1,DES2, [NULL/IMAGE EVENTS])

- DES3 = suprobs(DES1,DES2,[NULL/IMAGE EVENTS])

- DES3 = supconrobs(DES1,DES2,[NULL/IMAGE EVENTS])

(3) Procedures for (Hierarchical) Supervisory Control

- DES2 = vocalize(DES1, [STATE-OUTPUT PAIRS])

- DES2 = outconsis(DES1)

- DES2 = hiconsis(DES1)

- DES2 = higen(DES1)

(3) Procedures for (distributed) Supervisory Control

- {LOC1,LOC2,...,LOCm} = localize(PLANT,{PLANT1,...,PLANTm},SUPER)

    is the set of localizations of SUPER to the m independent components PLANT1,...,PLANTm of PLANT. Optionally, correctness of localization is verified and reported as ControlEqu(...) in MAKEIT.TXT. **localize** is mainly for use when SUPER is a decentralized supervisor with authority over PLANT1,...,PLANTm, and PLANT is their synchronous product.

Section 2:
An example of Using TCT

Small Factory (cf. Wonham & Cai's book on SCDES):

- Small factory consists of two machines, which are connected by a buffer with one slot.
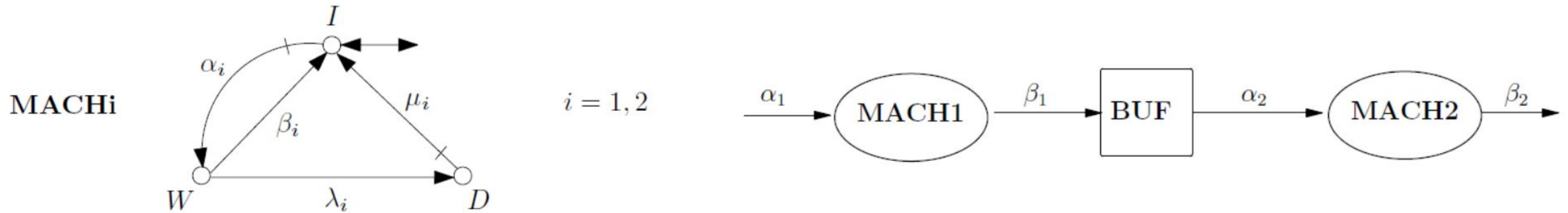
- The specifications on small factory are:

(1) The buffer must not overflow or underflow.

(2) If both machines are broken down, then MACH2 must be repaired before MACH1.

1. MACH1 = Create(MACH1,[mark0], [tran[0,11,1],[1,10,0],[1,12,2],[2,13,0]]) (3,4)

```
                    TCT PROCEDURES

0: Create          P0: Project        I: Isomorph
1: Selfloop        R0: Relabel        NC: Nonconflict
2: Trim                               OB: (S)Observable
3: Sync            H0: Vocalize       NO: Natobs
4: Meet            H1: Outconsis      SR: Suprobs
5: Supcon          H2: Hiconsis       UM: Uncertmod
6: Mutex           H3: Higen          E: Edit
7: Condat          H4: Allevents      B: BFS-recode
8: Supreduce                          UD: User file Directory
9: Minstate        SN: Supnorm        SE/SA/SX: Show DES/DAT/TXT
10: Complement     SS: Supscop        FE/FA/FD: File DES/DAT/ADS
11: Localize       RR: Supconrobs     CE/DE: Convert/Display DES
12: Force          QC: Sup(s)qc       X: Exit to main menu

                   Procedure desired:

User directory: F:\NWPU\DES\USER
Number files: 47
```


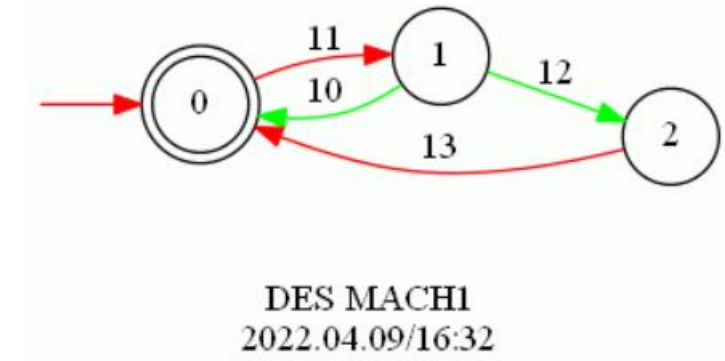DES MACH1
2022.04.09/16:32

2. MACH2 = Relabel(MACH1,[[10,20],[11,21],[12,22],[13,23]])   (3,4)


```
                  TCT PROCEDURES

0: Create          P0: Project        I: Isomorph
1: Selfloop        R0: Relabel        NC: Nonconflict
2: Trim                               OB: (S)Observable
3: Sync            H0: Vocalize       NO: Natobs
4: Meet            H1: Outconsis      SR: Suprobs
5: Supcon          H2: Hiconsis       UM: Uncertmod
6: Mutex           H3: Higen          E: Edit
7: Condat          H4: Allevents      B: BFS-recode
8: Supreduce                          UD: User file Directory
9: Minstate        SN: Supnorm        SE/SA/SX: Show DES/DAT/TXT
10: Complement     SS: Supscop        FE/FA/FD: File DES/DAT/ADS
11: Localize       RR: Supconrobs     CE/DE: Convert/Display DES
12: Force          QC: Sup(s)qc       X: Exit to main menu

                  Procedure desired:

User directory: F:\NWPU\DES\USER
Number files: 47
```


DES MACH2
2022.04.09/16:41
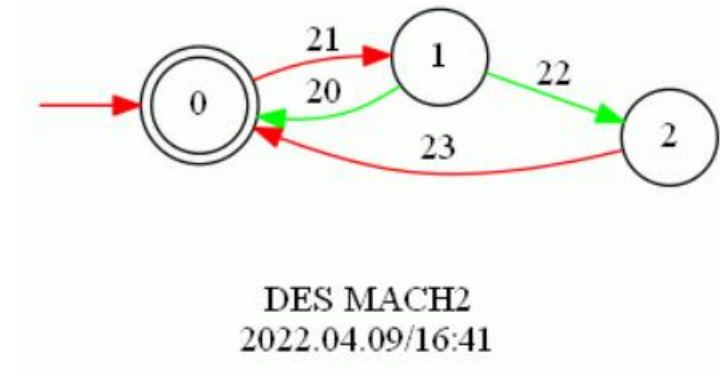
3. FACT = Sync(MACH1,MACH2) (9,24) Blocked_events = None


```
SYNC

DES = SYNC (DES1, DES2, ..., DESk, k)

Enter value of k ....... (between 2 and 30) 2

Enter name of DES1 ........ MACH1

Enter name of DES2 ........ MACH2

Enter name of DES ........ FACT

Filename FACT already exists.  OK to overwrite?  (*y/n)  Y




Events blocked in FACT: None.

Press <Enter> to return to TCT Procedures
```

DES FACT
2022.04.09/16:45
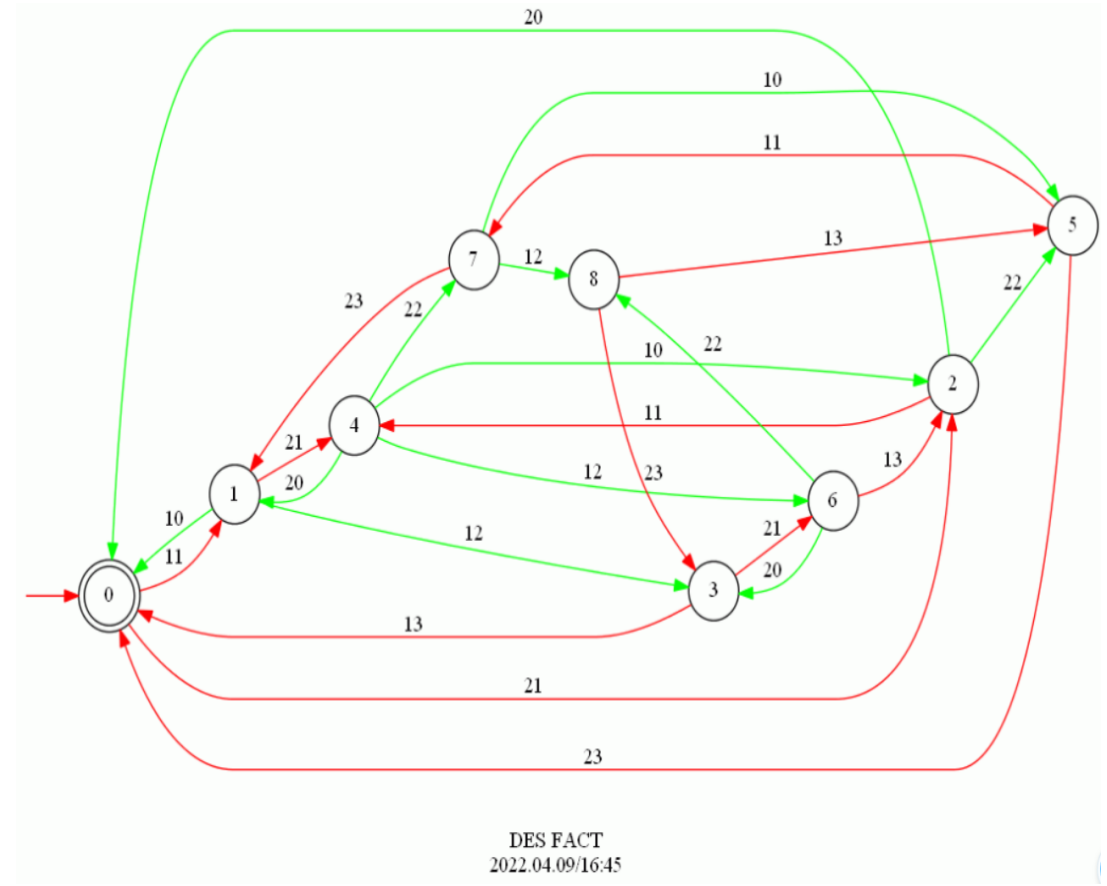
4. ALLFACT = Allevents(FACT) (1,8)


```
ALLEVENTS

DES2 = ALLEVENTS (DES1/DAT1/[EVENTLIST])


Select DES1 (to report all events occurring in existing DES1),
or DAT1 (to report all events tabled in existing Condat file DAT1),
or EVENTLIST (to report all events entered by user):

DES1/DAT1/EVENTLIST?  (*d/a/e) ... D

Enter name of DES1 to be searched .....   FACT


Enter name of target DES2 (single state, marked,
   with desired events attached as selfloops) ......   ALLFACT

Filename ALLFACT already exists.  OK to overwrite?  (*y/n)  Y




Press <Enter> to return to TCT Procedures
```
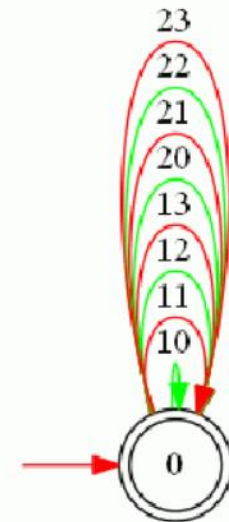

DES ALLFACT
2022.04.09/16:48

5. BUFSPEC = Create(BUFSPEC,[mark 0],[tran [0,10,1],[1,21,0]]) (2,2)

```
CREATE(BUFSPEC)


Enter transitions using:

   States                : integers 0,1,2,...,Size-1
   Uncontrollable Events : even integers 0,2,4,... <= 9998 and e
   Controllable Events   : odd integers 1,3,5,... <= 9999

To quit, enter -1 for Exit State.

Exit State:  0           Event Label:  10          Entrance State:  1
Exit State:  1           Event Label:  21          Entrance State:  0
Exit State:  -1




Press <ESC> to cancel
```


DES BUFSPEC
2022.04.09/16:51

6. BUFSPEC = Sync(BUFSPEC,ALLFACT) (2,14) Blocked_events = None

```
SYNC

DES = SYNC (DES1, DES2, ..., DESk, k)

Enter value of k ....... (between 2 and 30) 2

Enter name of DES1 ........ BUFSPEC

Enter name of DES2 ........ ALLFACT

Enter name of DES ......... BUFSPEC

Filename BUFSPEC already exists.  OK to overwrite?  (*y/n)  Y




Events blocked in BUFSPEC: None.

Press <Enter> to return to TCT Procedures
```


DES BUFSPEC
2022.04.09/16:54

7. BRSPEC = Create(BRSPEC,[mark 0],[tran [0,13,0],[0,22,1],[1,23,0]]) (2,3)

```
CREATE(BRSPEC)


Enter transitions using:

    States                 : integers 0,1,2,...,Size-1
    Uncontrollable Events  : even integers 0,2,4,...  <= 9998 and e
    Controllable Events    : odd integers 1,3,5,...  <= 9999

To quit, enter -1 for Exit State.

Exit State:  0          Event Label:  13        Entrance State:  0
Exit State:  0          Event Label:  22        Entrance State:  1
Exit State:  1          Event Label:  23        Entrance State:  0
Exit State:  -1



Press <ESC> to cancel
```
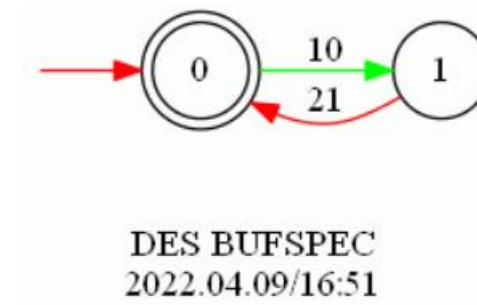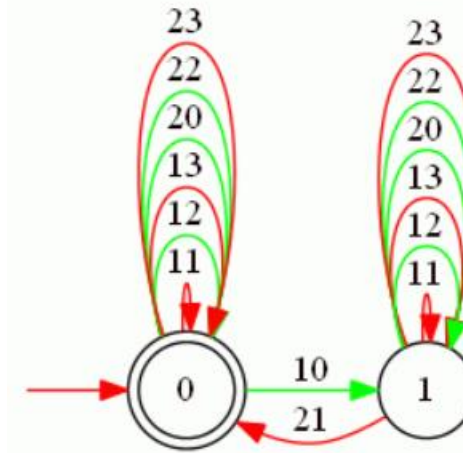

DES BRSPEC
2022.04.09/16:56
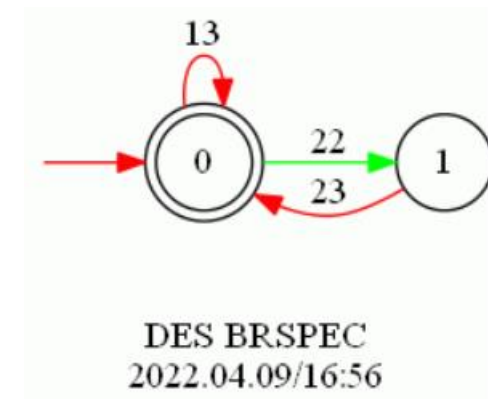
8. BRSPEC = Sync(BRSPEC,ALLFACT) (2,13) Blocked_events = None

```
SYNC

DES = SYNC (DES1, DES2, ..., DESk, k)

Enter value of k ....... (between 2 and 30) 2

Enter name of DES1 ........ BRSPEC

Enter name of DES2 ........ ALLFACT

Enter name of DES ......... BRSPEC

Filename BRSPEC already exists.  OK to overwrite?  (*y/n)  Y




Events blocked in BRSPEC: None.

Press <Enter> to return to TCT Procedures
```


DES BRSPEC
2022.04.09/16:57
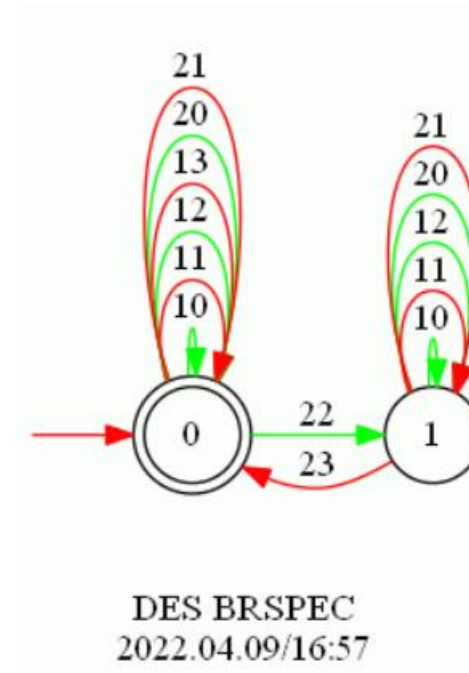
9. SPEC = Meet(BRSPEC,BUFSPEC) (4,22)


```
MEET

DES = MEET (DES1, DES2, ..., DESk, k)

Enter value of k ...... (between 2 and 30) 2

Enter name of DES1 ........ BRSPEC

Enter name of DES2 ........ BUFSPEC

Enter name of DES ........ SPEC

Filename SPEC already exists.  OK to overwrite?  (*y/n)  y

Press <Enter> to return to TCT Procedures
```
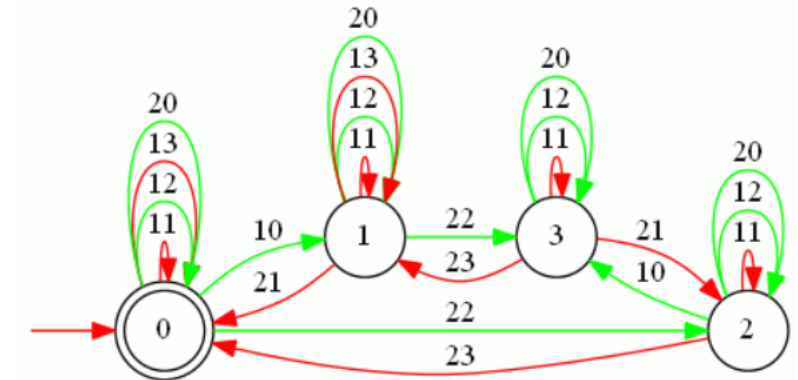

DES SPEC
2022.04.09/17:03

10. SPEC = Convert(SPEC)


```
                TCT PROCEDURES

0: Create          PO: Project         I: Isomorph
1: Selfloop        RO: Relabel         NC: Nonconflict
2: Trim                                OB: (S)Observable
3: Sync            HO: Vocalize        NO: Natobs
4: Meet            H1: Outconsis       SR: Suprobs
5: Supcon          H2: Hiconsis        UM: Uncertmod
6: Mutex           H3: Higen           E: Edit
7: Condat          H4: Allevents       B: BFS-recode
8: Supreduce                           UD: User file Directory
9: Minstate        SN: Supnorm         SE/SA/SX: Show DES/DAT/TXT
10: Complement     SS: Supscop         FE/FA/FD: File DES/DAT/ADS
11: Localize       RR: Supconrobs      CE/DE: Convert/Display DES
12: Force          QC: Sup(s)qc        X: Exit to main menu


                Procedure desired:


User directory: F:\NWPU\DES\USER
Number files: 48
```

DES SPEC
2022.04.09/17:03

11. SUPER = Supcon(FACT,SPEC) (12,24)


```
SUPCON

DES3 = SUPCON (DES1, DES2)

Enter name of plant generator DES1 ............    FACT

Enter name of legal language generator DES2 ....    SPEC

Enter name of supremal
   controllable sublanguage generator DES3 ......    SUPER

Filename SUPER already exists.   OK to overwrite?  (*y/n)   y




Press <Enter> to return to TCT Procedures
```
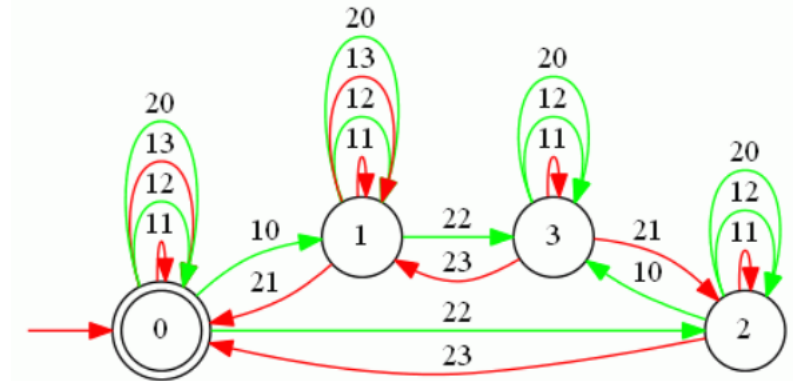
DES SUPER
2022.04.09/19:26
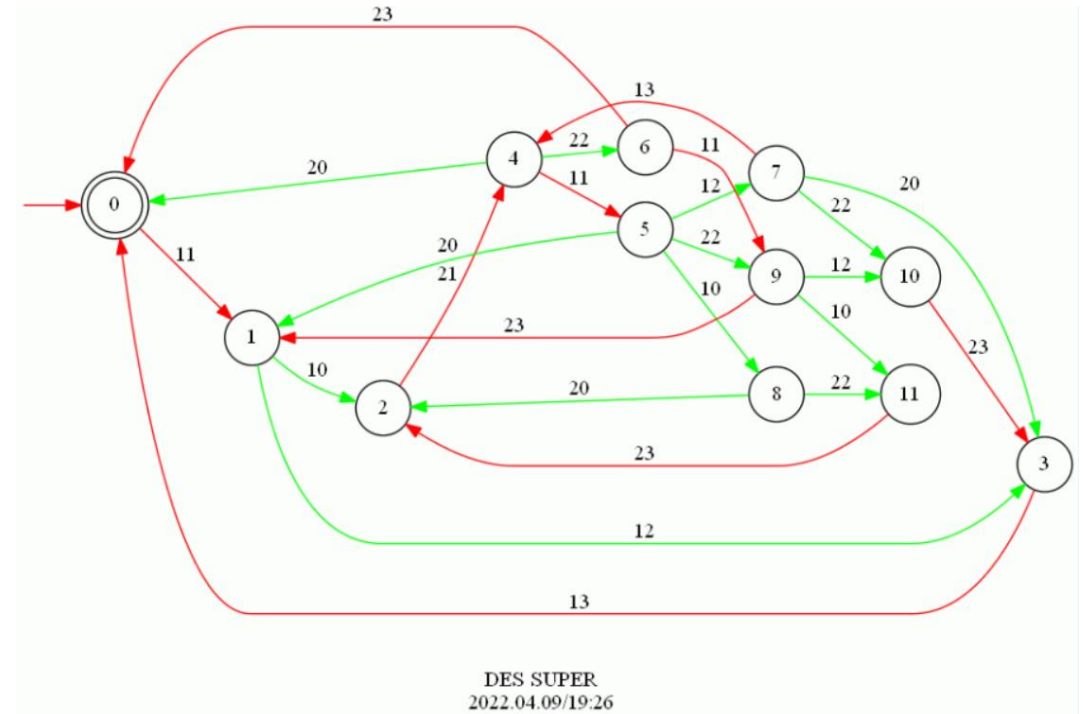
12. SUPER = Condat(FACT,SUPER) Controllable.


```
CONDAT

DES3 = CONDAT (DES1, DES2)

Enter name of plant generator DES1 ......   FACT

Enter name of supervisor DES2 ..........   SUPER

Enter name of control data file DES3 ....   SUPER

Filename SUPER already exists.   OK to overwrite?   (*y/n)   y




Press <Enter> to return to TCT Procedures
```


D:\Archives\Untimed DES\DES Examples\TCT.exe

```
Control data are displayed as a list of supervisor states
where disabling occurs, together with the events that must
be disabled there.

SUPER is CONTROLLABLE

control data:

        0:   21                              1:   21
        2:   11                              3:   21
        8:   11                             10:   13
       11:   11




Press <Enter> to return to TCT Procedures
```

13. SIM = Supreduce(FACT,SUPER,SUPER) (3,14;slb=3)


```
SUPREDUCE

DES3 = SUPREDUCE (DES1, DES2, DAT2)

Enter name of plant generator DES1 ..........    FACT

Enter name of DES2 [= Supcon(DES1,DES?)] ....    SUPER

Enter name of DAT2 [= Condat(DES1,DES2)] ....    SUPER

Enter name of DES3 ........................    SIM

Filename SIM already exists.  OK to overwrite?  (*y/n)  y

Compute slb estimate (at cost of run time increase)? ......  (*y/n)

Press <ESC> to cancel
```


DES SIM
2022.04.09/19:30
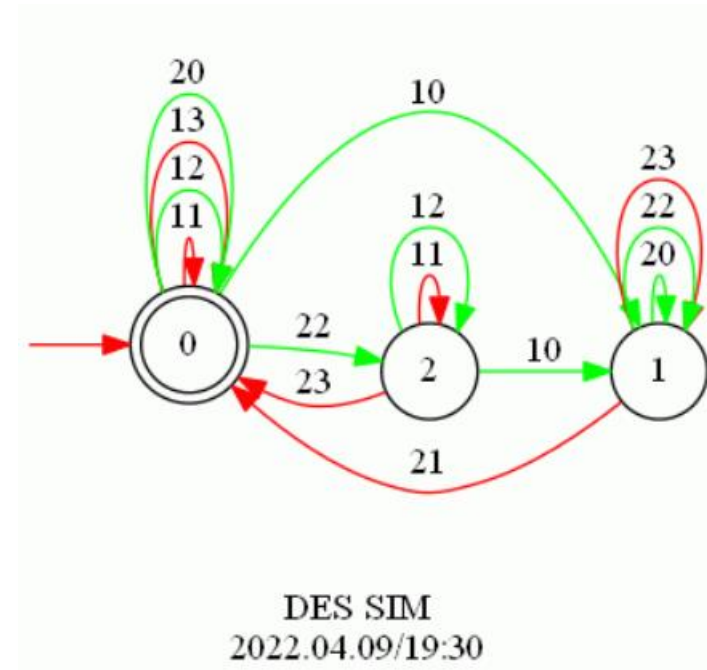
14. TEST=Sync(SIM,FACT)


```
SYNC

DES = SYNC (DES1, DES2, ..., DESk, k)

Enter value of k ....... (between 2 and 30) 2

Enter name of DES1 ........ SIM

Enter name of DES2 ........ FACT

Enter name of DES ......... TEST




Events blocked in TEST: None.

Press <Enter> to return to TCT Procedures
```
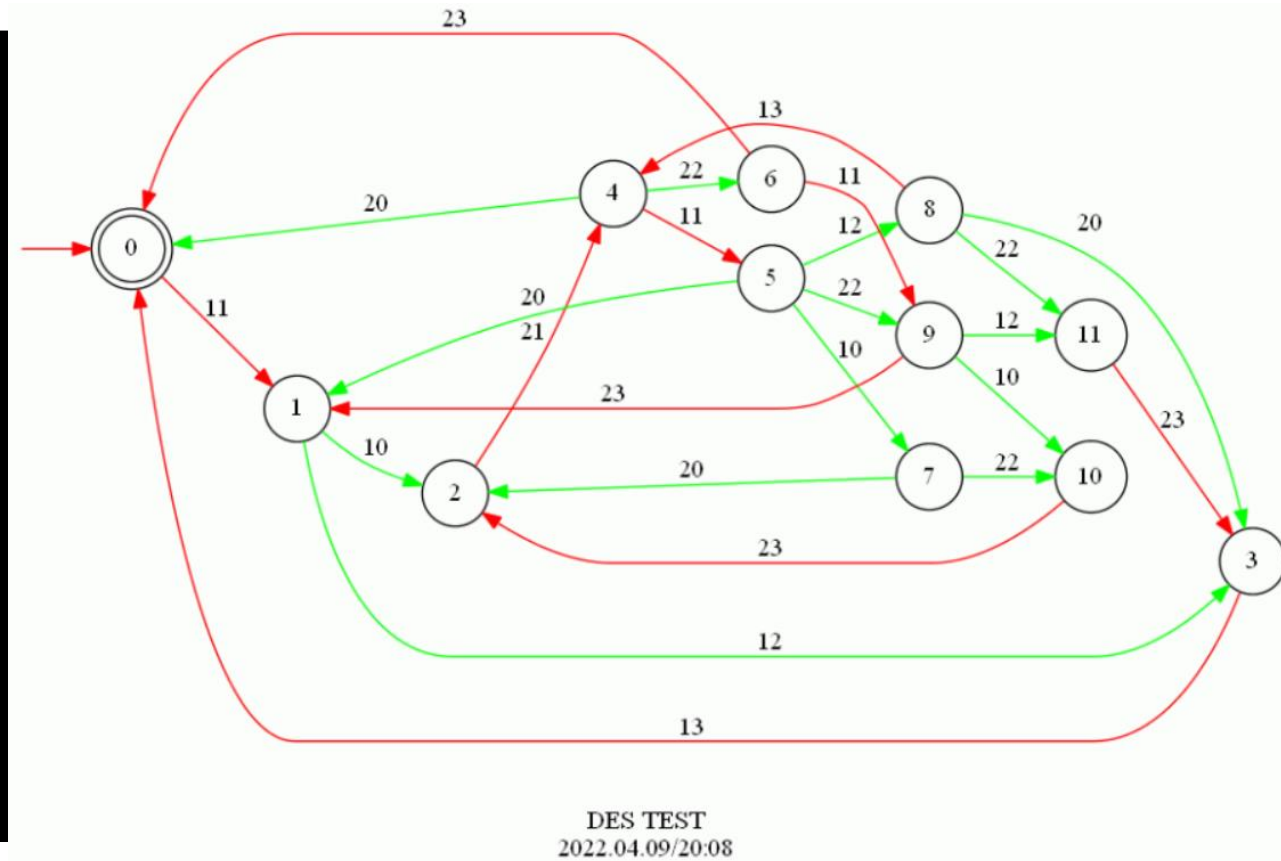
DES TEST
2022.04.09/20:08

15. true=Isomorph(TEST, SUPER)

DES TEST
2022.04.09/20:08

DES SUPER
2022.04.09/19:28
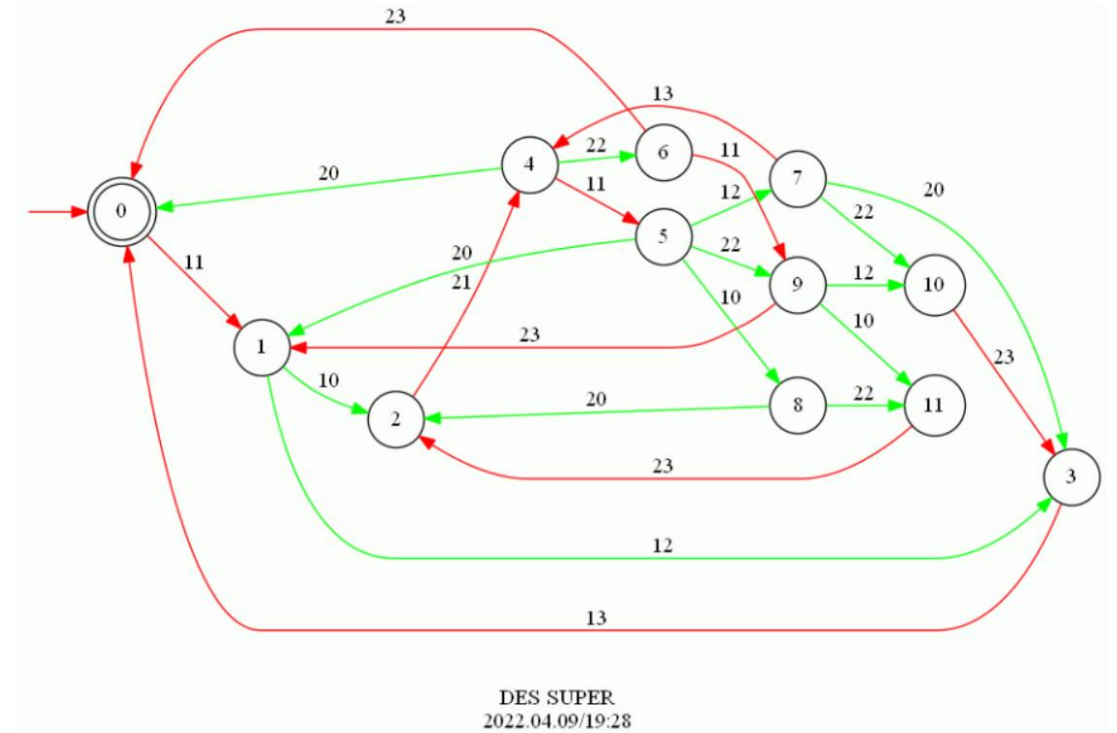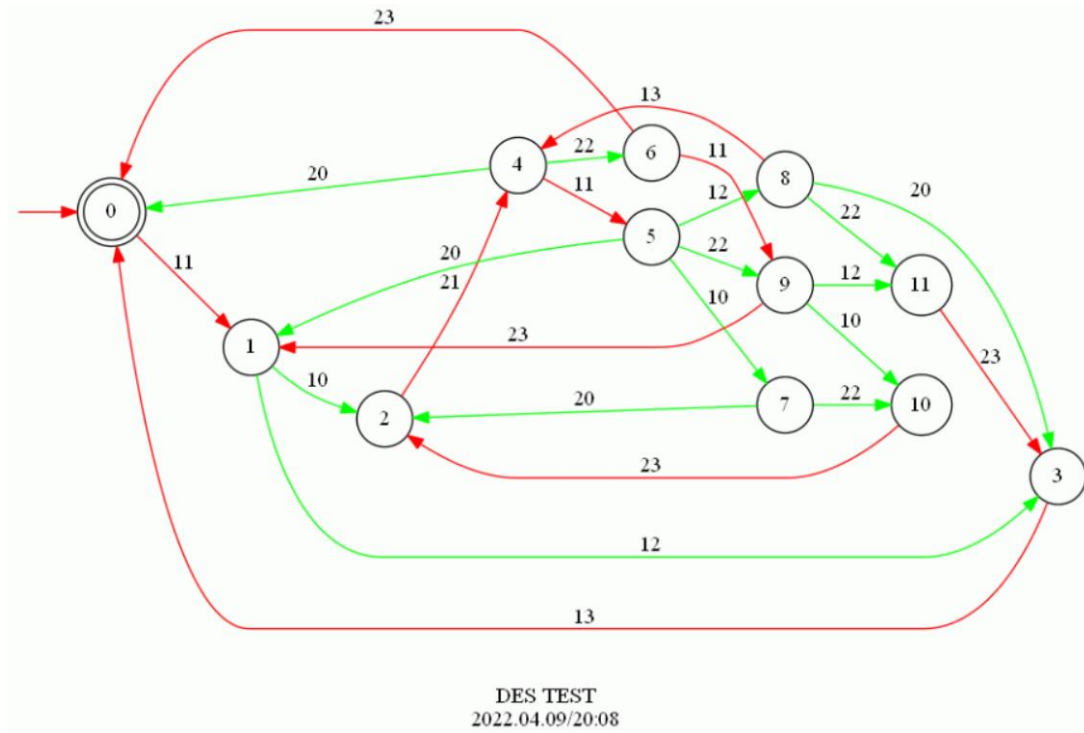
Section 3:
New Feature: call TCT procedures in Matlab

Call TCT procedures in matlab

```
 1   % Clear and close everything
 2 — clear all; close all; fclose all;
 3
 4   % Run setup.m
 5 — setup;
 6 — settctname('TCT64'); % Set the name of tct
 7
 8   % Set working folder
 9 — init('TRANLINE1');
10
11   % Supervisor design procedure
12   % Step 1
13
14   % Creat plant (components)
15 — Q = 2; % number of states
16        % the initial state q0 is always labeled "0"
17 — Qm = [0]; % marker state set
18 — delta = [0,1,1; % transition triples (exit state, event, enter s
19           1,2,0
20        ];
21 — create('M1', Q, delta, Qm); % create automaton
22
23   % Creat plant (components)
24 — Q = 2; % number of states
25        % the initial state q0 is always labeled "0"
26 — Qm = [0]; % marker state set
27 — delta = [0,3,1; % transition triples (exit state, event, enter s
28           1,4,0
29        ];
30 — create('M2', Q, delta, Qm); % create automaton
31
```

```
31
32   % Creat plant (components)
33 — Q = 2; % number of states
34        % the initial state q0 is always labeled "0"
35 — Qm = [0]; % marker state set
36 — delta = [0,5,1; % transition triples (exit state, event, enter st
37           1,6,0;
38           1,8,0
39        ];
40 — create('TU', Q, delta, Qm); % create automaton
41
42   % Creat specification (components)
43 — Q = 2; % number of states
44        % the initial state q0 is always labeled "0"
45 — Qm = [0]; % marker state set
46 — delta = [0,2,1; % transition triples (exit state, event, enter st
47           0,8,1;
48           1,3,0
49        ];
50 — create('B1', Q, delta, Qm); % create automaton
51
52   % Creat specification (components)
53 — Q = 2; % number of states
54        % the initial state q0 is always labeled "0"
55 — Qm = [0]; % marker state set
56 — delta = [0,4,1; % transition triples (exit state, event, enter st
57           1,5,0
58        ];
59 — create('B2', Q, delta, Qm); % create automaton
60
61
```

```
61
62   %Step 2
63
64 — sync('PLANT','M1','M2','TU');
65
66   %displaydes('PLANT') % display automaton
67
68 — allevents('ALL', 'PLANT');
69
70
71   %Step 3
72
73 — sync('SPEC', 'B1', 'B2', 'ALL');
74
75
76   %Step 4
77
78 — supcon('SUP', 'PLANT', 'SPEC');
79   %figure(1)
80   %displaydes('SUP') % display automaton
81
82
83   %Step 5
84
85 — condat('SUPDAT', 'PLANT', 'SUP');
86 — printdat('SUPDAT','SUPDAT')
87
```

The End!

Renyuan Zhang

ryzhang@nwpu.edu.cn