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A General Test Platform for Cyber-Physical Systems: Unmanned Vehicle with Wireless Sensor Network Navigation

Jiafu Wan[a, b], Hui Suo[b,*], Hehua Yan[b], Jianqi Liu[b]

[a]*School of Computer Science and Engineering, South China University of Technology, Guangzhou, China*
[b]*College of Information Engineering, Guangdong Jidian Polytechnic, Guangzhou, China*

Abstract

Cyber-Physical Systems (CPSs) integrate the virtual cyber world with the real physical world. Nowadays, the theories and applications of CPSs still face enormous challenges. In order to facilitate this emerging domain, a general test platform for CPSs, low-priced intelligent vehicle with Wireless Sensor Networks (WSNs) navigation, is designed to test and verify the proposed methods and theories. We in brief review the research progresses of CPSs, WSNs and unmanned vehicles. By means of deeply analyzing the test platform architecture and WSN navigation principle, the software and hardware of this platform are developed. The experiment results show that the resolution of wireless sensor navigation is less than 0.67m. On the basis of these, how to conduct studies from different perspectives is illustrated, and the implementation challenges are also outlined.

Keywords: Cyber-physical systems, wireless sensor networks, unmanned vehicle, navigation, intelligent road

1. Introduction

Cyber-Physical Systems (CPSs) integrate computing, communication, and control with the physical world [1]. Applications of CPSs include medical devices and systems, assisted living, traffic control and safety, advanced automotive systems, process control, energy conservation, instrumentation, critical infrastructure (e.g. power, water), distributed robotics, weapons systems, manufacturing, distributed sensing command and control, smart structures, biosystems, and communications systems [2-4]. Although the application prospects of this field are attractive, there are still many challenges.

In order to expedite development of this emerging domain, it is very necessary for CPSs to develop a general test platform. Taking unmanned vehicle with Wireless Sensor Networks (WSNs) navigation as an

*Corresponding author. Tel.: +86-13580418089.
E-mail address: suohui79@163.com.

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example, we designed software and hardware, and established a low-priced intelligent vehicle. This platform is a classic CPS, that is advantageous to verify the new methods and theories, and concludes two distinguishing features: (1) the vehicle and WSN may be designed by ourselves or purchased, whose prices are very low, and (2) most of challenges are embodied in this platform, and it is the most representative.

2. WSNs and CPSs

WSNs are more than just a specific form of ad hoc networks. The cost constraints and stringent miniaturization make economic usage of energy and computational power a significantly bigger problem than in normal ad hoc networks [5-7]. Nowadays, WSNs are widely used in tracking and monitoring. CPSs are not today's sensor networks, and they are more complicated than WSNs. In CPSs, one of the most conspicuous features is that control loops must close.

WSNs started to appear in the 1990s, and they have great potential for many applications in scenarios such as military target tracking and surveillance, natural disaster relief, biomedical health monitoring, hazardous environment exploration, and seismic sensing [6]. In these applications, all of them are not real-time systems. At present, though many practical applications have been conducted, there are still many challenges. These key issues include topology structure, communication protocol, implementation of protocols, limited battery power, energy conservation, energy harvesting, reliable communication and services, mass-data processing, etc [8].

In recent years, CPSs have been treated as a new development strategy by American government. The goals of CPSs research program are to deeply integrate physical and cyber design. Some researchers from related research institutes and universities discussed the related concepts, technologies, applications and challenges during CPSweek and the international conference on CPS subject [9]. The research results of CPSs mainly concentrate in the following respects, e.g. energy control, secure control, transmission and management, control technique, system resource allocation, and model-based software design, etc.[4, 10]. Now, this field is still in the beginning stage, which has been attracting the significant interest, and will continue for the years to come.

3. Unmanned vehicle

In nearly ten years, intelligent vehicles have become a fascinating field which attracts more attention over the world. In these unmanned vehicles, the vision navigation system plays a significant role in detecting physical environment. GPS and some other sensors are subsidiary to locate and navigate.

Nowadays, many practical applications have been implemented. The 2getthere develop Personal Rapid Transit (PRT) that is a transport method to offer personal, on-demand non-stop transportation between any two points on a network of specially built guide-ways. This system consists of a number of small automated vehicles [11]. Similarly, ParkShuttle is an automated people mover connecting two cities [12]. In addition, RobuRide and Serpentine system are also unmanned vehicles [13]. As a whole, unmanned vehicles are not now in widespread use because of some technological constraints.

With development of embedded systems and WSNs, CPSs as a newly-emerged domain are proposed. M. Li *et al* [14] propose to utilize WSN infrastructure as a CPS for navigating internal users during emergencies. In this system, the location information comes mainly from WSNs, while GPS and vision system provide ancillary datum. This mode with WSNs navigation is different from the mentioned method in the previous paragraph. Integrating intelligent road with unmanned vehicle is a classic feature.

4. A case of CPSs: unmanned vehicle with WSNs navigation

4.1. Platform architecture

For most researchers, a general and low-priced test platform for CPSs serves to conduct the theoretical and practical experiments. On the basis of available technologies such as WSNs, embedded systems and software design, we analyzed and discussed the proposed test platform from the following three aspects: platform architecture, navigation principle and highway application, and these include many challenges.

Fig. 1 shows the test platform architecture, which is mainly made up of WSNs and unmanned vehicles. Many sensor nodes (e.g. IEEE 802.15.4/ZigBee) construct wireless networks with the features of dynamically reorganizing and reconfiguring. The unmanned vehicles with sensor nodes get datum from WSNs and further process information so as to determine the behaviors of vehicles. An unmanned vehicle comprises vision system, GPS, main body mainboard, etc. The GPS and vision system serve as auxiliary location, while the unmanned vehicles primarily realize navigation depending on WSNs.

Two intelligent vehicles with wireless sensors are shown in Fig. 2. The left unmanned vehicle without vision system locates and navigates by means of WSNs and GPS. The open source Linux is chosen as operating system.

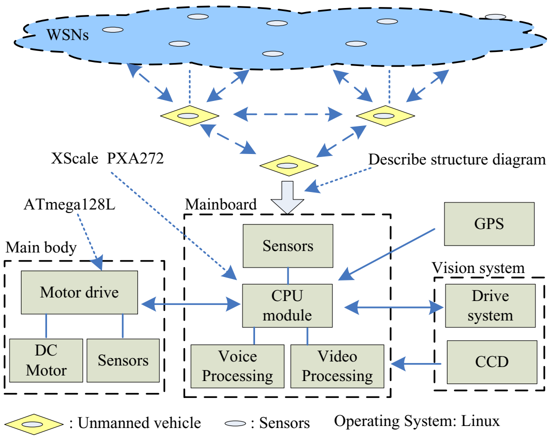

Fig. 1. Test platform architecture

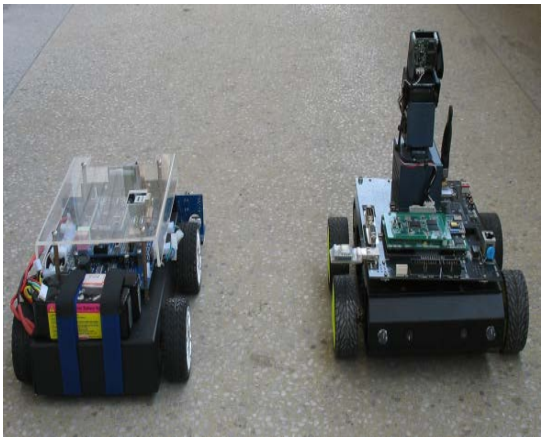

Fig. 2. Intelligent vehicle with wireless sensors

4.2. Navigation principle

The navigation principle of unmanned vehicle is given as shown in Fig. 3, which is formulated by WSNs and flat surface for vehicle trajectory. Via WSNs navigation, unmanned vehicle can move anywhere on the flat surface.

Assume that unmanned vehicle move from a starting point to an ending point. Before experiment, the location information about ending point should be sent to unmanned vehicle that conducts path planning so as to determine an optimizing trajectory. In the process of running, wireless sensor nodes belonging to unmanned vehicle exchange real-time data with WSNs. In this way, using the dynamic programming achieves a rational trajectory. According to current position of unmanned vehicle, wireless sensors for communications continually keep switching. If a sensor goes wrong, this fault is solved by now and again reorganizing and reconfiguring WSNs. The red line in Fig. 3 demonstrates the real trajectory.

4.3. Application: integrating intelligent road with unmanned vehicle

With the development of WSNs, embedded systems, etc., some new solutions can be applied to unmanned vehicle. Adopting the proposed test platform in this paper, we are conducting a program that intelligent road and unmanned vehicle are tightly integrated in the form of CPSs. Fig. 4 shows a case of CPSs. Both sides of highway install many wireless sensors nodes to form WSNs that provide navigation through exchanging and processing related information. For the proposed test platform, the resolution of the wireless sensor navigation depends on the positioning accuracy of WSNs, real-time performance, control algorithm, etc. The experiment results show that the resolution of wireless sensor navigation is less than 0.67m.

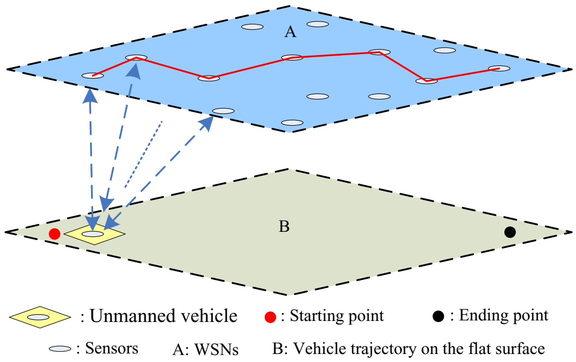

Fig. 3. Navigation principle of unmanned vehicle

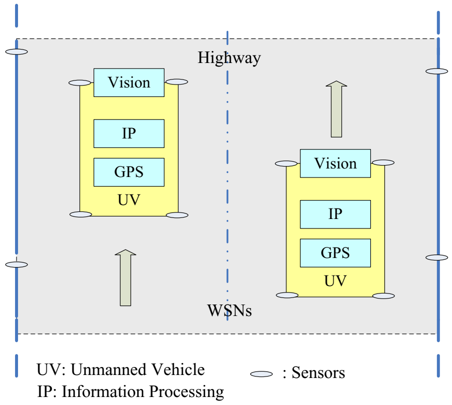

Fig. 4. A case of CPSs:
integrating intelligent road with unmanned vehicle

5. Studies from different perspectives

The studies from different perspectives are shown in Fig. 5. On the basis of this platform, the following aspects, e.g. system resource allocation, energy control, secure control, transmission and management, model-based software design, system modeling, control technology, etc. are tested and verified. It is fit for most of related researchers.

In the past ten years, many studies have been devoted to WSNs. Large numbers of outstanding achievements have been registered in this field. However, CPSs emphasize the salient features of integrating the virtual cyber world with the real physical world, which introduces many new challenges such as real-time performance, and control methods.

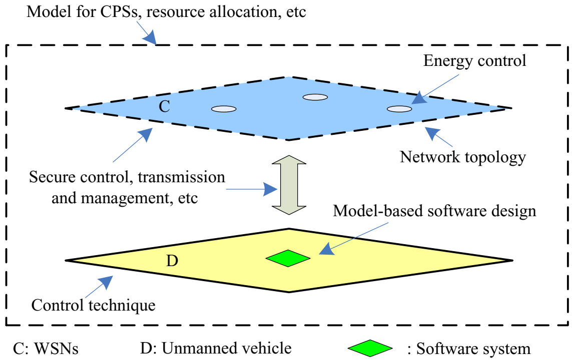

Fig. 5. Studies from different perspectives

6. Challenges

CPSs as a very active and new research field, a variety of questions need to be solved, at different layers of the architecture and from different aspects of systems design, to trigger and to ease the integration of the physical and cyber worlds [1]. The Common Challenges for CPSs include abstractions, model-based development, control and hybrid systems, sensor and mobile networks, robustness, reliability, safety and security, verification and certification [4].

Besides above common challenges, high performance unmanned vehicles still face some key issues. In addition, how to implement the innovative methods and theories is also a critical challenge. The vehicle speed is intimately associated with system performance. As the speed increases, we must ensure that real-time performance meets requirements. However, many factors such as hardware platform, and design methods, affect response speed. Besides this, the unmanned vehicles highlight high safety and reliability, and this is more rigorous than other CPSs. Therefore, an innovative methodology to guarantee system safety should be established. Now, the applications of unmanned vehicle with WSNs navigation have been conducting by means of miniature prototype, little work focuses on their practical implementations.

7. Conclusions

In the last few years, this emerging domain for CPSs has been attracting the significant interest, and will continue for the years to come. In spite of rapid evolution, we are still facing new difficulties and severe challenges. In this literature, we concisely reviewed WSNs and CPSs, and designed a general and low-priced test platform for CPSs. This platform includes some intelligent vehicles with WSNs navigation, which is widely applied to test and verify related theories. On this basis, a classic application, integrating intelligent road with unmanned vehicle, is used to show the good prospects. Then, we summarize several research issues and encourage more insight into this new field.

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References

[1]E. Lee, “Syber Physical Systems: Deisgn Challenges,” In Proc. of 11th IEEE Intl Symposium on Object Oriented Real-time Distributed Computing, May 2008, pp. 363-369.

[2]B. H. Krogh, “Cyber Physical Systems: The need for new models and design paradigms,” Presentation Report, Carnegie Mellon University.

[3]B. X. Huang, “Cyber Physical Systems: A survey,” Presentation Report, Jun. 2008.

[4]J. H. Shi, J. F. Wan, H. H Yan and H. Suo, “A survey of cyber-physical systems,” in Proc. of the Int. Conf. on Wireless Communications and Signal Processing, November 9-11, 2011.

[5]H. Karl and A.Willig, “A short survey of wireless sensor networks,” Technical Reports, Berlin, Oct. 2003.

[6]J. Yick, B. Mukherjee, and D. Ghosal, “Wireless sensor network survey,” Computer Networks, vol. 52, 2008, pp. 2292-2330.

[7]I. Khemapech, A. Miller, and I. Duncan, “Simulating wireless sensor networks,” Technical Reports, School of Computer Science, University of St Andrews, 2005.

[8]E. B. S. Kaler and E. M. K. Kaler, “Challenges in wireless sensor networks,” In Proc. of ISCET 2010. Available at: www.rimtengg. com/iscet/proceedings/pdfs/misc/176.pdf.

[9]Available at: http://www.cpsweek.org/.

[10]J. Z. Li, H. Gao, and B. Yu, “Concepts, features, challenges, and research progresses of CPSs,” Development Report of China Computer Science, 2009, pp. 1-17.

[11]Available at: http://www.2getthere.eu/Personal_Transit/.

[12]Available at: http://connectedcities.eu/showcases/parkshuttle.html.

[13]Available at: http://serpentine-systems.autoindustries.com/.

[14]M. Li, Y. H. Liu, J. L. Wang, and Z. Yang, “Sensor network navigation without locations,” In Proc. of IEEE INFOCOM 2009, Rio de Janeiro, Brazil, Apr. 2009, pp. 2419-2427.