Design and implementation of I2Vote – An interactive image-based voting system using windows mobile devices

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ABSTRACT

Purpose: To develop, implement and test a novel audience response system (ARS) that allows image based interaction for radiology education.

Methods: The ARS developed in this project is based on standard Personal Digital Assistants (PDAs) (HP iPAQ 114 classic handheld) running Microsoft® Windows Mobile® 6 Classic with a large 3.5 in. TFT touch screen (320 × 240 pixel resolution), high luminance and integrated IEEE 802.11b/g wireless. For software development Visual Studio 2008 professional (Microsoft) was used and all components were written in C#.

Two test sessions were conducted to test the software technically followed by two real classroom tests in a radiology class for medical students on thoracic radiology.

Results: The novel ARS, called I2Vote, was successfully implemented and provided an easy to use, stable setup. The acceptance of both students and teachers was very high and the interaction with the students improved because of the anonymous interaction possibility.

Conclusion: An easy to use handheld based ARS that enables interactive, image-based, teaching is achieved. The system effectively adds an extra dimension to the use of an ARS.

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1. Introduction

The value of a standard lecture in front of a large lecture hall in terms of the capability of the attendees to grasp the key issues from that lecture as well as the level of interaction with the students tends to be limited [1]. To enhance the participation of the audience during lectures, Audience Response Systems (ARS) can be used.

An ARS is an electronic tool that allows attendees of a lecture to directly respond to questions posed by the lecturer using a handheld device (also known as a clicker). These handheld voting devices can either be wired or wireless and in most cases the voting is anonymous. Wireless clickers are the most common devices nowadays and, although some devices use infrared communication, most of them are using radiofrequency (RF) to communicate with the central receiver. The clickers allow entry of numerical responses and the range of response possibilities are available from 10 upwards. Some clickers also allow the entry of text to enable open questions; however, the most common ones are still restricted to multiple choice questions. After the question has been posed to the audience, a limited amount of time will be allowed for the voting and once the audience has voted, the lecturer can display the results of the vote in, for example, percentages per answer. Research is ongoing to provide a more flexible way of implementation of an ARS [2,3].

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The usefulness of ARS in education has already been shown in multiple publications both outside and within the field of medicine [4–9].

However, in radiology teaching, the use of these systems is limited because of the limitation to multiple choice questions while radiology education is primarily image-based.

With increasing capabilities and decreasing price, Personal Digital Assistants (PDAs) and smart phones are increasingly finding their way into different professions. Uses vary from the general applications available on the device when bought to specialised applications dedicated to a certain user group. Increasingly, these PDAs and smartphones are equipped with large, high resolution, touch screen interfaces. The aim of this study was therefore to use these capabilities of a current device to create a novel, image based, ARS based on handheld devices.

2. Methods

The ARS developed in this project is based on standard Personal Digital Assistants (PDAs) (HP iPAQ 114 classic handheld) running Microsoft® Windows Mobile® 6 Classic with a large 3.5 in. TFT touch screen (320 x 240 pixel resolution), high luminance and integrated IEEE 802.11b/g wireless. The PDAs are operated using a stylus which enables accurate selection of a point on the screen. Based on these handheld devices an ARS solution was developed that allows direct audience interaction with images.

For software development Visual Studio 2008 professional (Microsoft) was used and all components were written in C#.

Evaluation of the system was conducted in two test sessions to test the software technically followed by two real classroom tests in a radiology class for medical students on thoracic radiology.

2.1. Database model

To allow easy access of all case and classroom session information a database model was designed that allows easy usage of available cases within multiple “active” classroom sessions (Fig. 1). To create a new classroom session first one must add all cases to be used within a session. Then the session itself can be created with the available cases. Once the session is finished the relations to the cases are copied within the database model to allow an “active” version with cases and the given answers. Using this method, results can be stored for later analysis. When a change occurs in a session the active sessions are not changed therefore keeping the original results. The changes will only be used when new sessions are made active.

The database model (Fig. 1) consists of multiple many to many and one to many connections between tables to allow multiple relations between the table rows and information fields. Classroom sessions are created within the table “SESSIONS” and have relations with relevant cases within the table “CASES” through the table “SESSIONCASES” allowing multiple cases to be used within multiple classroom sessions. Cases belong to a category with information within table “CATEGORIES” and have a case type definition from table “CASETYPES”. Cases are allowed to have multiple answers and these are stored in table “ANSWERS”. When using an existing classroom session, the software creates an active version of the relevant session. Classroom session information will be stored in the table “ACTIVESESSIONS” with relations to the given answers from that session. When students answer active cases the information will be stored in table “GIVENANSWERS” which in turn has a relation towards the table CASES for the correct answers in table “ANSWERS”. This database design allows easy access to all classroom session and case information.

2.2. Webservice

The IZVote webservice communicates on behalf of the FDA and Teacher clients with the database and, when needed, returns information from the database. The clients communicate with the webservice using WSDL (Web Services Description Language) interfaces that enable object-oriented communication using SOAP (Simple Object Access Protocol). On joining an active classroom session with a FDA client, the client asks the webservice all relevant data consisting of questions and images. The webservice reads the required data in realtime, compresses them as one dataobject and sends the data as bytes in a reply towards the client.

Currently, two webservices are implemented, the student (or FDA) client and the teacher client. Both services require authentication of user rights using a login. The teacher service additionally introduces the roles of normal teacher and administrator.
3. Results

A server client system was developed that allows easy entry of cases and easy construction of courses using a selection of those cases.

The I2Vote setup consists of a server running the I2Vote webservice, a PC running the I2Vote teacher client and one or more PDA's running the I2Vote PDA Client. In the most common classroom setup, the server and teacher PC are connected to the client through the LAN, while the PDA clients communicate with the server via a wireless LAN access point (Fig. 2).

3.1. Teacher client

The teacher software allows building questions and classroom sessions, selecting the question to ask during a classroom session and displaying the voting results during that session.

Currently, two types of questions are available: multiple choice (MCQ) and image based questions. Therefore, with one session a mix of standard MCQ and image based questions can be presented.

A teacher can build cases and assign those cases to a certain category by simple entry into the teacher tool (Fig. 3). With this tool the images required for image based questions can also be selected and the area of the right answer can be identified. Images can also be connected to standard MCQs as illustration without defining an area on the images. After constructing the cases, the teacher can then combine multiple cases into a classroom session. Cases are not solely connected to one classroom session, but can be used in multiple sessions if necessary.

A maximum time to answer the question in seconds is also assigned to each question and can be set differently per question depending on the level of difficulty.

During a classroom session, the teacher uses the same system to activate the session and to make questions active on the registered handhelds. The responses from the audience are visible on the projection screen on the image after the voting is closed as blue dots. The teacher can then discuss the answers and show (by changing the blue dots to green and

![Fig. 2 – Full I2Vote setup including all possible components.](image1)

![Fig. 3 – Category and case manager of the teacher client. With this tool categories, cases can constructed and maintained. The image shows the identified area of interest.](image2)
red) which answers were right and which were wrong (Fig. 4). After this, the teacher can either continue with his course or elaborate some more on the case at hand when many students have given wrong answers.

In case of standard MCQs, only the right hand pane (Fig. 4) with the status bars is used to present the results of the voting.

In the administrator mode, the teacher client can also be used for user management. Students and teachers can be added, changed or removed and rights can be assigned per user.

### 3.2. Student (PDA) client

The student (or PDA) client allows to login, select an active session, and participate in the voting by selecting answers of multiple choice questions or by selecting a location on a radiological image (Fig. 5). To ensure correct selection of the structure the student can zoom in and pan the image to get to the right location and select the point of interest. The student can change the selected point up until the time runs out or the answer is actively submitted by the student.

The voting has to be possible both during a classroom session and anyplace, anytime outside the classroom session. This means that the student can practice a pre-loaded set of questions on his or her device at any time without the requirement of a connection to the server. All sessions, both classroom and anyplace, anytime are logged into the device and the corresponding scores can be viewed by the user. New questions and the logfile containing the results of the previous set of questions are exchanged with the server during the next classroom session. This feature could also be used by the teacher to track progress of individual students.

### 3.3. Scalability

The implemented solution is extremely scalable and can be configured varying from a simple mobile setup for demonstration purpose to a large audience setup for classroom sessions. A simple mobile test setup uses the internal wifi bridge of a standard laptop with both server and teacher client running on the same hardware with one PDA client. Minimal require-
ments for the laptop are an Intel Celeron 1.4 GHz processor, 1 GB RAM, 20 GB harddrive and Wifi (Fig. 6).

An extended mobile setup can be configured using an external wifi access point with, again, both server and teacher client running on the same laptop (Fig. 7). In this case a limited number of PDA clients can be connected depending on the capacity of the laptop (approximately up to 40 clients). Minimal requirements for the laptop are an Intel Celeron 2 GHz processor, 2 GByte Ram, 20 GByte harddrive.

In a full setup the teacher client will be installed on a network connected laptop or PC. The server software will be installed on dedicated server hardware in the same network with one or more external wifi access points connected to that network. A theoretical estimate using extrapolation of the transfer load and number of connections between ten PDA clients and one Webservice with one access point results into the possible simultaneous use of up to about 500 PDA clients in a classroom session (Fig. 2). The number of access points required to run 500 PDA clients depends on the type of access point used because a combination of high connection count and transfer speeds is required. For our current hardware setup an estimated number of five access points would be needed to handle 500 clients.

In all cases, the laptop or PC running the teacher client can be connected to a projector to project the questions and results in a classroom.

Currently, the simple and extended setups were tested and the full setup was tested up until 40 PDA clients.

### 3.4. Pilot results

First technical tests were conducted with 10 participants and showed that the system was stable, fast, and easy to use by both students and teacher.

The system was then used in two actual two-hour thorax radiology courses with 37 and 20 students, respectively. From this we found the following pooled results based on a list of questions posed to the students after the course using the same ARS. Because we used the ARS, the response rate was 100%.

The questions were:

1) How do you rate the usefulness of this course? (1 = very bad; 5 = very good).
2) How do you rate the interaction during the course? (1 = very bad; 5 = very good).
3) Does this ARS add value to the course? (yes/no).
4) Does this ARS increase your active participation? (yes/no).
5) Do you think the ARS will help with knowledge retention? (yes/no).
6) If you could use the ARS questions anytime, anywhere, would you do this? (no/do not know/yes, sometimes/yes, regularly).
7) Are you in possession of a PDA/smartphone running windows mobile? (yes/no).
8) What overall grade to you give the ARS? (10 point scale with 10 being the highest grade).

The students feel that the course was useful with a score of 4.2 on a five point likert-scale (Fig. 8) and the interaction was scored at 3.8 on the same scale (Fig. 9).
Fig. 7 – More advanced setup with up to 40 PDAs connected to a single laptop through a wireless accesspoint.

Fig. 8 – Rating of the usefulness of the course on a five point Likert scale.

Fig. 9 – Rating of the interaction during the course on a five point Likert scale.

98% of the students thought the system has added value to the course and 96% felt that it improved the interaction during the classroom session. Furthermore, 93% reported the perception that knowledge retention would be better with the use of the I2Vote system when compared to a classroom session without the system. When asked whether they would use the anyplace, anytime capabilities when available, 89% of the students were positive about this possibility with 34% indicating that they would use this regularly (Fig. 10).

The teachers involved were also very positive of the first tests.

Only 8% of the students claimed to have a wifi-enabled PDA or smartphone running windows mobile that would be suitable for the current version of our PDA client.

The overall grade given by the students for the system was a 7.6 on a 10-point scale with 10 being the highest grade.
4. Discussion

ARS have been shown to result in active learning and are received positive by lecture attendees. However, the implementation of ARS in radiology is still limited [10].

It was already reported by Cain and Robinson [11] that several commercial systems are available that allow numerical or alphabetical entry to answer multiple choice questions or the entry of free text. However, since their publication the devices did not change that much. Another, more recent, approach is the use of mobile phone text messaging as a service to collect audience responses allowing free text entry. However, real feedback during sessions with large audience is cumbersome when using free text since evaluation of all responses requires a lot of time. To our knowledge none of the currently available commercial ARS support the use of images on the response devices.

Although the current ARS are already reported to be flexible and allow for many different types and lines of questioning [12], we feel that the main shortcoming of the conventional ARS for radiology teaching is the inability to interact with images, which is solved in our solution.

Most commercial ARS that are currently available use RF to communicate with a base station although some systems using infrared still exist. The use of RF over infrared is a huge benefit because it is less influenced by the environment since no 'line of sight' is required between the voting device and the base station. When developing the PDA based setup, both Bluetooth and WiFi were available for communication with the server. With Bluetooth the devices will have to sign on to get a connection and the distance between the base station and the devices is limited. WiFi was selected because it provides a more flexible, stable and versatile environment and allows easy setup and configuration.

The resolution of the screens on the PDAs is far below the native resolution of the radiological images. However, the combination of the use of the stylus and the fact that the student can zoom and pan the images allows enough accuracy to correctly mark the answers in a user-friendly way.

Evidently, application of this handheld based ARS is not limited to radiology, but it could also be used in other educational areas ranging from pre-school to university. To support this statement, during one of the test sessions other types of questions were performed. For example clicking on the mistake in a sentence, or indicating locations on a map. Those types of questions also worked and demonstrate the versatility of the system in terms of the possible applications.

Further developments could be found in the improvement of the user interface and the increase in the number of different types of cases. Possibly, integration of the teacher client within Microsoft PowerPoint will also prove to be a major benefit by increasing the usability during a classroom setting and by reducing the learning curve for the teacher. The widespread introduction of this system is still hampered by two factors, one being the high initial cost of the PDA and the other being the limited battery life of the PDA while running with wireless which hampers the use of the system during multi-hour courses. It was shown in our questionnaire that the availability of suitable devices supporting our specific PDA client implementation among the students was very low (only 8% claimed to have a WiFi enabled, Windows mobile device) and therefore an additional goal for the future is to port the student client to other platforms that might be more widespread under the students. A full PC client was already implemented and clients for other mobile devices could be implemented independently based on the existing communication protocol with the server. Alternatively, more general clients could be developed using DHTML or Java to prevent the eternal development of ports for future mobile devices.

In conclusion, an easy to use handheld based ARS that enables interactive, image-based, teaching was implemented and tested. The acceptance of both students and teachers was very high and the interaction with the students improved because of the anonymous interaction possibility. The system effectively adds an extra dimension to the use of an ARS.

Summary points
What was already known on the topic
- Standard lecture hall lectures have little interaction with the students.
- Audience Response Systems enhance participation during lectures.
- Application of Audience Response Systems in radiology is limited due to image based teaching.

What this study added to our knowledge
- Image based voting is feasible.
- Image based voting improves the interaction in radiology teaching.
- Image based voting facilitates using interactive teaching methods in radiology.

Authors’ contributions
P.M.A. van Ooijen – concept, development, implementation, test sessions, writing/review manuscript. A. Broekema – technical design and implementation, writing/review manuscript. M. Oudkerk – overall responsibility of research, contribution to test cases, writing/review manuscript.

Conflict of interest
None of the authors (P.M.A. van Ooijen, A. Broekema and M. Oudkerk) have any conflicts to report.

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