AALTO UNIVERSITY

FIRST SEMESTER, 2015/16

DISTRIBUTED INTELLIGENT AUTOMATION SYSTEMS

ELEC 8102

(Time Allowed: TWO hours)

NOTE: Fill your name and student ID on every page of this form.
You may attempt all questions.
Threshold to pass the course is 50 marks and more.
Put the answers in the same form, in the boxes below the questions.

SURNAME:

FORENAME(S):

ID:

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MARKS:		
1	Out of 20	
2	Out of 15	
3	Out of 10	
4	Out of 20	
5	Out of 15	
6	Out of 20	
7	Out of 15	
TOTAL: (Out of 115)		

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1. State-based design of automation control logic. 20 marks (15/5)

a). The automated oven, studied in the lectures, is presented in a sketch in Figure 1.a. Its controller in the form of a finite state machine is presented in Figure 1.b. Note the notation remarks under the figure. Create a ladder diagram for the oven control state machine. First, present the Boolean equations encoding the state machine and after that the ladder diagram based on the Boolean equations.

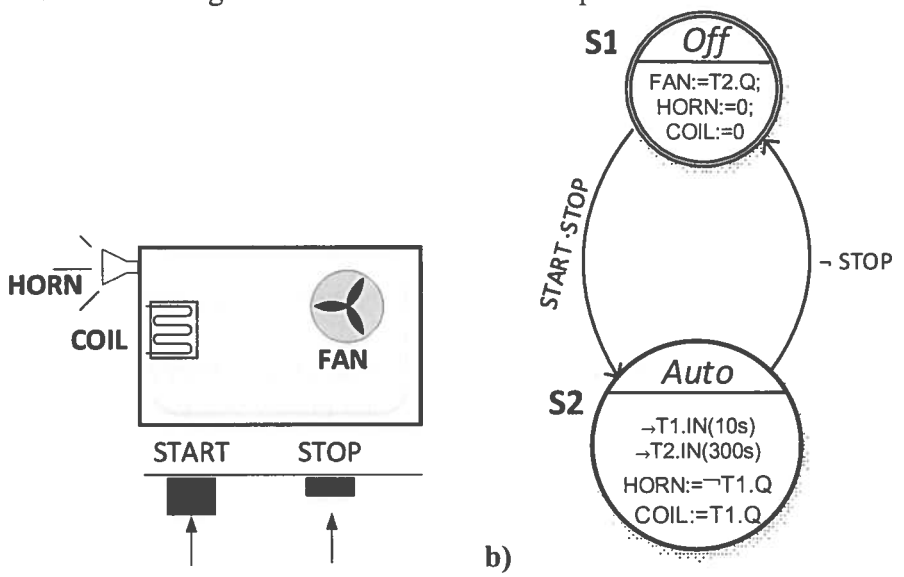

Figure 1. a) Sensors and actuators of the oven; b) State machine describing the controller.

Notation and declarations:

Timers are declared as follows

```
T1: TON;
T2: TOF;
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The notation ➔T1.IN(10s) means: start timer T1 at the arrival to state (rising edge).

For Boolean operations, please use the following notation:
A+B is A or B;
A B is A and B;
$\bar{A}$ – negation of A.

Put the Boolean equations in this box. Which method did you use? See the reminder below.

Method 1: The state transition condition for each state is the logical sum of conditions on all incoming arcs to the state and product of negations of conditions on outgoing arcs.

Method 2: The state transition function is the logical sum of conditions on all incoming arcs to the state including the virtual loopback arc conditions.

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Draw the ladder diagram in this box using the ladder guidelines. Extend the provided grid, if needed.

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(b) The state machine in Figure 2 represents a controller of the pneumatic cylinder as studied in the lectures: the cylinder has one actuator controlled by the logic signal MOVEF. It retracts by the force of a spring.
Modify the controller to blink the lamp with 500ms frequency when the cylinder retracts. Use the same notation as in the question 1.a). You can make the modification directly in Figure 2 or redraw and modify the state machine in the box below.

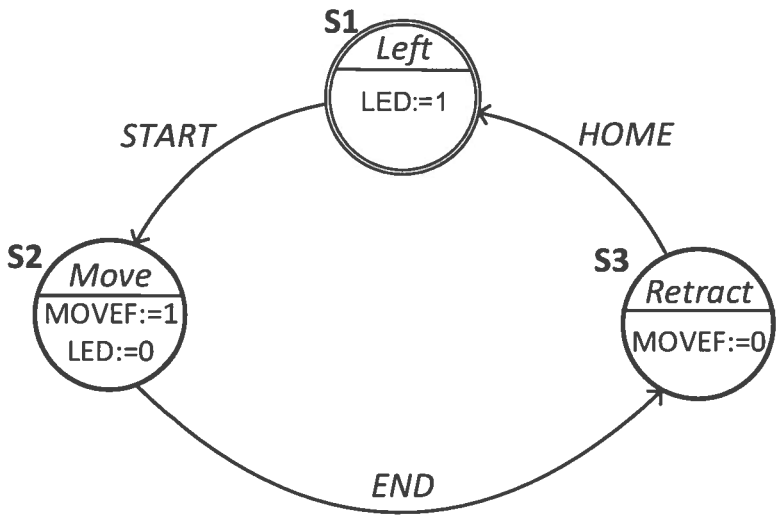

Figure 2. Controller of a pneumatic cylinder.

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2. Distributed processes and logical clocks

Three communicating distributed processes have internal clocks with different tick rates dT as illustrated in the figure below: dT_1=2, dT_2=4, and dT_3=3. If a process sends a message *m* in tick *t*, it includes its current clock reading, *C*(*t*), into the message denoted as *T*(*m*). At every clock tick each process executes the code shown in Figure 3 in the right hand side. The previous tick is referred in the code as *t*-1. It is assumed that only one message can be received in one tick (others are lost).

Answer three questions following the figure. **15 marks (5/5/5)**

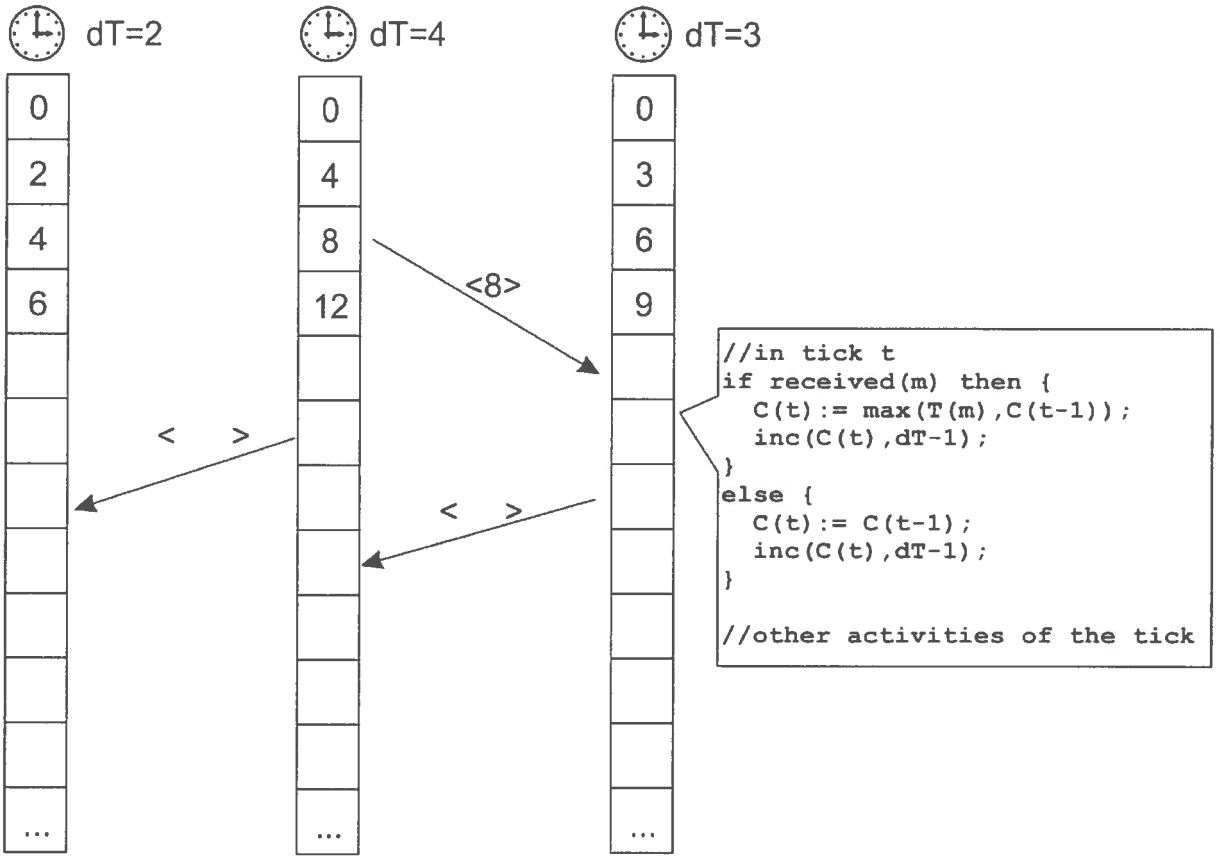

Figure 3.

a) Figure 3 shows only clock readings up to *t*=4. Fill the empty clock readings at *t* > 4 and also show the missing content of the messages.

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b) Do the clocks follow the monotonicity condition? Prove or disprove this.

c) Why is the clocks' monotonicity important in control applications?

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3. Clock synchronization.

A client attempts to synchronize with a time server. It records the round-trip times and timestamps returned by the server in the table below.

	Round-trip (ms)	**Time(hr:min:sec.msec)**
1	22	1:08:15.709
2	25	1:08:16.122
3	24	1:08:16.221
4	22	1:08:16.560

Answer the following three questions a) – c): **10 marks (2/3/5)**

a) Which one of these round-trip measurements should it use to set its clock and why?

b) To what time will the client set its clock in this synchronisation effort?

c) Estimate the accuracy of the setting with respect to the server's clock if it is known that the time between sending and receiving a message in the system concerned is at least 7 ms.

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4. **Modelling of systems with Petri nets.**

You are provided with a (simplified) Petri net which models a slot machine (see Figure 4). Places p_1 and p_2 indicate the state of the slot machine. There are also two places which stand for the number of coins the player and the machine have (p_3 and p_4, respectively). After inserting a coin (represented with a token), the player may either lose or win. In the latter case, the player will receive two coins.

Note the arc weights! The arc with a weight of 2 sourcing in p_4 requires 2 tokens in this place to enable transition t_3, which will remove 2 tokens from p_4 when it is executed. Another arc with a weight of 2 entering p_3 will cause p_3 to receive 2 tokens when t_3 fires.

Answer the following four questions a) – d). **20 marks (12/2/3/3)**

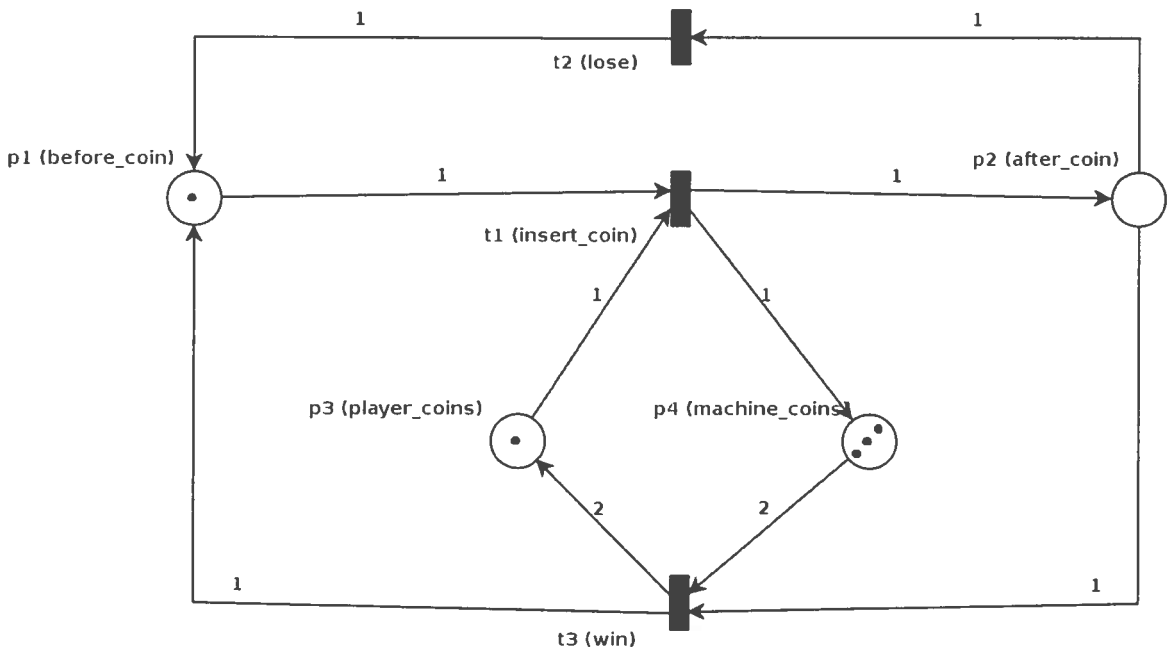

Figure 4. Petri net model of a slot machine.

a) In the box in the next page draw the state space graph for this model. Use the sample in the box and extend it with more states as needed. A state is represented by a vector of 4 place markings. State transition is marked with the name of Petri net transition that fires.

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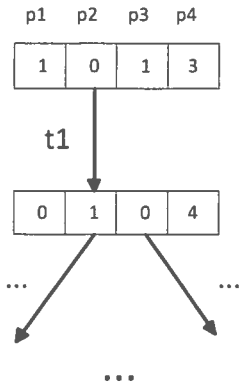

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b) Is the given Petri net bounded? Why?

c) Is the given Petri net safe?

d) If this net has a deadlock, provide a sequence of transitions, which leads to it from the initial marking.

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5. Function blocks and mutual exclusion.

Consider the system of three "user" function blocks that share a critical resource using services of three instances of the MtxProtocol function blocks interconnected as shown in Figure 5.
Answer two questions below the figure. **15 marks (8/7)**

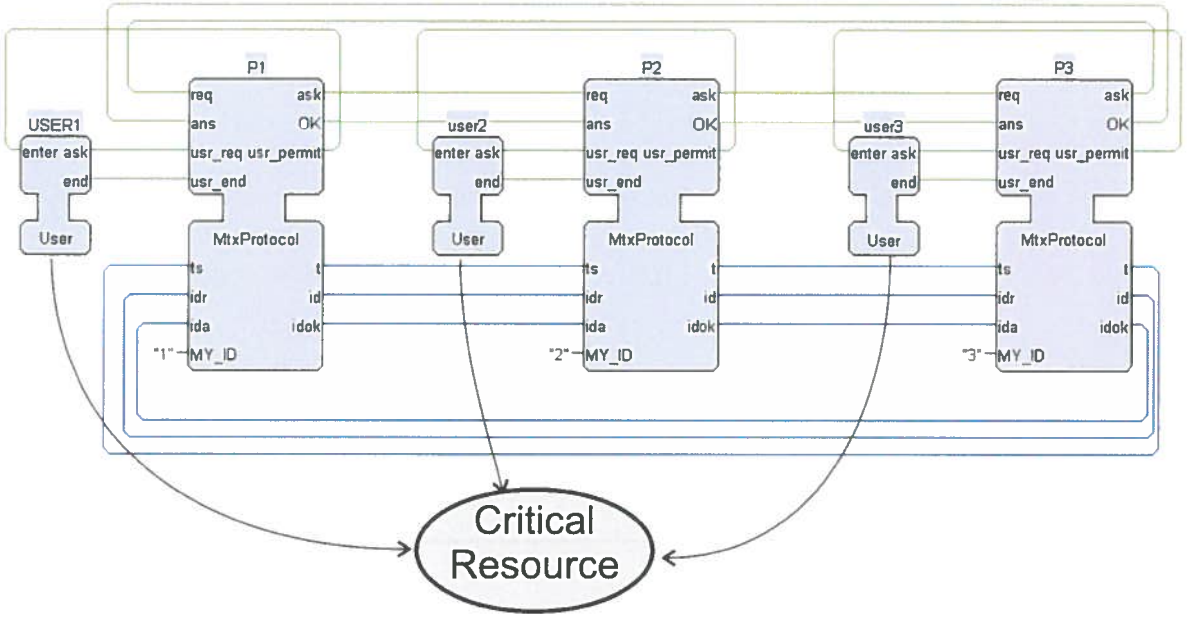

Figure 5.

Legend:

Inputs		Outputs	
usr_req	request from user	usr_permit	allow user access to critical resource;
usr_end	critical section released by user;		
req	request event from other processes;	ask	request event of CS access sent to other processes;
ans	reply event from other processes;	OK	positive reply to other processes;
ts	timestamp of the requester;	t	Lamport timestamp;
idr	ID of the requester;	id	own ID;
ida	ID of the process reply is sent to;	idok	ID of the process whom the positive reply is sent;
MY_ID	Constant – ID of this process;		

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a) Is this topology of connections sufficient to implement the multicast mutual exclusion algorithm? Discuss what are the limitations of the function block language one may encounter while trying to implement it. You may use Figure 5 to illustrate the extra corrections needed (if any), but also need to explain.

b) In case, if you see some limitations for implementation of the multicast mutex in the given function block application, propose how to overcome them without changing the rules of the function blocks language.

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6. Declarative programming languages

You are given a graph representing some relations between sets of numbers (see Figure 6). The "includes" relation tells that the first set includes the second one. The "disjoint" relation tells that two sets are disjoint.

Answer the following two questions. **20 marks (7/8)**

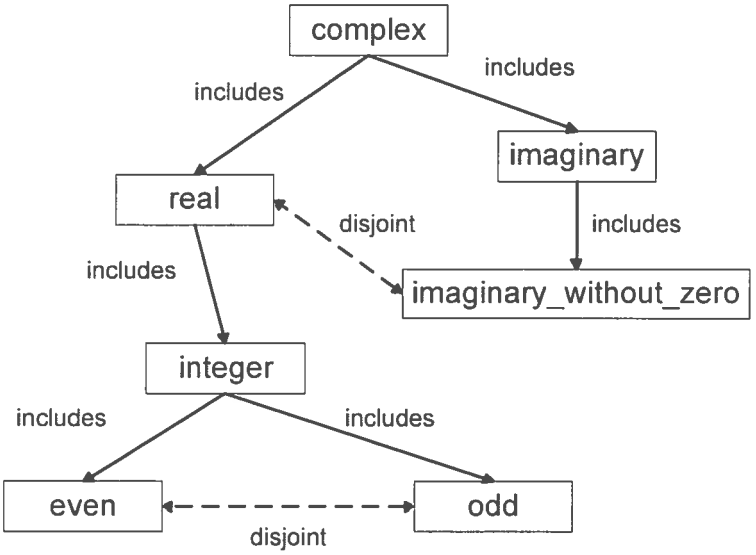

Figure 6.

a) Represent the given tree as a number of Prolog facts. While listing the facts, please use the names "fact_includes" and "fact_disjoint" for the relations: this will help you avoid problems in generalizing the relations in the next questions. Since the "disjoint" relation is reflexive, write two facts for each "disjoint" edge listing the sets in different order.

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b) Define the "includes" relation. Set A includes set B, if either of the following:

i. it is stated as a fact with "fact_includes";

ii. A = B;

iii. A includes another set C and C includes B.

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7. Fuzzy Prosumer Agent

A prosumer agent manages several *Distributed Energy Resources* (DER) in a smart grid. It applies *mamdani*-style fuzzy inference rules in deciding whether to buy or sell energy from/to the grid and how much to buy/sell.

The scales of the input and output variables *are* partitioned into three fuzzy subsets as depicted in Figure 7.

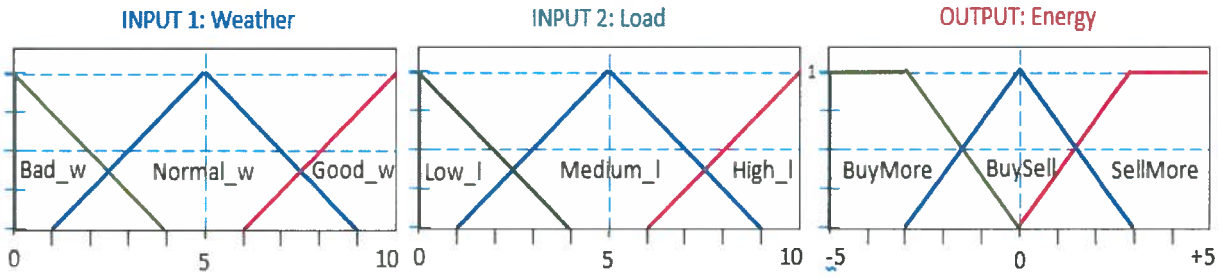


Figure 7.

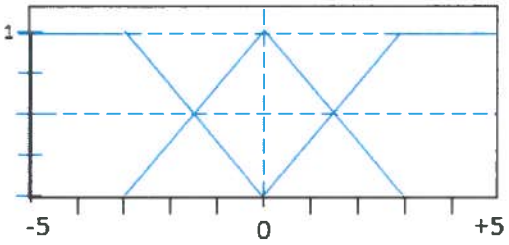
The preliminary version of the rule base of the fuzzy inference system (FIS) contains only three rules and the defuzzification method applied is Center-Of-Gravity (centroid).

1. IF (Weather is '*bad*') AND (Load is '*high*') THEN Energy is '*BuyMore*'
2. IF (Weather is '*good*') OR (Load is '*low*') THEN Energy is '*SellMore*'
3. IF (Weather is '*normal*') AND (Load is '*medium*') THEN Energy is '*BuySell*' (=Buy Or Sell a Little)

Fuzzy inference is computed for the crisp values of the input variables: Weather = 3; Load = 1.5.

Answer the following two questions. **15 marks (8 /7)**

a) Using the figure below, draw a sketch of the membership function of the aggregated fuzzy output set entailed by fuzzy inference.



b) Calculate or approximate the crisp output value (with precision +/- 0.5) and write down a formula how it could be calculated.