ROCHAS: Robotics and Cloud-assisted Healthcare System for Empty Nester

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ABSTRACT

In recent years, provisioning of human-centric services through body area networks, robotics technology and cloud computing is continuously attracting extensive attention from both academia and industry. In this paper, we propose a novel robotics and cloud-assisted healthcare system (ROCHAS), which combines these three technologies to provide pervasive healthcare services and especially the mental healthcare for empty-nester who are typically old-aged, lonely and depressed. ROCHAS includes four major components, i.e., robotics-assisted health monitoring and healthcare services, wireless and wired networks, cloud-assisted healthcare system, and healthcare service supporting infrastructure.

Keywords

cloud computing, mobile cloud, healthcare, robotics, body area networks

1. INTRODUCTION

According to the U.S. Census Bureau, worldwide population of elderly people aged 65 and over are expected to more than double by 2020, and more than triple by 2050 [1]. Among the aging population, the number of empty-nesters who live alone is increasing. According to 2013 Annual Report on Development of the Cause of Aging issued by China National Committee on Aging on February 27, 2013, the number of empty-nesters of China will be more than 100 million in 2013. Typically, empty-nesters do not live with their children or do not have children. Due to old age and long-time loneliness, they suffer by so-called "empty-nest" syndrome, which generates several consequences such as:

- *Changing mode of supporting elderly people family in China*: Since China conducts the one-child policy, the only children gradually enter middle age and their parents gradually enter old age. It is predicated that the empty-nest families will become the main mode of the elderly people family in China. In addition to economic supply and healthcare [2], "spiritual consolation" becomes another important issue to support the need of the elderly people in empty-nest families.
- *Growing market of health monitoring industry for elderly people*: According to the data issued by China Life Insurance Co., Ltd., in 2011, the consumption scale of aging population of China reaches CNY 1.3 trillion, which is forecasted to be CNY 28.4 trillion by 2050. As the empty-nest families are increasing in China, the old-age industry will develop rapidly and has a wide market prospect.
- *Not just physiological problem*: Since empty-nesters are old, weak and lonely, they often feel depressed with inappetence and insomnia, which may easily cause mental diseases. According to the statistics, 60% empty-nesters have psychological problems and the number of empty-nesters who have diseases and need medical attention and psychological intervention come at 10%-20%.

While the large number of empty-nesters has become a social problem that can not be ignored, the health monitoring industry on empty-nesters is still in the preliminary stage. To address this critical issue, this paper proposes a *Robotics and Cloud-assisted Healthcare System* (ROCHAS), which combines three technologies in terms of body area networks [3–6], robotics [7] and cloud computing [8–10]. This paper takes empty-nesters as the target users. In such scenario, ROCHAS mainly has the following characteristics:

- A household low-cost robot serves as bridge for empty-nester to communicate with his/her children in other places, which is mainly realized by the function of mobile multimedia communications. In addition, the robot also has intelligent speech recognition and entertainment functions. These three functions mainly provide spiritual consolation for empty-nester.
- Body sensors are deployed in or around empty-nester to collect physiological data, while environmental sensors are equipped in the robot. Both physiological and environmental data will be pre-processed by the robot, which further transmits the

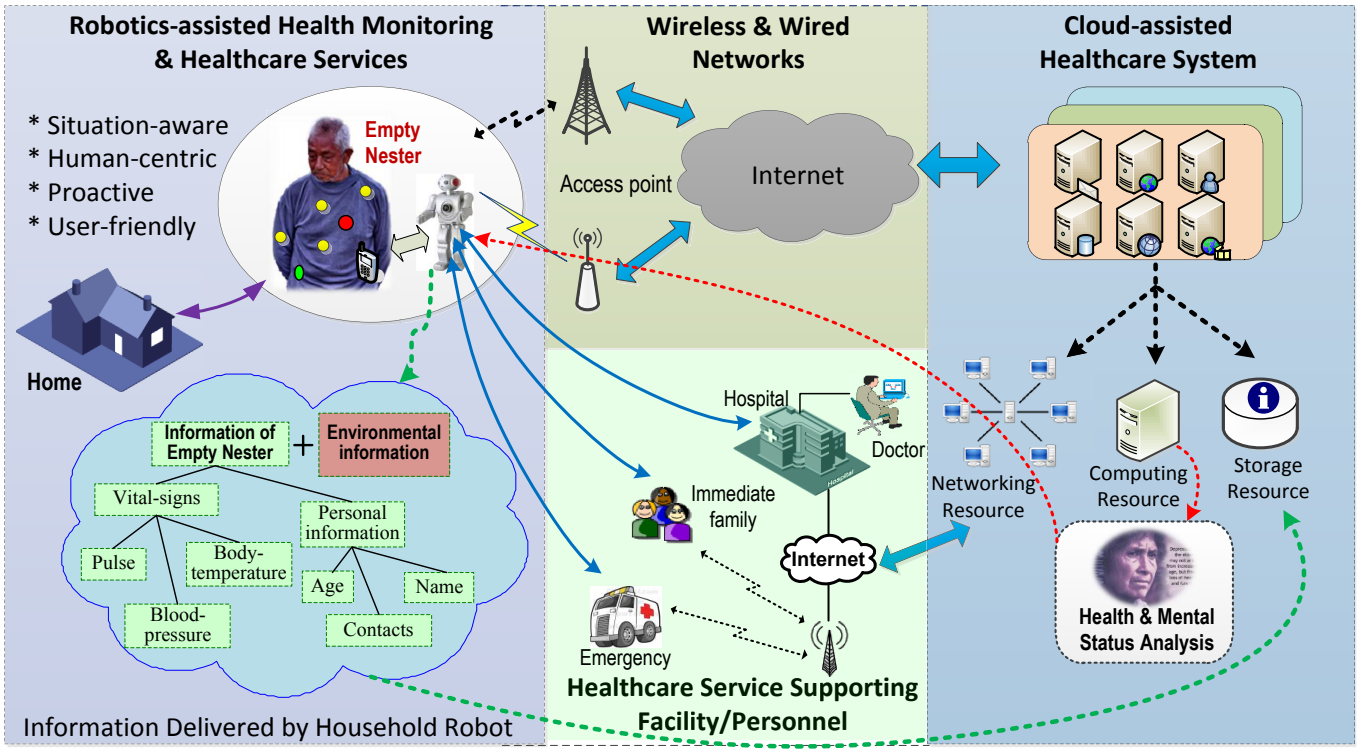


Figure 1: Architecture of ROCHAS

sensory data to a cloud health monitoring system in a real-time or on-demand fashion.

- The personalized health related data of elderly people will be stored and analyzed in the cloud-assisted healthcare system, which will properly provide expert-level services for empty nesters in terms of the mental status analysis, eating habits monitoring, early prevention of diseases, and other healthcare services.

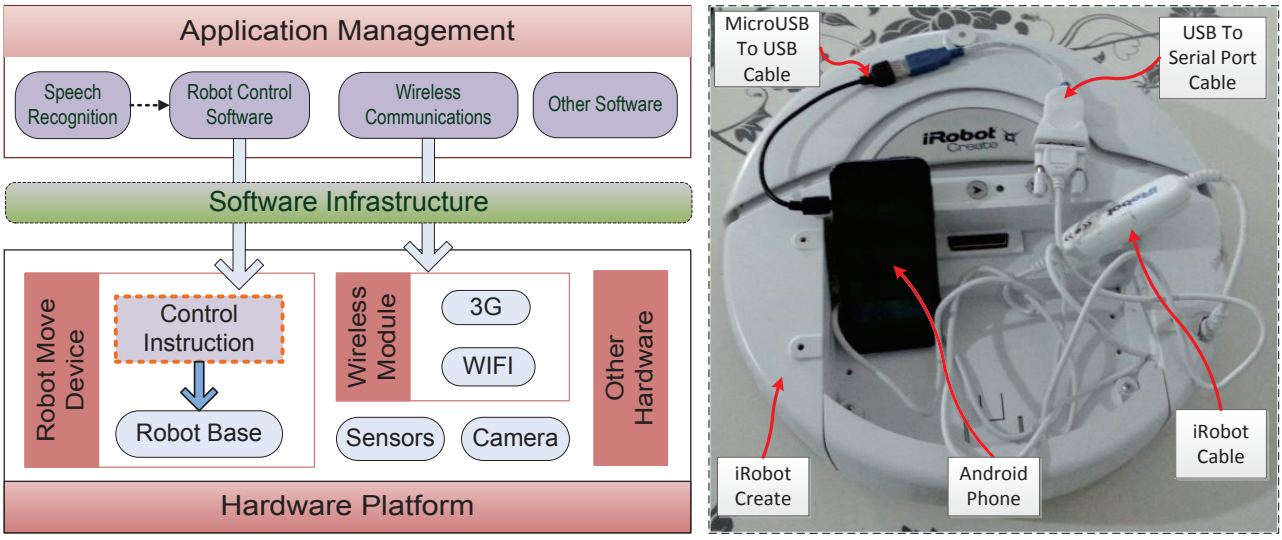
Though industrial robots is mature with market readiness, there does not exist a low-cost household health monitoring robot specially developed for empty-nester at home. First, the front end of ROCHAS includes a low-cost and autonomously moving robot platform with mobile multimedia communication and intelligent speech recognition, which is deemed as the fourth "screen" of families at present, with the top three ones of computer, TV, and mobile phone, so as to help empty-nesters realize the communication with their children in other places, the communities, and society. At the same time, their children in other places may also know the situation of the elderly people at home via video at any time. In order to realize health monitoring functionality, the robot in ROCHAS also integrates various kinds of sensor modules to collect the vital sign of empty-nester as well as environmental data in the house, and transmit such data to the cloud-assisted health monitoring system via wireless communications and mobile network, so as to master the health states of empty-nester at any time and improve the personalized health monitoring service for empty-nesters. As shown in Fig. 1, ROCHAS includes several key components, such as robotics-assisted health monitoring & healthcare services, wireless & wired networks, cloud-assisted healthcare system, and healthcare service supporting facility & personnel.

The remainder of this paper is organized as follows: In Section II, we introduce architecture of the basic robot platform. Section III describes some design issues of ROCHAS. Finally, Section IV concludes this paper.

2. ARCHITECTURE OF THE BASIC ROBOT PLATFORM

The intelligent mobile robot platform is the foundation of ROCHAS and its main functions include motion control, wireless communication and speech recognition. In the meantime, this platform is required to have strong expandability to be conducive to the increase of new functional components in later research and development. The realization of these functions involves several inter-disciplines. The motion control requires the robot to provide flexible control commands and realize the all around motion, turning motion, circling motion, and speed control, etc. of the robot, which must be easily called by other components. The robot platform must support the current mainstream wireless communication standards to meet the requirements of remote control and audio and video transmissions of the robot. Speech recognition is another technical issue, with which we may realize man-machine "dialogue" and substantially expand the application scope of the robot. In order to lower down the realization difficulty of speech recognition and improve the accuracy of speech recognition, the speech recognition technology based on cloud computing (e.g. cloud speech recognition technology of Google) may be utilized. With available network, the speech to be recognized is transmitted to the cloud platform for recognition and acquisition of recognition results. Without available network, the local speech recognition module is utilized to realize speech recognition. The overall structure of the intelligent mobile robot platform is shown in Fig. 2.

For sake of simplicity, we use the existing iRobot Create mobile platform product as the mobile base of the robot, as shown in Fig. 2(b), which provides two control interfaces including Com-



(a) System Architecture

(b) Interconnection of Functional Components

Figure 2: Illustration of The Basic Robot Platform

mand Module and Create Open Interface. Command Module is a hardware module of iRobot Create which integrates AVR SCM and supports C/C++ development. However, it is characterized with weak processing capacity and weak flexibility. Therefore, Create Open Interface is utilized during the development to provide an underling control command based on serial port communications and use any programming language to develop a powerful control program. In order to rapidly develop the platform model, two sets of Android mobile phones internally installed with 3G, WIFI, and Bluetooth communication modules are used as communication and control devices. One set of the Android mobile phone is connected to USB-serial cable via MicroUSB and, via USB-serial cable, is connected to iRobot Create to transmit it control commands to control the movement of the robot. This Android mobile phone is also responsible for the wireless communications of the robot. Another set of the Android mobile phone acts as a remote control terminal to transmit control commands to the robot and acquire sensor data from the robot.

When the speech recognition service of Google is accessible, Android online speech recognition technology is utilized. The offline speech recognition based on Android adopts PocketSphinx embedded speech recognition engine, which realizes the accurate recognition of speech input of speaker-independent speech within a small scope. All of its related software is developed base on Android platform to be conducive for alter transplant and function expansion. In the Android mobile phone connected to the robot, with Java, the server program is simplified to receive control commands transmitted from the remote control terminal and, meanwhile, be responsible for transmitting sensory data to the remote control terminal. In the Android mobile on the remote control terminal, the realized control software functions include transmitting command (including speech control) to the robot and remote photographing and remote video. Its running interface is shown in Fig. 2(a).

3. DESIGN ISSUES FOR ROCHAS

The development of ROCHAS involves artificial intelligence, machinery and electronics, intelligent speech recognition, mobile multimedia communication, wireless sensor network, body area network, tele-medicine, and cloud computing, etc. Therefore, it is a comprehensive inter-discipline with the following key technologies in addition to aforementioned technology for the basic robot platform.

3.1 Mobile video communication technology

With the mobile multimedia interaction technology [11], first, empty-nesters may have real-time communications with their children in other places and other people with the robot, second, such technology may realize the intelligent communication among robots and among robots and household appliances with the wireless video transmission rate that is larger than 30fps [12]. With the network bandwidth adaptive algorithm, the transmission bandwidth can be saved to realize 30kbps, which basically meets the requirement of video transmissions. In addition, the efficient power amplifier and software code and algorithm optimization may substantially save power consumption and prolong the battery lifetime of the robot. 3G/4G/WiFi mobile communication module and video coding compression technology based on H.264 are integrated in the robot system to let empty-nesters realize the real-time multimedia communication with their children in other places and other people and let their children in other places realize the remote control on the robot via the mobile network.

3.2 Man-machine interface technology

The man-machine interface technology, as an interactive mode between the user and household robot, must be reasonably and conveniently designed and is easily used, and the best interactive mode between the user and robot shall be economically considered. This family robot system is characterized with an intelligent speech recognition technology and is equipped with a 10.4-inches touch screen to be conducive to elderly people's operation. The appearance of a robot shall be designed in a personalized way and in consideration of both the operation convenience for the target user (elderly people) and the sensor layout, so as to provide convenience for the realization of other functions.

3.3 Health cloud platform

The health information collected by the robot may be transmitted to the remote health cloud service platform via multiple communication networks and the cloud service platform builds a mas-

sive health information warehouse with health information, conduct data analysis and processing on the database by the use of data mining technology, and intelligently provide the processed result for health experts, service personnel, or final users. With such data, health experts may provide some guidance on the health problems of elderly people and service personnel may provide personalized services for users, and via the cloud service platform.

The construction and operation of the household health monitoring system based on the cloud computing technology also stores the physiological data and daily activities of empty-nesters, and know their health situations. By the use of the cloud computing technology, we may establish an accurate model for the mental status and behavior pattern of the empty nesters. Building such kind of model accurately requires intensive computing resource, which is processed in cloud-assisted healthcare system, as shown in Fig. 1. The healthcare service supporting facility/personnel provide empty-nesters with personalized health monitoring service, help their children in other places take care of their parents, help empty-nesters enjoy independent and safe life, improve their living quality, etc.

3.4 Autonomous services supported by the robot

This technology aims at the improvement of the autonomous services supported by the robot.

- *Route planning:* That how to autonomously move to the target point under complex and unpredicated environments, and avoid obstacles is one of the most fundamental and important capacities of the robot, and is also its application basis.

- *Network connection*: Children in other places and communities need to keep contact with empty-nesters by the use of the robot. Therefore, this Project integrates mature telecom-level mobile communication technology to ensure the "always online" of the robot.

- *Automatic protection of the robot*: With the infrared and ultrasound sensors, etc., the safety of the robot during movement is ensured and effective obstacle avoiding and falling prevention is achieved. The robot is set with an automatic protection mode to automatically enter the protection mode in case of foreign object collision or parts failure.

- *Entertainment*: Inside the robot, such entertainment software that is suitable for elderly people to use may be installed, including the entertainment software which may cure diseases suffered by elderly people (e.g. software to relieve senile dementia), or internet is connected via wireless network to relieve their loneliness and bring them happiness.

4. CONCLUSION

This paper first designs a low-cost and autonomously moving robot platform with mobile multimedia communication and intelligent speech recognition, so as to help empty-nesters realize the communication with their children in other places. At the same time, their children in other places may also know the situation of the elderly people at home via video at any time. Then, the robotic system further integrates various sensor nodes to collect the vital body sign of empty-nesters and the environmental data, and transmit such data to the cloud-assisted health monitoring system via the mobile network. Based on the cloud computing platform, an accurate model of the mental status and behavior pattern for the empty nesters is established, facilitating personalized healthcare services for elderly people to enjoy independent and safe life while improving their living quality. The proposed robotics and cloud-assisted healthcare system is dubbed ROCHAS. Despite the design issues presented in the paper, there are many challenges that still need to be addressed, especially on high bandwidth and energy efficient communication protocols, low cost robot, and interoperability between robot and cloud platform. Engineers, researchers and practitioners from multiple disciplines must come together and strive hard to overcome technical roadblocks in order to bring the vision of ROCHAS to reality.

5. ACKNOWLEDGMENTS

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6. REFERENCES

[1] M. Chen, S. Gonzalez, A. Vasilakos, H. Cao and V. C. M. Leung, “Body Area Networks: A Survey,” *ACM/Springer Mobile Networks and Applications*, Vol. 16, No. 2, pp. 171-193, April 2011.

[2] M. Chen, S. Gonzalez, Q. Zhang, M. Li and V. Leung, “A 2G-RFID based E-healthcare System,” *IEEE Wireless Communications Magazine*, Vol. 17, No. 1, pp. 37-43, Feb. 2010.

[3] S. Ullah, H. Higgins, B. Braem, et al., “A Comprehensive Survey of Wireless Body Area Networks: on PHY, MAC, and Network Layers Solutions,” *Journal of Medical Systems*, Vol. 36, No. 3, pp. 1065-1094, June 2012.

[4] M. Chen, “MM-QoS for BAN: Multi-Level MAC-Layer QoS Design in Body Area Networks,” *IEEE Globecom 2013*, Atlanta, Georgia, USA, Dec. 9-13, 2013.

[5] H. Wang, D. Peng, W. Wang, H. Sharif, H. Chen, A. Khoynezhad, “Resource-aware Secure ECG Healthcare Monitoring through Body Sensor Networks,” *IEEE Wireless Communication Magazine*, vol. 17, no. 1, pp.12-19, Feb. 2010.

[6] S. Gonzalez, M. Chen, V. Leung, “Mobility Support for Health Monitoring at Home Using Wearable Sensors,” *IEEE Transactions on Information Technology in Biomedicine*, vol.15, no.4, pp.539-549, July 2011.

[7] G. Hu, W. Tay, Y. Wen, “Cloud robotics: architecture, challenges and applications,” *IEEE Network*, Vol. 26, No. 3, pp. 21-28, 2012.

[8] M. Chen, “AMVSC: A Framework of Adaptive Mobile Video Streaming in the Cloud,” IEEE Globecom 2012, Anaheim, California, USA, Dec. 3-7, 2012.

[9] M. Chen, Y. Wen, H. Jin, V. Leung, “Enabling Technologies for Future Data Center Networking: A Primer,” *IEEE Network*, Vol. 27, No. 4, pp. 8-15, July 2013.

[10] C. Lai, H. Chao, Y. Lai, J. Wan, “Cloud-assisted real-time transrating for http live streaming,” *IEEE Wireless Communications*, Vol. 20, No. 3, June 2013.

[11] M. Chen, C . Lai, H. Wang, “Mobile Multimedia Sensor Networks: Architecture and Routing,” *EURASIP Journal on Wireless Communications and Networking*, Vol. 2011, doi:10.1186/1687-1499-2011-159, 2011.

[12] M. Chen, V. Leung, S. Mao and M. Li, “Cross-layer and Path Priority Scheduling based Real-time Video Communications over Wireless Sensor Networks,” *IEEE VTC’08*, Marina Bay, Singapore, May. 11-14th, 2008.