Integrating Mobile Computing Solutions into Distance Learning Environments

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Abstract: This paper assumes that in the near future most students at universities are in possession of a mobile device with the ability to access the world wide web and display multimedia content. Observing the current development trends of mobile hardware, this seems to be justified. Even common mobile phones have multiple wireless communication interfaces and colour displays. More expensive devices are equipped with a large touch screen and are able to play videos in a reasonable quality. It is attempted to exploit this development and enhance the learning experience of students by gradually building up a pervasive computing infrastructure. A design is proposed that offers an open and extensible (distance) learning environment. Flexible standards such as the Hypertext Transfer Protocol (HTTP) for communication and the Extensible Markup Language (XML) for document transfer are used. This design allows to access and modify learning material stored in learning management systems (LMS), multimedia repositories and electronic voting system (EVS) locally and remotely. The supported technology ranges from PCs and laptops to mobile devices.

Keywords: mobile devices, education, distance learning, electronic voting system, multimedia, learning management system

1. Introduction

Mobile computing in learning environments is getting popular in recent years [15, 11, 16]. A typical example is that learners and teachers can make conversation through a handy mobile device. This research is to develop a novel system of web-based services to achieve that students have mobile access to all relevant learning material at any time and any place. The proposed structure propagates the use of open and flexible standards to allow adaptive representation of the content to match the constraints of the receiving device. It is assumed that in the near future most students will have a mobile device with a reasonable wireless connectivity and display.

Quite clearly, the use of mobile devices in education is capable of yielding many advantages, if introduced properly. At the current stage, there are learning management systems (LMS) solutions available and also systems that link them with an electronic voting system (EVS) or multimedia repositories.

The LMS are growing in functionality more and more and may become an universal knowledge data base for a university or school. They may not only store name lists and course documents, but also provide a source for multimedia content. Decreasing storage prices and increasing bandwidths allow to offer those services for low cost. From a distance it becomes clear that a modern e-learning environment introduces various intertwined services.

Learning seems to be more efficient, if it includes interaction and dialogue [6]. It can be argued that it is impossible to introduce very small learning groups everywhere to optimize the contact between teacher and learner. The interaction decreases even further, if distance learning technology such as video streaming is used [13].

In principle, the required functionality can be made accessible on mobile devices. Sufficiently powerful devices are even able to display multimedia content. This may simplify communication via LMS and other sources, where lecture material is made available for students. On top of the document managing these systems usually provide facilities to ask questions, discuss topics and send private messages.

1.1 Identification of Problems

Most teaching in universities and schools traditionally relies on lectures, meaning a single lecturer standing in front of a large audience. The audience is usually passive and listens to the speech of the teacher. In this kind of scenario, a real dialogue between teacher and learner cannot be established. Occasional questions where the learners either reply verbally or by showing hands are still no dialogue as described by Laurillard [6]. The majority of learners is not urged to think about the question or even justify a response. Thus, the feedback the lecturer receives is very low and does not indicate misunderstandings or other potential problems.

Current learning systems are usually relatively isolated applications that only run in a specific environment. The data provided is either stored in proprietary data formats or can only be exported in something like comma separated value (CSV) files, which are undeniably either too simplified or too complex to process easily. Also the communication interfaces and protocols are often highly specific.

Concerning the data transfer, the large amount of students in the audience needs to be considered carefully. Efficient wireless communication is restricted by the available frequencies and the amount of data transferred. Especially in large lecture theatres, the available bandwidth needs to be used wisely.

1.2 Aims & Objectives

It is attempted to enhance the learning experience of students by gradually building up a pervasive computing infrastructure. The research focuses on the construction of an evolutionary design to allow a stepwise improvement of mobile computing support in educational environments and distance learning. The basic use case scenario for this research is described by Stav et al. [14].

The aim is the development of a generic system design to offer services for static and mobile devices that improve interaction between teacher and audience, independent from the location of each person. A common learning service is the LMS functionality which may be enriched with EVS and a multimedia repository.

To be flexible and extensible, the system should be predicated on web services and agent technology. This allows to swap or add components if required. Each service should offer a simple interface and share data in an easily readable format. This allows user interfaces to be independent from the technology used and scalable to different input-output-devices.

2. Research Approach

In this paper, the use of an agent based design with flexible standard technology is suggested. This way, unnecessary overhead that may overburden simple devices is avoided. Yet, much more importantly an open system is provided that can be easily integrated in existing systems or can be extended in the future.

The following use-case is assumed: A university wants to enrich an existing LMS with educational EVS in lectures and a multimedia repository. The e-learning environment shall grow in the subsequent years and gradually offer better accessibility. At the same time, a distance learning solution shall be merged into the system [14].

Initially, the EVS is planned to be run in only a single lecture theatre for 100 students. Later, more rooms shall be equipped and students shall use their personal mobile devices for voting and browsing the on-line content. The response system shall also be working in distance learning set-ups with video streaming [12, 13]. The multimedia repository is filled with initial annotated example data of medical and technical images. Those samples visualize things like different stages of diseases or structural weaknesses of mechanical components. This illustrative material shall be used in interactive questions during lectures and also be accessible on-line.

This environment suggests an agent based architecture, in which every part offers and/or consumes services from other parts. Each part manages a set of resources (e.g. slides, multiple choice questions) that can be read or modified by others (e.g. beamer display, voting device). The representation of each resource depends on the technical capabilities of the consumer (e.g. handset, monitor). Thus, each consumer should be able to request a preferred response format. These characteristics match the Representational State Transfer (REST) style [4].

This style recommends to keep the transaction context on the clients, rather than on the server, which induces a high visibility, reliability, and scalability. Even though this inevitably increases the communication overhead, the impact on the mobile voting is expected to be rather low. In the voting scenario, the context merely includes student authentication in order to submit a valid choice. This is an atomic transaction without further dependencies. This message should easily fit into a single transmission frame containing merely header information and the target URL. In return, the concept of caching can be applied to minimize the transfer of multimedia content.

Taking a look at the sophisticated EVS systems during elections shows technologies which may also be useful in learning environments. An example is the choice of voting devices. Current EVS systems in lectures require special hardware during the lecture. If the questions are available on-line, other voting devices are possible. A suggested framework for elections at universities proposes the use of various input devices [10]. Of course, ballot-rigging in simple education obviously has a less hazardous impact than in politics. Security issues do not have to be taken as seriously, making things much easier.

Getting responses from the whole audience is only feasible in very small groups and does not scale very well. The introduction of EVS [7, 1] to improve the situation requires to equip each person in the audience with a voting device. This raises the question, how these are distributed or if learners may also use their own mobile equipment for answering. In the latter case, it is important to have access to the voting software and to register non-system hardware in it.

Concerning multimedia documents, even modern mobile devices only have a restricted screen size. While the progress of technology introduces higher memory capacities and faster connections, the display size itself has physical boundaries. Unless this could be solved by something like folding screens or miniature beamer technology, this will remain a serious constraint. Hence, specially designed user interfaces for mobile devices are required. The screen resolution/size is very low and does not allow to show many preview images at the same time. For those devices, the images need to be scaled down, which also saves bandwidth. A reasonable resolution for big screens seems to be at least 128x128 pixels, whereas small devices may require 64x64 or even smaller.

2.1 Techniques Deployed

As a design following the REST style is recommended, the use of a widely used communication protocol such as the Hypertext Transfer Protocol (HTTP) is obvious. All required resources can be made accessible via Uniform Resource Locator (URL). This way, most clients are able to communicate with the services. Linking all resources to a URL enables users to access especially multimedia content with their preferred software. Grounding the system on HTTP in the first place, instantly allows to make all services accessible virtually anywhere in the world wide web. Additionally alternatives such as the Wireless Application Protocol (WAP) or the Short Message Service (SMS) could be offered for mobile clients to provide a simplified gateway to the system.

The data format for transfers should be both uniform and flexible. The increasingly popular Extensible Markup Language (XML) in combination with Extensible Stylesheet Language Transformations (XSLT) is a useful standard. This ensures a high portability and allows external services to process the data easily. Further, it allows for the design of different user interfaces for a range of devices without much additional effort.

To visualize information, the best format needs to be chosen for each single case. Texts are usually displayable directly on most devices, either unformatted or formatted. Depending on the capabilities of the client device, the documents could be converted into formats such as HyperText Markup Language (HTML), Extensible Hypertext Markup Language (XHTML) or Wireless Markup Language (WML). The most severe issue would be the coding of special characters in very simple environments. A promising format for complex documents could be the OpenDocument format (ODF), which is not specialized for web browsing, but is also based on XML and is well documented [2].

In the use case discussed, pixel images and video streams are used during lectures. In order to keep the additional network traffic at a reasonable level this paper focuses on images but maintains space for further extensions. The original images should be store lossless, which may be done in the Tagged Image File Format (TIFF). Previews should preferably use common formats, such as Joint Photographic Experts Group (JPEG) and Portable Network Graphics (PNG) due to the wide support by clients. For vector graphics, such as the visualization of statistics, using the Scalable Vector Graphics (SVG) format is advisable, which is also derived from XML. In this scenario, the teacher may still include other media content such as audio/video that is displayed at the front and does not need to be widely distributed to wireless computers at that time.

For the transmission between voting device and voting server, several options are available. Commercial handsets often use infra-red or any type of radio. Other devices that can be used for wireless voting, such as mobile phones or PDAs (other gadgets with wireless transmission included) offer a wide range of solutions with individual advantages and drawbacks. The common Infrared Data Association (IrDA) is the only widespread optical system, but is unsuitable due to the short transmission range and error-proneness. Mobile phones use communication such as Global System for Mobile communications (GSM), General Packet Radio Service (GPRS) or Universal Mobile Telecommunications System (UMTS), which is in most scenarios reliable in lecture theatres (to the displeasure of lecturers). For this service, a commercial network provider needs to be paid for the transmissions. In enclosed areas the use of Wi-Fi (IEEE 802.11), Bluetooth or ZigBee offers a cheap and easily controllable alternative. Yet, not all mobile devices offer these options.

In the initial stage of EVS introduction, there should be sufficient distributed handsets available for the audience. For transmission, Wi-Fi technology is used in the initial setting. It provides a high bandwidth and reliability for lecture theatres and a low effort to set it up. A single access point should be able to handle at least 25 clients at the same time [5].

In the future, the handsets could be gradually substituted by personal devices such as mobile phones and PDAs. As many people already carry around a mobile device with wireless capabilities, these should also be used for voting. A possible drawback is that the attention of the audience may be distracted to the device, especially if it offers further services such as chatting or games. In the future, other wireless options may become available.

An example for a multimedia repository is described in the master thesis and a further publication of one of the authors [8, 9]. It provides access to image data in multiple ways and introduces a query language for mixed textual and content based queries.

2.2 Methods

The framework design is separated into two main layers: the core services and various clients. The component diagram (fig. 1) is simplified and omits the persistence layer. It is considered to be a minimal system, containing all the relevant services for an e-learning environment offering LMS, EVS and multimedia content. As the design is meant to be openly accessible and extensible, further services could be added later on.

Each one of the core services offers a set of interfaces that can be accessed by other services or external clients. The main tasks and interfaces are described below.

The user management has a very important task. It holds information of all users that are allowed to use the restricted services. In this service, students could securely register mobile devices for detailed information access and the permit for participating in votes.

The LMS offers the common services. It is a central communication point where lecturers and students exchange information about different modules and other university related content. It also acts as a document repository for course material where students can find the slides of a lecture, tasks, assignments and additional information. In the use-case described above, the LMS should also be used to publish the URLs of multimedia content (i.e. images) which is stored in the image repository.

The image repository is a specialized storage for images. This service could either store the original images themselves or only the corresponding URL plus downscaled preview images. The main benefits of this service would be the ability to perform content-based image retrieval (CBIR).

Another core service is the voting server. It is used during a session to electronically collect the votes for questions prepared by the lecturer. To perform the counting correctly, it is important to check the “one person - one vote” constraint. In current systems, this can be obtained by only counting the votes of previously registered handsets. In the extended case, personal mobile devices of students need also to be registered.

After the relevant data is collected, it is useful to visualize it somehow to simplify interpretation. Votes with multiple choice option are often displayed as bar chart. Thus, a statistics service converts the raw data into vector-based charts. These charts can be displayed via projector or even in downscaled versions on the display of a mobile device. In addition to the simple aggregation for a single vote, all previously collected data could be summarized in charts and diagrams, which is of particular use to provide lecturers with a report.

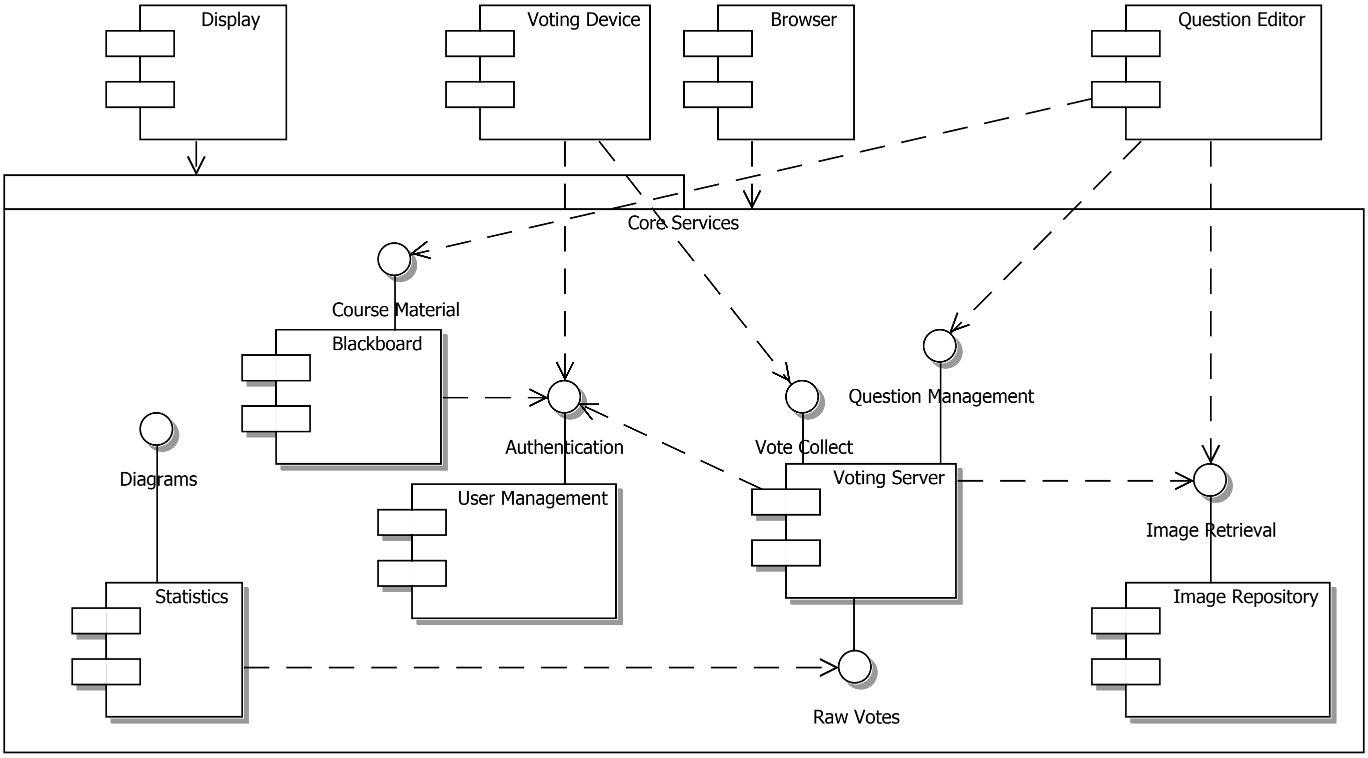


Fig. 1. The Framework Component Diagram shows the main interaction between the services. The persistence layer and global authentication links are omitted. Clients that may access all services point to the complete subsystem.

In the simplest case, all the services are directly accessed via the HTTP protocol. However, mobile devices may have some specific needs. In addition to the appropriate transmission hardware on the university side, it is crucial to support WML and maybe a plain format for SMS texts. Those devices could either directly request their preferred format from each server or need to be routed through a gateway that translates the requests into HTTP. It is hoped that gateways are only a transitional solution and can be omitted at some point in the future.

The second part of the proposed system deals with the devices for interaction. The hardware can range from desktop PCs down to minimal mobile devices.

The most powerful part is the browser. It is independent from the hardware, and its main task is to browse the services along different links. The browser accepts URLs as input and loads the content from the given location. The returned document is usually formatted in an XML derived format that has been requested by the browser. Inside the document should preferably be a set of further URLs to continue browsing.

To meet the lecture and EVS requirements, three specialized components need to be considered. First of all, lecturers can create slides and questions with a question editor. The slides are uploaded into the LMS and contain links to the corresponding votes, which are stored on the voting server. Those slides may also contain links to multimedia content from the repository. During a lecture, the slides appear on a display, visible to all students. For every question, the voting server waits for the votes from students, who can submit their choice with any previously registered voting device. After a certain time, the display reads the newly generated charts from the statistics service.

In the diagram, the display is an independent output-only component. In a real application, this is usually the computer at the lecturers desk which is connected to the beamer. Unlike in simple EVS scenarios, the machine containing the presentation and the machine displaying it, are separated. Depending on the specific needs, the voting server can remain accessible, even if the machine in the lecture theatre (display) is switched off.

2.3 Implementation

As mentioned above, the main interface of the services is implemented in RESTful HTTP. This allows for direct access to resources, supports underlying caching functionality and provides a high extensibility. The four most important methods are *GET*, *PUT*, *POST* and *DELETE*. As *GET* is defined as side-effect free, it is easily possible to use existing caching approaches, reducing the overall traffic [4].

In this section, some interface examples are explained on the base of a sequence diagram (fig. 2) that describes a minimal voting scenario. The commands in the example are shortened and do not contain the actual data that is transferred. Figure 3 shows the voting process from the view of a mobile voting device with a colour display. The student sees the vote as depicted in figure 2.3.

Prior to a lecture, the lecturer creates a set of slides with questions and uploads them to the LMS blackboard (1.) and voting server (2.).

```
PUT slides
http://blackboard.example.net/
```

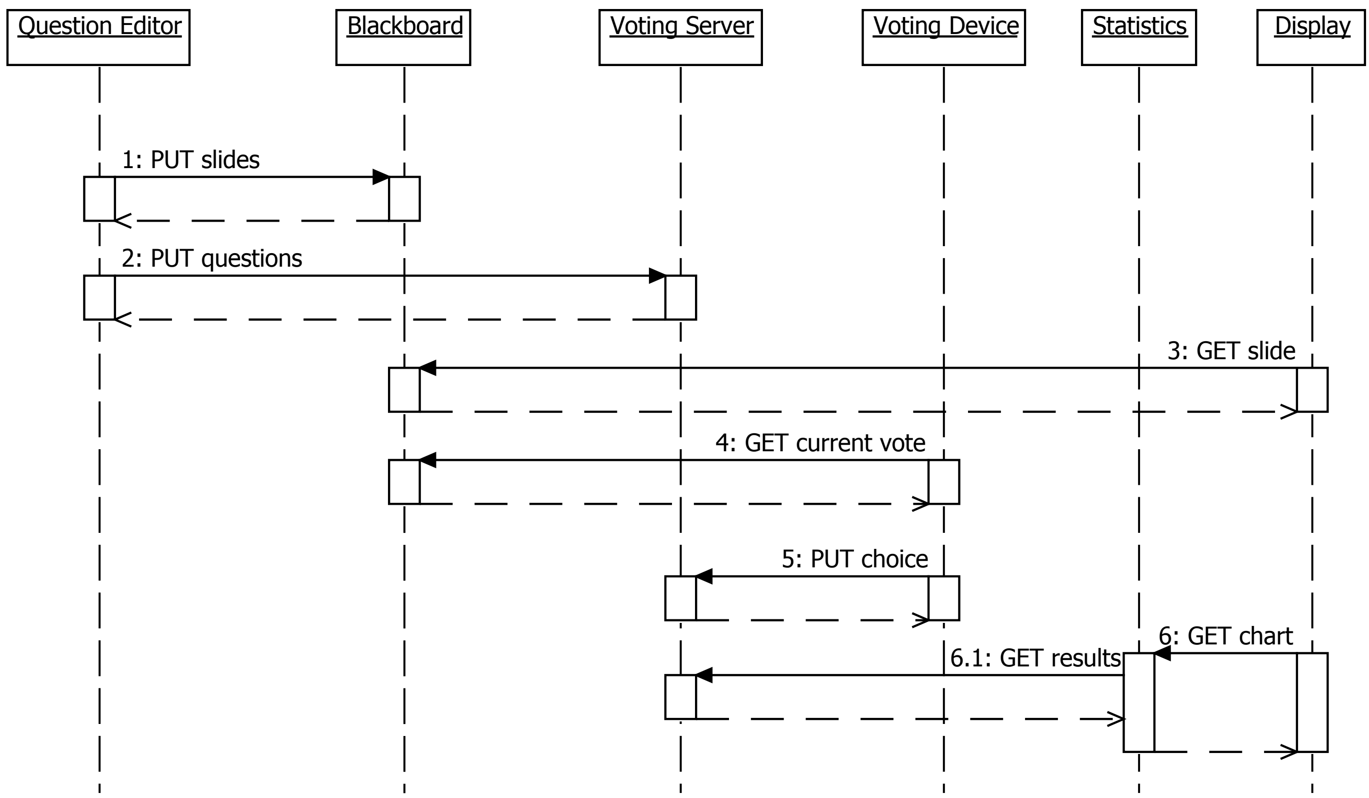


Fig. 2. Sequence Diagram for a minimal voting scenario that shows the communication between different agents.

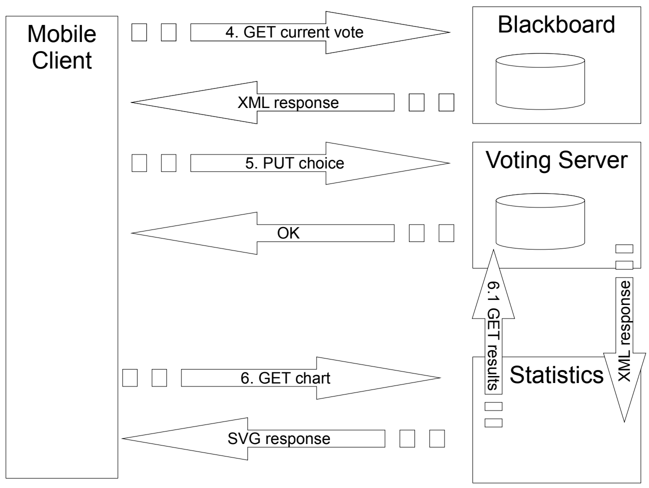


Fig. 3. Collaboration Diagram from the view of a mobile client.

```
<lecture>/<session>/
```

```
PUT questions
http://votingserver.example.net/
<lecture>/<session>/
```

Later in the lecture, the laptop of the lecturer subsequently reads the slides from blackboard (3.).

```
GET slide
http://blackboard.example.net/
<lecture>/<session>/<page>
```

At some point, a slide containing a question pops up on the display. The URL to the current question could be displayed to allow students to follow the link with any mobile device. Alternatively, the voting device asks at the blackboard to return the URL to the current question (4.). If not done automatically, the student triggers this event. The display title (figure 4(a)) is to confirm that the student is sitting in the right lecture.

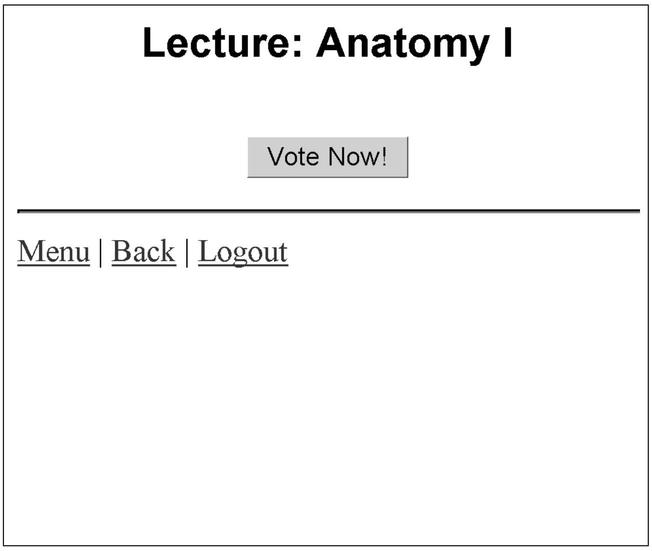
```
GET current vote
http://votingserver.example.net/
<lecture>/<session>/current
```

The voting URL can be used to submit a choice (5.). Dependent on the type of question, this choice may differ. In the returning dataset, the voting server confirms the reception of the vote and may also indicate the correct answer. If it has the appropriate capabilities, it can display the different options as shown in figure 4(b). In this case, an optional GET access to the image repository is triggered. Otherwise it simply renders a textual representation.

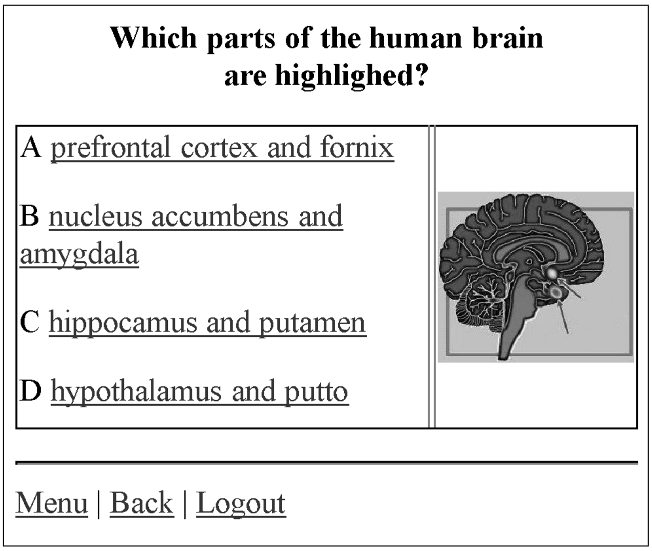
```
PUT choice
http://votingserver.example.net/
<lecture>/<session>/<questionId>/<choiceId>
```

After a certain amount of time, the vote is finished and the lecturer opens up the vote results on the beamer. This is done by asking the statistics service to generate a chart (6.). The statistics service reads the results from the voting server (6.1) and returns a generated vector image. On a mobile device, this may look like figure 4(c).

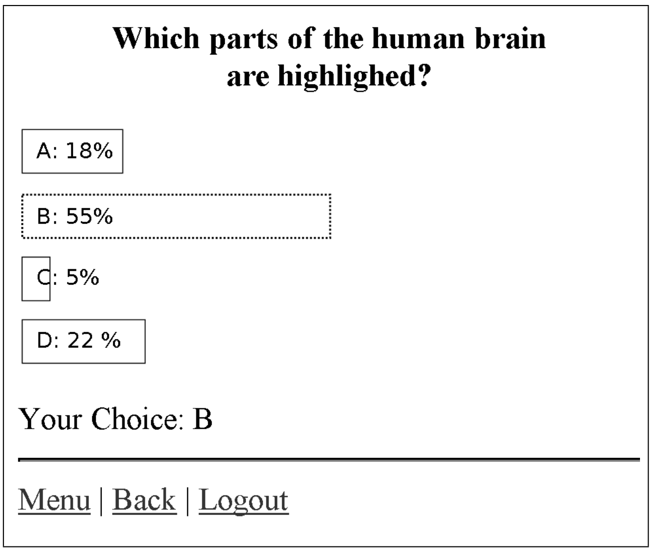
```
GET chart
http://statistics.example.net/
<lecture>/<session>/<questionId>
```



(a) Waiting for initiation of vote



(b) Displaying the options (sample image from Caltech-101 [3])



(c) Showing the results

Fig. 4. Display on a voting device during a vote

```
GET results
http://votingserver.example.net/
<lecture>/<session>/<questionId>
```

2.4 Discussion

The system is specifically designed to be extensible. Deploying the system can be done subsequently. The most likely starting point is an already existing LMS with a user management. This minimal configuration can be used without any additional services.

The voting server can be added at any time. The crucial part is to create slides with the correct URLs for voting. The perfect solution would be the use of an XML based slide format that contains the URLs in specific tags. In early stages, a simple somehow tagged URL in the slide body would be enough, as long as the LMS can extract it from the presentation file. Also, it should be possible to send each slide separately on a *GET slide* call. This way, the LMS server is able to keep track of the current progress of the lecture and can return the correct voting URL on a *GET current vote*. Each slide may also contain multimedia content, by linking the corresponding URL from the repository. The remaining involved statistics services can be minimal in the first version, simply generating a bar chart from the raw results. In later versions, it should also generate aggregated reports over a complete session or lecture. If the voting is not anonymous, it may also alert the lecturer to initiate additional help to weak students.

The system described above contains all important components required by the use-case (section 2).

3. Conclusion and Future Work

This paper suggests an open system consisting of multiple loosely coupled agents. In the current stage, it is designed to cover the interaction between LMS, EVS and multimedia repositories. Implementing simple interfaces based on the plain HTTP protocol enables virtually any web enabled client to access the resources offered at any location. The use of XML documents as a default response provides a great flexibility for generating appropriate end user documents.

The user interface of the EVS is reduced to the essentials. Users from the audience only need to input the initial URL to the voting service and push a few buttons in order to participate. The implemented system currently merges EVS and image retrieval. Each vote may be enriched by URLs of corresponding images from the repository. Reversely, the EVS results can be stored as meta information to tag the images (e.g. “Please select the most aesthetic image.”).

3.1 Problems Remaining

Currently, the most severe issue is to gain access to the LMS, as often commercial products with a restrictive API are used. Further, integrating links between digital lecture slides and the voting system requires both control of the slide internals and the presentation tool.

Finally, the impact of hundreds of students browsing the servers and downloading multimedia content at the same time may cause problems, if not controlled carefully.

3.2 Future Work

In the next stage, it is attempted to integrate presentation files into the EVS, first by a dedicated service, later within a real LMS. At that stage, the described voting scenario will be complete and the system will then be tested in on-site and in distance learning lectures.

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