Online radiological examination: open-source tool for federal certification

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Introduction

Following the introduction of new criteria for the Swiss federal certification of radiologists as part of the Swiss Medical Association (FMH), the Service of Medical Informatics (SIM) at the University Hospital of Geneva (HUG) was asked to develop a computerised examination.

The training of radiologists in Switzerland is supervised by the FMH. This training is evaluated by two examination stages in order to assess the future-radiologists' level of knowledge. Passing the examination is the prerequisite for obtaining the official professional certification. The second-part of the examination contains questions related to radiological-pathology, based on image analysis and description. This examination uses case-based problems and open questions (the quiz) and multiple-choice questions (the super-quiz). The quiz is composed of 30 questions, and the super-quiz of 15 questions. Both contain important radiological images of each case, selected by a group of expert radiologists.

Before the introduction of a computerised examination, images had to be copied manually on films and displayed on wall-mounted backlit screens located in the hospital's corridor. Each candidate had then to walk from one case to another in order to respond to the different questions. Using digital imaging and standard computer technology simplifies the case building as well as the examination process [1].

Each expert should have access to a secure web page where one can build and manage the cases.

Each candidate had to have access to one workplace from which one could browse the cases instead of walking from and to the backlit displays that were used previously. The quality of the final image display had to be good enough to contain pertinent radiological information, while using the standard computers, web browsers, internet connectivity and standard CRT displays available. Questions and texts had to be presented in at least 3 languages: French, German and English.

Materials and methods

As human and financial resources for the project were limited, the choice of using open source packages was made. This choice included the use of Web standards for display and interface design. The use of an open source software foundation seemed to be the best way to minimise costs, to have access to many useful multimedia functionalities, and to preserve a high level of system security and stability. At the same time, future free use of the open source package in our hospital and in other academic infrastructures was guaranteed. In order to ensure an active developer community and future portability, we chose to develop the system under the BolinOS [2, 3] web platform, which relies on worldwide standard open-source software packages: Apache [4], PHP [5] and MySQL [6]. Building the examination system as a BolinOS plug-in opened the door to many improvements. For example, the complex management of users, groups and experts was an immediate benefit of using this existing platform. But many other functions were readily available, such as authoring history, user tracking, backups, graphical looks, image manipulation. Moreover, CD-ROM or USB key content creation were offered by libraries that were included in the BolinOS package. This existing foundation facilitated the development of the examination system; most of the work was limited to adaptation, parameterisation or fine-tuning of existing functionalities.

In addition, as BolinOS includes a widely used basis such as Apache Web server, PHP scripting language and the MySQL database, all tests, developments and production of both client and server side applications were run on Linux, MacOS X (BSD Unix), Windows, and Solaris machines. This allowed the examination system to rely on

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minimal requirements for the future operating system independence.

The use of the standard BolinOS system facilitated the integration of basic libraries of functions as well as the other plug-ins that were already available in the system, such as anatomy atlas, image collections management or navigation. The image functions library is used for image generation, format conversion, and image catching. The quiz system extensively uses users and groups management capabilities and adds increased security and possibilities to manage specified examination session duration, result tracking (for online answering), and detailed interactive-browsing analysis. The ability of the system to natively manage different languages, the "languages selector" plug-in, and a multi-language functions library were very helpful to implement the multi-lingual aspect of the plug-in.

We used the standard BolinOS data class to implement the data side of the plug-in. Table generation and update, as well as basic forms, archiving and restoring are covered by this BolinOS object. For advanced html edition we used the multimedia editor.

Another major point for the general acceptance of the system was its close relationship with experts. All developments could be realised by the BolinOS team in charge of the Department's intranet and internet websites and could therefore be done immediately after meetings with the radiological experts. These clinicians often proposed pragmatic and sometimes dramatic changes to the tool after using it. The fast response of the development team and the fulfilment of most requirements, both for functionalities or interface goodies, were key factors for the success of the project. Many developments were made after the first three examination sessions. Users and experts provided the development team many suggestions for improvement. In addition, the development team tried, through multiple brainstorming sessions, to foresee and develop other functionalities that might facilitate the tool's usability and increase its efficiency.

Results

This tool has been used since 2001, and has enabled more than 20 radiologists to pass their second-part specialisation examinations yearly. Each year, about 17 experts are implied in the realisation of the 30 cases for the quiz and the 15 cases for the super-quiz. This results in the upload of more than 150 images, for a final of about 100 images that are used.

The computerised examination environment is easy to use and is user-friendly. Users must log in the system using their username and password through an encrypted connection. The login gives access to personalised levels of authority on the system and quiz plug-in. User's profiles can be edited at all time according to the necessary conditions and any level of granularity can be created to encompass needs. Four profiles were needed to fulfil the needs of the examination system:

1. *Administrator:* grants all accesses to the site functionalities and contents. A few functionalities will require extra rights in order to get access to the data. Administrators can edit pages, data and user's profiles;
2. *Managers:* administrator rights on the cases but no other rights on pages, they can go through all cases, track who and when questions and cases have been added or modified, are notified automatically by email, can manage cases and related documents, check answers, download stand-alone result sheets, and manage authoring history of cases;
3. *Authors:* authoring rights on their own cases and browsing cases the same way examinees do. Authors can use the edit-mode to edit cases, but this right will only give them access to their own cases. They can upload and delete image files as well as add, edit and destroy their own questions. At the same time they have access to other authors' cases which illustrates the dynamics of the work-group;
4. *Examinees:* have only the right to access and browse their assigned cases during the granted time of an exam session and from a defined place on the net (serves as identity and login during the examination session).

Figure 1. *Author's view. Data and images edition of case 3. Authors can upload new images, edit multi-lingual legends and change image order. The diagnosis field is only accessible by authors and manager and helps them to manage their cases.*

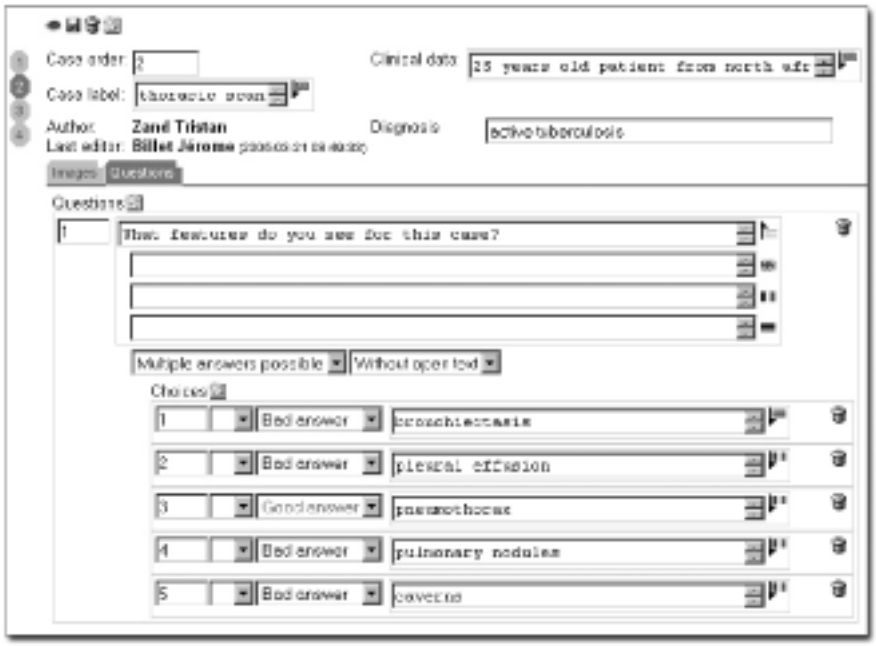

Figure 2. *Author's view. Multi-lingual questions and answers edition form of case 2.*

The image case collections are using the basic file manipulation of BolinOS. Source images are uploaded to the server, while defining rights that were given to the user and page where the quiz plug-in is situated. These are physically stored on the web page's corresponding file system secured-folder. Each image is related to one or more cases according to what has been decided by the question's author. The images that will be displayed on the client Web browser are distributed in minimal-loss JPEG format. If the uploaded image is in another format, such as DICOM, PNG or bitmap among others, the BolinOS / ImageJ layer of the core system will automatically convert these to the appropriate format in order for the quiz plug-in, or any other image related plug-ins, to be able to manipulate them correctly (figure 1).

All questions in each language are stored in their respective database-specific plug-ins (figure 2 and figure 4), linked to the cases images, and to the answers of all examinees. Answers are stored along with session information, including things such as time stamp, place of examination, corrections and retries, chronology and sequence of browsed cases, as well as technical information such as browser, operating system, hardware, etc.

Inherent to the development of the examination system are the additions of many functionalities to the core system of BolinOS. The main enhancements that are offered to the open source community were related to image manipulation functionalities and complex user rights organisation, tracking and result management. The integration of the National Institutes of Health open source project ImageJ (Java application) was improved in order to offer an alternate case browser with real-time brightness and contrast adjustments capabilities (figure 3).

In addition, the very constraint and robust environment required for a federal examination imposed the development of three modes of execution:

1. *Standard mode:* uses full server connectivity. Images and texts are served by the web server, as well as answers registration;
2. *Mixed mode:* images are stored locally to minimise the need of a large bandwidth. Questions and other texts are stored by the web server.

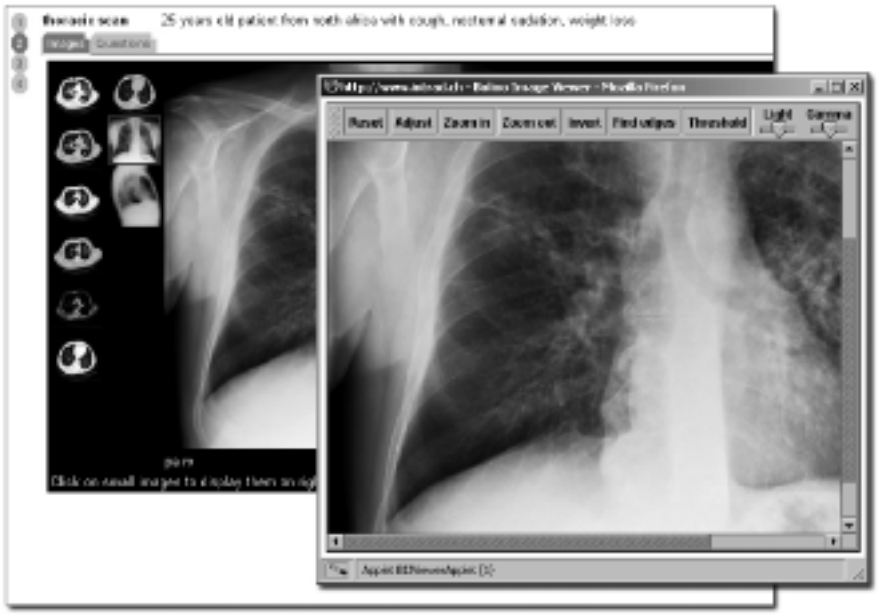

Figure 3. *Candidate view of case 2. Examinees can browse images using thumbnails and use the BolinOS embedded viewer to display one image with advanced features like brightness and contrast adjustments capabilities.*

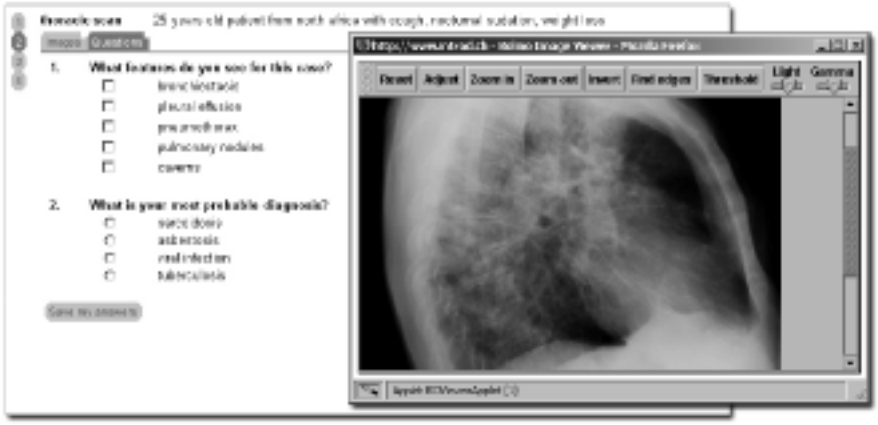

Figure 4. *Candidate view of case 2. Questions and related texts are displayed according to the language selected by the examinee.*

3. *Local mode:* a complete static version with JavaScript and Java code inclusion is dynamically generated and transferred to computers. The network connection is only used to register answers.

The team leading the examinations is formed by experts, professional radiologists, coming from all parts of Switzerland. They discuss the cases, choose images, and prepare the questions and multiple-choice answers. Several secretaries are also involved. They coordinate mostly, type the questions, prepare translations, ensure that the question leaflets used during the exams are well printed, and organise the examination dates. A few photographers are involved, to scan the rare non-digitised films, usually historical cases, to be used when necessary. The experts receive an account on the BolinOS web server and create / manage their own cases, both for the quiz and super-quiz, entering questions in the language they are used to. The experts meet a few times during the year in order to decide which questions and images are best, to verify and/or translate questions and other texts displayed during the examination, and to review the whole examination before the real date.

The team of developers devoted to the project varied from one to three during the past three years, mostly working on a punctual basis for the project. Their task included development of the tool, user's support, debugging and documentation creation.

The project benefited from two important up-scaling processes. The first one was at the occasion of first use in our hospital for examinees, while the second one was reached with the nation-wide extension of the system. By now, experts can use the system from their own workplace in Switzerland, managing their time as desired while having access to other experts' current work. Basic teaching of the tool by our development team, the self-registration of authors in the system, a few glitches on users and development sides finally resulted in a small web-savvy (?) radiological community with concrete expertise of simple online examination tools. More surprisingly, the system has even been used as a kind of general forum place, where experts and other radiologists exchanged ideas and experience.

Discussion

We demonstrate that using a standard open-source based content management system to implement a completely new and rather complex set of functionalities devoted to a federal medical certification was feasible at reasonable costs and in a short time frame. In addition to the core functionalities focused on examination (complex management of users, production and management of each case, organisation of the examination, scheduling, examination management, and result processing) we enhanced the core of the BolinOS CMS. One of the major

improvements was the extension of a digital image browser that was adapted to the examination process and running on a heterogeneous infrastructure. During the first three years, the candidates were able to work on individual stations, thus definitely replacing the cumbersome old-fashioned backlit film viewing in a corridor. The development process, based on extreme programming techniques using fast cycles of *develop-test-correct* coupled with a strong user-oriented and focused approach led to intensive collaboration between developers and experts or users. The gain was immediate, with a strong acceptance and fine congruence between expectations and realisation. This led also to a good vision of the possibilities and limitations of Web-compatible tools for users, which helped keeping goals reachable. The development of the online examination answering system, while not yet used for the certification, has given rise to new sights for group-oriented authoring, results management and tracking of radiological quizzes.

The integration of other open source projects was also a unique opportunity to be involved in the creation of worldwide-academic internet-based tools for radiology, and to share efforts and experience to improve the development of online radiology tools, independently from economical or political needs, hoping to promote such approaches and research in this field.

This examination environment, along with other radiology-related developments at the University Hospital of Geneva, has become one of the first internet accessible examples of academic open source radiological tool developments. This project supports other academic groups worldwide to use and enhance open source applications as a sound alternative to software design, based on sharing knowledge, experience, and realisations. The complete source code is therefore available to any interested person in academic settings. We hope to contribute to the development of a new philosophy in informatics and, in general, in science and information technologies. We believe that knowledge belongs to human kind and that shared common efforts are needed to progress in our fields.

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