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Quick Response Multimodal Learning System with Raspberry Pi

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Abstract: Learning introductory programming languages at 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. Various systems have been introduced to increase student interest using smartphones and multimodal learning content but the small screens of these devices could hinder learning efficiency. The television or TV is one of the better candidates to replace the smartphone as a learning device due to its larger screen size and is commonly available at home. The potential of using lecture notes, a television and a computer screen concurrently to realize the concept of learning-by-doing can engage beginners to become more active in mastering introductory programming languages outside the classroom. 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 quick response 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.

Key words: T-learning, television, introductory programming, undergraduate, teaching, tap-to-learn interaction

INTRODUCTION

Learning to program is an elementary skill that students must acquire in most undergraduate 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 taught to freshmen in their degree programs, usually C or C++. These languages and concepts are difficult tounderstand, especially for beginners with no programming background. As a result, many undergraduate students find it difficult to grasp the logic, algorithm and syntax in introductory programming courses (Robins *et al*., 2003; Tan *et al*., 2009). The traditional way of teaching introductory programming concepts in classrooms and conducting hands-on sessionsin computer laboratories may also not very effective. Although, lecture notes are generally accessible through learning management systems like moodle (Jin, 2012), many students still rely on reference books or other online resources such as video tutorials, to learn how to code. However, most to the syllabus of the introductory programming course offered at the university. Consequently, students feel frustrated using the unorganized web content and lose motivation to revise coding independently outside the formal teaching space. Over the years, new emerging approaches have been introduced by researchers utilizing advanced information and communication technology, combined with web-enabled devices such as smartphones or tablets, to aid students in mastering introductory programming subjects (Huang *et al*., 2014; Konecki and Kadoic, 2015). Most of these systems focus on using multimodal learning content, namely, text, audio, picture and video, to increase students' interest in learning and performing better in class. In spite of being a more flexible and interesting way of learning, the small screens of these devices could hinder learning efficiency (Maniar *et al*., 2007), hence not achieving the desired result.

In addition, there does not appear to be much research on the concurrent use of multiple devices such as televisions and computers as a way to encourage students in learning introductory programming languages. The potential of using multiple devices to help beginners understand complex concepts of programming

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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 (Leyer *et al*., 2014). For example, students can follow the video tutorial on a large television display while reading about the complex programming concept from a textbook and learning to code on a laptop, concurrently, making it easier to grasp the programming concepts.

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 in this study, utilizing RPI, QR codes and televisions to introduce students to introductory programming languages 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 usedas an aid to motivate and engage students to spend more time in learning programming independently beyond the classroom.

Related study: Rapid advancement of the single board computer such as the RPI and the pervasive exploitation of QR codes 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. In this study, the related study on QR code and RPI technologies are discussed with reference to the proposed system in disseminating knowledge to students at home.

Raspberry Pi: RPIs were first released to the public in 2012. It was the size of a credit card (BBC News, 2012). RPI operates on an ARM11 microprocessor 700 MHz 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 (Raspberry, 2014). The 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. RPIs can access the internet either through a USB WiFi dongle or an Ethernet cable. The basic functionality of the RPI can be expanded further with external boards for NFC readers, motor controllers, Arduinos, etc. Although, the RPI was designed for educational purposes, the exclusive characteristics of the RPI, such as low power consumption, economical, expandable, fully configurable and programmable have driven a number of industrial applications in automotive safety (Stan *et al*., 2014), environmental monitoring (Nikhade, 2015), home automation (Jain *et al*., 2014), water treatment (Lagu and Deshmukh, 2014), etc. In the education sector, RPIs have been utilized innovatively in both universities and schools to enhance learning activities like teaching bioinformatics (Barker *et al*., 2013), mechatronics (Chao *et al*., 2015), physics (Ioannou *et al*., 2014), robotics (Saleiro *et al*., 2013), console servers (Kyuchukova *et al*., 2015) and so on.

Quick response code: 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. 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 (Bajpai, 2015), mobile tutoring (Pietro and Frontera, 2012) and outdoor teaching (Chin *et al*., 2014). Because the 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.

MATERIALS AND METHODS

System design: The proposed QR Multimodal Learning System (QR MLS) has been engineered to integrate external displays, typically televisions and educational

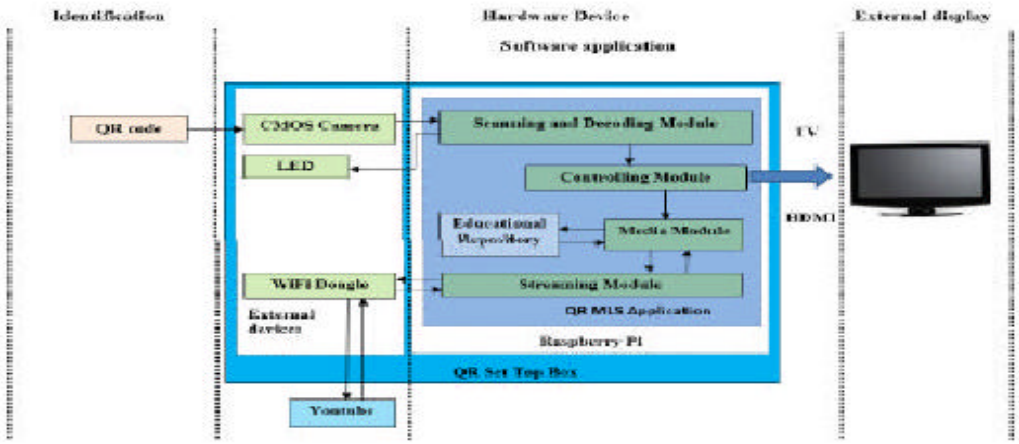

Fig. 1: System architecture of the QR MLS

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 the RPI, coupled with an external camera to scan the QR codes which result in a fast and easy way of accessing and interacting with educational content on a television. The system is divided into four parts: identification, hardware device, software application and external display as illustrated in Fig. 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 world. 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 lighting 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 in a step by step approach. 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.

RESULTS

System implementation: The proposed QR MLS is a learning platform that combines handouts, a television and a laptop computer to assist students study at home. The prototype teaches junior degree students (freshmen) 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 Fig. 2, consists of a 3D printed enclosure with a transparent acrylic top surface, a miniature WiFi module, LED, a model B RPI 2 and an RPI camera module. Aside from the compact size and low price tag (USD 39), the model B 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 dataobtained from the RPI camera module and converts it to pertinent controlling services for the OMX player to play the educational content.

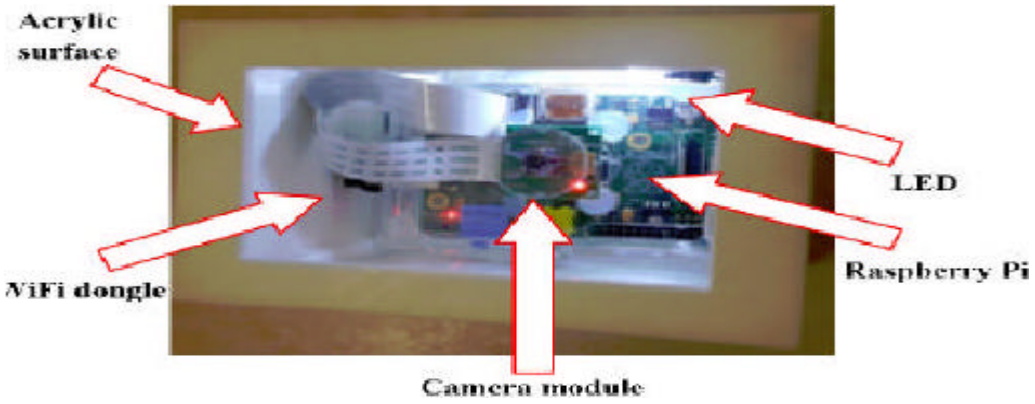

Fig. 2: Hardware prototype of the QR MLS

DISCUSSION

Typical programming notes use text, flow charts, programming code, syntax, 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, hence this could be discouraging to students when practicing coding by themselves. Through the QR MLS, more structured and organized digital instructional content is embedded in lecture notes, accessible on television and the computer screen simultaneously, to help students cope with the subject material. Simply tap the associated QR codes from the lecture notes on the QR MLS, 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.

An example use case is as follows: a student follows the structured handouts uploaded by a lecturer; when the student wishes to view a video tutorial for better understanding of a programming concept, the student simply takes out the QR code from the handouts and places it on the QR MLS; the data from the QR code isread and passed to the QR MLS application running on the RPI; 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 while following the guide on the television, the student can pause or resume the screencast video and compile the code using a laptop; likewise, the student 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 to compliment the learning of programming concepts within the text books or handouts. The implemented QR MLS utilizes affordable single board computer namely RPI and QR codes to realize simple tap-to-learn interaction and facilitate learning on a large television display. Although, Near Field Communication tag can also be employed to achieve similar tap-to-learn interaction, the cost of ownership is much more expensive as compared to QR codes. The QR MLS can be used to complement the small screen of mobile devices such as smartphone or tablets (Huang *et al*., 2014; Konecki and Kadoic, 2015) to enhance learning of introductory programming subjects through multimodal devices. Although there are other alternative way to complement the small display of mobile devices to apprehend learning on a large display such as screencast technology like Chromecast. However, screencast technology does not truly support learning through multimodal devices because it merely replicate the screen of a smartphone and display the content on the television. Students cannot access different educational content simultaneously on the smartphone and television.

CONCLUSION

The cost effective design and implementation of the QR MLS presented in this study, that leveraging on 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: programming theories and code segments are tied together to facilitate learning-by-doing where students can learn systematically using a combination of lecture notes, instructional videos on the television and programming on a computer; 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. Although, feedback given by a group of undergraduate engineering students in the pilot test was encouraging on the usage of QR MLS in learning the introductory C programming language, the number of participants were too small. Therefore, quantitative evaluations on a larger number of participants are underway to evaluate and substantiate the effectiveness of the QR.

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