Quality features of *TCExam*, An Open Source Computer-Based Assessment Software

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Abstract
General advantages of Computer-Based Assessment (CBA) systems over traditional Pen-and-Paper Testing (PPT) have been demonstrated in several comparative works. Scientific literature generally tends to be very poor in identifying a set of criteria that may be useful to select the most appropriate CBA tool for a specific task and a lot of work is still necessary to analyse all the issues when choosing and implementing a CBA tool, even if a relevant effort has been made in this field with the ISO9126 standard for "Information Technology – Software Quality Characteristics and Sub-characteristics". In this paper, I propose to take into consideration the specific quality features of TCExam, not included in ISO9126 but extremely relevant for CBA design. TCExam is a simple, free, Web-based and Open-Source CBA system that enables educators and trainers to author, schedule, deliver, and report on surveys, quizzes, tests and exams. The paper discusses some quality features of the TCExam without entering in-depth software functionality details.

Introduction

Computer-based assessment (CBA), also known as *Computer-based testing* (CBT) or *e-exam,* has been available in various forms for more than four decades. In the past dozen years, CBA has grown from its initial focus on certification testing for the IT industry, to a widely accepted delivery model serving elements of virtually every market that was once dominated by Paper-and-Pencil Testing (PPT). Today, nearly one million tests per month are delivered in high-stakes, technology-enabled testing centres in all over the world (Tomson Prometric, 2005).

Several comparative works in scientific literature confirm the general advantages of CBA systems over traditional PPT (Vrabel, 2004). These general advantages include: increased delivery, administration and scoring efficiency; reduced costs for many elements of the testing lifecycle; improved test security resulting from electronic transmission and encryption; consistency and reliability; faster and more controlled test revision process with shorter response time; faster decision-making as the result of immediate scoring and reporting; unbiased test administration and scoring; fewer response entry and recognition errors; fewer comprehension errors caused by the testing process; improved translation and localization with universal availability of content; new advanced and flexible item types; increased candidate acceptance and satisfaction; an evolutionary step toward future testing methodologies.

While CBA is now an accepted testing solution there are still many factors that must be considered when choosing and implementing a assessment solution. The scientific literature is very poor in respect of identifying a set of criteria that may be useful to an educational team wishing to select the most appropriate tool for their assessment needs. Relevant help is provided in this direction by a number of research studies in the field of Software Engineering providing general criteria that may be used to evaluate software systems (Valenti et al, 2002). Furthermore, progress has been made, in this field by the International Standard Organization that in 1991 defined the ISO9126 standard for "Information Technology – Software Quality Characteristics and Sub-characteristics" (ISO, 1991). The ISO9126 standard is a quality model for product assessment that identifies six quality characteristics: functionality, usability, reliability, efficiency, portability and maintainability. Each of these characteristics is further decomposed into a set of sub characteristics. Thus, functionality is characterised by the categories suitability, accuracy, interoperability, compliance and security.

Nowadays several CBA tools are available on the market, but unfortunately most of them are proprietary, closed, centralized, complex, expensive and do not fully cover the aforementioned ISO9126 quality model. This is

why the author decided to start the *TCExam* project, a simple, free, web-based and Open-Source CBA system that enables educators and trainers to author, schedule, deliver, and report on surveys, quizzes, tests and exams. *TCExam* project was started in 2004 and now it is translated in several languages and freely used all over the world by universities, schools, private companies and independent teachers.

In this paper I propose to take into consideration specific quality features of the *TCExam* software, not included in ISO9126 but extremely relevant for CBA design. After a brief introduction to the tool, the proposed quality features will be described in detail and finally discussed.

TCExam general information

TCExam (http://www.tcexam.com) is a free Web-based and Open-Source Computer-Based Assessment (CBA) software application hosted on the *SourceForge.net* repository.

TCExam is divided into two main sections: public and administration. The public area contains the forms and the interfaces that will be used by users to execute the tests. In order to access this area, the users must login, inserting their username and password in the specific form. Once logged in, the users will see a page with the list of the tests to complete, and possibly the tests already done. The list of tests visualized depends on the relative time frames, the user IP address, the user's group and the condition if they have already been performed or not. The list of active tests shows, other than the test name, a list of links which can be different case by case: *info* – to display test information; *execute* – to start the test; *continue* – to continue previously interrupted test; *results* – to display test results (*TCExam* automatically grades the users' answers in real-time, considering the question difficulty and the test base score).

The test execution form contains two sections. In the first section the user may answer the selected question. The second section contains a menu to select the questions and display their status (selected, displayed, answered, difficulty). The user is freely allowed to change the answers at any time during the test. Users may leave a general comment to the test and also terminate the test at any time. It is not necessary to confirm the end of the test since it is considered to be concluded when the expiration time has been reached.

The administration area contains the forms and the interfaces to manage the whole system, including the user and database management, the generation of the tests and the results. The access to the various administration sections depends upon the user's level and group. The test-takers activity could be monitored in real time by administrators. An administrator has the privileges to stop, restart or increase the remaining time of each test. Once a test is completed, an administrator can: manually grade the TEXT answers; display, export (CSV, PDF) and print the general and detailed results; send the results to each user by email; display the test statistics. *TCExam* may also generate tests in PDF format to be printed and used in a traditional Pen and Paper Testing (PPT).

Currently *TCExam* support four question types:

- MCSA (Multiple Choice Single Answer): The test taker can only specify one correct answer (radiobutton).
- MCMA (Multiple Choice Multiple Answer): The test taker may select all answers that apply (checkbox).
- ORDER (Ordering Answers): The test taker has to select the right order of the alternative answers.
- TEXT (free-answer questions, essay questions, subjective questions, short-answer questions): Answer can be a word, phrase, sentence, paragraph or lengthy essay. Essay questions are scored manually. Short-answers are automatically graded.

Since *TCExam* is in continuous development, additional question types will probably be added in the future.

TCExam Quality Features

In addition to the aforementioned ISO9126 quality model and general CBA features, *TCExam* introduces other specific quality features that are discussed in this section.

Free and Open Source
Open Source promotes software reliability and quality by supporting independent peer review and rapid evolution of source code. *TCExam* is

a Free Libre Open Source Software (FLOSS) by adopting the GNU-GPL (General Public License). The general advantages derived by the Open Source model adoption are (Wieërs, 2008):

- Openness: All advantages of Open Source are a result of its openness. Having the code makes it easy to resolve problems (by you or someone else). You, therefore, don't have to rely on only one vendor for fixing potential problems.
- Stability: Since you can rely on anyone and since the license states that any modification shipped elsewhere should be equally open, this means that after a period of time Open Source software is more stable then most commercially distributed software.
- Adaptability: Open Source software means Open Standards, thus it is easy to adapt software to work closely with other Open Source software and even closed protocols and proprietary applications. This solves vendor lock-in situations which “ties your hands and knees” to one and only one vendor if you choose one's products.
- Quality: A wide community of users and developers does not only ensure stability, but also supplies new possibilities, making Open Source software a feature-rich solution. New features, less bugs and a broader (testing) audience (peer-review) are significant to the quality of a product.
- Innovation: Competition drives innovation and Open Source keeps competition alive. As no-one has an unfair advantage, everybody has the possibility to add value and provide services.
- Security: It is widely known that security by obscurity is not a secure practice in the long run. By opening the code and by wide adoption of Open Source software, it grows more secure.
- Zero-price: *TCExam* software is freely available and doesn't cost any additional licenses per user/year. This is probably why *TCExam* is more used on developing countries.

Community Support

The *TCExam* project is managed and distributed trough the *SourceForge.net* repository. *SourceForge.net* is currently the world's largest Open Source software development web site. *SourceForge.net* provides free hosting to Open Source software development projects with a centralized resource for managing projects, issues, communications, and code. Through the *SourceForge.net* Web site, *TCExam* users can download the latest version, read the latest news, get support, submit bugs, submit patches or request new features.

The community support is an important part of the *TCExam* development process. *TCExam* is in continuing development to reflect the real needs of the users and improve all aspects of the software quality.

Platform Independent

TCExam is a Web-based application developed on the popular LAMP platform (GNU-Linux Operative System, Apache Web server, MySQL Database Management System and PHP programming language). Part of *TCExam*’s attraction is that it can be installed on almost any server that can run PHP, including Unix, Solaris, Mac OS X and Windows systems. The database is fully documented to be easily extended or accessed by external applications. In addition, PostgreSQL can be used instead of MySQL and it is also possible to add drivers for other DBMS. No additional commercial or expensive software is required to run *TCExam*. This gives *TCExam* great installation flexibility in existing environments (i.e. a PC on a school computer room or a commercial remote Web-Server).

TCExam uses a common Three-Tier structure as in figure 1. Administration and public areas are physically separated on file system to improve security.

As a Web-based application, *TCExam* runs on a Web server and uses Web pages as the user interface. For users, all *TCExam* requires is a computer or PDA with a Web browser (i.e. Mozilla Firefox or Internet Explorer) and an Internet or Intranet connection to the *TCExam* Web server. No additional software or specific hardware is required to use *TCExam*.

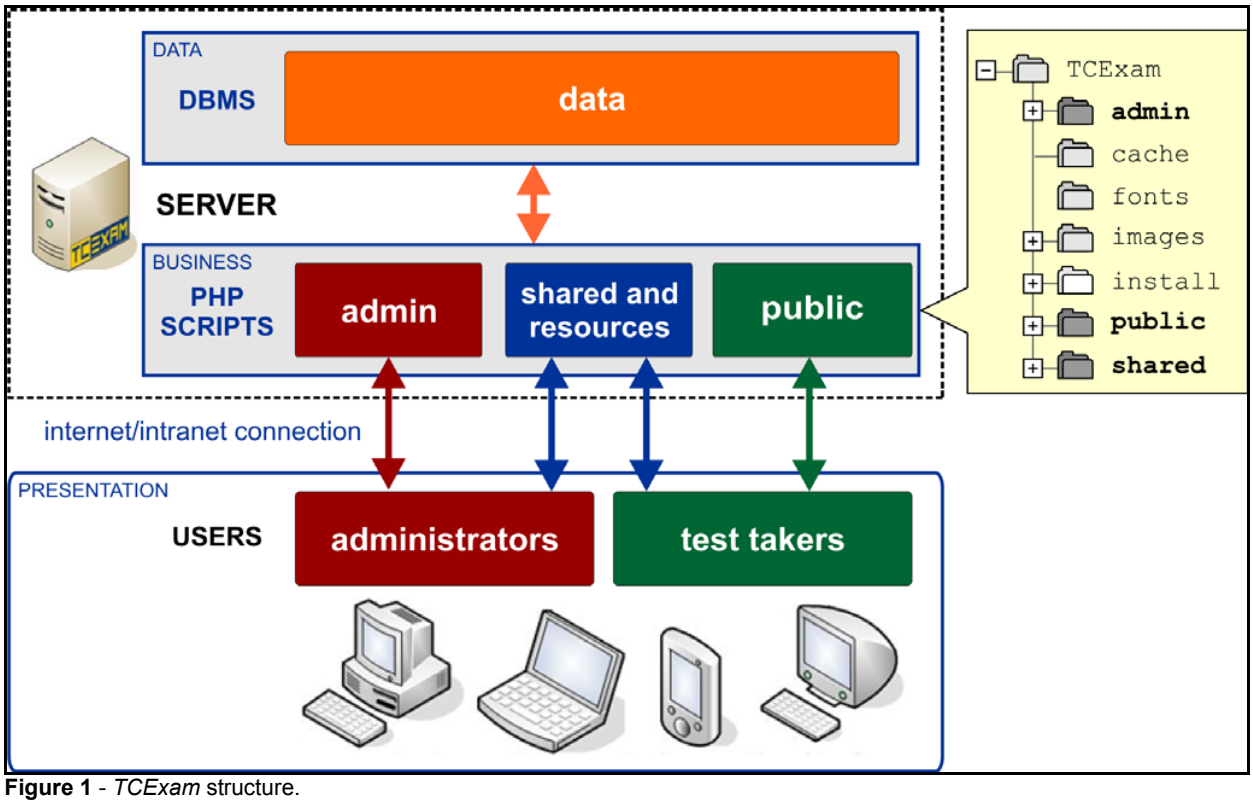

Figure 1 - *TCExam* structure.

No Expensive Hardware Requirements
The LAMP platform and the flexible technical requirements make it possible to install *TCExam* on almost any computer and even run it on shared Web servers managed by Web hosting providers. Experimental results show that a five years old PC, based on AMD Athlon XP 2400+ processor, 1GB RAM and a 100Mbps Ethernet card, may easily handle 50 tests at the same time. This feature is particularly important to bridge the gap of the digital divide with developing countries or rural areas, where modern hardware is unavailable or too expensive.

Internationalization (I18N)
TCExam is language independent by adopting the UTF-8 Unicode charset (Unicode Inc, 2005) and TMX (Translation Memory eXchange) standard (Savourel, 2004). TMX (Translation Memory eXchange) is the vendor-neutral open XML standard for the exchange of Translation Memory (TM) data created by Computer Aided Translation (CAT) and localization tools. The purpose of TMX is to allow easier exchange of translation memory data between tools and/or translation vendors with little or no loss of critical data during the process. All *TCExam* translations are included in a single XML file that could be easily edited manually or with a dedicated CAT tool. In this way everyone may download *TCExam* and add a new language translation without waiting the next software release.

TCExam supports Right-To-Left languages (i.e. Arabic, Hebrew, Persian) and already includes translations in several languages. The users may change the interface language at any time by using the selector at the end of each page.

Accessibility and Usability
It is essential that CBA tools be accessible in order to provide equal access and equal opportunity to people with disabilities. *TCExam* generates Web interfaces that conform to the XHTML 1.0 Strict standard (Pemberton et al, 2000) and W3C-WAI-WCAG 1.0 Accessibility (Chisholm et al, 1999) and Usability (US Department of Health and Human Services, 2005) guidelines. The graphic aspect of the user's interfaces is fully handled by CSS level 2 style sheets (Bos et al, 1998). CSS benefits

accessibility primarily by separating document structure from presentation (Jacobs et al, 1999). Style sheets were designed to allow precise control - outside of mark-up - of character spacing, text alignment, object position on the page, audio and speech output, font characteristics, etc.

Accessibility means that people with disabilities can use the *TCExam*. More specifically, means that people with disabilities can perceive, understand, navigate, and interact with the *TCExam* software. Accessibility also benefits others, including people with "temporary disabilities" such as a broken arm, and people with changing abilities due to aging. Web accessibility encompasses all disabilities that affect access to the Web, including visual, auditory, physical, speech, cognitive, and neurological disabilities. Web accessibility also benefits people without disabilities in certain situations, such as people using a slow Internet connection.

Usability measures the quality of a user's experience when interacting with the software application. In general, usability refers to how well users can learn and use a product to achieve their goals and how satisfied they are with that process. It is important to realize that usability is not a single, one-dimensional property of a user interface. Usability is a combination of factors including:

- Ease of learning - How fast can a user who has never seen the user interface before learn it sufficiently well to accomplish basic tasks?
- Efficiency of use - Once an experienced user has learned to use the system, how fast can he or she accomplish tasks?
- Memorability - If a user has used the system before, can he or she remember enough to use it effectively the next time or does the user have to start over again learning everything?
- Error frequency and severity - How often do users make errors while using the system, how serious are these errors, and how do users recover from these errors?
- Subjective satisfaction - How much does the user like using the system?

With the support of the University of Bologna, *TCExam* has been successfully tuned to be easily used by blind users.

Data Import and Export

To improve the software flexibility and compatibility with other CBA software, e-learning applications or existing databases, *TCExam* includes some tools to directly export or import users, questions or results data using various open formats: CSV (Comma Separated Values), XML (eXtensible Mark-up Language) and PDF (Portable Document Format). The detailed results in PDF format can be automatically sent by e-mail to each user. In addition, the database is fully documented in order to make it easily accessible by external applications (i.e. phpMyAdmin) to perform custom data import/export or backup procedures.

The current *TCExam* version includes RADIUS (Remote Authentication Dial In User Service) and LDAP (Lightweight Directory Access Protocol) modules, to directly access existing large database of users. Other authentication modules can be easily added to *TCExam* to meet specific needs.

Rich Content

TCExam uses a custom mark-up language to add text formatting, images, multimedia objects (audio and video) and mathematical formulas (supports LaTeX). *TCExam* includes a simple graphic interface with buttons to easily format the text or add external objects (i.e. images, audio files, videos, flash animations, etc). Generally, any object that could be rendered with a Web browser using a specific plug-in can be added to the *TCExam* questions, alternative answers or general descriptions.

The mark-up language used by *TCExam* is similar to the common BBCode (Bulletin Board Code), the lightweight mark-up language used to format posts in many message boards. The available tags are indicated by rectangular brackets surrounding a keyword, and they are parsed by the *TCExam* system before being translated into a XHTML or PDF. The *TCExam* mark-up code was devised to provide a safer, easier and more limited way of allowing users to format their content.

Using the special tag “[tex]” or TEX button it’s possible to add LaTeX code to represent mathematical formulas, tables or graphs. LaTeX is a document preparation system for high-quality typesetting. It is most often used for medium-to-large technical or scientific

documents but it can be used for almost any form of publishing. The *TCExam* LaTeX renderer converts the code to a PNG image to be displayed or printed.

Unique Test
In *TCExam*, questions are grouped into topics. *TCExam* can store an unlimited number of topics. Each topic can contain an unlimited number of questions and each question can have an unlimited number of alternative answers. A *TCExam* test can include several topics. For each topic or group of topics *TCExam* randomly extracts a specified number of questions with certain characteristics (i.e.: question type, question difficulty and number of alternative answers to be displayed). If the question bank is large enough, *TCExam* may generate unique test for each user by randomly selecting and ordering questions and alternative answers. This drastically reduces or eliminates the risk of copying between users.

Final remarks

The interest in Computer-Based Assessment systems has increased in recent years, and this raise the problem of identifying a set of quality criteria that may be useful to an educational team wishing to select the most appropriate tool for their assessment needs. In this paper I have proposed to take into consideration the specific quality features of specific CBA software called *TCExam*, in addition to the ISO9126 software quality model. The proposed quality features not only improves the quality of CBA software but also positively influence its diffusion and developing model.

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