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Quick Response Multimodal Learning System with Raspberry Pi

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Abstract – Learning introductory programming in universities has become significantly more challenging for beginners. Although educational content is freely available on the web, students feel overwhelmed by the amount of unstructured content. Although various systems were introduced to increase student interest using smartphones and multimodal learning content, the small screens of these devices could hinder the learning efficiency. Televisions have larger screen sizes and are commonly available in homes. The potential of using lecture notes, a television and a computer screen concurrently to apprehend the concept of learning-by-doing can engage beginners to become more active in mastering introductory programming outside the classroom. Therefore, an inexpensive Quick Response Multimodal Learning System is proposed using Raspberry Pi to generate interest and make programming concepts easier to comprehend. Through the proposed tap-to-learn interaction paradigm that uses QR codes to bind together programming concepts and hands on coding, the process of acquiring organized learning content becomes more convenient, faster and easier, while encouraging students to learn independently at home.

Keywords – T-learning, television, introductory programming, undergraduate students

INTRODUCTION

Learning to program is an elementary skill that students must acquire in most engineering degree programs. Proficiency in programming is important as it is required in various industries ranging from computers, smartphones, wearable devices, and home appliances to industrial equipment. Although most students show an interest in programming, many of them are unable to cope with it. This is partially due to the selection of the first programming language used to teach freshmen in engineering degree programs, for example, C or C++. They are difficult to understand, especially for beginners. As a result, many undergraduate students find it difficult to grasp the logic, algorithm and syntaxes in introductory programming courses [1,2]. The traditional way of teaching introductory programming concepts in classrooms and conducting hands-on sessions in computer laboratories may also not be very effective. Although lecture notes are generally accessible through Learning Management Systems like Moodle [3], many students still rely on reference books or other online resources, such as video tutorials, to learn how to code. Furthermore, most online resources are unorganized and may not be relevant to the syllabus of the introductory programming course offered in the university. Consequently, students feel frustrated over the unorganized web content and lose motivation to revise coding independently outside the formal teaching spaces.

Over the years, new emerging ways were introduced by researchers utilizing advanced information and communication technology combined with web-enabled devices like smartphones or tablets to aid students in mastering introductory programming subjects [4, 5, 6]. Most of these systems focus on using multimodal learning content like text, audio, picture and video to increase the interest of students to learn so that they can perform better in class [7]. In spite of being a more flexible and interesting way of learning, the small screens of these devices could hinder learning efficiency [8].

Meanwhile, there does not appear to be much research on the use of multiple devices concurrently, such as televisions and computers, as a way to encourage students in learning introductory programming. The potential of using multiple devices to help beginners understand complex concepts of programming course is tremendous. One compelling reason to use more than one device simultaneously in the learning process is to provide students with more degrees of freedom in accessing, viewing and practicing programming concepts. This can expedite learning-by-doing [9]. For example, students can follow the video tutorial on a large television display, while reading about the complex programming concept in a textbook, and learning to code on a laptop sumultaneously, making the programming concepts easier to grasp. Although Raspberry Pi (RPI) and Quick Response (QR) code has led to numerous promising learning applications, the adoption and integration of QR into RPI to create a multimodal learning environment is still nascent. The impact to the learning process could be profound. There have been no previous reports of utilizing RPI and QR code to help students in accessing educational content easily on televisions.

Given this backdrop, an inexpensive multimodal learning system is proposed, utilizing RPI, QR codes and televisions to introduce students to introductory programming in the field of engineering education within a new and interesting environment. The objective of the system is to generate interest and make programming concepts easier to comprehend through multiple learning devices. By correlating a unique QR code with the associated multimedia learning content in the virtual world, the students can instantly view on a television the learning content associated with the theoretical programming concepts simply by tapping the corresponding QR code found in the textbook or lecture notes on the system. Through this innovative tap-to-learn approach, the process of acquiring the relevant learning content becomes faster, easier and more interesting. The proposed system can be used as an aid to motivate and engage students to spend more time in learning programming independently beyond the classroom. The rest of this paper is organized as follows: Section 2 depicts the related work which leads to the development of the multimodal learning system. Section 3 presents the detailed design of the proposed system. Section 4 explains the implementation of the prototype, Section 5 discusses the usage of the system in learning the introductory programming language and finally, Section 6 concludes the paper.

RELATED WORK

Rapid advancement of the single board computer such as RPI and the pervasive exploitation of QR code are two crucial technologies that can be used by researchers and academicians to create an affordable multimodal learning system for beginners to more easily learn introductory programming beyond the classroom. In this section, the related work on QR code and RPI technologies are discussed with reference to the proposed system in disseminating knowledge to students at home.

RPI was first released to public in 2012. It is the size of a credit card [10]. RPI operates on an ARM11 microprocessor @700MHZ with 512 MB of RAM memory and equipped with most of the functionalities of a desktop computer at an affordable price. In 2014, the RPI model A+ was priced at USD 20 [11]. RPI is powered via a microUSB power slot and booted through an external micro SD card installed with Raspian, an open source Linux-based operating system. Input peripherals such as mouse and keyboard can connect though the RPI’s USB ports while output devices like televisions can connect through the HDMI port. A dedicated camera connector is available to support an external camera module. RPI can access the internet either through a USB WiFi dongle or an Ethernet cable. The basic functionality of RPI can be expanded further with external boards like NFC readers, motor controllers, Arduinos, LEDs, etc. Although RPI was designed for educational purposes, the exclusive characteristics of RPI, such as low power consumption, economical, expandable, fully configurable and programmable, have driven a number of industrial applications in automotive safety [12], environmental monitoring [13], home automation [14], water treatment [15], etc. In the education sector, RPIs have been utilized innovatively in both universities and schools to enhance learning activities like teaching bioinformatics [16], mechatronics [17], physics [18], robotics [19], console servers [20] and so on.

QR codes are combinations of black and white pixels of two-dimensional matrixes that revolutionized storing and accessing data like numbers and alphabetical characters persistently in the virtual world. By using a camera-enabled device like a smartphone along with a QR code reader application to scan a QR code, the data stored in these square matrix patterns can be retrieved instantly. The small printable size and non-powered consumption requirements of QR code in storing, distributing and retrieving of data have resulted in wide acceptance among universities, particularly in libraries [21], mobile tutoring [22] and outdoor teaching [23].

Because RPI has sufficient processing power to drive a QR reader application, as well as the extendibility to connect a camera and television, it offers unprecedented opportunities for researchers to develop a compact and cost effective multimodal learning system that could be more appealing and enjoyable to students while learning introductory programming.

SYSTEM DESIGN

The proposed QR Multimodal Learning System (QR MLS) has been engineered to integrate external displays like televisions and educational content using RPI and QR codes to facilitate simple tap-to-learn interaction. The principal design of the QR MLS is to exploit the processing power and storage capabilities of RPI, coupled with an external camera to scan the QR codes which result to a fast and easy way of accessing and interacting with educational content on a television. The system is divided into four parts: (1) identification, (2) hardware device, (3) software application, and (4) external display as illustrated in Figure 1. The identification process involves the scanning of the QR code whenever one is placed on top of the QR MLS. Each QR code contains a small amount of data that is associated with the individual learning content stored in the virtual word. The hardware device is made up of an RPI connected to a CMOS camera and a Light Emitting Diode (LED) as well as a WiFi dongle. The LED supplies a bright ambient for the CMOS camera to capture the QR code effectively, while the WiFi dongle enables the QR MLS to wirelessly stream educational content from YouTube. The RPI serves as the repository storage for the educational content and acts as a digital media server to play the multimedia content.

The QR MLS software application is designed to read the QR code, translate it into control signals, and display the associated educational content on a television. The QR MLS application comprises of four main modules: the scanning and decoding module, the controlling module, the media module and the streaming module. These modules present knowledge in the form of short segmented structured video tutorials on the television for visual and auditory students to learn coding step by step. Other information like flow charts and animations are also available to compliment the programming concepts within the text books or handouts. The scanning and decoding module captures the QR code using the CMOS camera and decodes it. If the decoded data is valid, the controlling module will be invoked to generate the appropriate control signals to the media module, such as playing, stopping, pausing, increasing the volume, etc. For example, a "Play" signal will cause the media module to retrieve the relevant educational content either within the RPI or from an external server like YouTube and play the content on the television.

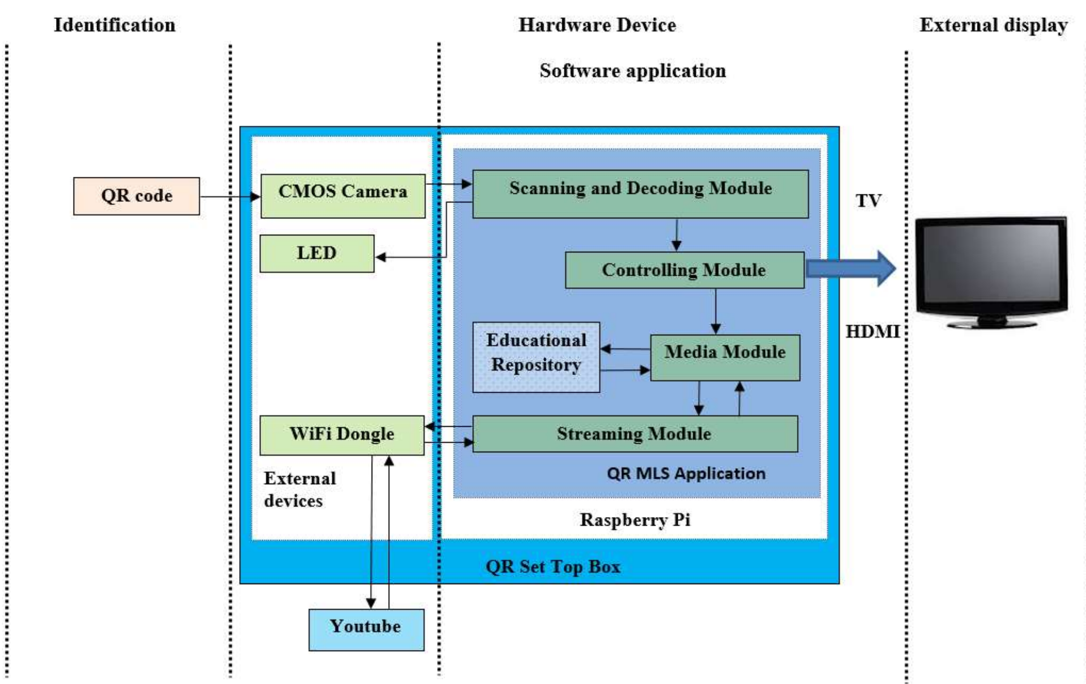

Fig. 1: System architecture of the QR MLS

SYSTEM IMPLEMENTATION

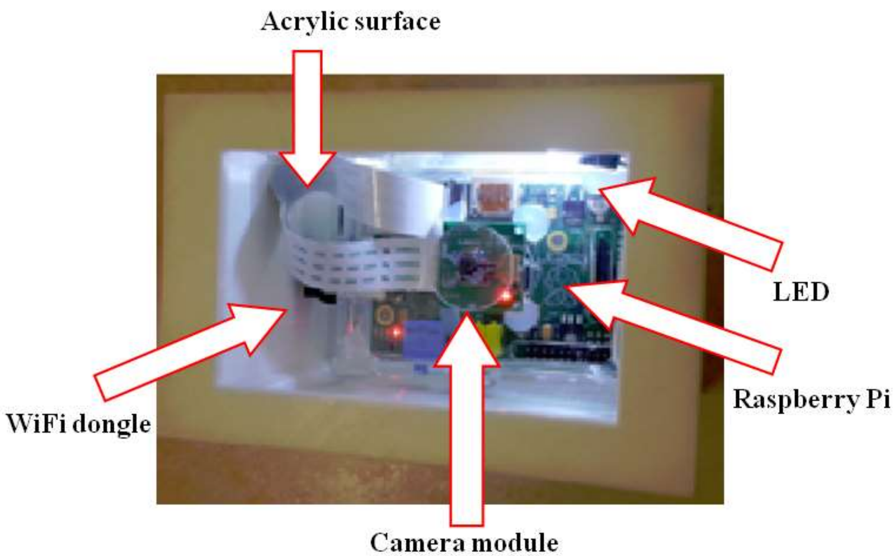

Fig. 2: Hardware prototype of the QR MLS

The proposed QR MLS is a learning platform that combines handouts, a television and a laptop computer to create a multimodal learning system that helps students learn beyond the classroom. The prototype teaches junior students an introduction to the C programming language. The QR MLS has been successfully developed through the integration of software and hardware implementations at the Faculty of Engineering (FOE), Multimedia University (MMU), Malaysia. The hardware prototype of the QR MLS, depicted in Figure 2, consists of a 3D printed enclosure with a transparent acrylic top surface, a Miniature WiFi Module, LEDs, an RPI 2 model B and an RPI camera module. Aside from the compact size and low price tag, the model B of RPI 2 was selected because its higher processing power is sufficient to decode QR codes and play the educational content in full HD mode. Data related to the educational content, such as the control operation, name of the digital file, and the storage location, is encoded in the QR codes. Whenever a QR code is placed on top of the transparent acrylic surface, the RPI camera module will capture the QR code and quickly display the corresponding educational content on the television. This hassle-free tap-to-learn interaction may greatly simplify the process of searching for learning content online. Python scripts are used to implement the QR MLS application that runs on the Raspian operating system of the RPI. The application reads and decodes the data obtained from the RPI camera module and converts it to pertinent controlling services for the OMX player to play the educational content.

DISCUSSION

Typical programming notes contain text, flow charts, programming code, syntaxes, diagrams etc., to explain programming concepts and algorithms to students. At times, ambiguities and confusion may arise as the students search for more information on the web. Although free educational content on the programming concepts are abundantly available on the web, most of them are unstructured and scattered. This makes it difficult for the young apprentices to find the relevant information, which can be discouraging to students when practicing coding alone. Through the QR MLS, more structured and organized instructional content is available in lecture notes, on television, and the computer screen concurrently, to help junior undergraduate engineering students cope with the subject material. By tapping the associated QR codes from the lecture notes on the QR MLS, the students can conveniently and instantly access additional instructional content on a television. By binding the C programming concepts and hands on coding together through the simple tap-to-learn interaction using the QR codes, students are more motivated to practice the concept of learning-by-doing at home independently which could potentially engage students to become more active in their learning instead of taking a passive role.

Here is an example use case: (1) a student follows the structured handouts uploaded by lecturers. When the student wishes to view a video tutorial for a better understanding of a programming concept, the student simply takes out the QR code from the handouts and places it on the QR MLS; (2) the data from the QR code is read and passed to the QR MLS application running on the RPI; (3) based on the decoded information, the specific learning content, such as a sample code execution of a program segment, or a step-by-step in-depth explanatory video on coding a program, will appear on the television as shown in **Figure 3** **(Photo will be taken)**; (4) while following the guide on television, the student can pause or resume the screencast video and compile the code using a laptop; (5) likewise, the students can access other information such as a flow chart or an audio explanation on the television by placing different QR codes on the QR MLS. A pilot test was carried out on a group of undergraduate engineering students to evaluate the proposed QR MLS in learning the C programming language. Overall, the participants gave positive and encouraging feedback. Although the feedback given by the participants show that the QR MLS can keep the interest of the students high, quantitative evaluations on a larger number of participants are underway to evaluate the effectiveness of the QR MLS in learning the introductory programming course.

CONCLUSION

The cost effective implementations of the QR MLS presented here that leverages RPI and QR codes to maximize the learning outcome represents a significant step in redefining the existing methods of learning introductory programming in two ways: (1) programming theories and code segments are tied together to facilitate learning-by-doing. Students can learn systematically using a combination of lecture notes, instructional videos on the television, and programming on a computer; (2) The tap-to-learn interaction lets students navigate and interact with the instructional content faster and easier. The proposed QR MLS could potentially transform learning introductory programming beyond the classroom through a hassle-free learning environment that is more dynamic, interesting and enjoyable.

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