CHAPTER 13

TOWARDS DESIGNING A PORTABLE ONLINE ASSESSMENT SYSTEM

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Abstract

Tablet devices, iPads in particular, have paved the way for new means of interactive online e-learning and assessment opportunities, especially in higher education. The ubiquity of tablet devices, especially among younger generations, stresses the promising potentials of the available tablet-based systems to flourish in higher education for the coming generations. While the availability and the affordability of tablet devices have come a long way in the recent years, there is still a dire need for affordable and portable online assessment systems. This is especially crucial in developing countries, where providing a supporting infrastructure for tens and hundreds of tablet devices can be an issue.

In this paper, we present our portable wireless assessment system that can provide instructors with the ability to conduct exams and quizzes in their classes and on the move. The system design focuses on providing high levels of usability, portability, reliability, security, and scalability. We have evaluated our system design and implementation with the help of more than 25 instructors and 40 students. Our proposed system provides an affordable solution to performing online assessments and helps improve the interactivity between instructors and students.

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Introduction

With the current ubiquity of mobile devices and tablet computers, e-learning and mobile learning received a significant boost in popularity that encourages decision makers to adopt tablets and iPads as an essential component of the learning process. By the end of 2014, Apple announced that it sold over 225 million iPads (Protalinski, 2014). In addition, tablet users are expected to surpass 1 billion users by the end of 2015 and to reach 1.43 billion by 2018 (eMarketer, 2015). iPad penetration in the United States has reached the high percentage of 25% (i.e., one in four United States residents has an iPad; Statista, 2015). All these figures demonstrate the current influence and the great potential of using iPads, and tablets in general, in higher education.

Tablet computers offer tremendous opportunities to encourage collaborative practices in higher education that benefit the learning process greatly (Aubusson, Schuck, & Burden, 2009; Haag, 2011). Tablets, as e-learning devices, provide the means to connect to limitless learning resources not constrained by place nor time. In addition, tablet devices provide rich media to help students better understand the topics at hand, while providing invaluable insights on how they follow the teaching process inside and outside classrooms (White, 2003).

As noted by Vrasidas and McIsaac (1999), there are four main factors influencing in-class interactions between instructors and their students in online courses: class structure, class size, the ability to provide timely feedback to the students, and students’ prior experience with online technologies. It has been widely accepted since then that timely feedback between instructors and students increases the level of interactions and improves overall teaching quality.

In addition, Boyle, Kolosh, Allier, and Lambrecht (2003) listed several characteristics to be considered when designing an effective online assessment system, among which is the ability to use software effectively to represent realistic assessments and e-learning scenarios aligned with course objectives. Although online assessment systems are considered more challenging to instructors as they require more effort to create an interactive and innovative assessment system (Robles & Braathen, 2002), Bartlett, Reynolds, and Alexander (2000) and Farmer (2005) have summarized several benefits that can be achieved by using online assessment tools. These benefits are: (a) instant exam grading and archiving, (b) faster access to exam grades for students, (c) better support for student-centered teaching methodologies, (d) and more accurate learning measurements.
Nevertheless, it has been noted that there is a slow adoption of the e-learning technologies among educators (Phelps, Graham, & Kerr, 2004). One of the possible causes, as discussed by Aubusson et al. (2009), is the low level of connectivity between educators, their teaching environment (i.e., classrooms and laboratories), and their students. This issue is quite evident in many universities, where online assessment tools and software applications are available but not widely used due to many reasons. One key reason is that connecting all classes with a reliable online assessment system is considered as both a logistical and a fiscal challenge. Therefore, most universities have dedicated halls for online exams to overcome this issue. These halls are often limited to certain courses, and there is usually a long procedural process associated with reserving these halls.

To increase the rate of mobile e-learning adoption among next generations without requiring universities to invest in costly setups and infrastructures, we need to define the characteristics of a suitable solution that can convert any classroom to an online assessment environment. Such a solution needs to be portable in terms of size, weight, and required power resources. In addition, the solution needs to be affordable to allow wide adoption among educators in both developed and developing countries.

In this paper, we propose an innovative solution for providing an affordable portable online assessment system. The proposed system provides a reliable and an easy-to-use user interface that motivates educators to utilize it in their classes. The rest of this paper is organized as follows: The System Design section describes the proposed system design and the key provided features. The System Implementation section discusses the implementation choices of our system, and how these choices meet the system design guidelines. The System Evaluation section shares some of the evaluation results and discusses the users’ concerns related to our design and implementation choices. The final section concludes the paper and provides a short discussion of possible future enhancements to our proposed solution.

**System Design**

Taking into consideration the online assessment system requirements discussed in the introduction section, we conducted several informal meetings with both faculty members and students to discuss and define what can represent a viable mobile assessment system. These informal meetings were conducted after each major iteration of the system. The
meetings started with defining the current status/features of the system while explaining what changes have been made since the last iteration.

Students and instructors are asked to interact with the system to identify any shortcomings in the current design. These informal meetings did not have a specific structure but were based on a collaborative approach and engaging discussions between us and the intended users to reach the best possible design.

The outcomes of these discussions were carefully considered to provide a detailed design of a mobile wireless assessment server that is capable of providing the necessary infrastructure to instructors and students to perform the online assessment process effortlessly. The proposed solution introduces a small mobile server that is capable of connecting instructors and students over Wi-Fi. The conceptualized mobile server, as shown in Figure 13.1, acts as a wireless hotspot connecting instructors and students regardless of the availability of a wireless infrastructure, and provides the necessary online assessment backend services, such as online computations, exam monitoring, and data manipulations. In this system, both instructors and students use their iPad devices to communicate with the server and complete the online assessment process.

![Diagram of proposed mobile assessment system](image)

*Figure 13.1. Overview of the proposed mobile assessment system and the overall interactions between the proposed system and the intended users.*

During the design phase, we have categorized the required features of the proposed system into five categories: usability, reliability, portability, security, and scalability. It is worth noting that these desired features were updated continually as the system development progressed from the received feedback of both instructors and students.

**Usability:** The system software design should provide an intuitive interface for both instructors and students. It should be easy to use with minimal training or guidance. With the current state of mobile and desktop
applications, users are more used to intuitive interfaces that perform the necessary functionality with a minimum number of steps and transitions. Users expect a gratifying experience every time they use their applications.

We addressed these concerns by developing the user interface over a number of iterations. We started by collecting user interface requirements from our stakeholders (i.e., instructors and students), and then we implemented these requirements to the best of our understanding and taking into consideration the latest user interface (UI) design recommendations. After each implementation phase, we reviewed it with our stakeholders to explore any modifications necessary before settling on the final user design. In general, we found that most of our stakeholders were happy with the current design, which was evident in the results of our system evaluation phase.

**Reliability:** The online assessment system should operate in a reliable manner and should provide its users with a high level of confidence in using it on a regular basis. Reliability is usually correlated with the number of technical issues associated with product usage. The lower the number of technical problems faced, the higher the perceived reliability (Mall, 2014).

Hence, reliability in software systems increases over time as the number of technical issues decreases. While designing reliable systems is still a major concern even for software giants, it is necessary to design software applications in a manner that facilitates the tasks of any necessary corrective and perfective maintenance processes in the future. We have designed our system based on a three-tier architecture that allows us to break it into easy-to-manage modules. The three-tier architecture divides systems into a database tier, a backend services tier, and a user interface tier. In addition, we performed thorough unit and integration testing processes on our software to assure its high level of reliability.

**Portability:** One of the key features of the proposed system is its portability. Systems with small form factor (SFF) are more suitable for mobility and ease any logistic requirements for in-class setups. One important aspect of mobility is the dependency of the solution on the available power sources to operate. Systems with the ability to run on batteries have significant advantages over outlet-operated systems.

We addressed these concerns on portability by focusing on selecting a compact low-cost portable mini-desktop machine that acts as an online assessment server and as a wireless hotspot simultaneously. The selected mini-desktop machine can also operate on batteries, which improves the overall portability of the system.
Security: Security is one of the key concerns in any online assessment system. Online assessment systems should provide the necessary authentication processes to secure access to the assessment system for both students and instructors. Another key issue in online assessment systems is that it is usually open to many security attacks from inside and outside the network. Wireless networks are usually more prone to these types of attacks because of their broadcasting nature. One of the most used security measures is to limit the wireless broadcast coverage area, which creates a physical barrier against intruders.

All system users are required to log in to the system to be authenticated through their credentials. All user-related information, including their usernames and passwords, is encrypted inside the system database to secure the data from security threats associated with portable devices. Further security measures can be implemented to limit the number of users allowed to access the portable server wireless network, including obfuscating the presence of the server as a Wi-Fi hotspot and limiting the allowed devices to connect to the wireless server to a specific list of devices based on their MAC addresses.

In addition, one of the most requested features in any online assessment system is the ability of the exam supervisors to lock the users into the assessment application to stop them from switching to other applications (e.g., web browser) during the exam. This app-locking mechanism is commonly integrated into the iPad devices provided by the teaching institution itself, where institutions can lock their iPad devices physically, using custom iPad accessories/cases, and/or functionally, using Guided Access or custom profile features.

In our proposed system, we assume that the exam supervisors instruct their students at the beginning of each exam not to switch from the online assessment application. If a student switches from the online assessment application, by hitting the home button and thus putting the online assessment application into the background, our online assessment application is notified. There is a need for flexibility in enforcing any action since students can hit the home button key by mistake. The current version of our online assessment system does not take any enforcing actions regarding this unwanted behavior, since these enforcing actions are usually associated with exam and university policies. Instead, universities and exam supervisors/instructors can determine what the best course of action is to be taken. For example, the online assessment application can be programmed to stop the exam for misbehaving students, or to simply notify the exam supervisors instead.
**Scalability:** In order to replace infrastructure-based online assessment systems, our proposed system should be designed to accommodate the ever-increasing number of students and instructors. The scalability concerns should be addressed at both user interface and server sides.

Our system’s three-tier architecture has been proven to be successful in providing scalable structures (Greenspun, 1999). In our proposed system, both the software interface and the system database are designed to accommodate an indefinite number of users. The current system design’s only limitation in accepting larger numbers of users is the Wi-Fi coverage range of the wireless assessment server (typically around 100 feet). The range can be extended by using high gain wireless antennas, or off-the-shelf wireless range extenders.

After the brief discussion of our system design choices to address and accommodate the concerns of our stakeholders, we will discuss in the next section the implementation details of our proposed system and the realized assessment processes.

**System Implementation**

As stated before, the proposed system is based on the three-tier architecture that consists of a user interface tier, a backend (or web) services tier, and a database tier as shown in Figure 13.2. Both the database and web services tiers are implemented in the portable wireless online assessment server.

![Figure 13.2. The proposed system three-tier architecture.](image)

We selected Raspberry Pi 2 (RP2) to host and perform the functionality of the online assessment server. Raspberry Pi are extremely portable devices with small dimensions of 85.60 mm x 56 mm x 21 mm (or 3.37” x 2.21” x 0.83”), and weigh only around 45g (or 1.6 oz). RP2 devices come with 900 MHz processor, 1 GB of RAM, four USB ports,
micro-SD port, and are powered using the universal micro-USB port used by most mobile devices and Power Banks. Raspberry Pi devices are considered relatively inexpensive and are usually sold for less than $50. With the recent addition to the Raspberry Pi family, namely Raspberry Pi Zero, the price of the required online server drops to $5. In addition, Raspberry Pi Zero has a smaller footprint with dimensions of 6.5cm × 3cm × 0.5cm (2.55” × 1.18” × 0.19”).

Raspberry Pi devices run a bare-bone version of the open source Linux operating system (Raspbian) that allow users to install their necessary and bare-minimum software applications to conserve the scarce computational and power resources. As shown in Table 1, the total system cost ranges from $15 to $65 depending on the selected additional components like using an external case, and a battery pack. All the software components used to deploy our online assessment system are free and open source. Therefore, we argue that the proposed system is provided with a very competitive price, which is one of its main attractive aspects.

Table 13.1

*List of the Proposed System’s Components and Their Prices*

<table>
<thead>
<tr>
<th>System Component</th>
<th>Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>Raspberry Pi 2 Model B</td>
<td>OR $35</td>
</tr>
<tr>
<td>Raspberry Pi Zero</td>
<td>$5</td>
</tr>
<tr>
<td>WiFi USB Adapter</td>
<td>$5</td>
</tr>
<tr>
<td>Micro-SD Card</td>
<td>$5</td>
</tr>
<tr>
<td>Optional: Plastic Case + Power Adapter</td>
<td>OR $15</td>
</tr>
<tr>
<td>Optional: Plastic Case + External Battery</td>
<td>$20</td>
</tr>
<tr>
<td>Total Price</td>
<td>$15 ~ $65</td>
</tr>
</tbody>
</table>

We have configured our RP2 to work as a wireless hotspot to provide users with the necessary wireless connectivity. The database tier is implemented using the open source database server MySQL. MySQL is widely known for its reliability and ability to scale well with a large number of users.

The web services tier is implemented using PHP, the open source server-side scripting language. PHP is also known for its reliability and versatility. The web services tier is responsible for supporting the user interface tier functionality with several secure web services. In addition,
all user interface tier communications to the database to retrieve and store information must go through the implemented secure web service channels. Such a separation allows for better security procedures to be implemented and provides better overall system modularity.

The user interface tier provides system users (i.e., instructors and students) with the necessary visual interfaces to perform online assessment operations with ease. As mentioned before, the user interface designs were continually improved over several requirement analysis iterations. We have implemented the iPad mobile application that represents the user interface using Telerik cross-platform\(^2\). We chose Telerik since the application development process is done in a similar fashion to web development. This allows us to design user interfaces that scale well regardless of the user’s iPad of choice (e.g., iPad, iPad Air, iPad mini, and even the new iPad Pro).

As mentioned before, one of the concerns of using our wireless assessment is to assure its wireless coverage can reach all students in a typical classroom. Figure 13.3 shows the Wi-Fi coverage of our proposed system in a typical classroom in Yarmouk University. Using a simple Wi-Fi adapter in our system, the range of Wi-Fi signal strength value did not drop below -60dBm (decibel milliwatts), which indicates an excellent signal coverage for the entire classroom with the dimensions of 6.5m × 9m (21.3’ × 29.5’). As can be noticed in Figure 13.3, the system can cover the entire classroom, even when placed near one of the ends of the room. Figure 13.4 shows students using their personal iPads to test the proposed online assessment system.

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\(^2\) Telerik UI framework and app development tool (www.Telerik.com)
In the following paragraphs, we describe how online exam assessments can be performed using our proposed system. During which, we discuss the key features of the user interface design on both the instructors’ and the students’ sides.

To start an exam, the instructor turns on the portable online assessment server by connecting it to the power supply. Once the wireless server is on, it will broadcast its name to allow users to connect to it using their tablets (iPads) over Wi-Fi. The instructors then can log in to the system and list the exams available on the server associated with their corresponding accounts. As shown in Figure 13.5(a), the instructor can view the list of

Figure 13.3. WiFi coverage of a typical classroom using a simple WiFi adapter.

Figure 13.4. Students using their personal iPads to test our online assessment system.
available exams and activate the desired exam(s). One of the implemented features in this system that was requested during our iterated requirement-analysis cycles is to allow instructors to activate more than one exam to allow the system to serve students from different classes co-located in the same exam hall when needed.

The instructors can then view who logged into the system, as shown in Figure 13.5(b), and see if any of the students need help accessing the online assessment system. The instructor is able to control the exam flow by starting it, pausing it when necessary, and stopping it as shown in Figure 13.5(c). When the exam timer expires, all the students are logged-off and their exam marks are shown immediately to them and to their instructors. In future versions, we plan to show instructors more statistical summaries of their students’ exam results.

(a) Activate exams           (b) List connected users      (c) Manage multiple exams

Figure 13.5. An overview of the instructor online assessment interface main tasks.

On the students’ side, they log in to their accounts once the online assessment server is on. As shown in Figure 13.6(a), students can only see the exams activated and associated with their accounts (only students registered in the course can see the activated exam). Students will have to wait for the instructor to start the exam to be able to begin answering the questions. We designed the exam layout interface [see Figure 13.6(b)] to allow students to easily view the exam contents while being aware of the exam timer.

Another requested feature implemented in the current version of the user interface is the ability to allow the instructor to decide if the students are allowed to go back and forth between questions. All questions and
their answers are randomly ordered for each student to reduce the probability of cheating. Students are logged-off the exam when they complete all its questions, choose to end the exam by clicking the Finish button, or when the exam timer expires.

![Exam layout](image)

(a) List of activated exams  (b) Exam layout

*Figure 13.6. An overview of the student online assessment interface.*

While there are still many features to be added to the current version of the proposed software interface, as with any other solution, we believe that the current user interface state allows instructors and students to have engaging and gratifying experiences. As we discuss in the next section, the results of our system evaluations have shown a high level of satisfaction among the users corresponding to the proposed system design and the implementation choices.

**System Evaluation**

For the system evaluation phase, we tested our solution with the help of 71 participants from three groups: course instructors, lab instructors/engineers, and students. At the beginning of each of our four test rounds, we provided a brief summary of the system main objectives and features, introduced its main components and how they interact with each other, and provided a short demonstration of how the system works. The short demonstration was intentional to see if the evaluators can characterize the user interface and the system interactions as intuitive. We
let the users interact with the system depending on their rules, and then we collected their feedback.

The course instructors sample consisted of nine males and two females who represent computer engineering, electronics engineering, electrical engineering, and law departments. The sample consisted of nine Ph.D. degree and two Master degree holders. Most of the instructors have a very good background in both using and developing applications in their respective fields. In addition, three of the instructors had the chance to work on commercial products related to e-commerce and online banking.

The instructors rated the system portability and security features highly as shown in Figure 13.7. In addition, they generally complemented the user interface and most of them considered its usability level above average. As for the implemented security features, they liked that questions and their answers are randomly ordered, and that the Wi-Fi signal coverage is limited, which reduces the possibility of online security attacks.

As for the reliability and scalability aspects of our design, they showed some concerns about the ability of the system to handle traffic from a large number of students. We clarified that the system consumes very small traffic volume, since it only requires the question id and its answer to be sent from the student side to produce the final mark (total exam requires a few hundreds of bytes per student). The level of portability the system provides was very well received by the instructors, since the proposed online assessment server is extremely portable in terms of dimensions, weight, and required power sources.

![Figure 13.7. Instructors’ evaluation results.](image)

The second sample of users are lab instructors represented by 16 bachelor degree holders from computer engineering, biomedical
engineering, and communication engineering departments. All participants were female instructors. Lab engineers represent university top graduates who have very good knowledge in working with different types of applications as a part of their job. In addition, lab engineers have taken several advanced courses in software engineering and computer security, which allows them to have a more objective view of the proposed system.

As shown in Figure 13.8, the lab instructors received the system enthusiastically and they were quite happy to test it with their students. As the evaluation progressed, they commended our design decisions and the level of usability of the system user interfaces.

During the evaluation phase, lab engineers showed concerns about the system’s ability to handle interrupts like when either the iPad user or the teacher shuts off their tablet. In our current design, all system states are recorded in the database. If any of the system sides (student, teacher, or/and server) are turned-off, they can return to the previous state when they log back in. The instructor’s ability to pause exams can also help manage any possible widespread issues during the exam.

The third user sample consisted of 44 bachelor degree students, 10 males and 34 females, from both computer and communication engineering departments. We changed the evaluation feedback sheet for this user sample to better represent the students’ side of evaluating our proposed system. In their evaluations, we did not include the scalability section since students are not experienced in determining the system capability of supporting larger number of students.

Once more, the students liked the user interface design and the usability of the system overall, as shown in Figure 13.9. They also liked
the idea of using their personal iPads for activities besides taking notes and other general media consumption activities.

![Figure 13.9. Students evaluation results](image)

As we have shown in this section, our proposed design and implementation have been well received from a diversified sample of users. While there is room for more features and enhancements in future, we believe that the current state of our proposed solution provides an engaging experience for its users and an innovative solution as a portable and an affordable online assessment system.

**Conclusions**

In this paper, we presented our innovative solution to converting typical classrooms into interactive online assessment environments using an affordable and an extremely portable online assessment setup. We have evaluated our design and implementation choices with a diversified set of users from different majors and different educational backgrounds. The overwhelming responses from our evaluations indicate that our design and implementation choices and the current state of our system provide a promising solution to online assessment challenges.

We are planning to improve our current design in the future by adding the ability for educators to quickly survey their students without requiring them to login into the system. This can be very handy when dealing with a large number of users as well.
References


