Sławomir JASZCZAK, **Krzysztof MAŁECKI**
DEPT. OF COMP. SCIENCE, WEST POMERANIAN UNIVERSITY OF TECHNOLOGY, ZOLNIERSKA 49 STREET, SZCZECIN, POLAND

Hardware and software synthesis of exemplary crossroads in a modular programmable controller

Sławomir JASZCZAK, PhD

Since 1994, as an assistant at the Faculty of Maritime Technology and Transport at Szczecin University of Technology, carrying out research on controlling remotely operated vehicles with the use of artificial intelligence. Since 2002 employed as an adjunct at the Artificial Intelligence Division. Current interests connected with the implementation of complex discrete and digital control PLC algorithms.

71-210 Szczecin, ul. Żołnierska 49
e-mail: sjaszczak@wi.zut.edu.pl.

Krzysztof MAŁECKI, PhD

Since 1997, as an assistant at the Faculty of Computer Science and Information Technology, conducting research on system design. Since 2001 employed as an adjunct at the West Pomeranian University of Technology in Szczecin. Current interest connected with modelling and simulating complex systems, especially those related to traffic. To achieve those goals, cellar automata and their graphic interpretation are used.

71-210 Szczecin, ul. Żołnierska 49
e-mail: kmalecki@wi.zut.edu.pl

Abstract

The aim of this article is to present the achievements in the field of the execution of a road junction model as well as the design of traffic managing algorithms and programs based on a modular programmable controller (S7 – 200 CPU 222), i.e. under conditions of restricted program and data memory along with limited syntax of the programming language. The authors have shown that it is possible to produce a simulation environment (of a structure similar to real conditions), which will allow for experiments with the algorithms controlling traffic lights and observation of vehicles behaviour in the newly adjusted environment.

Keywords: hardware and software synthesis, PLC, traffic

Synteza sprzętowo-programowa przykładowego węzła drogowego w programowalnym sterowniku modułowym

Streszczenie

Celem niniejszego artykułu jest przedstawienie dokonań w zakresie wykonania makiety skrzyżowania dróg oraz opracowania algorytmów I programów dla potrzeb sterowania ruchem na bazie programowalnego sterownika modułowego (S7 – 200 CPU 222) tj. w warunkach ograniczonej pamięci programu i danych oraz ograniczonej syntaktyki języka programowania.
Sterowanie ruchem drogowym nie jest zagadnieniem trywialnym, przede wszystkim z racji istnienia różnych rozwiązań architektonicznych (tj. różne układy dróg i skrzyżowań, w tym skrzyżowań o ruchu okrężnym) oraz stale zmieniającej się charakterystyce ruchu drogowego. Konstruktorzy systemów do sterowania ruchem często muszą eksperymentować na rzeczywistym obiekcie, dobierając eksperymentalnie czasy faz, ustalając możliwe sytuacje kolizyjne itp., co praktycznie skutkuje zaburzeniami w ruchu drogowym. Istnieje zatem potrzeba wytworzenia środowiska symulacyjnego (o strukturze zbliżonej do warunków rzeczywistych), który pozwoli na eksperymentowanie z algorytmami sterującymi sygnalizacją świetlną i obserwacji zachowania pojazdów w nowo-wysterowanym środowisku. W artykule przedstawiono specyfikę sterowników modułowych (zwanych wcześniej micro), syntezę sprzętowo-programową środowiska symulacyjnego i przykładowe algorytmy sterowania sygnalizacją świetlną.

Słowa kluczowe: synteza sprzętowo-programowa, PLC, ruch drogowy

1. Introduction

Analysis and modelling of traffic is a difficult task, what with the complexity of the problem and its stochastic nature. Road administration and scientists, not wanting to expose drivers to inconveniences connected with attempts of controlling an area (e.g. a crossroads or a couple of intersections in close vicinity), make use of various simulators. Over the last few years, many publications have covered the attainments in this field. In general, they can be categorised as software, hardware or hardware and software solutions. The most common are probably software solutions, e.g. complex systems, such as MATSim, VISSIM [7], TRANSIMS [18], MITSIM, AIMSUN, SUMO [11] and CORSIM, as well as theories [5],[17], smaller simulations: [2], [3], [13] or those regarding pollution [24]. Some authors focus on solutions close to real-time simulation [8]. As far as hardware is concerned, a wide variety can be observed. Multiple models representing certain road junctions have been created, such as [6], [9], [12], [19], hardware-in-the loop systems [4], [25], real object scale models [14] and GPU utilising solutions [21].
This article presents the achievements in controlling a micro scale real object.

2. Selected aspects of the example shown in the article

The task of the developed control system is sequential control of traffic lights of a crossroads model of an assumed scale, according to the declared needs.
The system is meant to be used as a teaching aid in laboratory classes and can be the basis for discussing the methodics of design and implementation of traffic lights controlling algorithms and the rules of coupling actors and sensors with programmable controllers. Basing on the initial assumptions, the following functions of the system have been defined:

- checking initial condition necessary for the correct work of the device,
- communication with the operator – receiving commands,
- signalling states of phases,
- signalling alarm states.

The aforementioned functions have been depicted in fig.1.

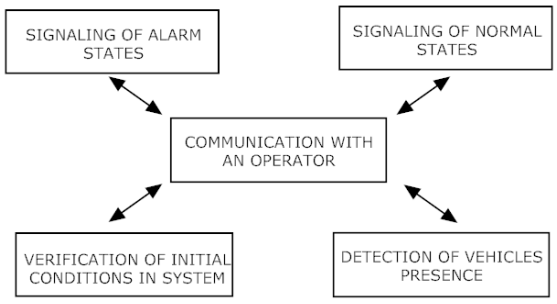

Fig. 1. A functional structure of the control system [own research].
Rys. 1. Struktura funkcjonalna systemu sterowania [opracowanie własne].

Device design begins with breaking down a control system into functional modules, presented in fig. 2.

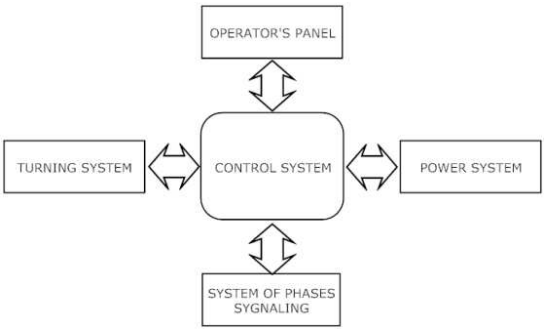

Fig. 2. A functional modules of the traffic lights control system [own research].
Rys. 2. Moduły funkcjonalne systemu sterowania sygnalizacją świetlną [opr. własne].

A real crossroads model, created accordingly to the presumptions is presented in fig. 3.

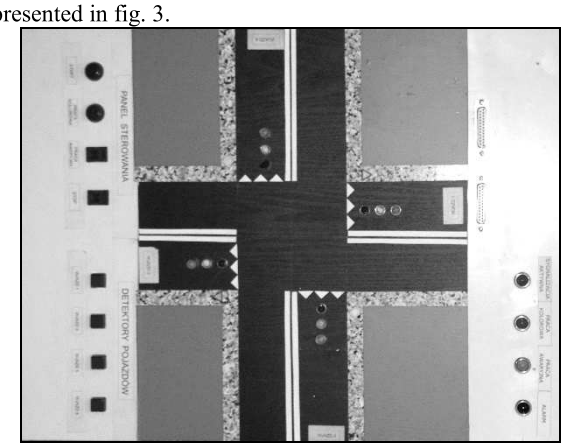

Fig. 3. A physical model of the real crossroads [own research].
Rys. 3. Model rzeczywistego skrzyżowania [opr. własne].

3. Conclusion

The main aim of this work was to prove that with the use of micro controllers it is possible to prepare a simulation environment of an exemplary crossroads. For this article, the following has been prepared:

- a crossroads model with traffic lights and a set of buttons simulating detectors of vehicles entering the intersection and control panel managing the traffic lights,
- traffic lights controlling programs, created with Siemens Step-7 MicroWIN software.

The model can be used for educational purposes (used controller does not fulfil the criteria of the Minister of Infrastructure regarding traffic lights controllers). It allows for learning about the essence of design and execution of the software controlling traffic lights at intersections.

4. References

[1] Adamski M., Kołopieńczyk M., Mielcarek K., Doskonała sieć Petriego w projektowaniu współbieżnych układów sterujących, Pomiary Automatyka Kontrola, nr 6, 2011, s. 656-660
[2] Barcelo J., Codina E., Casas J., Ferrer JL., Microscopic traffic simulation: A tool for the design, analysis and evaluation of intelligent transport systems, Springer Journal of Intelligent and Robotic Systems, Vol. 41, Issue 2-3, pp. 173-203, 2005
[3] Bloomberg L., Dale J., A Comparison of the VISSIM and CORSIM Traffic Simulation Models On A Congested Network, Journal of Transportation Research, 2000
[4] Bullock D., Urbanik T., Hardware-in-the-loop evaluation of traffic signal systems, Int. Conf. on Road Transport Information and Control, p. 177–181, 2000
[5] Chowdhury D., Santen L. and Schadschneider A., Statistical physics of vehicular traffic and some related systems, Physics Reports, vol. 329, pp. 199-329, May 2000.
[6] Dzierżek K., Ostaszewski M., Intersection model with configurable control system, Zeszyty Naukowe AM w Szczecinie, s.36-39, 2010
[7] Fellendorf M., VISSIM: A microscopic simulation tool to evaluate actuated signal control including bus priority, in 64th Institute Transportation Engineers (ITE) Annu. Meeting, Dallas, TX, USA, 1994, pp. 1-9.
[8] Franzese O., Joshi S., Traffic simulation application to plan real-time distribution routes, Proc. of the Winter Simulation Conference, 2002
[9] Han X., Sun H., The Implementation of Traffic signal Light Controlled by PLC, Journal of Changchun Institute of Optics and Fine Mechanics, 2003
[10] Kołopieńczyk M., Application of adress converter for decreasing memory size of compositional microprogram control unit with code sharing, Lecture Notes in Control and Computer Science, Vol. 12, 2008
[11] Krajzewicz D., Hertkorn G., Rössel C., Wagner P., SUMO (Simulation of Urban MObility) - An open-source traffic simulation, MESM2002 Proc., 2002
[12] Kwon E., Kim S., Kwon TM., Pseudo real-time evaluation of adaptive traffic control strategies using hardware-in-loop simulation, IECON'01, 2001
[13] Małecki K., Iwan S., Development of Cellular Automata for Simulation of the Crossroads Model with a Traffic Detection System, Communications in Computer and Information Science, Springer, no. 0329, ss.276-283, 2012
[14] Małecki K., Jaszczak S., Sokołowski R., Synteza sprzętowa i programowa symulatora sterowania ruchem pojazdów na określonym obszarze, Pomiary Automatyka Kontrola, No. 7/2012, Polska, 2012, ss. 608-610
[15] Miao Q., Zhu F., Lv Y., Cheng C.-J., Chen C. and Qiu X., A game-engine-based platform for modeling and computing of artificial transportation systems, IEEE Transactions on Intelligent Transportation Systems, vol. 12, no. 2, pp. 343-353, 2011
[16] Mielcarek K., Adamski M., Zając W., Czy prawidłowa sieć Petriego jest siecią doskonałą?, Metody Informatyki Stosowanej, nr 3, 2010, s. 169-176
[17] Nagel K. and Michael S., A cellular automaton model for freeway traffic, Journal de Physique I, vol.2, pp. 2221-2229, Dec. 1992.
[18] Nagel K. and Rickert M., Parallel implementation of the TRANSIMS micro-simulation, Parallel Computing, vol.27, pp. 1611-1639, Nov. 2001.
[19] Popescu M.C., Ranea C., Grigoriu M., Solutions for Traffic Lights Intersections Control, Proceedings of the 10th WSEAS, 2010
[20] Sacha K.: Projektowanie oprogramowania systemów sterujących, Oficyna Wydawnicza Politechniki Warszawskiej, Warszawa, 1999.
[21] Shen Z., Wang K., Zhu F., Agent-based traffic simulation and traffic signal timing optimization with GPU, Intelligent Transportation Systems, 2011
[22] Strippgen D. and Nagel K., Multi-agent traffic simulation with CUDA, in International Conference on High Performance Computing & Simulation, Leipzig, Germany, 2009, pp. 106-114.
[23] Wang F.-Y., Parallel control and management for intelligent transportation systems: concepts, architectures, and applications, IEEE Trans. on Intelligent Transportation Systems, vol. 11, no. 3, pp. 630-638, 2010.
[24] Taosheng J., Lixin F., Application of GIS to modified models of vehicle emission dispersion, Elsevier, 2005
[25] Wells R.B., Fisher J. et al., Hardware and software considerations for implementing hardware-in-the loop traffic simulation, The 27th Annual Conference of the IEEE, IECON, vol. 3, p. 1915–1919, 2001