

Modelling a crossroad as a discrete event system in Matlab

¹Matej Oravec, ²Anna Jadlovská, ³Štefan Tutko

^{1,2,3} Department of Cybernetics and Artificial Intelligence, Faculty of Electrical Engineering and Informatics, Technical University of Košice, Slovak Republic

¹matej.oravec@tuke.sk, ²anna.jadlovska@tuke.sk, ³stefan.tutko@student.tuke.sk

Abstract — The aim of this article is to create a simulation model of a crossroad in Matlab/Simulink using toolbox Stateflow. Firstly is characterized the crossroad which is the object of modelling. The article then defines formal description of the crossroad. According to formal description is created the simulation model of the crossroad and verified its correctness.

Keywords — discrete event system, crossroad, Stateflow

I. INTRODUCTION

The rapid evolution in information and communications technologies over the past years has brought formation of new dynamic systems which are often highly complex. These systems can be found all around us: computer networks, control, communication and information systems, intelligent buildings, automobiles and a lot other. Dynamics in most of them is characterized by asynchronous occurrences of discrete events. Examples of events are pushing of a button or data obtained from some sensors [1].

Simulation models of described systems allow us to imitate their real working. Through the simulation model we can change parameters of the real system and examine how changes influence the system behaviour. For creating simulation models we need to define performance of the system and its properties properly. We can create simulation models in computing environment Matlab. It offers toolbox Stateflow which is focused on modelling of discrete event systems. We are designing a model of an X-shaped crossroad [2].

II. CHARACTERISTICS OF THE CROSSROAD

We are concerning with the X-shaped crossroad which is composed from two high roads and four pedestrian crossings. We come out from a real model which is in the Fig. 1 and is located at Department of Cybernetics and Artificial Intelligence in laboratory V144 (<http://kyb.fei.tuke.sk/laboratoria/modely/krz.php>). In this picture are included tramways also, but we leave them out from our models. Arrows in Fig. 1 indicate directions in which can vehicles go through the crossroad. It is obvious, that they can move straight or turn right from all ways. It is not possible to turn left from any road [3].

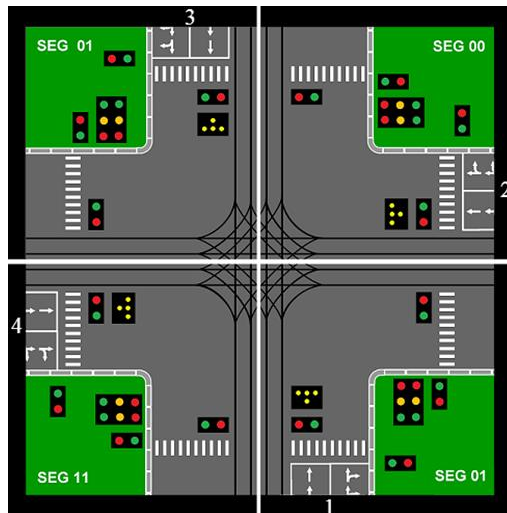


Fig. 1 Crossroad

Movements of vehicles and pedestrians through the crossroad are defined below:

- A1 – vehicles from road 1 moving straight,
- A2 – vehicles from road 1 turning right,
- A3 – vehicles from road 2 moving straight,
- A4 – vehicles from road 2 turning right,
- A5 – vehicles from road 3 moving straight,
- A6 – vehicles from road 3 turning right,
- A7 – vehicles from road 4 moving straight,
- A8 – vehicles from road 4 turning right,
- CH1, CH3 – pedestrians crossing roads 1 and 3,
- CH2, CH4 – pedestrians crossing roads 2 and 4.

States of the crossroad are defined by combinations of these possible movements of vehicles and pedestrians through the crossroad. Colors of lights displayed by traffic lights cause transitions between particular states. Combinations of displayed lights are events which occurs in this system and cause state transitions. Colors of lights displayed by traffic lights change among each other after fixed time periods [2].

III. MODEL OF THE CROSSROAD

This model presents control of the entire crossroad. It includes all semaphores for vehicles and also for pedestrians. States, which represent the functioning of the crossroad, are defined as follows:

- S_1 – vehicles A1, A2, A5, A6 passing through the crossroad,
- S_2 – vehicles A1, A5 and pedestrians CH2, CH4 passing through the crossroad,
- S_3 – vehicles A3, A4, A7, A8 passing through the crossroad,
- S_4 – vehicles A3, A7 and pedestrians CH1, CH3 passing through the crossroad.

We need six semaphores for controlling all directions of vehicles and crossings for pedestrians. For real on the crossroad are 12 semaphores – 4 for pedestrians and 8 for vehicles. But we can integrate opposite semaphores because lights displayed by them are in the same color at all times. We are using these six semaphores [2]:

- Semaphore 1 – for vehicles A1, A5
- Semaphore 2 – for vehicles A3, A7
- Semaphore 3 – for vehicles A2, A6
- Semaphore 4 – for vehicles A4, A8
- Semaphore 5 – for pedestrians CH2, CH4
- Semaphore 6 – for pedestrians CH1, CH3

Changes of colors of displayed lights depend on time. Each color is displayed for fixed time period. Combinations of colors displayed by semaphores are events, which occurrence causes state transitions of the crossroad. These events are:

K_1 – green on semaphore 1 and 3, red on all others semaphores
 K_2 – green on semaphore 1 and 5, red on all others semaphores
 K_3 – green on semaphore 2 and 4, red on all others semaphores
 K_4 – green on semaphore 2 and 6, red on all others semaphores

The model of the crossroad based on the mentioned states of the crossroad and events, which affect these states, we can define formally as follows:

States set: $X = \{S_1, S_2, S_3, S_4\}$

Events set: $E = \{K_1, K_2, K_3, K_4\}$

Initial state: $x_0 = S_1$,

Transition function:

$$f(S_1, K_2) = S_2,$$

$$f(S_2, K_3) = S_3,$$

$$f(S_3, K_4) = S_4,$$

$$f(S_4, K_1) = S_1.$$

The characteristics of the crossroad we can represent graphically through the state diagram. The state diagram of the crossroad is illustrated in Fig. 2.

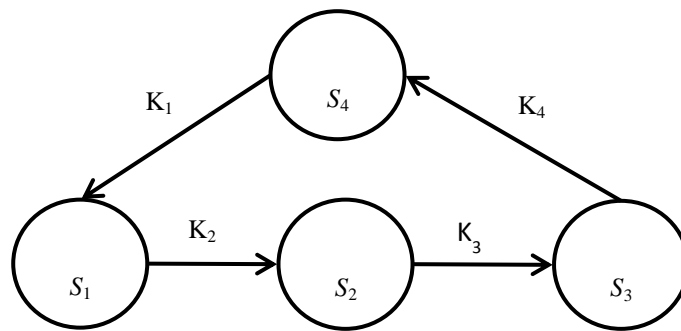


Fig. 2 State diagram of the crossroad

IV. SIMULATION MODEL OF THE X-SHAPED CROSSROAD IN TOOLBOX STATEFLOW

According the formal definition of the crossroad we created its simulation model in Simulink with the use of toolbox Stateflow. Insight of the simulation model is in Fig. 3 [2].

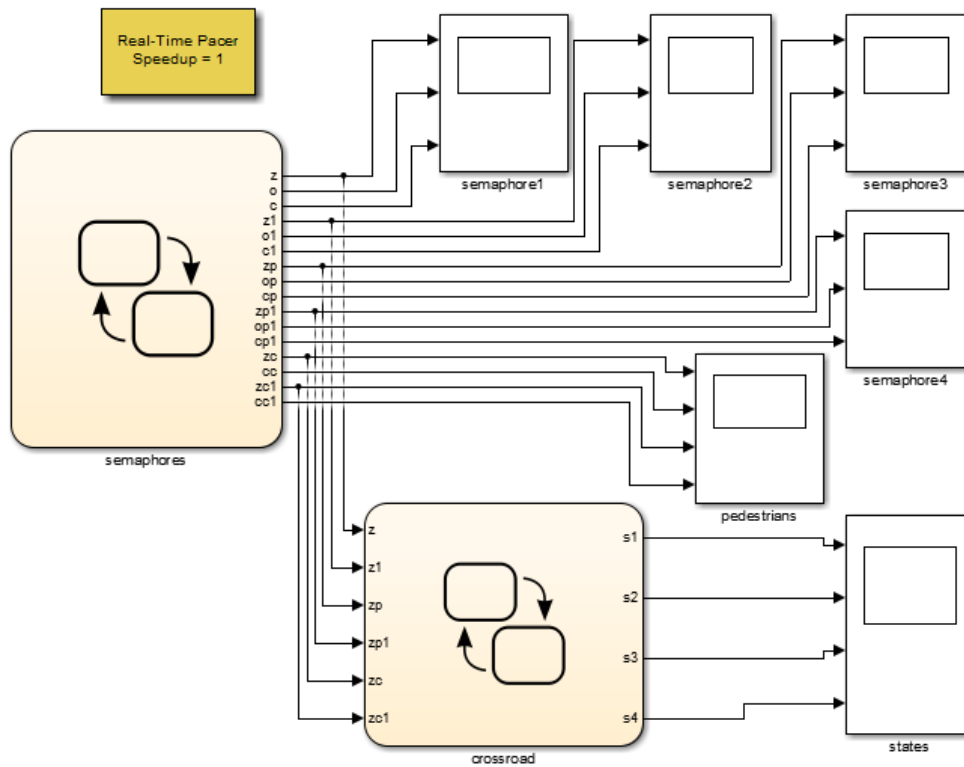


Fig. 3 Simulation model of the crossroad

We needed to use two charts built up in toolbox Stateflow as we can see in Fig. 3. The chart named *semaphores* is dedicated to control semaphores. It has no input variables, because changes of signals displayed by semaphores are dependent on time of simulation. Output variables from this chart are representation of particular lights displayed by each semaphore. The structure of the chart *semaphores* is in Fig. 4.

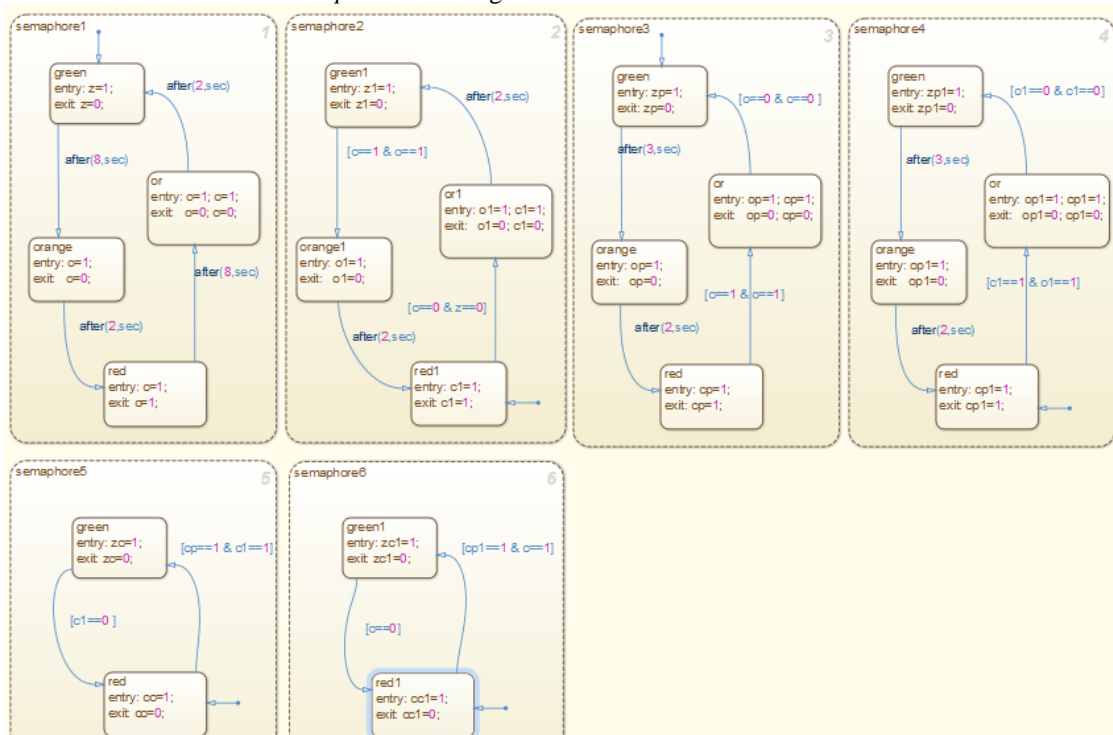


Fig. 4 Semaphores of the crossroad in toolbox Stateflow

The second chart named *crossroad* in Fig. 3 contains all states of the crossroad and transitions between them, which we described. Input variables in this chart are light signals from chart *semaphores*. We just need signals of green color, because chart *semaphores* ensures, that if two semaphores display green light other semaphores display red light. Orange lights displayed by semaphores don't influence particular states of the crossroad. They present only a temporary state of the semaphore when green light is turning to red or reversely. Output variables from chart *crossroad* are representing states of the crossroad. How states and transitions between them are organized in this chart is illustrated in Fig. 5.

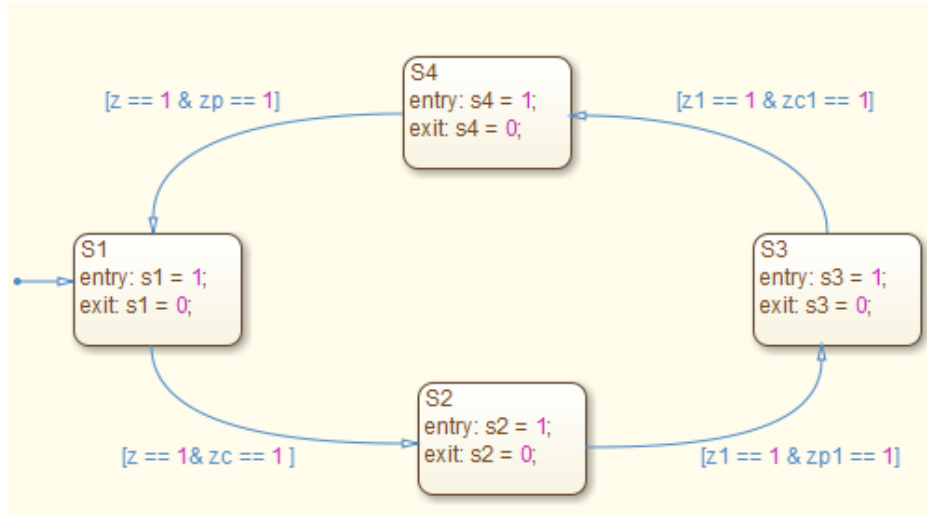


Fig. 5 States of the crossroad

States and lights displayed by semaphores are recorded during a simulation graphically to diagrams. Diagrams of particular lights displayed by each semaphore during 60-seconds simulation is in Fig. 6. In Fig. 7 are illustrated developments of states of the crossroad model obtained from the same simulation [2].

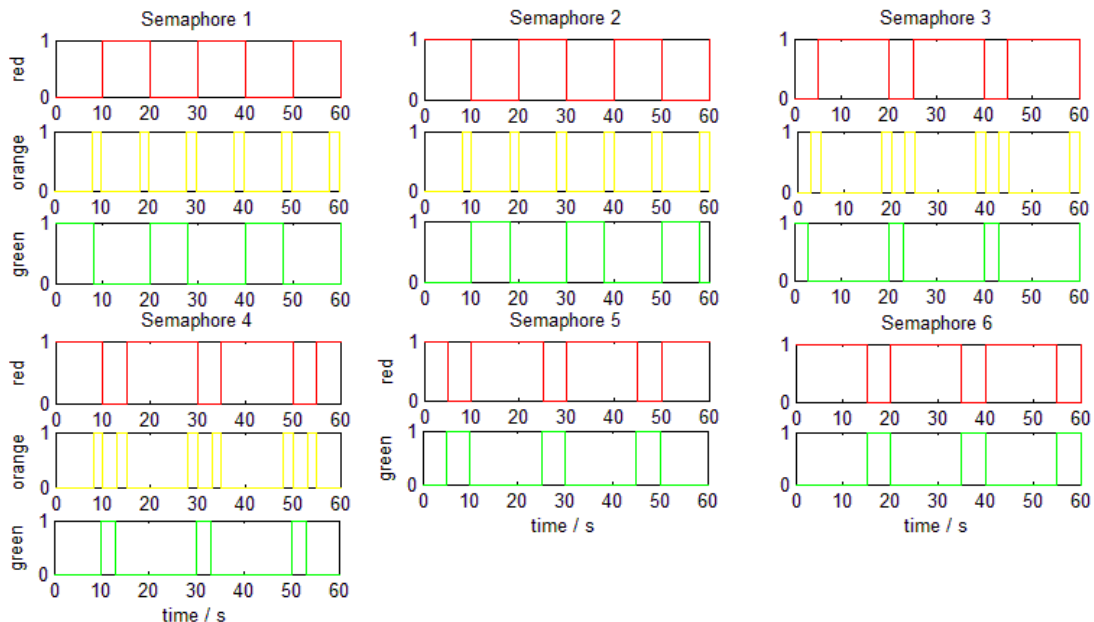


Fig. 6 Developments of lights displayed by semaphores during the simulation

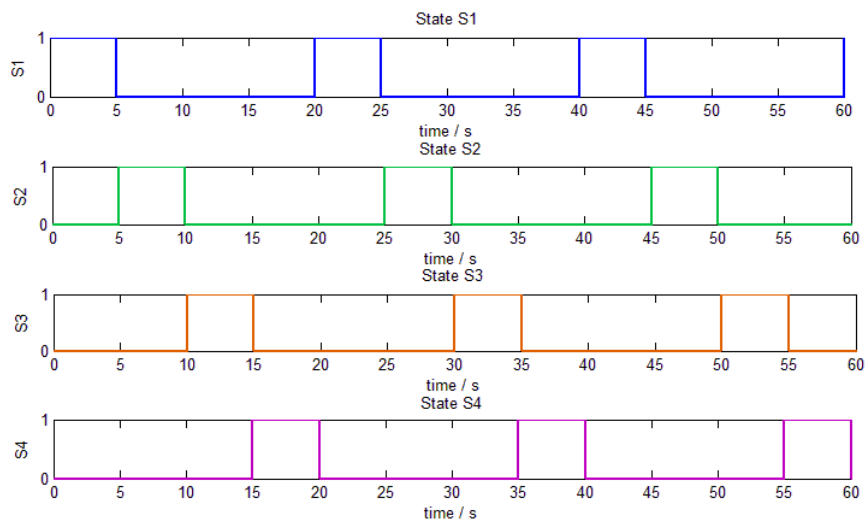


Fig. 7 Developments of states of the crossroad model during the simulation

The development of the simulation of created crossroad model captured in Fig. 6 and Fig. 7 verifies if our simulation model of the crossroad imitates the functioning of the crossroad correctly. From both figures we can declare that simulation model satisfies the formal definition of the crossroad.

V. CONCLUSION

The main point of this article is designing a simulation model of the crossroad in toolbox Stateflow in software package Matlab/Simulink. The article describes the model of the crossroad formally and based on this description presents the simulation model created in Matlab/Simulink. Control of the crossroad and its semaphores is designed in toolbox Stateflow. Correctness of the simulation model is verified through graphical developments of its variables which represent particular lights displayed by semaphores and states of the crossroad. The simulation model is designed to imitate the real function of the crossroad.

ACKNOWLEDGMENT

This work has been supported by the Research and Development Operational Program for project: University Science Park Technicom for innovative applications with knowledge technology support, ITMS code 26220220182, co-financed by the ERDF (80%) and by grant KEGA - 001TUKE-4/2015 (20%).

REFERENCES

- [1] CASSANDRAS, Christos G., LAFORTUNE, Stéphane: Introduction to Discrete Event Systems. Second edition. New York: Springer, 2008. 771 p. ISBN 978-0-387-33332-8
- [2] TUTKO, Štefan: Design of simulation models for system with discrete events in Matlab: Bachelor's thesis. Košice: TU – FEI, 2015. 46 p.
- [3] KAČMÁR, Matej: Multi-level crossroad model: Bachelor's thesis. Košice: TU – FEI, 2009. 62 p.
- [4] MATHWORKS.COM: Stateflow: Model and simulate decision logic using state machines and flow charts [online]. Massachusetts: MathWorks. Web: < <http://www.mathworks.com/products/stateflow/index.html>>
- [5] KARRIS, Steven T.: Introduction to Stateflow® with Applications. Orchard Publications, 2007. 520 p. ISBN 978-1-934404-07-2