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QT QUALITY VISUALIZATION

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ABSTRACT

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The idea for this Bachelor's thesis came from Digia, which develops Qt, a cross-platform application and UI framework for software developers, together with the Qt Project, a meritocratic consensus-based open source developer community. The main objective of this thesis was to improve the visualization and communication of the Qt quality by creating a web portal to collect and display metrics on required Qt process areas, focusing on continuous integration. Raw results are available from many process areas already, but the problem is that the results are not very valuable without better visualization. In addition, manual work is required to report some key information from the results. The Qt teams in Digia and the global Qt developer community, i.e. those individuals and teams that develop the Qt library components and the Qt tools, are the target audience.

Requirements to the web portal solution included a specification of some key metrics, recommendation to use open source solutions, to enable anyone in Qt developer community to modify the content or create new, and to document the design and implementation. The work started by studying and analyzing some of the most promising solutions for web, database and report development against the portal requirements and needed competence as well as against the existing server environment and current processes and practices used in the Qt Project. The system architecture consists of the report builder as the front-end, and the parser and the database as the back-end. The selected technical solutions were Perl for the parser, MySQL for the database, and HTML, CSS, PHP and AJAX for the report builder. The thesis project used the same contribution practices and tools that are used for the actual Qt software implementation.

The result was the Qt metrics system which was launched and taken into public use as planned. The system is running on the existing Qt testresults server on the qt-project.org domain. The functionality as well as the guidelines to further develop the system was documented into Qt Project wiki. The system was utilized already during the implementation phase by the key users in their daily operations. Received and requested user feedback, both before and after the launch, has been positive. The development proposals to the Qt metrics system are related to adding new content and functionality to the current metrics page, adding new metrics pages for some identified process areas, and improving the overall performance of the system still further. The thesis project itself was kept on schedule, and the effort was well under control.

Keywords:
Web portals, Databases, Reports, Metrics, Quality, Software, Open source

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Finally, I want to dedicate this thesis to my wife and children, and thank them for their unconditional support and understanding during this challenging thesis project.

September 2013, Oulu.

Juha Sippola

CONTENTS

LIST OF TERMS AND ABBREVATIONS

.NET	A software framework by Microsoft
AJAX	Asynchronous JavaScript and XML
AMP	Apache, MySQL and Perl/PHP/Python; a software bundle
Apache	An open source HTTP web server software
API	Application Programming Interface
ASP	Active Server Pages
BI	Business Intelligence
BSD	Berkeley Software Distribution
CAPTCHA	Completely Automated Public Turing test to tell Computers and Humans Apart
CI	Continuous Integration
CMF	Content Management Framework
CMS	Content Management System
CSS	Cascading Style Sheets
DBMS	Database Management System
DOM	Document Object Model
DST	Daylight Saving Time
DW	Data Warehouse
ER	Entity Relationship
EWS	Early Warning System
FTP	File Transfer Protocol

GD	Graphics Draw (or GIF Draw)
GIF	Graphic Interchange Format
Git	A distributed version control and source code management system
Gitorious	A web site hosting collaborative for open source projects using Git
GPL	General Public License
GQM	Goal/Question/Metric
GUI	Graphical User Interface
HTML	Hypertext Markup Language
HTTP	Hypertext Transfer Protocol
ICT	Information and Communications Technology
IDE	Integrated Development Environment
JavaScript	A scripting language for web development
Jenkins	An open source continuous integration tool
JPEG	Joint Photographic Experts Group
JSON	JavaScript Object Notation
LGPL	Lesser General Public License
MIKKO	"Mittauskehikko", a software measurement framework
MPL	Mozilla Public License
MySQL	An open source relational database management system
ODBC	Open Database Connectivity
OSI	Open Source Initiative

Oulu UAS	Oulu University of Applied Sciences
PDF	Portable Document Format
PHP	Hypertext Preprocessor
PNG	Portable Network Graphics
Puppet	An open source system configuration management tool
QML	Qt Meta Language
Qt	A cross-platform application and UI development framework
RDBMS	Relational Database Management System
RTA	Release Test Automation
Solaris	A computer operating system by SUN
SQL	Structured Query Language
SSH	Secure Shell
TDD	Test-Driven Development
UI	User Interface
URL	Uniform Resource Locator
W3C	World Wide Web Consortium
WAMP	A software bundle of Apache, MySQL and Perl/PHP/Python for Windows
WYSIWYG	What You See Is What You Get
XML	Extensible Markup Language
XP	Extreme Programming
XSLT	Extensible Stylesheet Language Transformations

1 INTRODUCTION

Qt is a cross-platform application and UI framework for software developers. It is developed by Digia together with the Qt Project, a meritocratic consensus-based open source developer community interested in Qt. Digia owns all Qt trademarks and is responsible for the commercial and open source licensing of Qt. The idea for this thesis came from Digia in Oulu to improve the visualization and communication of the Qt quality and its progress by creating a web portal to collect and display metrics on required Qt process areas, focusing on continuous integration (CI). The target audience of the portal includes the Qt development and CI teams in Digia and the global Qt developer community, i.e. those individuals and teams that develop the Qt library components and the Qt tools.

Raw results are available from the most of the process areas already, but the problem is that the results are not very valuable without better visualization. In addition, manual work is required to report some key information for instance in the CI release cycle. On the other hand, there are web pages for results visualization for some of the areas already, but the speed, quality or features of the visualization are not on satisfactory level.

To fulfill the visualization need, a new web portal was required to display statistics and metrics about the Qt quality. Objective was to automate laborious manual work and to provide real-time information with good performance. It was required that the web portal is hosted on the public Internet under the Qt Project web site. The scope of the development project was to implement the front-end web pages and the back-end data storage, as well as to document the design and implementation into Qt Project wiki. The ultimate goal was to have one entry point which can collect all metric and report information for example for Qt continuous integration, code coverage, autotest, release test automation and manual test, by showcasing at least one of these areas as a result of the thesis project.

This document starts with an introduction to the Qt and the Qt Project, continuing with the most promising frameworks and solutions for web, database and report development in the defined context. Then, the requirements for the Qt metrics system are detailed and the selected solutions are described. Finally, the Qt metrics system design and implementation is explained both to understand how the solution works and how to expand the system in the future. The document closes with an analysis of the thesis subject, its execution and learning experience.

2 QT

This section gives a brief introduction to the open source development as well as to the Qt framework and the Qt Project in general, and then details the governance, contribution and continuous integration practices used in the Qt Project.

2.1 Open Source Software

In brief, open source software means software that can be freely used, modified, and shared, with an access to the source code. It must be noted that "free" here means "freedom", not necessarily "gratis". It is similarly important to distinguish the freedom from obligation. That is, users of open source software can modify it, if they feel it is appropriate, but they are not forced to do so. In the same way, they can redistribute it, but in general, they are not forced to do so. Hence generally anyone is allowed to use open source software as they wish for whatever and wherever it is technically appropriate, modify it with fixes and extended functionality, create forks or branches of it, port it to new operating systems and processor architectures, and share it with others, who again could themselves use it according to their own needs. (1)

Development of open source software is based on community cooperation. These communities are typically a combination of individual voluntary programmers and large companies. Some of the characteristic activities in such communities include, in addition to software development itself, for example internationalization and localization, integration, quality and usability activities. The development environments in open source communities usually include a source code repository with version control, error management system, servers and integration machines, as well as different communication means. Typically these all use open source solutions as well. The development model may vary from cathedral-like model to bazaar-like model, as described by Eric Raymond. Cathedral-like development is characterized by a clearly defined management structure, and a rigorous plan for code releases, as well as by a relatively strong control on design and implementation with a control on who can submit patches to the code and how they are integrated, while the bazaar-like development is based on informal communication and several small and medium coding efforts that can be chosen at will by the volunteers. Open source software projects can use almost any model between those two extremes, whereas proprietary software projects must select more or less a cathedral-like model, and thus cannot benefit from the features of a bazaar-like one. While the cathedral-like development releases only from time to time by using higher quality assurance procedures, the bazaar-like development releases with high frequency so that programmers and users willing to test and improve those versions can do it. This process can even be extended to the code management system so that a snapshot of what the programmers are working on at any given time is publicly available. Furthermore, open source development is characterized by cooperation and competition. Developers within open source projects usually cooperate at levels higher than those in proprietary software projects and are therefore more committed to the project. On the other hand, most projects organize themselves to use some kind of meritocracy, where the developer who does more for the project deserves more credit, and is given more weight in decisions. Open source projects and companies are compelled to collaborate by fixes and improvements to the same source code. Motivation may come from the fact that if they tried to avoid assisting their competitors, they would have to move away from the open source model, which would usually give them more problems than benefits. At the same time, open source projects also compete between themselves. Projects must fight for their survival by maintaining high levels of quality, or they will start losing users and developers, which creates a chance that some of the developers will branch a new independent development project to compete with the old one. In fact, this is one of the mechanisms to ensure good quality in open source development. (1)

There are many advantages when using open source software. The companies, communities or individual users can install the software in as many devices or machines as wanted with reduced or zero license fees and without a need to track license compliance. The quality of open source software is expected to be better than in proprietary software because anyone can fix bugs without having to wait for the next release. If the group that originated the code decides to stop development, the code still exists and it is possible to continue the maintenance and improvement by another group without legal or practical limitations. Because of the free availability of the source code, users or for example an IT department can study the software in detail and make modifications that they find appropriate to suit their needs. In addition, support from the development community is typically available at any time. However, there are some disadvantages or considerations for using open source software as well. Ongoing parallel development effort may create confusion on what functionalities are present in which versions. On the other hand, there is no guarantee that development will happen, and it may be difficult to know the current status or even existence of the development project. Open source software may not be entirely free, in that it may involve unanticipated implementation, administration, support or training costs. Although the development community is there for the support, no one is obligated to help in case of questions or problems. In addition, there may be problems connected to intellectual property rights. (1)

The Open Source Initiative (OSI) defines the criteria for open source distribution license. The definition says for example that there are no restrictions, royalties or other fees to any party from selling or giving away the software, that the program must include source code, or it must be freely available without charge, that modifications and derived works and their distributions are allowed under the same terms as the original software, that there are no restrictions from making use of the program in a specific field of endeavor, and that the license must not set provision on any individual technology or style of interface. For example, the Apache license, the Berkeley software distribution (BSD) license, the GNU general public license (GPL), the GNU lesser general public license (LGPL), the MIT license and the Mozilla public license (MPL) are popular OSI-approved open source licenses. A software product can also be distributed using multi-licensing, a combination of both open source and commercial license, where the commercial license typically includes additional functionalities and product support. The terms free open source software and commercial open source software are used correspondingly. (2) (3)

It can be said that the history of open source software goes back about as far as the history of software itself. In the 1960s, when IBM and others sold the first large-scale commercial computers, the computers came with some software which could be freely shared among users. It came with source code, and it could be improved and modified. Later on, proprietary software was born, and it quickly dominated the software landscape. In the early 1980s Richard Stallman launched the Free Software Foundation and the GNU Project to build a free operating system. As a legal tool, the GNU GPL was designed not only to ensure that the software produced by GNU will remain free, but to promote the production of more and more free software. In the early 1990s Bill Jolitz made a version of BSD Unix that was free of copyrighted code, and Linus Torvalds implemented the first versions of the Linux kernel, later completed as the Linux operating system with GNU GPL license. The OSI was formed in 1998 to maintain the open source definition and to review and approve licenses that conform to that definition. In the late 1990s open source systems were gaining public acceptance and became a real alternative to proprietary systems. In 2010 an increase was reported in demand for open source based on quality, reliability and speed, not just cost savings. The survey behind the report showed that 78 percent of enterprise companies were either using or experimenting open source software in their business, led by the financial services sector while the public sector lagged behind. 76 percent of respondents considered quality, not the cost, to be the major selling point of open source, followed by 71 percent for improved reliability, and 70 percent for stronger security and bug fixes. 20 percent of software developments were in open source (in 2009), and expected to rise. One finding, however, was that only 29 percent of the companies were willing to contribute their own solutions back to the community. (1) (3) (4)

Today open source is applied in numerous fields of software, for instance GIMP graphics editor, Mozilla Firefox web browser, OpenOffice.org office suite and WordPress web publishing platform in application software, Linux based Android in operating systems, Perl and PHP (hypertext preprocessor) in programming languages, and Apache HTTP (hypertext transfer protocol) web server, Drupal content management system and MongoDB and MariaDB databases in server software. MySQL database and Qt development framework are examples of open source software utilizing multi-licensing. One recent newcomer, and a typical case of developing something on top of something, is the Sailfish operating system for the new Jolla smartphones. Sailfish is built on top of the Mer project and Qt version 5, and is based on MeeGo operating system and software platform by Nokia and Intel, which again was based on the Mer branch in Maemo, an earlier Linux based software platform by Nokia (5).

2.2 Qt and Qt Project

People are increasingly using multiple devices with different screen sizes for personal and enterprise use. Users begin to expect the same user experience, performance and flexibility across all the devices they use. Developers, on the other hand, are looking for means to target multiple operating systems quickly to make their applications available everywhere. (6)

Qt is a cross-platform application and UI development framework. With Qt, developers are able to create one graphical user interface (GUI) application and run it on multiple desktop, embedded and mobile platforms. In practice, application is first created for one platform and then built and run to deploy on other platforms. Qt accesses the native features of a device and lets user interface (UI) designers and developers design and render highly-performing graphically-rich user interfaces. Qt provides a seamless developer experience and consistent performance across all operating systems and processor architectures. Qt is used by market-leading companies in tens of industries, for example in systems such as mobile platforms, industrial automation, TVs, set-top boxes and in-vehicle infotainment, and in applications like enterprise, deep-sea advanced visualization, Hollywood film animation and air traffic control. (6)

Using the Qt development framework will enable developers to decrease the development and maintenance effort, as well as cost, due to the cross-platform support, speed up time to market with easy prototyping, and to improve quality for instance with the native user experience in the platform it is deployed.

The complete Qt development framework consists of the Qt Framework application programming interfaces (API) for C++ and Qt meta language (QML), Qt Creator integrated development environment (IDE) including UI designer tools and on-device debugging, and tools for example for internationalization support. Qt supports all major desktop, embedded and mobile platforms. Development is supported on Windows, Linux/X11 and Mac OS X desktop platforms, on Embedded Linux, Windows Embedded, and on several embedded Real-Time Operating Systems. In addition, the Windows 8 (WinRT) and BlackBerry 10 mobile platforms are supported, and most recently, Qt 5.1 introduces support for Android and iOS platforms with technology preview status. Qt is available under a commercial and open source license (using GNU LGPL/GPL) designed to accommodate the needs of various users. (7) (8) (9) (10)

The history of Qt goes back to 1991 when the original developers Haavard Nord and Eirik Chambe-Eng began development of the first versions under their company that was later named as Trolltech. The first two versions of Qt had support for Unix and Windows. Nokia acquired Trolltech in 2008 and turned Qt into one of their main application development platform for its devices, including a port to the Symbian S60 platform. The source code was made available over Gitorious, a community oriented Git source code repository, to gather a broader community to help improving Qt. In 2011 Nokia announced the sale of Qt commercial licensing business to Digia. All remaining Qt business was transferred to Digia in September 2012. The latest Qt version 5.1 was released in July 2013. (11) (12)

Qt is developed by Digia together with the Qt Project, a meritocratic consensus-based open source community interested in Qt. Anyone can join the community, participate in its decision making processes, and contribute to the development of Qt. Qt community has over 500,000 developers worldwide. The Qt Project is not a separate legal entity or organization. Digia retains all Qt trademarks and is responsible for commercial and open source licensing. The Qt Enterprise commercial license offers varied licensing terms and includes additional functionality, support and product updates. Digia provides support for its commercial customers in their Qt projects by working hand-in-hand with the Digia Qt R&D developers in areas of architecture and design, user experience, platform integration, application development, and Qt customization. (13) (14) (15) (16) (17) (18)

Digia is a Finnish software solutions and service company and has nearly 1,000 employees. It delivers information and communications technology (ICT) solutions and services to various industries, focusing especially on finance, public sector, trade, services and telecommunications. Digia operates in Finland, Russia, China, Sweden, Norway and in the U.S. The company is listed on the NASDAQ OMX Helsinki exchange. (19)

2.3 Qt Governance Model

In general, a governance model describes the roles for project participants and the decision making process within the project. In addition, it describes the ground rules for project participation and the processes for communicating and sharing within the project team and community. Especially in the context of an open source project, the governance model prevents the project from descending into chaos. In a meritocratic governance model the participants gain influence over a project through the recognition of their contributions. That is, the more merit, the more influence. Hence a meritocracy is not a democracy. Only those who have earned the recognition through positive contribution have a binding vote. This allows project leaders to ensure that only those that share a common vision and, just as importantly, are willing to work towards that shared vision, are given decision making authority. A notable aspect is also the fact that the governance model in a project will evolve over time as the project and its community develop. (20) (21)

The governance model in the Qt Project is based on the meritocratic governance model template by OSS-Watch. The objective of the governance model is to put decision power in the hands of the community, i.e. the people who contribute to the success of the project, and to make it easy to understand how to get involved and make a difference. The documented model describes five levels of participation and how community members get involved in making decisions. (14)

The five levels of involvement, or roles, within the project are Users, Contributors, Approvers, Maintainers and Chief Maintainer. Users are community members who have a need for the project. They typically raise the awareness of the project and give feedback from a user perspective. Anyone can be a User. Those who continue to engage with the community will often become more and more involved, and may find themselves becoming Contributors. Contributors are community members who provide significant input to the project. Although their typical contribution is programming, there are numerous other ways of contribution, for example suggesting future developments, reporting and fixing bugs, commenting on others' code in reviews, writing documentation, participating in the release process, providing graphics and web design, supporting and coaching new Users, improving the Qt contribution process, and being active in the community for instance on mailing lists, forums, IRC, and at events. The profile of the Contributor will increase as he or she gains experience with the project and makes significant contributions to it. As a result they may be nominated as an Approver. Approvers are community members who have shown that they are committed to the project and its objectives, and perform an essential role safeguarding its long-term success. Approvers review all code contributions and decide which are accepted for commitment based on technical and logical fit. Approvers are expected to provide constructive feedback, participate on relevant mailing lists, and coach Contributors. Maintainers are recognized leaders in their area, and have been identified as owners of a component, and to be responsible for the overall quality of it. Maintainers are expected to participate in strategic planning, approve changes to the governance model, manage intellectual property rights discussions within the community, and review code contributions which have not been reviewed by others. The process of becoming an Approver or Maintainer works on nomination basis. The Chief Maintainer leads the Maintainer group by coordinating and facilitating its activities, and will also oversee contributions from a strategic and roadmap perspective. When the Chief Maintainer decides to step down, the Maintainers will arrange a vote to choose a successor. (14)

Any community member can make a proposal for consideration. This is done either by submitting an implementation patch to the review tool, or by sending an email to the project Contributor mailing list. The goal of the review or discussion is to gain approval for the contribution. The decision making process is based on a policy of lazy consensus. That is, as long as nobody explicitly opposes a patch or proposal, it is recognized as having the support of the community. This allows large group of people to make decisions without formal consensus, as well as without lengthy discussions among the large number of involved people. Lazy consensus, however, still needs a reasonable amount of time before assuming no objections to ensure everyone is given enough time to read, digest and respond to the proposal. The Maintainers or the Chief Maintainer will make the decision in those cases where consensus is not reached through review or discussion. (14)

2.4 Qt Contribution

The Qt developer community is created around the development of Qt libraries, Qt related tools and add-ons (22). The contribution process is explained here to the extent that is applicable in the scope of the implemented Qt metrics system.

The servers, database, and tools related to the Qt open governance code contribution process as well as their interactions are illustrated in FIGURE 1.

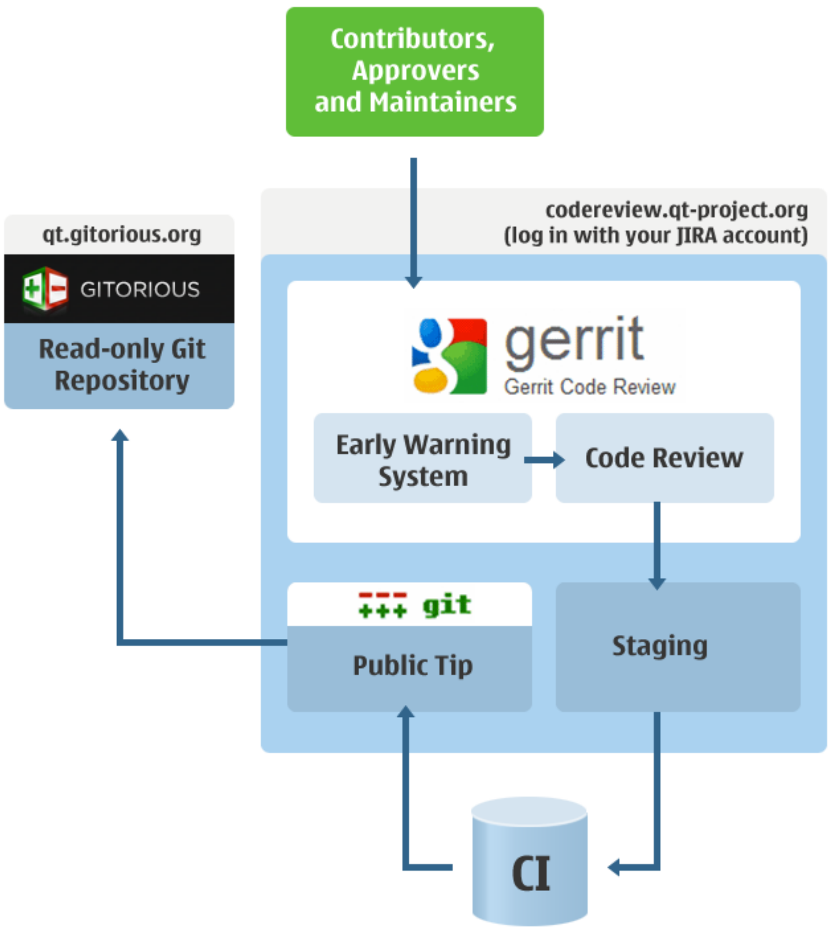


FIGURE 1. The servers, database, and tools related to the Qt code contribution process (23)

The process has been designed to provide transparency and quick pass-through for code contributions. The core of the process is the code review tool, Gerrit. The tool is available for everybody, and it supports both automated quality checks and human reviews. It is used for the contributions and their documentation as well as for review notes and possible fix patches. In addition, it can be utilized for studying the code of other contributors and contributions as well. The code is pushed into its Qt library repository, also called as a project in the Qt metrics system, for example QtBase, QtConnectivity, QtMultimedia, QtDoc or QtTools. The repository includes the entire history of all its files. (22)

The staging area is a powerful concept, making it easy to work on multiple files simultaneously while still creating small incremental changes. By using staging areas the changes can be studied and reviewed before becoming a part of the code base in the related branch. Dedicated branches are useful to gain more flexibility during development, without risking the quality of the other branches. Qt Project uses one or several branches for its projects, for example development, stable and release branches. (24) (25)

Continuous Integration (CI) system is used for building and testing. The CI system fetches reviewed and staged changes from Gerrit, builds the related project branches, and runs tests for the changes. Then it merges the changes with the corresponding branch in the Git repository of Gerrit. In addition, the repository is pushed to Gitorious repository on qt.gitorious.org, which can be used to download the latest Qt source code to develop UI and applications with Qt. (23)

This first-commit-then-review process is efficient, as it allows everyone to make direct contributions into the review system. It levels the field between Contributors and Approvers, ensures that all contributions are reviewed, and allows all reviews and their comments to be tracked by the community as a whole (14). Below, the overall activity in the Qt Project is illustrated by the contributing organization (FIGURE 2), as well as by the number of contributors (FIGURE 3). It can be noticed that currently the majority of contributions come from Digia, while there are dozens of individual contributions each week as well.

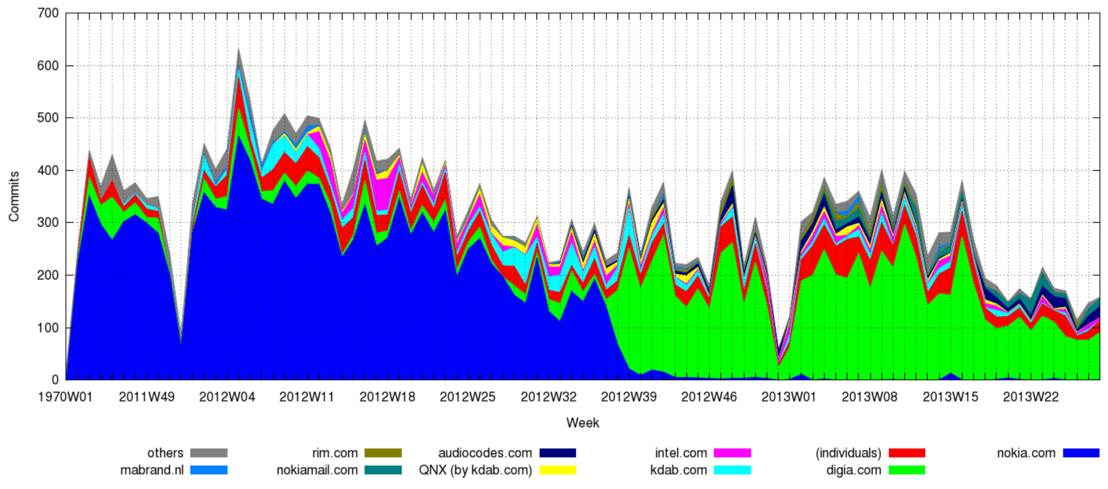


FIGURE 2. Overall activity in the Qt Project by contributing organization (26)

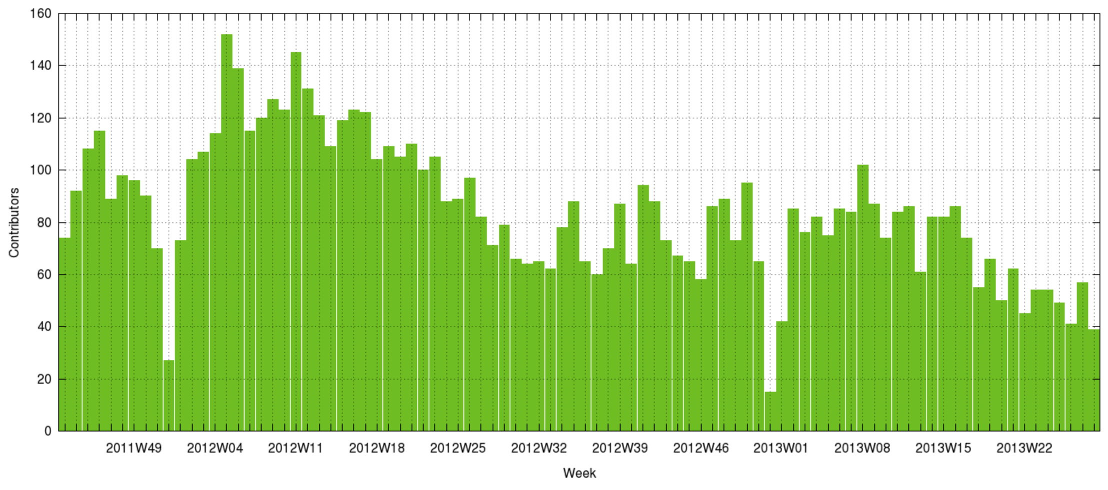


FIGURE 3. Overall activity in the Qt Project by number of contributors (26)

2.5 Qt Continuous Integration

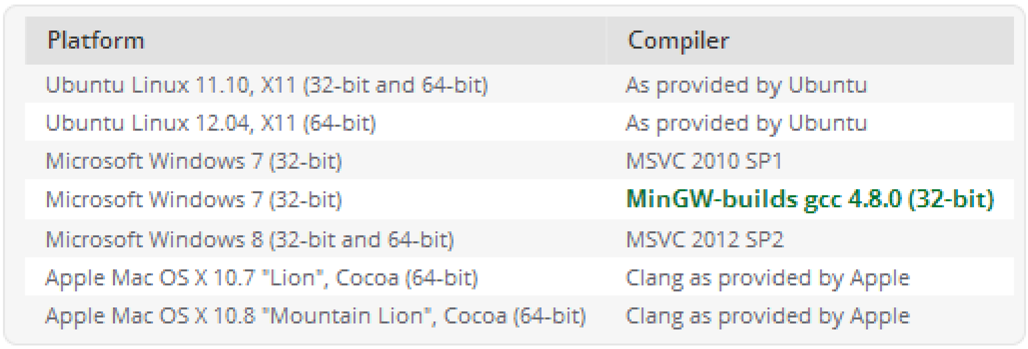
Shortening the time between a defect injection and its detection and correction has significant cost benefits. First introduced as part of extreme programming (XP), the continuous integration (CI) introduces a practice where everyone on the team integrates their new or changed code frequently, usually daily, against a controlled source code repository, leading to multiple integrations per day. Each of the integration is verified by an automated build, combined with automated unit tests as highlighted in the test-driven development (TDD) process, to detect integration problems as quickly as possible. Many teams find that this approach leads to significantly reduced integration problems and allows a team to develop cohesive software more rapidly. (25) (27)

It is important to notice that there are a few key practices that make up an effective CI. The use of a source code management system is essential to maintain a common and well known source code repository. Building and launching the system should be automated to the level that only a single command is required. In addition to compiling, linking and building an executable program, the automated build scripts usually generate also the related documentation, statistics, reports etc. Then, the build should be made self-testing by including automated tests in the build process. The automated tests must be updated together with the new or changed source code. As a rule of thumb, every developer should commit to the repository every day. The benefit of frequent commits is that the possible conflicting changes are detected early, and that it encourages developers to break down their work into small deliverables. It should also be ensured that regular builds happen on an integration machine, and only if this integration build succeeds, should each commit be considered to be done. For its part, it again ensures that development can happen on a known stable code base, or in case the build does break, however, it is important that it gets fixed fast. Since CI requires frequent commits and builds, it is important that the builds themselves are fast. The XP guideline is a ten minute build. A common practice is setting up a deployment pipeline, or staged builds, where in fact multiple builds are done in sequence. The point of testing is to detect and remove, under controlled conditions, any problems that the system would have in production. Therefore the test environment should be as exact a mimic of the production environment as possible. The use of virtualized machines can furthermore simplify the establishment of multiple test environments. (27)

The agile development processes expect and take advantage of the fact that it is easier to see something that is not quite right and say how it needs to be changed by using a running system instead of specifying all in advance. Therefore the latest executable should be made easily available for anyone to run it for testing, demonstrations, or just to see what changed this week. In addition, it is important to automate the deployment by having scripts that will allow deploying an application into any environment easily because the executable applications are moved between these environments multiple times a day. Continuous Integration is all about communication, and one of the most important things to communicate is the state of the builds. In fact, this CI practice is in key focus for the development of the Qt metrics system. (27)

The goals of the CI system in the Qt Project are to implement an automated quality gate that blocks poor quality changes from being merged to the stable codebase, to run an exhaustive set of configuration tests in a nightly fashion, and to make test results available to developer in a clear, concise, and user friendly way. Qt Project builds and tests Qt on the so-called reference configurations on a frequent basis. A reference configuration is a combination of an operating system version, a compiler version, and a graphics system. The TABLE 1 lists the current reference configuration platforms. In addition to the reference platforms, Qt is occasionally tested on other configurations in which it is known to run well. (8) (25)

TABLE 1. Qt 5.1 reference configuration platforms and compilers (8)



Platform	Compiler
Ubuntu Linux 11.10, X11 (32-bit and 64-bit)	As provided by Ubuntu
Ubuntu Linux 12.04, X11 (64-bit)	As provided by Ubuntu
Microsoft Windows 7 (32-bit)	MSVC 2010 SP1
Microsoft Windows 7 (32-bit)	**MinGW-builds gcc 4.8.0 (32-bit)**
Microsoft Windows 8 (32-bit and 64-bit)	MSVC 2012 SP2
Apple Mac OS X 10.7 "Lion", Cocoa (64-bit)	Clang as provided by Apple
Apple Mac OS X 10.8 "Mountain Lion", Cocoa (64-bit)	Clang as provided by Apple

The CI setup is aligned with the Qt 5.1 repository structure. Git module repositories exist for each Qt submodule (for example QtBase, QtConnectivity, QtMultimedia), while a superproject repository (for instance Qt5) contains several Git submodules. The modules may use one or several branches to gain more flexibility during development. The module-branch pair is referred also as project in the Qt metrics system. Qt Project uses Jenkins, an open source continuous integration tool, as the server setup for building the projects and running of autotests continuously. Jenkins allows builds to be started by various means, including being triggered by commit in a version control system, scheduling via a cron-like mechanism, building when other builds have completed, or by requesting a specific build manually. Jenkins is used both in physical and virtual machines for the Qt CI. There are approximately 20 physical machines in use for the Mac operating system, and roughly 200 virtual machines for the other operating systems.

CI builds are triggered by approved change reviews when an Approver changes the status of the change commit to Staged. The CI system collects the staged commits for each repository and their branch so that each new commit starts or restarts a five minute timer. The build starts automatically if no further commits are staged within those five minutes. Prior to the change approval some automatic checks are executed by an early warning system (EWS) tool as part of the CI system. Its purpose is to provide immediate and early feedback to developer regarding for example line ending characters, big file additions and common spelling mistakes. Although the check messages are advisory and may be overridden by the Approvers, it is recommended to provide a corrective patch to the commit, and the CI process to continue. The major part of the CI machine setup is maintained under source control, in the “qtqa/sysadmin” repository which holds metadata about the test machines and servers such as the set of installed packages and configuration of tools used in the test process. Most of the CI machines are controlled by a system administrator tool called Puppet. (25) (28) (29) (30)

The simplified Qt contribution and continuous integration process flow is illustrated in FIGURE 4. It combines the steps to contribute a commit, the main steps in the CI system, the commit statuses as seen in the code review tool and the specific results that are available and used from the Qt CI system for reporting and analysis. (31)

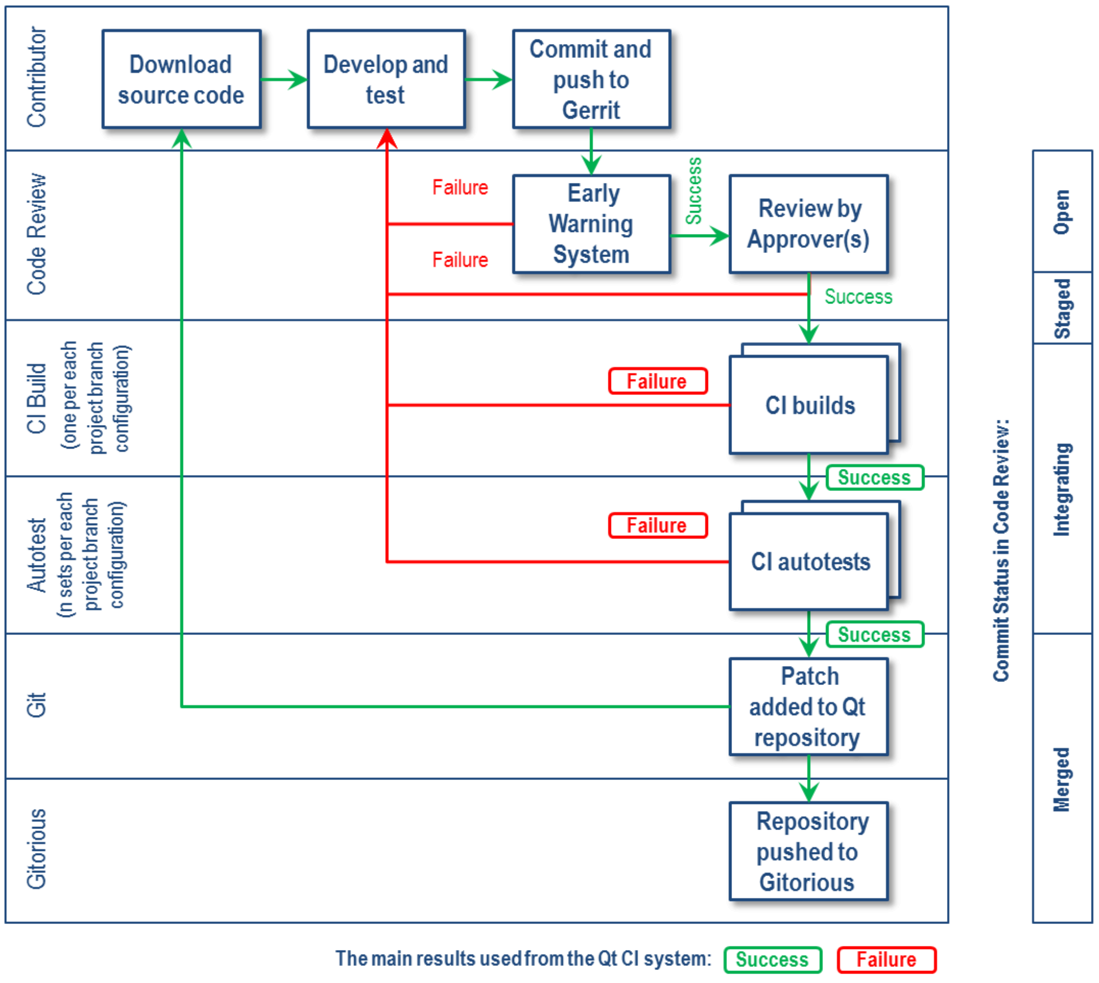

Contributor
Code Review
CI Build (one per each project branch configuration)
Autotest (n sets per each project branch configuration)
Git
Gitorious
Download source code
Develop and test
Commit and push to Gerrit
Early Warning System
Review by Approver(s)
CI builds
CI autotests
Patch added to Qt repository
Repository pushed to Gitorious
Failure
Failure
Success
Success
Failure
Success
Failure
Success
Commit Status in Code Review:
Open
Staged
Integrating
Merged
The main results used from the Qt CI system:
Success
Failure

FIGURE 4. Qt contribution and continuous integration process flow.

FIGURE 4 indicates the main results that are used from the Qt CI system to compile the data into visual and easy-to-read report format for the CI metrics page of the implemented Qt metrics system. The CI builds are done in a hierarchy of first building each applicable configuration for a project branch, and then combining those configuration builds into one project branch build. However, not all the builds are always done in practice. To optimize the use of the CI machine processing capacity, a project branch build is stopped in case one configuration build fails, and at the same time the remaining configuration builds are aborted. As a result, the autotests, a set of test cases dedicated to a project, are also skipped for the aborted builds. This all means that the result of every configuration build for every project branch is not always available, and that the number of autotest runs depends on the success of other configuration builds for the project branch. In addition, only the information of failed autotests is available in detail in the CI build log files.

From the whole CI point of view the configuration build result indicates both the result of the build process itself and the result of the autotests that were run. Therefore, in an ideal case, a successful build requires that both the build process and all the autotests are successful. In addition, a successful project branch build requires that each configuration build is successful. However, such a strict criterion may not always be reasonable in reality. For example, in case of a new or an immature configuration, it is not reasonable to let the whole project branch build fail because of that. To put flexibility to the CI process, a few flags are used for autotests and configurations. An autotest can be tagged as "insignificant" so that possible failure will not lead to configuration build failure. Also a configuration can be tagged as "insignificant" so that the configuration build will not fail even though some significant autotests would fail. In addition, a configuration can be tagged as "force success" so that even if the configuration build failed, it is forced to succeed, and therefore a failed configuration build will not block the whole project branch build. The final result of a build is a combination of the build and autotest results and the use of the flags. A typical case that needs attention, and corrective actions, is where a failed autotest blocks a configuration build and also the whole project branch build. Studying these cases continuously from the thousands of build log files is very laborious, or practically impossible considering the time and resources available. The Qt metrics system automates this data collection work and visualizes the problem areas as clearly and detailed as possible. The raw log files from the Qt CI system are available at http://testresults.qt-project.org/ci/.

To get an overall picture about the size of the Qt CI system, here are some statistics during a period of one month from mid-June to mid-July in 2013. Totally round 1,000 builds, with a success rate of 52%, had been made in 67 project branches. Some project branches has been built only once, while for instance the Qtbase stable branch has been built 182 times. The Qtbase stable branch had 21 active configurations, and those had been built about 3,800 times in total. There were approximately 18 configurations per project branch, and by multiplying it with the round 1,000 configuration builds, the total number of builds during this time period was roughly 18,000. However, this number includes both the run and the aborted builds. The number of failed autotests was approximately 300 during this time period. (32)

3 WEB AND DATABASE DEVELOPMENT FRAMEWORKS

This section introduces web, database and report development, as well as their most promising frameworks and solutions in the context of the thesis project target setting.

3.1 Web Development

Web development, in general, is about developing a web site to be available in the Internet, or in company intranet for example. The use and purpose of a web page or pages can range from publishing static information to applications and services with interactive operations and dynamic data searches. A list of tasks related to the web development typically consists of user interface or usability design, content development, client and server side scripting and web server configuration. This section focuses on the techniques, tools and methods that are applicable in the scope of the implemented Qt metrics system.

Architecture for a web application or service usually follows a three-tier model, where presentation tier, a browser or user interface of an operating system, is connected to logic tier, where the detailed processing is performed as functionality of the application. The third tier, data tier, consists of database server or servers where the data is stored and retrieved from. FIGURE 5 illustrates a generic web application architecture using the three-tier model. (33 p. 274) (34)

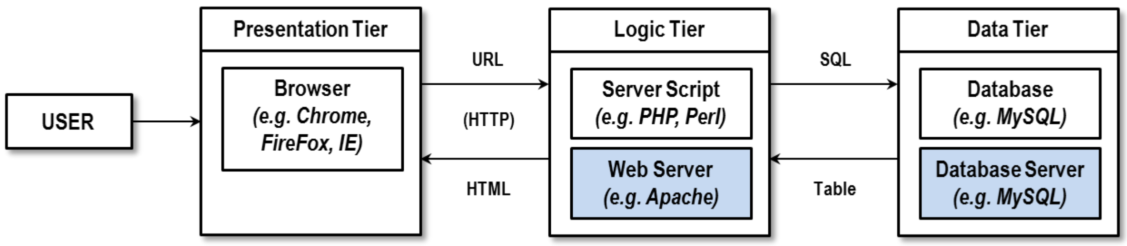


FIGURE 5. Three-tier model

A web page contains for example the content as plain text, and images, page layout and formatting as hypertext markup language (HTML), visual appearance as cascading style sheets (CSS), and interaction and functionality as JavaScript. Web pages reside on a web server, which is a piece of hardware and software that can be accessed through the Internet. To display a web page on a browser, user enters a web location as uniform resource locator (URL), after which the browser sends a request to the server, and the server responses with an HTML document. Web browser is a software application that retrieves, interprets and presents the requested web content, which is in the format of tagged markup language such as HTML or scripting language such as JavaScript. There are several web browsers available, for example Google Chrome, Mozilla Firefox and Microsoft Internet Explorer, and they all have their own implementation to interpret the HTML and other web documents. As for web servers, they use both scripting languages and computer programming languages. The common behavior of markup and scripting languages is that they are interpreted run-time in the browser or in the server, while the computer programming languages must be compiled into an executable program before they can be run. Web uses the HTTP protocol to send the requests from client, a web browser for example, to server, and the responses from server back to the client. The HTTP itself is a stateless protocol where each communication is an individual request-response event and there is not any connection to previous communications. However, HTTP provides several methods to send data and to implement page or application logic for a web site. (35)

Web development can be split to client-side, server-side and database technologies and to their programming techniques. Client-side programming refers to the scripts that are executed client-side by the web browser of the user. In addition to HTML, CSS and JavaScript, client-side technologies include for example JQuery, which is a JavaScript library, and AJAX (asynchronous JavaScript and XML), an asynchronous connection to the server to update only a part of a page. As for server-side programming, it refers to the scripts or programs that are executed on the web server upon web page request to generate usually an HTML document with the requested content. Server-side development can utilize for example open source languages such as Perl, Python, Ruby and PHP, computer programming language Java, and proprietary technologies such as active server pages (ASP) and .NET. Using server-side implementation has an additional security aspect that may be beneficial in some cases: user is not able to see the server-side script code as such via the browser, but only the resulting HTML code. Database is typically the third component in a web service. It is the core of the service around which the user interface is built to fulfill the purpose of the web site, and eventually to justify the existence of it. Database connection is made by the server-side script or program. Commonly used database management systems (DBMS) include MySQL, which is an open source system, and Microsoft SQL Server and Oracle Database, which are proprietary. (35)

It is important both for web users and web developers that the web technologies are standardized. Users are able see and use the web pages in a similar fashion regardless of the browser they use, and developers can build web sites that work with any browser or server environment. In reality, however, web development is not as easy as it could be. The latest versions of HTML and CSS standards, HTML5 and CSS3, are still in progress, and the support of the new features varies between the browsers although the browser developers continue to add new features to their latest browser versions. The web standards are created and maintained by the World Wide Web Consortium (W3C). They also provide validation service for web developers to be able to check their web pages against the web standards. (36)

3.1.1 Tools and Frameworks

Web pages can be created with a great variety of tools from basic text editors to online web site builders, depending on the size and needs of the web service or application, on company infrastructure and guidelines, and also on personal preferences of the developer.

Simple HTML scripts can be created using a text editor, like WordPad for example, and then the file or files can be transferred to the web server with a file transfer protocol (FTP) tool. Dedicated and often free source code editors like CoffeeCup HTML Editor, Notepad++ and NetBeans IDE, for example, improve the programming experience by including functionalities such as syntax and structure highlighting, real-time syntax checking, code completion for objects and functions, wizards to create HTML elements, built-in FTP upload, and working with multiple files at the same time. Using a text editor or a source code editor requires deep knowledge of the scripting or programming language used. (37)

Word processors and spreadsheet applications like Microsoft Word and Excel are able to export the documents created with them to HTML format, either manually or automatically with scripts. However, for example Microsoft Word is not recommended for web programming itself because the resulting file may include extra characters or formatting that was not the original intent, and therefore different browsers may display the content differently. (37)

WYSIWYG (what you see is what you get) editors raise the development experience from mere programming to visual user interface design by generating HTML code from the design. They do not necessarily require deep knowledge of the programming language generated. Pages created with these editors may be stored in a proprietary format and then exported as HTML format. The proprietary Adobe Dreamweaver features rapid layout design and code generation, preview pane together with the HTML code window for previewing the HTML as seen by the browser, support for JavaScipt and AJAX, extensions from simple rollover effects to full-featured shopping carts by the developer community, built-in FTP upload and support for version control system. (37) (38)

Web site builders are tools that allow constructing web sites without manual coding, and many companies also provide web server hosting. Online web site builders typically require developers to sign up to the web server, and may also include user access control to manage different roles, for example editors to edit or add pages, modifiers to modify the web site structure, and the web site owners to maintain the user access control itself. The main advantage of a web site builder is that it is easy to use and often does not require experience on the scripting languages, although it may allow direct editing of source code and styling. Examples of web site builders are WordPress and Microsoft SharePoint Designer. WordPress is a free and open source blogging tool and a content management system (CMS) based on PHP and MySQL. It is currently the most popular blogging system used on the web (39). Creating a web site is heavily based on the use of available components like themes and widgets via the browser, although the generated PHP and CSS code can be edited directly as well. The components are developed also by the WordPress community. Microsoft SharePoint, a content and document management platform, is used by 78% of Fortune 500 companies (40). Designing SharePoint sites with Microsoft SharePoint Designer is done online to the web server. SharePoint includes user access control and a workflow management for example to first create draft documents or pages, and to publish them later. (41) (42)

The size of the code generated by WYSIWYG editors and web site builders is typically bigger than when writing code by hand. In addition, the manual coding effort may be justified for example in performance critical environments. (37)

3.1.2 Development Process

A web site is actually never ready. It may be realized during the development that the initial list of functionality is neither correct nor complete. The developers or the users may also identify improvement needs for instance to navigation or performance. Everything cannot be known beforehand, nor everything can be expected to be perfect, the site just needs to be published, after which feedback is collected to continue the development. In addition, web sites are typically used in changing environments where the content changes, priorities change, developers change, and so forth. Hence the traditional waterfall development model, with its long lead times, is not suitable in a fast pace environment. Web development therefore often follows some kind of iterative and incremental, or agile, development models. Their characteristic features are for example not defining everything in advance, creating prototypes, delivering small portion of functionality at a time, delivering in short cycles of time, and using the learnings from previous delivery in next deliveries. Project management is still an essential part of a project, but it uses different practices than in a waterfall project.

Development process can be widely different depending on the environment, activities and projects. Jennifer Fleming describes a fairly generic six-phase approach. The phases are: information gathering, strategy, prototyping, implementation, launch, and maintenance & growth. The information gathering phase focuses on collecting the background information such as project goals and mission, target audience and their needs, and the resources available. In addition, the communication methods in the team and project are put in place. The scope of the strategy phase is to identify problems, explore real-world examples, brainstorm possible solutions, define the concept and scope, organize content, and finally select the design and technical solution. Here it is very important to distinguish the problems from the solutions, not to jump into a solution before understanding the problem and its cause first. In the prototyping phase it is identified how the site will work and how to move through the information, for example. It is also important to test the solution with the users, using anything from a rough text-only walkthrough to a working live demo, to show the information design and interface features. Additionally, the final architecture plan is created and the product specifications are outlined. The user or customer should be involved throughout the strategy and prototyping phase. After the revised solution from the prototyping phase, the site is then built in the implementation phase. The content is prepared and edited, interface design is completed, the back-end system developed, and eventually all these are integrated together. Most likely new problems will arise, which then need to be prioritized and solved in a timely manner. The launch covers the period of just before and after the public premiere. Here the final quality assurance testing is conducted to have a final look for example to the usability, consistency and content validity, preferably with the people who have not been directly involved in the development. The launch itself may be for example an informative email or classroom introduction. Web marketing includes also submitting the site to search engines and directories using the HTML meta tags. The development continues next to the maintenance phase, which can actually be a cycle of repeating some or all the previous phases. In this phase new content or features need to be managed, either as items intentionally left out from the launch or as new items surfacing for example from user feedback or because of changes in the back-end solutions. (43 pp. 75-103)

The user experience of a web site does not happen by accident and without conscious, explicit intent. Jesse James Garrett introduces practices to break the job of crafting user experience down into separate elements, or planes or layers as they are also called. The layers, when starting to peel them away from the most visual and concrete level, are: surface, skeleton, structure, scope and strategy. On the contrary, building a web site starts from the most abstract level: the strategy. Strategy plane defines and balances both the user needs and the site objectives. The user needs to include for example what the audience wants from the web site. The site objectives mean the objectives from the developer point of view, like business goals for example. The list of features and functions, defined in the form of functional specifications and content requirements, constitutes the scope plane. The structure plane defines the way in which the various features and functions of the site fit together through information architecture, and how the system behaves in response to the user through interaction design. The skeleton is designed to optimize the arrangement of elements, like buttons, tabs, photos, and blocks of text, for maximum effect and efficiency, for example through navigation design. The surface finally defines the visual design, including colors, fonts, icons, graphics, images and so forth. The decisions, which are made on each level, build upon each other and influence all the aspects of the user experience. (44 pp. 21-34)

3.1.3 Quality Assurance

Web users and developers usually perceive quality in a different way. Users may expect accurate information, easy navigation and quick downloading. Developers, on the other hand, value simple implementation, quick delivery, manageable development environment and easy maintenance. These expectations should still not be contradictory. In fact, there are several commonly used practices to improve the quality of web sites from both perspectives.

Web site should be verified with all major browsers and, if possible, with their mostly used versions. Web site should work regardless of the browser option selections, like cookie or JavaScript settings, and the client computer platform, like Windows or Mac. The increasing use of smartphones and tablets makes it important that the web pages either show correctly with different screen resolutions or, in its extreme, follow a responsive design to automatically adjust according to the client screen resolution. For the same reason, it is vital that, in addition to powerful computers and connections, the pages work fluently enough also when used by computers with lower performance and smaller memory size. Like mentioned earlier, the pages should be validated against the HTML and CSS standards. When using the latest features of HTML5 and CSS3 it must be taken into account that all browsers may not support their functionality. For example, date or email input field validation is not yet supported in all major browsers. If the site requires certain browser to be used, it must be stated clearly. (45 pp. 376-377)

Performance is one the most critical factor for a web site. Navigating in the web site, and especially loading the home page, should follow the common five or seven second rule within with the pages should be usable. The speed comes from restricting the size of images and content, and from loading the content from their sources, from databases for example. Images should be downsized to the shown resolution, content should be available while the images are still loading, the length of scrollable content should be considered, the server-side scripts should not be used for stable content, and implementing the page layout using HTML tags and CSS styling instead of tables. These are all good practices to improve the web site performance. In addition, the database design and the related server-side script implementation have great influence on the speed. (45 pp. 376-377)

The style inside a page and across the pages should be consistent, for example with the layout, navigation and links. Navigation is another essential factor for the user experience. In addition to being consistent, a successful navigation can be easily learned, uses clear and understandable labels, provides feedback and clear visual messages, offers alternatives, requires an economy of action and time, appears in context and is appropriate to the purpose of the site, and supports the goals and behaviors of the users (43 pp. 13-14). The audience of the web site should be understood and defined prior to web design. Different audience has different expectations, experience and wishes. Furthermore, a web site to be really beneficial must have correct content. The content must be targeted to its audience, it must be trustworthy, and it must be kept up-to-date according to the agreed procedure. It is useful to show the date and time of last update. Users also value the general appearance of the web site. The colors used, the contrast between text and background, and the fonts and font sizes have big impact to usability. If the audience includes disabled users, the font size, for example, should be adjustable via the browser instead of being fixed, or the web design should consider the use of voice browsers as well. In case of international use, the meaning of colors, symbols and images shall be understood, as well as the length of supported languages in the page layout. (43 p. 30) (45 pp. 376-377)

Web security is a set of procedures, practices, and technologies to protect web users, web servers and the organizations surrounding them. Web as an environment poses security risks that are usually not present in other publishing environments. Internet is a two-way network from servers to users and vice versa. Web is increasingly being used for instance by corporations to distribute important information and conduct business transactions, and web servers and browsers are exceedingly complicated pieces of software with many potential security flaws. Once their security is compromised, web browsers and servers can be used by attackers as a launching point for conducting further attacks against users and organizations. The web security consists of the security of the web server and the data on it, information travelling through a network, the computer of the user, and the applications used. Web server security ensures that the server can continue its operation, the information on the server is not modified without authorization, and the information is only distributed to those individuals to whom wanted it to be distributed. One good strategy for securing the information on the web server is to restrict access to the web server, by restricting login access for example with the use of passwords or secure shell (SSH) protocol, and by using a firewall which is a device that isolates the internal network of an organization from the Internet allowing only specific connections to pass and blocking others. Security of information in transit is about assuring that information the user supplies to the web server, like usernames, passwords and bank account data, cannot be read, modified, or destroyed by others. Encrypting the information as it travels between the web server and the user is a practical technique so that the information cannot be decoded by any party who does not possess the proper key. User computer security is to assure users that information, data, or programs downloaded to their systems will not cause damage. Typical practices to ensure computer security is using the latest versions of the browser and operating system combined with a well-known security and anti-virus software. Application security focuses on actions taken to prevent security related flaws and vulnerabilities by incorporating security controls into whole software development process. Common application security vulnerability is the so-called structured query language (SQL) injection, which is used to attack data driven applications. (46) (47)

Testing is a common quality assurance practice in all software development. However, unstructured testing without actions does not improve the quality of the software. Instead, test design, which may be done even before software implementation, improves understanding the scope and the functionality of the software, followed by test execution phase which documents the test results and helps considering additional or ad-hoc test cases. Finally, the error correction cycles after the testing then actually improve the quality of the software itself.

It is good practice to include means to contact the author to give comments and feedback. In order to avoid possible automatically sent junk messages, a CAPTCHA (completely automated public Turing test to tell computers and humans apart) image validation technique can be used. In addition, there may be company guidelines and style guides for the web and intranet design and implementation in their environment.

3.1.4 Evaluation of Solutions

One common requirement set for the Qt metrics system was that, because Qt Project is heavily based on open source, it would be good to use open source technologies also on metrics system front-end and back-end solutions. Hence the solutions evaluated here are scoped to open source technologies or frameworks, and are mostly free of charge. Evaluation is done by introducing the solutions in the context of the developed Qt metrics system. The actual solution selection is described and explained later in this document.

Apache, PHP and AJAX

PHP is currently the most popular server-side language for developing web sites (48). A commonly used approach for a dynamic web application implementation is the combination of HTML, PHP and AJAX languages running on Apache web server, together with a MySQL database. PHP has certain benefits compared to other script languages because it has been originally designed for web development, although it is also used as a general-purpose programming language. PHP code is interpreted by a PHP processor in web server, which then generates the resulting, typically HTML, script for the web page. The simple basic language structure, loose typing discipline, and the fact that PHP scripts can be embedded directly into

HTML, make it also easy to learn, especially for those who have prior experience on C or C++ languages. The syntax is versatile, yet not as complicated as in Perl. PHP supports both the procedural and object-oriented programming styles. The data and structures, like forms, cookies and headers, from the browser can be accessed directly. PHP runs efficiently as an Apache module. There are plenty of function libraries and extensions available for example for date, string and array manipulation, file system and database access. Because of its popularity, documentation and support is widely available. For the same reason however, the more software code is written the more software bugs are written as well. It has been reported that about 29% of all web application security vulnerabilities are linked to PHP, although the vulnerabilities are caused mostly by inexperienced developers or those not following best practice programming rules (49). In addition, pieces of code and code examples are easily available in different forums, but their quality or performance often cannot be guaranteed. The flexibility of the language has its downsides as well. Because there are tens of ways to implement a feature or functionality, the refactoring and maintenance of the software may become difficult in the long run. (33 p. 13)

AJAX is not a technique as itself, but a group of interrelated client-side web development techniques for creating asynchronous web applications. They are: HTML and CSS for standards-based presentation, document object model (DOM) for dynamic display and interaction, extensible markup language (XML) and extensible stylesheet language transformations (XSLT) for data interchange and manipulation, XMLHttpRequest for asynchronous data retrieval, and JavaScript to bind everything together. Developing with AJAX requires certain level of knowledge of all the previously mentioned techniques, but JavaScript experience is needed the most. With AJAX, web applications can communicate with a server in the background, without interfering with the current state of the web page. User observes this so that only a part or parts of a web page change at a time, without the whole page being reloaded. AJAX use cases could be for example retrieving and showing movie details when moving cursor above a poster, or validating user input by dynamically changing selection list values according to previous selections in a form. The dynamic behavior, however, brings some usability related concerns. One problem is how the user gets visible enough indication that some content in a page is updating or has updated. Another issue is that, when browsing through AJAX generated content, the states are not saved in browser history, which means the “back” button does not return the browser to the earlier state of the AJAX page. In addition, because the URL does not change, it is not possible to bookmark a certain page state or content, or to send it to a friend as a link. Performance and the general user experience of many parts of a page updating simultaneously may become a challenge as well, especially with slow or unstable server connection, together with how fluently the server-side script is executed. Pages built with AJAX require that the browser used supports the JavaScript, and that it is not disabled by the user. In addition to the JavaScript support, the increasing use of smartphones and tablets highlights the design issue that touch screen devices are operated in a different way than the traditional mouse or pointer operated devices, for example regarding to the mouse-over action. Nevertheless, there are technical solutions and design guidelines available to solve these issues. (50 pp. 13-18) (51)

PHP is not limited to output just HTML. It can also be used to create image files in different image formats, such as GIF (graphic interchange format), JPEG (Joint Photographic Experts Group) and PNG (portable network graphics) among others. The dynamic image creation capabilities can be included by integrating a GD (graphics draw) open source code library. The most common applications of GD involve web site development to generate charts, graphics and thumbnails on the fly. To be able to use the GD library, PHP needs to be compiled with it and with possible additional libraries, depending on which image formats are needed. (52) (53)

There are many free web development environments available as a bundle of web server, database server and server-side script language that supports PHP, for example WAMP (Apache, MySQL and Perl/PHP/Python for Windows). The selection of the editor to actually edit the scripts, can be done according to personal preferences. However, compared to a basic text editor, a source code editor helps for example in language syntax checking.

WordPress

Like mentioned, WordPress is a popular blogging tool and a CMS based on PHP and MySQL. It features a plug-in architecture and a template system. The themes allow developers to change the look and functionality of a web site without altering the information content or structure of the site itself. Some themes support responsive design for small screens. The plug-in architecture extends WordPress abilities beyond the core installation to customize the developed sites with additional plug-ins like widgets and navigation bars. A widget can be a web form, an event calendar or an image carousel, for example. By using the provided themes and widgets, building a simple web site or blog should be quick and easy. On the other hand, implementing a web site with strictly defined layout, navigation and content may need deep knowledge of the WordPress web site builder itself and the HTML, CSS and PHP languages, as well as some experience on programming. Some concerns have been expressed towards security vulnerabilities, for example regarding the SQL injection. (42)

Other Systems and Frameworks

Joomla is an open source CMS for publishing content. It is written in PHP, uses object-oriented programming techniques, and stores data for example in a MySQL database. Joomla is estimated to be the second most used CMS on the Internet after WordPress (39). In addition to common web sites and applications, Joomla framework enables developers to build for example inventory control systems and data reporting tools. (54) (55)

Ruby on Rails is an open source web application framework which runs on the Ruby programming language. It is a full-stack framework: it allows creating pages and applications that gather information from the web server, talk to or query the database, and render templates out of the box. Ruby on Rails is typically not connected to the Internet directly, but through some front-end web server like Passenger or Apache. In addition, Ruby on Rails has a built-in support for AJAX through its extensive use of JavaScript libraries. (56)

Drupal is an open-source content management framework (CMF) written in PHP. It is also described as a web application framework to develop dynamic websites, web applications and web services. It is used for knowledge management and business collaboration as well. Drupal runs on any platform that supports both a web server capable of running PHP (Apache for instance) and a database (such as MySQL, MongoDB or MariaDB). Drupal has received criticism for example on its learning curve, performance, and the usability of the administration interface. (57)

3.2 Database Development

A database is an organized collection of uniform data. Database is designed, built and filled with data for a certain purpose for a certain audience. Many web applications use databases as their data storage. Two types of databases exist according to their usage: operational databases and analytical databases. Operational databases are used in situations where there is a need to collect, modify and maintain data on continuous basis. The data changes constantly and always reflects the latest information. Analytical database, or data warehouse (DW), is used for reporting and data analysis. It is a central and typically read-only repository of data which is created by including historical data and by integrating data from one or more different sources, and is a valuable asset when there is a need to track trends and view data over a long period of time for tactical of strategic business decisions. Analytical databases often use data that passes through an operational database before they are used for reporting, so these two types of databases are somehow associated, although their design methodologies are quite different. This thesis utilizes certain aspects from both operational and analytical databases. (58) (59 pp. 4-5)

DBMS is software designed to allow definition, update, retrieval and administration of databases. Data definition includes defining new data structures for a database, removing data structures from the database, and modifying the structure of existing data. Data update means inserting, modifying, and deleting the data. Retrieval is obtaining data either for end-user queries and reports, or for processing by applications. Administration includes registering and monitoring users, enforcing data security, monitoring performance, maintaining data integrity, dealing with concurrency control, and recovering information in case of system failures. Many databases have application software that accesses the database on behalf of end-users, without exposing the DBMS interface directly. Application developers, on the other hand, use databases through their API. Database designers and database administrators interact with the DBMS through command-line interface to database server or by using dedicated tools to build and maintain the databases, and thus need some more knowledge and understanding about how the DBMS operates and what are the DBMS tuning parameters, for example. Physically, database servers are dedicated computers that hold the actual databases and run the DBMS and related software. The same DBMSs may be used both for operational and analytical databases. (58) (60)

Both a database and its DBMS conform to the principles of a particular database model. Common database models include for example relational model, object model and document model. (60)

In a relational database, a relation is usually described as a table, which is organized into rows and columns, also referred as records and attributes respectively. Each table must identify a unique primary column, called the primary key, used for identifying a row of data. Tables can relate to other tables by using a foreign key, a link to the primary key in another table. Primary key may be one column, a numeric id for example, or multiple columns where the combination of the column values creates a unique row. Retrieving data from multiple tables is done by joining the needed tables in the query command. In addition to the use of the primary keys, relational databases emphasize data integrity by minimizing the redundancy and the dependency of the data. Each piece of data appears only once and is therefore updated only to one place, and the data is allocated to tables so that a table includes only interdependent data. These and other related practices are called database normalization, which usually involves dividing large tables into smaller ones and defining relationships between them instead. The most popular relational database management systems (RDBMS) are Oracle Database, Microsoft SQL Server and MySQL. (61) (62)

While the use of relational databases maintains a clear division between the database model and application, using object-oriented databases combines database capabilities with object-oriented programming language capabilities. Hence the programmers can maintain consistency within one environment, in that both the Object-Oriented Database Management System OODBMS and the programming language, such as C#, C++, Ruby, Python, Perl and Java, will use the same model of representation. Compared to RDBMS, access to data can be faster because joins are often not needed, because an object can be retrieved directly without a search. However, because of industry disagreements, less stable standards and reduced availability of support and OODBMS tools, the object-oriented databases have not replaced the relational databases, at least yet. The most popular OODBMS currently is Intersystems Caché. (62) (63)

An object-relational database can be said to provide a middle ground between relational databases and object-oriented databases. Object-Relational Database Management System (ORDBMS) is similar to RDBMS, but with an object-oriented database model; objects, classes and inheritance are directly supported in database schemas and in the query language. PostgreSQL is an open source ORDBMS available in supplied packages of vast majority of Linux distributions, although supported also for example in Solaris, Windows and Mac. (64) (65)

A document-oriented database is designed for storing, retrieving, and managing document-oriented data, around an abstract notion of a document. Document-oriented databases are one of the main categories of so-called NoSQL (Not only SQL) databases. NoSQL databases provide a mechanism for storage and retrieval of data that uses looser consistency models than the relational databases, and they are finding growing industry use in big data and real-time web applications. While each document-oriented database implementation differs on the details, in general they all assume documents encapsulate and encode data in some standard format or encoding. Encodings in use include XML and JavaScript object notation (JSON), as well as binary forms like portable document format (PDF) and Microsoft Office documents (Word, Excel, and so on). MongoDB is currently the leading open-source document-oriented database. It is available for Windows, Linux, Mac, and Solaris, and supports all major programming languages. (62) (66)

A database transaction is a group of operations with atomic, consistent, isolated, and durable (ACID) properties. Atomic means that either all of the operations in the transaction succeed or none of the operations persist, consistency ensures that if the data is consistent before the transaction begins, then it will be consistent after the transaction finishes, isolation is that the effects of a transaction that is in progress are hidden from all other transactions, and durability is defined so that when a transaction finishes, its results are persistent and will survive a system crash. Most DBMSs support transactions, at least in some of their storage engines. A database storage engine is the underlying software component that the DBMS uses to create, retrieve, update and delete data from a database. The storage engine is selected when creating a database, although DBMS may allow it to be changed also while in operation, like in MySQL for example. (58) (67)

3.2.1 Database Design

The database management systems include wizards to automate the definition and creation process for a database and its tables. However, before that the database designer must go through a logical design process by himself or herself to design the data model for the database. There are certain qualities for a well-designed operational relational database: it shall support the retrieval of both the required and ad hoc or unpredictable information, it includes effective table structures where each table defines only one purpose and each record can be identified by a unique attribute or combination of them, it takes care of data integrity in attribute, table and relationship levels, it can adjust to future growth, it is easy to modify and maintain the database structure so that changes in one attribute or table do not damage other attributes or tables, it is easy to modify the data so that for example changing a value is done only once into one place, it is easy to retrieve the data, and it is easy to develop and build the applications using the database. The analytical databases address data retrieval, analysis and reporting. Hence they have different key qualities, such as storing the history data for trend generation, standardizing the data from different operational systems by using standard ids and keys, defining clear and intuitive data structure to make the retrievals easy, creating derived data for most commonly used information needs, storing the data in fine enough granularity, and ensuring fast enough response time for the retrievals. In addition, regardless of the database type, it is important that the database supports business rules relevant to the organization by providing valid and accurate information, and that the database lends itself to future growth as the business information requirements change and grow . (58) (59 p. 33) (68 p. 134)

The database design process includes both logical and physical steps, regardless of the actual methods used. Logical, product independent, phases are typically requirements analysis, data structure definition and normalization. In the requirements analysis phase the company or community is examined, by interviewing the users and management to analyze and understand needs in general, both in short and long term. Next, the data structure is defined, for example using so-called entity relationship (ER) diagrams, by visualizing the tables, table attributes, table relationships and their properties, as well as the use of primary and foreign keys for the relationships, see FIGURE 6. Some DBMS administration tools support this phase, although this can be done simply on paper or whiteboard as well. In the normalization phase the defined database structure is verified against a list of few normalization rules, and modified in case of problems found. The goal is to remove the possible problems that would have been run into later when using the database. This usually involves dividing large tables into smaller ones and removing duplicate data attributes between the tables. However, some selective denormalization can subsequently be done for example for performance reasons. The physical phases in the database design process are database implementation and performance tuning, and their implementation depend on DBMS and its language. The DBMS is selected in the database implementation phase at latest, and the database is actually created according to the defined database structure. This can be done using the query language, like SQL, on the database server, or utilizing the DBMS wizards for example directly from the ER diagrams. The performance tuning phase usually means indexing, but may include also sorting the order of table rows, refining the structure definitions, modifying database parameters, denormalization, adding tables for derived data, analyzing the server memory, processor and disk solutions, and prioritizing processes at the operation system level. Index is a copy of a part of a table, like a sorted index of a book. Purpose of an index is to improve the speed of data retrieval from a table, although the costs are slower write operations and use of more storage space. Indexing alone can significantly improve the performance of the use of the database, without touching the application, but finding the optimal and best index is not a simple task. Indexing can be done or refined both before and after the launch of the database and its application. In addition, the application implementation and the query commands can affect greatly on the performance as a whole. Database management systems include an optimizer which receives the query command and tries to find the fastest access path for it, for example by comparing whether to use an index or full database scan. DBMS also decides whether a specific read operation can be done from the cache or from the physical disk, which again has a big impact to the performance. (58) (68 pp. 12,24-25,144-145)

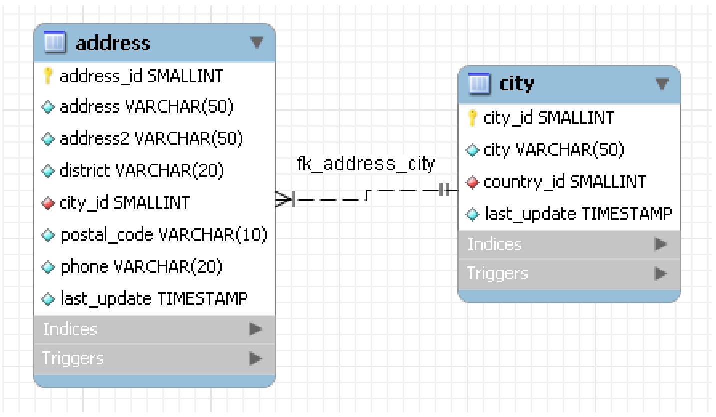


FIGURE 6. Entity Relationship diagram using MySQL Workbench (69)

3.2.2 SQL

SQL is a special-purpose programming language designed for managing data in relational database management systems such as Oracle Database, Microsoft SQL Server and MySQL. SQL is a non-procedural, or declarative, language, which means that it specifies what data to retrieve, rather than providing the steps indicating how to retrieve it. SQL statements can be divided into five types: query statements (like SELECT) to retrieve data, data manipulation statements (like INSERT) to modify the data in a table, data definition statements (like ALTER) to modify the structure of database and its tables, transaction control statements (like COMMIT) to manage a series of statements, and data control statements (like GRANT) to manage user access. The result of the SELECT statement is a table called result-set, with columns and rows specified in the statement. The statement can include several clauses or operators to detail (like FROM), sort (ORDER BY) and narrow down (like WHERE) the result set, as well as to join data from several tables (JOIN) and to combine results from several SELECT statements (UNION). Hence the SELECT statements may become quite complicated and, combined with the database design and the use of indexes, is a place for careful design and optimization if needed. SQL queries can be executed on the server with a command line interface, on workstation using the DBMS administrations tools, and as embedded piece of code with application programming languages such as PHP, C# or Java. (58) (68 p. 10)

SQL has been adopted as a standard by the American National Standards Institute (ANSI) and the International Organization for Standardization (ISO). That said, SQL has received criticism about the incompatible implementations between database systems. In particular date and time syntax, string concatenation, NULLs, and comparison case sensitivity vary from vendor to vendor. As a result, SQL code can rarely be ported between database systems without modifications. There are several reasons for this lack of portability. The SQL standard is big and complex, and that is why most vendors do not support the entire standard. The standard leaves several database behaviors and language constructs open or less well-defined for vendors to decide the implementation of the behavior. Many database vendors have large existing customer bases and may therefore be unwilling to break backward compatibility. The incompatibilities may also be business decisions to provide a strong incentive for their existing users to remain loyal. (70)

3.2.3 Evaluation of DBMSs

Like in the evaluation for web development solutions, the evaluation here is scoped to open source systems. Evaluation is done by introducing the solutions in the context of the developed Qt metrics system. The actual solution selection is described and explained later in this document.

MySQL

MySQL is one of the most widely used relational database management system in the world. It is named after the daughter, My, of the co-founder Michael Widenius. MySQL is a popular choice of database for use in web applications, and is a central component of the widely used AMP (Apache, MySQL, Perl/PHP/Python) open source web application software bundles. MySQL is available as open source community edition and as several commercial editions with additional functionality by Oracle. MySQL is often used by free-software and open source projects which require a full-featured database management system. MySQL is used in many high-profile website companies for one or several content types, including Wikipedia, Facebook, Twitter and YouTube, and in large organizations such as NASA and CERN. (62) (71) (72)

MySQL ships without GUI tools to administer MySQL databases or manage data contained within the databases. Users may use the included mysql and mysqladmin command line clients, or MySQL front-end desktop software or web applications. MySQL Workbench by Oracle is a visual database design desktop tool that integrates SQL editor, database design and database administration into a single IDE for the MySQL database system. It supports also database migration as well as export and import functionalities. MySQL Workbench is available as open source community edition and commercial edition. Another commonly used administration tool is phpMyAdmin. It is an open source web application and IDE intended to handle the administration of MySQL. It can perform various tasks such as executing SQL statements, importing and exporting data, managing users and permissions, and to monitor MySQL server activity like connections, processes, CPU/Memory usage. The phpMyAdmin is included in many web development environments or software bundles, like in EasyPHP DevServer WAMP. (73) (74)

The MySQL pluggable storage engine architecture enables a database designer to select a specialized storage engine for a particular application need. Commonly used engines with a MySQL database are MyISAM and InnoDB. They have certain differences according to their targeted use. MyISAM has been designed for need of speed while InnoDB has been designed for maximum performance when processing large data volumes. Use of MyISAM is optimal if the table is more static with more data retrieval and less update and delete. MyISAM uses full table-level locking while InnoDB has row-level locking, which increases multi-user concurrency and performance. To maintain data integrity, InnoDB supports foreign key constraints so that inserts, updates, and deletes are all checked to ensure they do not result in inconsistencies across different tables. InnoDB supports transactions to be able to commit and rollback, while in MyISAM once a statement is issued it is done. MyISAM supports fulltext search indexes, and InnoDB doesn't. InnoDB has crash-recovery capabilities to protect user data. InnoDB tables arrange data based on primary keys, while MyISAM organizes data by default in storage order. InnoDB stores its tables and indexes in a tablespace, MyISAM stores its tables, data and indexes in diskspace using three different files. Backup of InnoDB tables can be done just by taking a snapshot of the file system, while MyISAM requires using the mysqldump client but the result is not guaranteed to be consistent. (58) (75) (76)

Many programming languages with language-specific APIs include libraries for accessing MySQL databases. These include for example C# and Java, and languages that support the open database connectivity (ODBC) interface to communicate with a MySQL database, such as PHP and Perl. Like other SQL databases, MySQL does not currently comply with the full SQL standard for some of the implemented functionality, including foreign key references when using some storage engines other than the InnoDB. MySQL, like most other transactional relational databases, is strongly limited by hard disk performance. This is especially true in terms of write latency. (77)

MariaDB

MariaDB database is truly open source and is compatible with the MySQL while providing new extensions and features. Customers and users value MariaDB for its performance. In addition to MySQL, it is capable of interfacing with NoSQL database systems like Cassandra and LevelDB as well as to access data in other formats thanks to its pluggable storage engines. Hence the customers are able to leverage the capabilities of the latest database technologies as well as to access data in legacy systems without expensive and risky database migrations. MariaDB is a community-developed fork, a source code branch, of the MySQL database. What this means is that the developers have taken the freely available MySQL code and then added to it. One major objective is the community maintenance of its free status under GPL as opposed to any uncertainty of MySQL license status under its current ownership by Oracle. The intent is also to maintain compatibility with the MySQL, ensuring a drop-in replacement capability with library binary equivalency and exact matching with MySQL commands, for example. Regarding the ports and sockets, the client APIs and protocols that MariaDB uses are all the same as in MySQL. All MySQL connectors, those bits of code which allow programming languages like Java, C, PHP, .Net, Perl, Python, and Ruby to talk directly to a MySQL database, all work unchanged with MariaDB. All client programs that can talk to MySQL databases can also talk to MariaDB databases without any changes. In addition, the on-disk format of the databases is the same, which allows MySQL to open a database created with MariaDB just like MariaDB is able to open one created with MySQL. This all means that in most cases, uninstalling MySQL and installing MariaDB is enough to continue operations. Every project which works with MySQL also works with MariaDB. Specifically documented tools to support MariaDB are front-end applications such as HeidiSQL and phpMyAdmin, and web site builders such as WordPress and Drupal. (78) (79) (80) (81) (82)

The benefit of MariaDB, in addition to being truly open source, comes from new features, performance improvements, better testing, and bug fixes which are not found in MySQL. Some of these were developed in-house by the core MariaDB developers, and others come from individual contributors and companies such as Facebook, Twitter, Google, and others. New features include extended user statistics to better understand the server activity and to identify the sources of database load, progress messages from the server for long running commands, faster joins and sub-queries, as well as NoSQL-style features like dynamic and virtual columns, and so-called HandlerSocket to provide fast and direct access to InnoDB tables by skipping the SQL layer. Several enhancements found in MariaDB are performance related, including improved optimizer which performs significantly faster than the MySQL one on complex workloads, enhanced replication, and co-called table elimination to optimize the use of views to access highly normalized data. Regarding the better testing, many improvements have been made to the testing infrastructure of MariaDB. That together with the deep knowledge and experience of the MariaDB developers and the focus on compiler warnings has already resulted in reduction in the overall number of bugs and compiler warnings. MariaDB includes pluggable storage engines like XtraDB as a replacement for InnoDB, and new transactional storage engine Aria to enable faster complex queries than MyISAM. MariaDB version numbers followed the MySQL version numbers until 5.5. Thus, all features from MySQL 5.5 were available in MariaDB 5.5. After version 5.5 it was decided to start a branch numbered as 10.0 to make clearer that MariaDB will not import all features from MySQL 5.6 into MariaDB 10.0. (81) (83) (84)

The MariaDB Foundation promotes, protects, and advances the MariaDB codebase, community, and ecosystem. The Monty Program is a center of engineering excellence for MariaDB, the Aria storage engine, MySQL, and other associated technologies. This Finnish based company was founded by Michael "Monty" Widenius, the founder and creator of MySQL; MariaDB is named after the younger daughter of Monty, Maria. Significant arrangements have been made lately when SkySQL, a Finnish based company which provides open source database solutions for MySQL and MariaDB users in the enterprise and cloud, announced in April 2013 that they are merging with Monty Program Ab. This merger reunited key members of the original MySQL AB developer and services teams, and their aim is to bring cloud and big data capabilities together, and to develop MariaDB into a truly interoperable, NewSQL open source database in collaboration with its customers, partners and the community. (80) (85) (86)

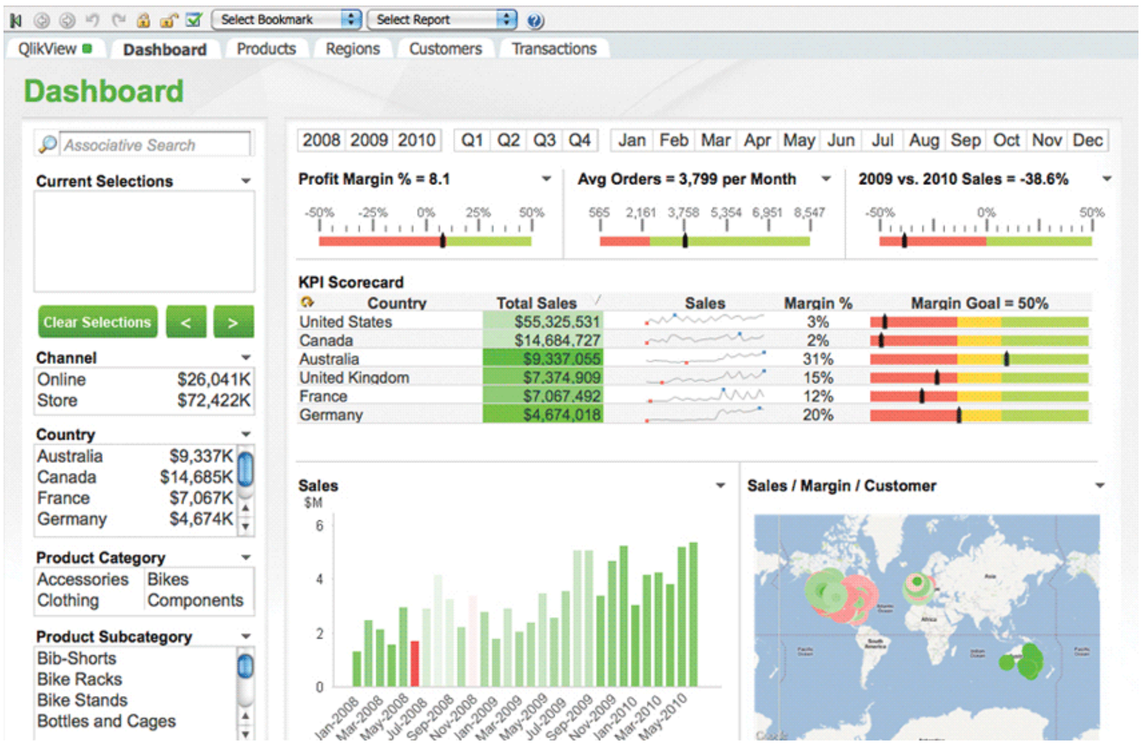
One remarkable achievement was made in April 2013 when Wikipedia announced the completion of the migration of the English and German Wikipedias to MariaDB 5.5. They prepared the change from late 2011, first upgraded from MySQL 4.0 to 5.1 and then to 5.5, and finally changed to MariaDB 5.5, with the help of the MariaDB team regarding a pair of bugs. (87)

3.3 Reporting Tools

A database stores data, but the data must be processed in some manner before it turns into meaningful information. Data itself is static while information is dynamic in the sense that it constantly changes to reflect the latest data, and also as data can be processed and presented in innumerable ways. Information can be provided only if the data is valid, accurate and appropriate, and if the database is well structured to support the required information. Information can be presented in many ways, from spreadsheet reports and prepared slideshows to interactive applications and complete business intelligence (BI) solutions. (59 pp. 45-46,129-130)

On-line reports are commonly accessed via a browser application or web portal. Essential quality for a web based solution is the usability. Jakob Nielsen defines usability as five components: learnability, efficiency, memorability, errors and satisfaction (88). Learnability is that how easy it is for users to accomplish basic tasks the first time they encounter the design. Efficiency means that how quickly users can perform tasks once they have learned the design. Memorability is that how easily users can reestablish proficiency when returning to the design after a period of not using it. Errors relate to how many errors users do make, how severe those errors are, and how easily they can recover from the errors. Satisfaction identifies how pleasant it is to use the design. If the usability of the system is poor, the users may spend a considerable amount of time trying to figure out how to use the system, or they may become frustrated or may not be able to really use the system at all, and eventually simply stop using it. Additionally, there are other desirable features for web portals in general and report portals in particular. The portal should be rich in content, instead of pure report printing tool, in that it should contain additional functionality such as advice, help, support information and documentation. The portal should be clean i.e. designed so that it is easily understandable and not over complex as to confuse the users. The portal must reflect the latest available data and hence shall be updated regularly. The portal should be interactive to make it easy for the users to use its functionality and encourage them to use the portal. Scalability and customization give means to fit the portal to each user. It is important that the portal is value oriented so that the users have the feeling that the application is a valuable resource that is worth working on. (88) (89)

In its general meaning, a dashboard in a vehicle is a panel located in front of the driver to help him or her to control the vehicle. In the information technology, a digital dashboard is a view to the key indicators of an organization at one glance to enable instantaneous and informed data-based decisions. A good dashboard is easy to read, often single-page graphical view with a real-time user interface, showing a presentation of the current status (snapshot) and historical trends. Typically, users see first the high-level summary and are then able to drill down into low level information. The use of red-yellow-green color coding is a very common approach. A dashboard can be a stand-alone software application, a web application, or a so-called desktop widget driven by a widget engine. FIGURE 7 illustrates a sample digital dashboard. (90)



Channel	
Online	$26,041K
Store	$72,422K

Country	
Australia	$9,337K
Canada	$14,685K
France	$7,067K
Germany	$4,674K

KPI Scorecard

Country	Total Sales	Sales	Margin %	Margin Goal = 50%
United States	$55,325,531		3%	
Canada	$14,684,727		2%	
Australia	$9,337,055		31%	
United Kingdom	$7,374,909		15%	
France	$7,067,492		12%	
Germany	$4,674,018		20%	

FIGURE 7. A digital dashboard (91)

It must be remembered though that any dashboard or metrics reporting solution is only as good as the metrics defined in it.

3.3.1 Evaluation of Solutions

In addition to open source systems, evaluation scope includes few commercial applications. Again, evaluation is done by introducing the solutions in the context of the developed Qt metrics system, and the actual solution selection is described and explained later in this document.

Spreadsheet

A spreadsheet application, such as Microsoft Excel, supports creating charts, graphs, or histograms from specified table of data. The pivot table functionality in the Excel is useful especially for analyzing purposes. The Excel allows to read data from an ODBC supported database and to build a set of reports with bar charts or history trend graphs. Sheets or areas of sheets can be saved in HTML format in to network disk or web server for viewing. In addition, it is possible to utilize the Visual Basic for Applications (VBA) language to automate for example the data retrieval, operations to update the report sheets, and to save the reports as HTML into specified location. This way it is possible to generate up-to-date information to the users. However, users are not able to tailor or customize the views, unless the views are separately implemented for each usage and purpose.

Reporting software

There is also open source and commercial reporting and querying software available to extract, sort, summarize, and present selected information. (92)

Pentaho offers an open source BI product called Pentaho Business Analytics. It provides operational and interactive reporting, data discovery and interactive analysis, interactive dashboards and visualization, data access and integration, predictive analytics, Online Analytical Processing (OLAP), and mobile experience. However, not all functionality is available in the community edition but only in the commercial edition. Pentaho can be deployed on-premise, in the cloud, or embedded into other software applications. (93)

QlikView is a commercial BI tool, with a free personal edition, for building dynamic reporting services. It provides consolidating relevant data from multiple sources into a single application, exploring the associations in the data, enabling social decision making through secure and real-time collaboration, visualizing the data with engaging graphics, searching across all data, interacting with dynamic applications, dashboards and analytics, and accessing, analyzing and capturing the data from mobile devices. The ability to drill down the view from the graphs is a valuable feature from the user point of view. (91)

Tableau Software produces a family of interactive data visualization products focused on BI, for example desktop and server versions are available. In their BI solution they emphasize speed, self-reliance, visual discovery, large and diverse data, ubiquitous collaboration, and flexible configurations. Tableau features typical BI functionality, it is able to query multiple sources, such as relational databases, cubes, cloud databases and spreadsheets, and to generate a number of graph types that can be combined into dashboards and shared over a computer network or the Internet. Tableau shows its strength in visualizing data for analysis purposes. (94) (95)

Self-made application

It may also be viable to create a self-made application, most likely a web-based one. Application would consist of user interface, data retrieval and publication capabilities, and the database solution together with the practices to store required data to the database, which in this case would be some component to read the various source data and to store it into database in a uniform format. The same report portal qualities mentioned above still apply for this reporting solution as for any reporting product.

4 QT METRICS SYSTEM

Introduction to the Qt metrics system is divided here to first list the needs and requirements to the system, its target audience and their key use cases. The selected solution is described with the rationale to the selection. Then the Qt metrics system itself is described from both the user and developer point of view. Lastly the project team is introduced and the development process used is summarized.

4.1 Requirements

The following requirements were set for the metrics system in the beginning of the development.

1. The web page should be hosted on public Internet under the qt-project.org domain.
2. Since Qt Project is heavily based on open source, it would be good to use open source technologies on both metrics system front-end and the back-end solutions.
3. The selected technologies and technical solutions should fit also to the areas that will be implemented later on. The first phase will focus on CI reports (where stored data size is reasonable), but the next ones will focus for instance on RTA reports (where stored data size might be very big), and code coverage reports (where results would be integrated from third parties).
4. Anyone in the Qt developer community should be able to create new reports on the metrics pages. By combining the efforts it would be possible to get more running reports than the initial development team alone would be able to make.
5. The user of the web page should be able to filter the information based on different criteria, and to browse relevant information for his or her needs. The performance of these operations should be in good enough level to provide positive user experience.
6. The web site design should be documented in such a level that the Qt community can take responsibility of the site maintenance.

4.2 Target Audience and Use Cases

Target audience for the CI metrics part of the Qt metrics system includes the Qt development and CI teams in Digia and the global Qt developer community, i.e. those individuals and teams that develop the Qt library components and the Qt tools.

Although many information needs are common to the both user groups, there are also some needs and use cases for the system that are specific to either one.

The CI team is interested for example in how the CI coverage, for example in terms of repositories, has progressed, how the CI pass/fail rate has progressed, what breaks the CI in general, what projects or autotests failed most often thus affecting the CI stability, which CI build machines failed most often, and which CI builds and phases take the longest time to execute. In addition, data could be collected about the configurations that are flagged insignificant, and hence it would be possible to analyze whether the flag could be removed for some of those configurations. The same case is for the autotests.

A developer or development team is interested in the components and the autotests on their responsibility. One may want to check if an autotest failed in the latest builds or in all the builds during the last two weeks, for example. After possible corrections or changes to the autotests, it is important to see that the previous failures now result success, or that the autotests continue to be successful, in all affected projects and configurations. It may also be interesting to check the execution time of builds and autotests.

4.3 Framework and Tool Selection

The solutions for the web, database and report development were selected by analyzing the system requirements and the development competence needs. Easy integration to the existing server environment and to the current processes and practices in the Qt Project were also very important factors for the selection of the implementation framework.

The target system was considered to orient more to information than to visual appearance, which resulted to selecting the PHP and AJAX approach for web development to enable dynamic functionality and full customization, as well as to guarantee wide competence space for maintenance and future development. Using the WordPress or any other web site builder would have been an overkill compared to the needs for the system and to the estimated effort to get a demo version up-and-running and to develop and maintain the system, based on limited experience however.

A natural choice for the database solution, to accompany PHP scripting language, was MySQL for its popularity and availability of development environments. The database could be replaced later with MariaDB if needs arise for example regarding performance and database size.

A separate reporting tool was not considered necessary as the PHP and AJAX approach allows building the reports and views needed at this point. The QlikView tool has been in use in Digia, but it was not considered as a viable option in this case because of its licensing costs with the expected number of users.

4.4 System Overview

The implemented Qt metrics system consists of three main components: the parser, the report builder and the database, see FIGURE 8. The parser reads the build logs, test results or other files that are created in the development process, and pushes the data into the database. The report builder reads the data from the database, and shows predefined metrics and reports on a web interface where the user is able to scope and filter the information based on his or her interests and needs. The parser is implemented with Perl, and the report builder with HTML, CSS, PHP and AJAX. The database is a MySQL database. The system is running on the existing Qt testresults server.

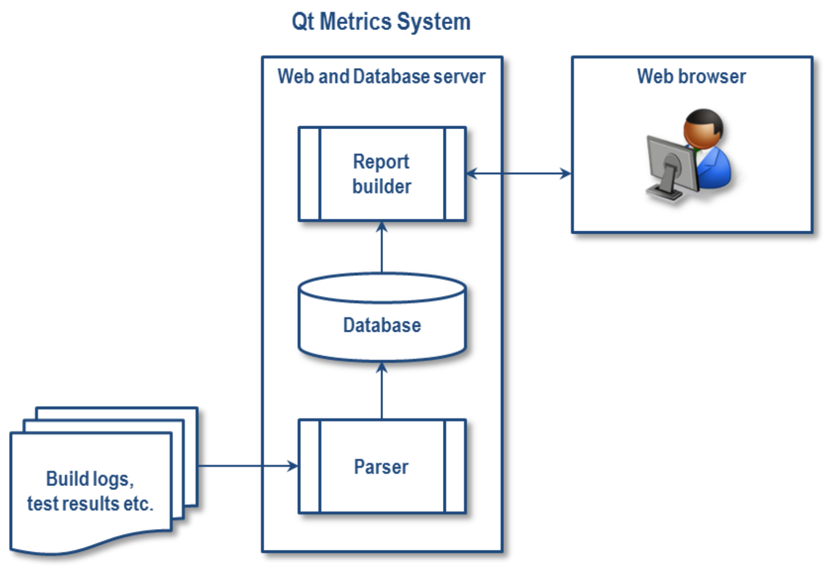


FIGURE 8. Generic system architecture

The tool and the documentation can be found at:

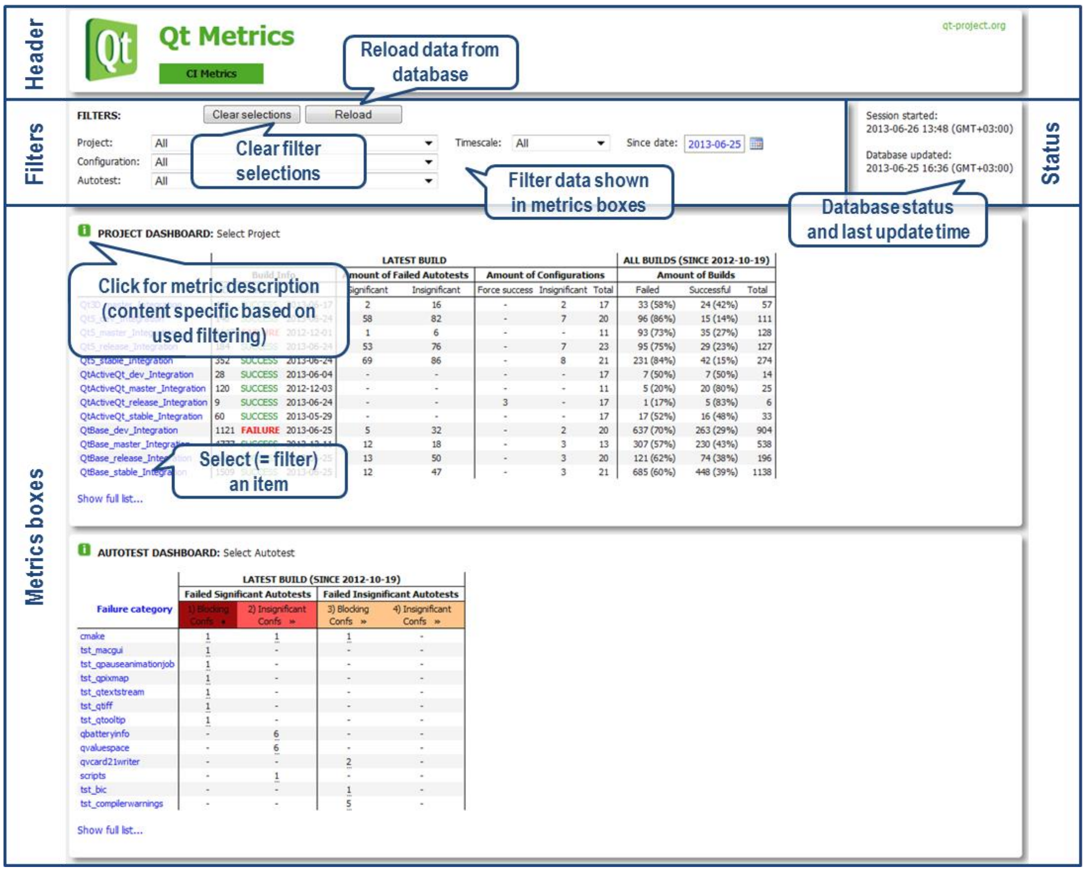
- Qt metrics system: http://testresults.qt-project.org/qtmetrics/
- Documentation: http://qt-project.org/wiki/Qt_Metrics_Page_Description
- Change backlog: http://qt-project.org/wiki/Qt_Metrics_Page_Backlog. An extract is available in Appendix 1.

4.5 Using the System

This section introduces the Qt metrics system from the user point of view.

4.5.1 Report Builder Overview

The report builder is a collection of PHP files which reside on the existing Qt testresults server (Solaris running Apache) on the qt-project.org domain. It utilizes AJAX, JavaScript, and HTML/CSS (HTML5/CSS3 for some visual appearance). The FIGURE 9 below describes the logical elements and functionality of the report builder.


Header
Filters
Metrics boxes
Status
Qt Metrics
CI Metrics
qt-project.org
Reload data from database
Clear filter selections
Filter data shown in metrics boxes
Database status and last update time
Click for metric description (content specific based on used filtering)
Select (= filter) an item
Clear selections
Reload

FILTERS:

Project: All
Configuration: All
Autotest: All
Timescale: All
Since date: 2013-06-25

Session started:
2013-06-26 13:48 (GMT+03:00)

Database updated:
2013-06-25 16:36 (GMT+03:00)

PROJECT DASHBOARD: Select Project

	LATEST BUILD								ALL BUILDS (SINCE 2012-10-19)		
	Build Info			Amount of Failed Autotests		Amount of Configurations			Amount of Builds		
				Significant	Insignificant	Force success	Insignificant	Total	Failed	Successful	Total
Qt3D_master_Integration	[illegible]	SUCCESS	2013-06-17	2	16	-	2	17	33 (58%)	24 (42%)	57
Qt5_dev_Integration	[illegible]	SUCCESS	2013-06-24	58	82	-	7	20	96 (86%)	15 (14%)	111
Qt5_master_Integration	[illegible]	FAILURE	2012-12-01	1	6	-	-	11	93 (73%)	35 (27%)	128
Qt5_release_Integration	184	SUCCESS	2013-06-24	53	76	-	7	23	95 (75%)	29 (23%)	127
Qt5_stable_Integration	352	SUCCESS	2013-06-24	69	86	-	8	21	231 (84%)	42 (15%)	274
QtActiveQt_dev_Integration	28	SUCCESS	2013-06-04	-	-	-	-	17	7 (50%)	7 (50%)	14
QtActiveQt_master_Integration	120	SUCCESS	2012-12-03	-	-	-	-	11	5 (20%)	20 (80%)	25
QtActiveQt_release_Integration	9	SUCCESS	2013-06-24	-	-	3	-	17	1 (17%)	5 (83%)	6
QtActiveQt_stable_Integration	60	SUCCESS	2013-05-29	-	-	-	-	17	17 (52%)	16 (48%)	33
QtBase_dev_Integration	1121	FAILURE	2013-06-25	5	32	-	2	20	637 (70%)	263 (29%)	904
QtBase_master_Integration	[illegible]	SUCCESS	[illegible]	12	18	-	3	13	307 (57%)	230 (43%)	538
QtBase_release_Integration	[illegible]	[illegible]	[illegible]	13	50	-	3	20	121 (62%)	74 (38%)	196
QtBase_stable_Integration	1509	SUCCESS	2013-06-25	12	47	-	3	21	685 (60%)	448 (39%)	1138

Show full list...

AUTOTEST DASHBOARD: Select Autotest

	LATEST BUILD (SINCE 2012-10-19)			
	Failed Significant Autotests		Failed Insignificant Autotests	
Failure category	1) Blocking Confs »	2) Insignificant Confs »	3) Blocking Confs »	4) Insignificant Confs »
cmake	1	1	1	-
tst_macgui	1	-	-	-
tst_qpauseanimationjob	1	-	-	-
tst_qpixmap	1	-	-	-
tst_qtextstream	1	-	-	-
tst_qtiff	1	-	-	-
tst_qtooltip	1	-	-	-
qbatteryinfo	-	6	-	-
qvaluespace	-	6	-	-
qvcard21writer	-	-	2	-
scripts	-	1	-	-
tst_bic	-	-	1	-
tst_compilerwarnings	-	-	5	-

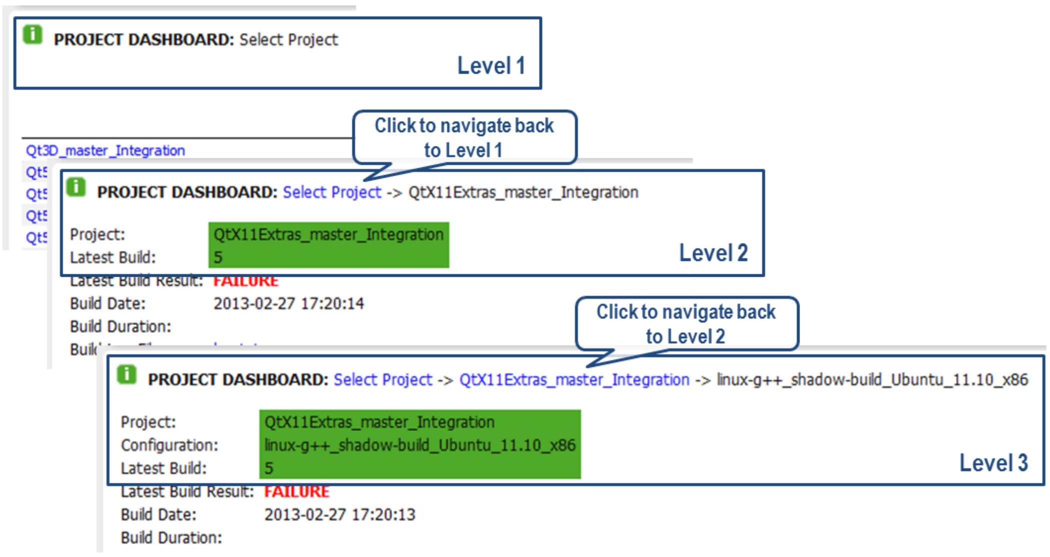
Show full list...

FIGURE 9. Report builder elements and functionality

The data that is shown in the metrics boxes can be selected with the filters. The data can be studied on different levels: for instance, list of projects, one project, or one configuration in a project with the Project dashboard. In addition to using filters for selecting the desired level, the navigation can be done by clicking for example a project or configuration in a metrics box.

The status box shows the time when the data was updated (scanned) from the log files to the database, and the session start time identifying when the data displayed was updated from the database. In addition, the status box will notify if the database is being updated.

The metrics box title row shows the current navigation level, and the links in that row can be used to navigate back to the previous level as illustrated in FIGURE 10 below.


PROJECT DASHBOARD: Select Project

Qt3D_master_Integration
Qt5
Qt5
Qt5
Qt5

PROJECT DASHBOARD: Select Project -> QtX11Extras_master_Integration

Project: QtX11Extras_master_Integration
Latest Build: 5
Latest Build Result: FAILURE
Build Date: 2013-02-27 17:20:14
Build Duration:

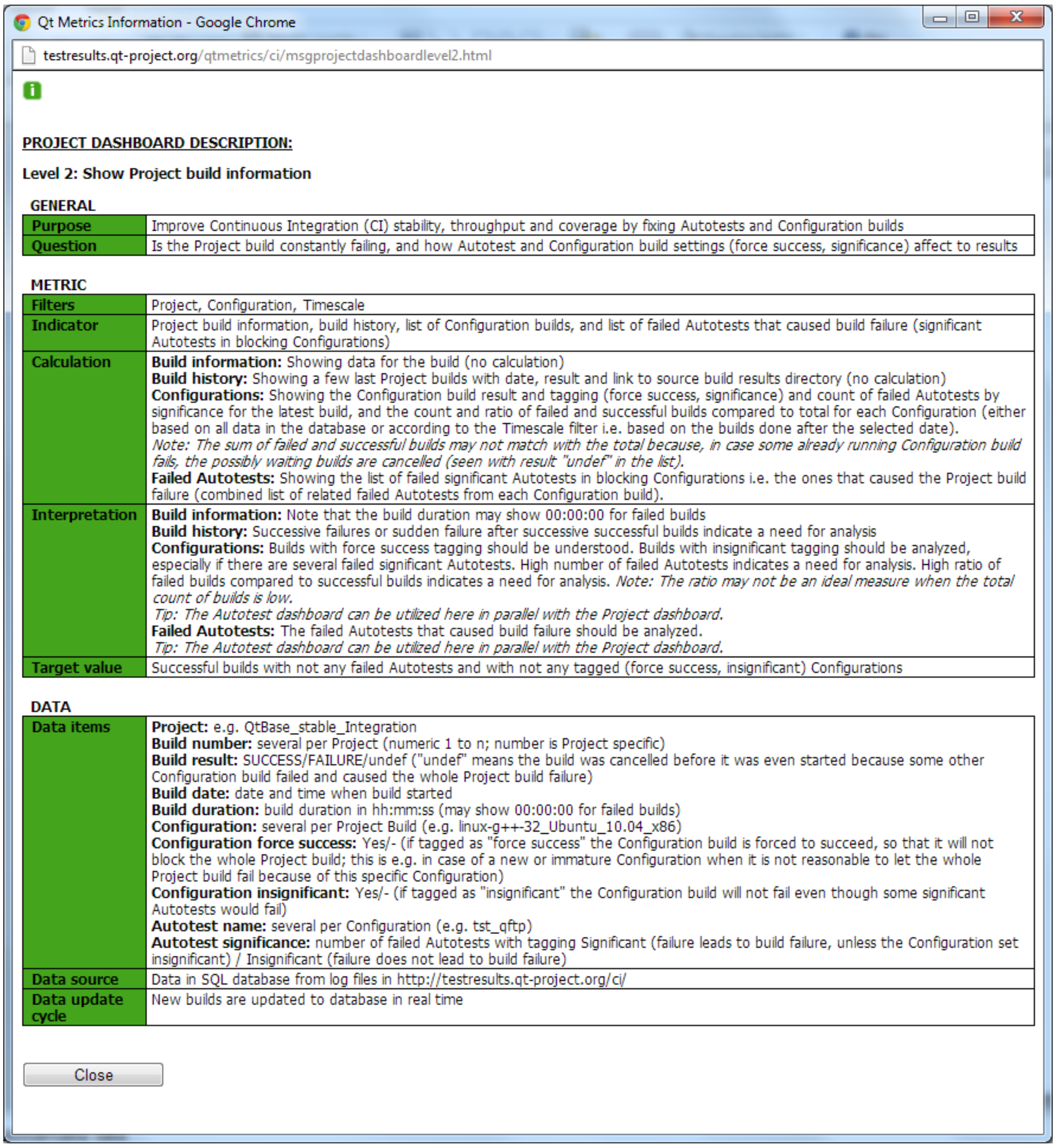
PROJECT DASHBOARD: Select Project -> QtX11Extras_master_Integration -> linux-g++_shadow-build_Ubuntu_11.10_x86

Project: QtX11Extras_master_Integration
Configuration: linux-g++_shadow-build_Ubuntu_11.10_x86
Latest Build: 5
Latest Build Result: FAILURE
Build Date: 2013-02-27 17:20:13
Build Duration:

Level 1
Click to navigate back to Level 1
Level 2
Click to navigate back to Level 2
Level 3

FIGURE 10. Levels and navigation in the Project dashboard

There is a description of each metrics box available (the "i" icon), including the purpose, detailed description and the data used in the metrics. The description is adjusted to the currently selected level describing the details on that specific level. FIGURE 11 shows a sample metrics description, which opens as a new browser window when clicking the "i" icon.


Qt Metrics Information - Google Chrome
testresults.qt-project.org/qtmetrics/ci/msgprojectdashboardlevel2.html
Close

PROJECT DASHBOARD DESCRIPTION:

Level 2: Show Project build information

GENERAL

Purpose	Improve Continuous Integration (CI) stability, throughput and coverage by fixing Autotests and Configuration builds
Question	Is the Project build constantly failing, and how Autotest and Configuration build settings (force success, significance) affect to results

METRIC

Filters	Project, Configuration, Timescale
Indicator	Project build information, build history, list of Configuration builds, and list of failed Autotests that caused build failure (significant Autotests in blocking Configurations)
Calculation	**Build information:** Showing data for the build (no calculation) **Build history:** Showing a few last Project builds with date, result and link to source build results directory (no calculation) **Configurations:** Showing the Configuration build result and tagging (force success, significance) and count of failed Autotests by significance for the latest build, and the count and ratio of failed and successful builds compared to total for each Configuration (either based on all data in the database or according to the Timescale filter i.e. based on the builds done after the selected date). *Note: The sum of failed and successful builds may not match with the total because, in case some already running Configuration build fails, the possibly waiting builds are cancelled (seen with result "undef" in the list).* **Failed Autotests:** Showing the list of failed significant Autotests in blocking Configurations i.e. the ones that caused the Project build failure (combined list of related failed Autotests from each Configuration build).
Interpretation	**Build information:** Note that the build duration may show 00:00:00 for failed builds **Build history:** Successive failures or sudden failure after successive successful builds indicate a need for analysis **Configurations:** Builds with force success tagging should be understood. Builds with insignificant tagging should be analyzed, especially if there are several failed significant Autotests. High number of failed Autotests indicates a need for analysis. High ratio of failed builds compared to successful builds indicates a need for analysis. *Note: The ratio may not be an ideal measure when the total count of builds is low.* *Tip: The Autotest dashboard can be utilized here in parallel with the Project dashboard.* **Failed Autotests:** The failed Autotests that caused build failure should be analyzed. *Tip: The Autotest dashboard can be utilized here in parallel with the Project dashboard.*
Target value	Successful builds with not any failed Autotests and with not any tagged (force success, insignificant) Configurations

DATA

Data items	**Project:** e.g. QtBase_stable_Integration **Build number:** several per Project (numeric 1 to n; number is Project specific) **Build result:** SUCCESS/FAILURE/undef ("undef" means the build was cancelled before it was even started because some other Configuration build failed and caused the whole Project build failure) **Build date:** date and time when build started **Build duration:** build duration in hh:mm:ss (may show 00:00:00 for failed builds) **Configuration:** several per Project Build (e.g. linux-g++-32_Ubuntu_10.04_x86) **Configuration force success:** Yes/- (if tagged as "force success" the Configuration build is forced to succeed, so that it will not block the whole Project build; this is e.g. in case of a new or immature Configuration when it is not reasonable to let the whole Project build fail because of this specific Configuration) **Configuration insignificant:** Yes/- (if tagged as "insignificant" the Configuration build will not fail even though some significant Autotests would fail) **Autotest name:** several per Configuration (e.g. tst_qftp) **Autotest significance:** number of failed Autotests with tagging Significant (failure leads to build failure, unless the Configuration set insignificant) / Insignificant (failure does not lead to build failure)
Data source	Data in SQL database from log files in http://testresults.qt-project.org/ci/
Data update cycle	New builds are updated to database in real time

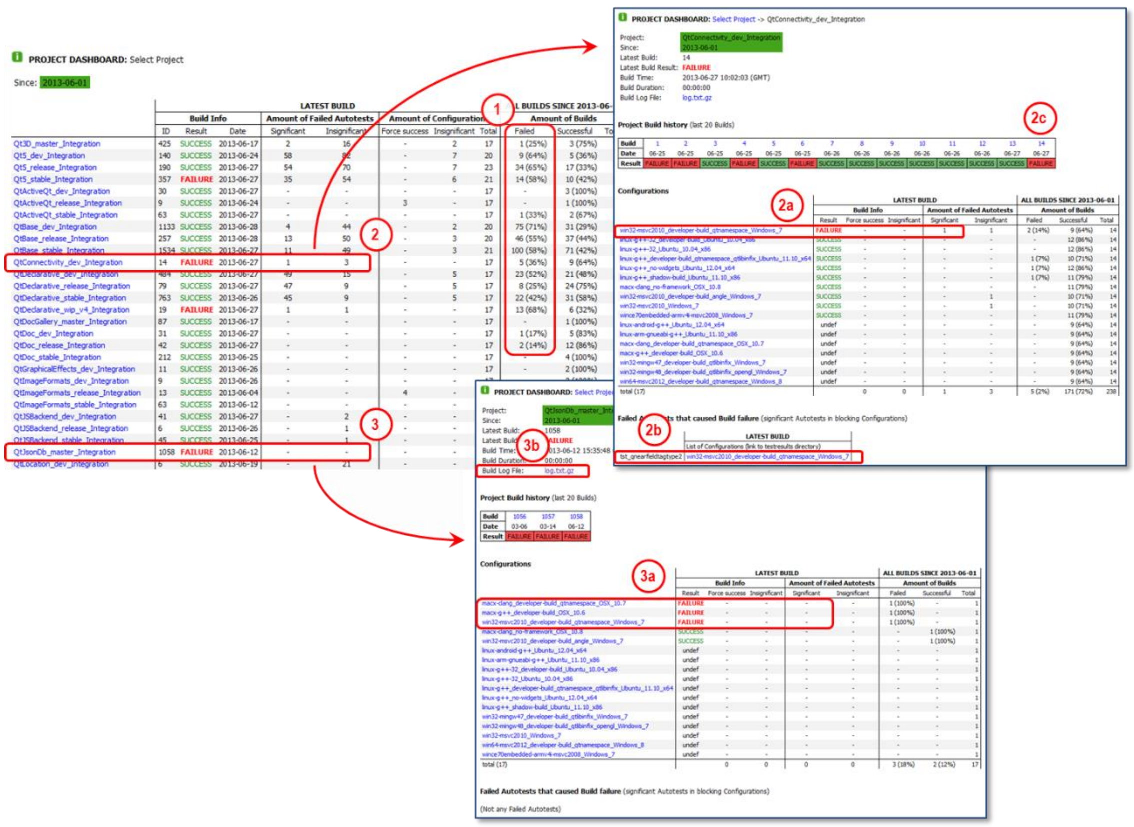
FIGURE 11. Metrics description

4.5.2 Use Cases

This section shows how to use the Qt metrics page for a couple of CI analysis and information study cases.

Check what breaks the CI

First, a filter may be defined by selecting recent builds, for example, the builds of this month. FIGURE 12 below shows an example of the resulting Project dashboard view.



PROJECT DASHBOARD: Select Project

Since: 2013-06-01

	LATEST BUILD								L BUILDS SINCE 2013-06-	
	Build Info			Amount of Failed Autotests		Amount of Configuration			Amount of Builds	
	ID	Result	Date	Significant	Insignificant	Force success	Insignificant	Total	Failed	Successful
Qt3D_master_Integration	425	SUCCESS	2013-06-17	2	16	-	2	17	1 (25%)	3 (75%)
Qt5_dev_Integration	140	SUCCESS	2013-06-24	58	82	-	7	20	9 (64%)	5 (36%)
Qt5_release_Integration	190	SUCCESS	2013-06-27	54	70	-	7	23	34 (65%)	17 (33%)
Qt5_stable_Integration	357	FAILURE	2013-06-27	35	54	-	6	21	14 (58%)	10 (42%)
QtActiveQt_dev_Integration	30	SUCCESS	2013-06-27	-	-	-	-	17	-	3 (100%)
QtActiveQt_release_Integration	9	SUCCESS	2013-06-24	-	-	3	-	17	-	1 (100%)
QtActiveQt_stable_Integration	63	SUCCESS	2013-06-27	-	-	-	-	17	1 (33%)	2 (67%)
QtBase_dev_Integration	1133	SUCCESS	2013-06-28	4	44	-	2	20	75 (71%)	31 (29%)
QtBase_release_Integration	257	SUCCESS	2013-06-28	13	50	-	3	20	46 (55%)	37 (44%)
QtBase_stable_Integration	1534	SUCCESS	2013-06-27	11	49	-	3	21	100 (58%)	71 (42%)
QtConnectivity_dev_Integration	14	FAILURE	2013-06-27	1	3	-	-	17	5 (36%)	9 (64%)
QtDeclarative_dev_Integration	484	SUCCESS	2013-06-27	49	15	-	5	17	23 (52%)	21 (48%)
QtDeclarative_release_Integration	79	SUCCESS	2013-06-27	47	9	-	5	17	8 (25%)	24 (75%)
QtDeclarative_stable_Integration	763	SUCCESS	2013-06-26	45	9	-	5	17	22 (42%)	31 (58%)
QtDeclarative_wip_v4_Integration	19	FAILURE	2013-06-27	1	1	-	-	17	13 (68%)	6 (32%)
QtDocGallery_master_Integration	87	SUCCESS	2013-06-17	-	-	-	-	17	-	1 (100%)
QtDoc_dev_Integration	31	SUCCESS	2013-06-27	-	-	-	-	17	1 (17%)	5 (83%)
QtDoc_release_Integration	42	SUCCESS	2013-06-27	-	-	-	-	17	2 (14%)	12 (86%)
QtDoc_stable_Integration	212	SUCCESS	2013-06-25	-	-	-	-	17	-	4 (100%)
QtGraphicalEffects_dev_Integration	11	SUCCESS	2013-06-26	-	-	-	-	17	-	2 (100%)
QtImageFormats_dev_Integration	9	SUCCESS	2013-06-26	-	-	-	-			
QtImageFormats_release_Integration	13	SUCCESS	2013-06-04	-	-	4	-			
QtImageFormats_stable_Integration	63	SUCCESS	2013-06-12	-	-	-	-			
QtJSBackend_dev_Integration	41	SUCCESS	2013-06-27	-	2	-	-			
QtJSBackend_release_Integration	6	SUCCESS	2013-06-26	-	1	-	-			
QtJSBackend_stable_Integration	45	SUCCESS	2013-06-25	-	1	-	-			
QtJsonDb_master_Integration	1058	FAILURE	2013-06-12	-	-	-	-			
QtLocation_dev_Integration	6	SUCCESS	2013-06-19	-	21	-	-			

PROJECT DASHBOARD: Select Project -> QtConnectivity_dev_Integration

Project:	QtConnectivity_dev_Integration
Since:	2013-06-01
Latest Build:	14
Latest Build Result:	FAILURE
Build Time:	2013-06-27 10:02:03 (GMT)
Build Duration:	00:00:00
Build Log File:	log.txt.gz

Project Build history (last 20 Builds)

Build	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Date	06-25	06-25	06-25	06-25	06-25	06-25	06-26	06-26	06-26	06-26	06-26	06-26	06-27	06-27
Result	FAILURE	FAILURE	SUCCESS	FAILURE	SUCCESS	FAILURE	SUCCESS	SUCCESS	SUCCESS	SUCCESS	SUCCESS	SUCCESS	SUCCESS	FAILURE

Configurations

	LATEST BUILD					ALL BUILDS SINCE 2013-06-01		
	Build Info			Amount of Failed Autotests		Amount of Builds		
	Result	Force success	Insignificant	Significant	Insignificant	Failed	Successful	Total
win32-msvc2010_developer-build_qtnamespace_Windows_7	FAILURE	-	-	1	1	2 (14%)	9 (64%)	14
linux-g++-32_developer-build_Ubuntu_10.04_x86	SUCCESS	-	-	-	-	-	12 (86%)	14
linux-g++-32_Ubuntu_10.04_x86	SUCCESS	-	-	-	-	-	12 (86%)	14
linux-g++_developer-build_qtnamespace_qtlibinfix_Ubuntu_11.10_x64	SUCCESS	-	-	-	-	1 (7%)	10 (71%)	14
linux-g++_no-widgets_Ubuntu_12.04_x64	SUCCESS	-	-	-	-	1 (7%)	12 (86%)	14
linux-g++_shadow-build_Ubuntu_11.10_x86	SUCCESS	-	-	-	-	1 (7%)	11 (79%)	14
macx-clang_no-framework_OSX_10.8	SUCCESS	-	-	-	-	-	11 (79%)	14
win32-msvc2010_developer-build_angle_Windows_7	SUCCESS	-	-	-	1	-	10 (71%)	14
win32-msvc2010_Windows_7	SUCCESS	-	-	-	1	-	10 (71%)	14
wince70embedded-armv4i-msvc2008_Windows_7	SUCCESS	-	-	-	-	-	11 (79%)	14
linux-android-g++_Ubuntu_12.04_x64	undef	-	-	-	-	-	9 (64%)	14
linux-arm-gnueabi-g++_Ubuntu_11.10_x86	undef	-	-	-	-	-	9 (64%)	14
macx-clang_developer-build_qtnamespace_OSX_10.7	undef	-	-	-	-	-	9 (64%)	14
macx-g++_developer-build_OSX_10.6	undef	-	-	-	-	-	9 (64%)	14
win32-mingw47_developer-build_qtlibinfix_Windows_7	undef	-	-	-	-	-	9 (64%)	14
win32-mingw48_developer-build_qtlibinfix_opengl_Windows_7	undef	-	-	-	-	-	9 (64%)	14
win64-msvc2012_developer-build_qtnamespace_Windows_8	undef	-	-	-	-	-	9 (64%)	14
total (17)		0	0	1	3	5 (2%)	171 (72%)	238

Failed A ts that caused Build failure (significant Autotests in blocking Configurations)

	LATEST BUILD
	List of Configurations (link to testresults directory)
tst_qnearfieldtagtype2	win32-msvc2010_developer-build_qtnamespace_Windows_7

PROJECT DASHBOARD: Select Proje

Project:	QtJsonDb_master_Int
Since:	2013-06-01
Latest Build:	1058
Latest Buil	AILURE
Build Time:	013-06-12 15:35:48
Build Duration:	00:00:00
Build Log File:	log.txt.gz

Project Build history (last 20 Builds)

Build	1056	1057	1058
Date	03-06	03-14	06-12
Result	FAILURE	FAILURE	FAILURE

Configurations

	LATEST BUILD					ALL BUILDS SINCE 2013-06-01		
	Build Info			Amount of Failed Autotests		Amount of Builds		
	Result	Force success	Insignificant	Significant	Insignificant	Failed	Successful	Total
macx-clang_developer-build_qtnamespace_OSX_10.7	FAILURE	-	-	-	-	1 (100%)	-	1
macx-g++_developer-build_OSX_10.6	FAILURE	-	-	-	-	1 (100%)	-	1
win32-msvc2010_developer-build_qtnamespace_Windows_7	FAILURE	-	-	-	-	1 (100%)	-	1
macx-clang_no-framework_OSX_10.8	SUCCESS	-	-	-	-	-	1 (100%)	1
win32-msvc2010_developer-build_angle_Windows_7	SUCCESS	-	-	-	-	-	1 (100%)	1
linux-android-g++_Ubuntu_12.04_x64	undef	-	-	-	-	-	-	1
linux-arm-gnueabi-g++_Ubuntu_11.10_x86	undef	-	-	-	-	-	-	1
linux-g++-32_developer-build_Ubuntu_10.04_x86	undef	-	-	-	-	-	-	1
linux-g++-32_Ubuntu_10.04_x86	undef	-	-	-	-	-	-	1
linux-g++_developer-build_qtnamespace_qtlibinfix_Ubuntu_11.10_x64	undef	-	-	-	-	-	-	1
linux-g++_no-widgets_Ubuntu_12.04_x64	undef	-	-	-	-	-	-	1
linux-g++_shadow-build_Ubuntu_11.10_x86	undef	-	-	-	-	-	-	1
win32-mingw47_developer-build_qtlibinfix_Windows_7	undef	-	-	-	-	-	-	1
win32-mingw48_developer-build_qtlibinfix_opengl_Windows_7	undef	-	-	-	-	-	-	1
win32-msvc2010_Windows_7	undef	-	-	-	-	-	-	1
win64-msvc2012_developer-build_qtnamespace_Windows_8	undef	-	-	-	-	-	-	1
wince70embedded-armv4i-msvc2008_Windows_7	undef	-	-	-	-	-	-	1
total (17)		0	0	0	0	3 (18%)	2 (12%)	17

Failed Autotests that caused Build failure (significant Autotests in blocking Configurations)

(Not any Failed Autotests)

FIGURE 12. Use case: Check what breaks the CI

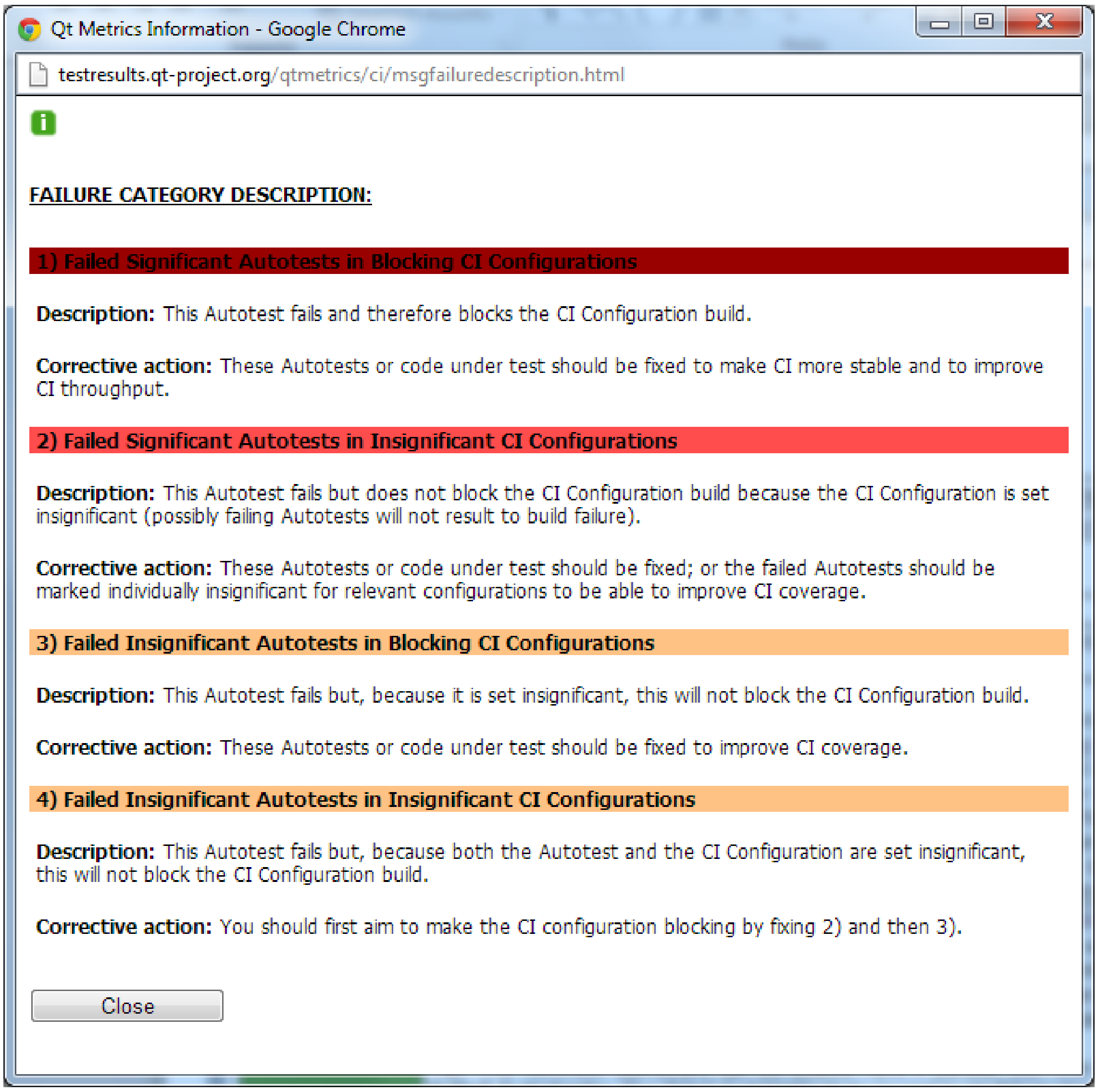
The following can be noticed:

1. Several builds have a fail percentage higher than 50 %
2. The latest QtConnectivity_dev_Integration build have failed with significant autotests
   a. One blocking configuration has failed (and caused several builds to be aborted)
   b. The build failed because the autotest tst_qnearfieldtagtype2 failed
   c. The latest build 14 was a failure after several successful builds. Note that all builds have been made during the past few days
3. The latest QtJsonDb_master_Integration build has failed without any failed autotests
   a. Three configurations have failed

b. The failure reasons can be found in the project log file. To check the log file for each configuration, click each configuration (3a)

Which autotests failed most recently

First, a filter may be defined by selecting recent builds, for example, the builds of the past two weeks. Then the list can be sorted by builds having failure category 1. FIGURE 13 lists the failure categories based on “insignificant” and “force success” flags explained in 2.5 Qt Continuous Integration.


Qt Metrics Information - Google Chrome
testresults.qt-project.org/qtmetrics/ci/msgfailuredescription.html

FAILURE CATEGORY DESCRIPTION:

1) Failed Significant Autotests in Blocking CI Configurations

Description: This Autotest fails and therefore blocks the CI Configuration build.

Corrective action: These Autotests or code under test should be fixed to make CI more stable and to improve CI throughput.

2) Failed Significant Autotests in Insignificant CI Configurations

Description: This Autotest fails but does not block the CI Configuration build because the CI Configuration is set insignificant (possibly failing Autotests will not result to build failure).

Corrective action: These Autotests or code under test should be fixed; or the failed Autotests should be marked individually insignificant for relevant configurations to be able to improve CI coverage.

3) Failed Insignificant Autotests in Blocking CI Configurations

Description: This Autotest fails but, because it is set insignificant, this will not block the CI Configuration build.

Corrective action: These Autotests or code under test should be fixed to improve CI coverage.

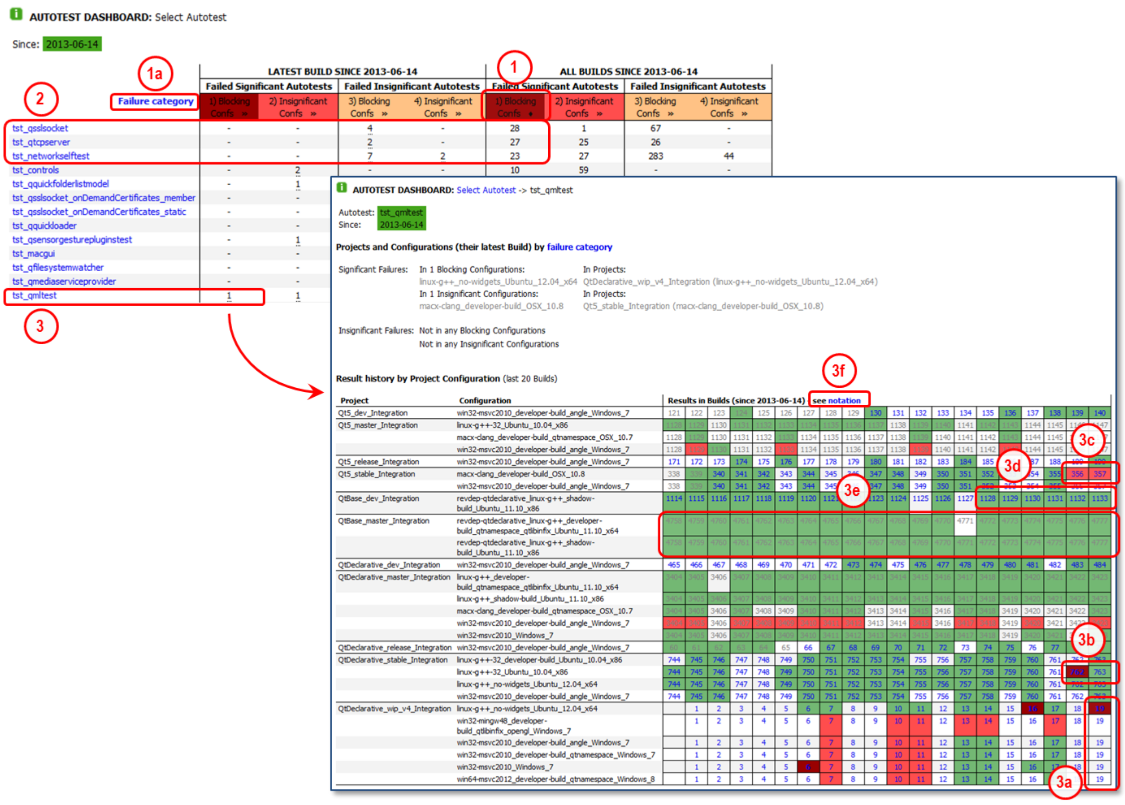
4) Failed Insignificant Autotests in Insignificant CI Configurations

Description: This Autotest fails but, because both the Autotest and the CI Configuration are set insignificant, this will not block the CI Configuration build.

Corrective action: You should first aim to make the CI configuration blocking by fixing 2) and then 3).

FIGURE 13. Failure category description

FIGURE 14 below shows a sample of the resulting autotest dashboard view.


AUTOTEST DASHBOARD: Select Autotest

Since: 2013-06-14

Failure category	LATEST BUILD SINCE 2013-06-14				ALL BUILDS SINCE 2013-06-14			
	Failed Significant Autotests		Failed Insignificant Autotests		Failed Significant Autotests		Failed Insignificant Autotests	
	1) Blocking Confs »	2) Insignificant Confs »	3) Blocking Confs »	4) Insignificant Confs »	1) Blocking Confs ♦	2) Insignificant Confs »	3) Blocking Confs »	4) Insignificant Confs »
tst_qsslsocket	-	-	4	-	28	1	67	-
tst_qtcpserver	-	-	2	-	27	25	26	-
tst_networkselftest	-	-	7	2	23	27	283	44
tst_controls	-	2	-	-	10	59	-	-
tst_qquickfolderlistmodel	-	1						
tst_qsslsocket_onDemandCertificates_member	-	-						
tst_qsslsocket_onDemandCertificates_static	-	-						
tst_qquickloader	-	-						
tst_qsensorgesturepluginstest	-	1						
tst_macgui	-	-						
tst_qfilesystemwatcher	-	-						
tst_qmediaserviceprovider	-	-						
tst_qmltest	1	1						

AUTOTEST DASHBOARD: Select Autotest -> tst_qmltest

Autotest: tst_qmltest
Since: 2013-06-14

Projects and Configurations (their latest Build) by failure category

Significant Failures:	In 1 Blocking Configurations:	In Projects:
	linux-g++_no-widgets_Ubuntu_12.04_x64	QtDeclarative_wip_v4_Integration (linux-g++_no-widgets_Ubuntu_12.04_x64)
	In 1 Insignificant Configurations:	In Projects:
	macx-clang_developer-build_OSX_10.8	Qt5_stable_Integration (macx-clang_developer-build_OSX_10.8)
Insignificant Failures:	Not in any Blocking Configurations	
	Not in any Insignificant Configurations	

Result history by Project Configuration (last 20 Builds)

Project	Configuration	Results in Builds (since 2013-06-14) see notation																			
Qt5_dev_Integration	win32-msvc2010_developer-build_angle_Windows_7	121	122	123	124	125	126	127	128	129	130	131	132	133	134	135	136	137	138	139	140
Qt5_master_Integration	linux-g++-32_Ubuntu_10.04_x86	1128	1129	1130	1131	1132	1133	1134	1135	1136	1137	1138	1139	1140	1141	1142	1143	1144	1145	[illegible]	1147
	macx-clang_developer-build_qtnamespace_OSX_10.7	1128	1129	1130	1131	1132	1133	1134	1135	1136	1137	1138	1139	1140	1141	1142	1143	1144	1145	[illegible]	[illegible]
	win32-msvc2010_developer-build_angle_Windows_7	1128	1129	1130	1131	1132	1133	1134	1135	1136	1137	1138	1139	1140	1141	1142	[illegible]	1144	1145	[illegible]	[illegible]
Qt5_release_Integration	win32-msvc2010_developer-build_angle_Windows_7	171	172	173	174	175	176	177	178	179	180	181	182	183	184	185	[illegible]	[illegible]	188	[illegible]	[illegible]
Qt5_stable_Integration	macx-clang_developer-build_OSX_10.8	338	339	340	341	342	343	344	345	[illegible]	347	348	349	350	351	352	[illegible]	[illegible]	355	356	357
	win32-msvc2010_developer-build_angle_Windows_7	338	339	340	341	342	343	344	345	[illegible]	347	348	349	350	351	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
QtBase_dev_Integration	revdep-qtdeclarative_linux-g++_shadow-build_Ubuntu_11.10_x86	1114	1115	1116	1117	1118	1119	1120	[illegible]	[illegible]	1123	1124	1125	1126	1127	1128	1129	1130	1131	1132	1133
QtBase_master_Integration	revdep-qtdeclarative_linux-g++_developer-build_qtnamespace_qtlibinfix_Ubuntu_11.10_x64	4758	4759	4760	4761	4762	4763	4764	4765	4766	4767	4768	4769	4770	4771	4772	4773	4774	4775	4776	4777
	revdep-qtdeclarative_linux-g++_shadow-build_Ubuntu_11.10_x86	4758	4759	4760	4761	4762	4763	4764	4765	4766	4767	4768	4769	4770	4771	4772	4773	4774	4775	4776	4777
QtDeclarative_dev_Integration	win32-msvc2010_developer-build_angle_Windows_7	465	466	467	468	469	470	471	472	473	474	475	476	477	478	479	480	481	482	483	484
QtDeclarative_master_Integration	linux-g++_developer-build_qtnamespace_qtlibinfix_Ubuntu_11.10_x64	3404	3405	3406	3407	3408	3409	3410	3411	3412	3413	3414	3415	3416	3417	3418	3419	3420	3421	3422	3423
	linux-g++_shadow-build_Ubuntu_11.10_x86	3404	3405	3406	3407	3408	3409	3410	3411	3412	3413	3414	3415	3416	3417	3418	3419	3420	3421	3422	3423
	macx-clang_developer-build_qtnamespace_OSX_10.7	3404	3405	3406	3407	3408	3409	3410	3411	3412	3413	3414	3415	3416	3417	3418	3419	3420	3421	3422	3423
	win32-msvc2010_developer-build_angle_Windows_7	3404	3405	3406	3407	3408	3409	3410	3411	3412	3413	3414	3415	3416	3417	3418	3419	3420	3421	[illegible]	3423
	win32-msvc2010_Windows_7	3404	3405	3406	3407	3408	3409	3410	3411	3412	3413	3414	3415	3416	3417	3418	3419	3420	3421	[illegible]	[illegible]
QtDeclarative_release_Integration	win32-msvc2010_developer-build_angle_Windows_7	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	[illegible]	[illegible]
QtDeclarative_stable_Integration	linux-g++-32_developer-build_Ubuntu_10.04_x86	744	745	746	747	748	749	750	751	752	753	754	755	756	757	758	759	760	761	[illegible]	[illegible]
	linux-g++-32_Ubuntu_10.04_x86	744	745	746	747	748	749	750	751	752	753	754	755	756	757	758	759	760	761	762	763
	linux-g++_no-widgets_Ubuntu_12.04_x64	744	745	746	747	748	749	750	751	752	753	754	755	756	757	758	759	760	761	[illegible]	[illegible]
	win32-msvc2010_developer-build_angle_Windows_7	744	745	746	747	748	749	750	751	752	753	754	755	756	757	758	759	760	761	762	[illegible]
QtDeclarative_wip_v4_Integration	linux-g++_no-widgets_Ubuntu_12.04_x64		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
	win32-mingw48_developer-build_qtlibinfix_opengl_Windows_7		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
	win32-msvc2010_developer-build_angle_Windows_7		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
	win32-msvc2010_developer-build_qtnamespace_Windows_7		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
	win32-msvc2010_Windows_7		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	[illegible]	[illegible]	19
	win64-msvc2012_developer-build_qtnamespace_Windows_8		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	[illegible]	[illegible]	19

FIGURE 14. Use case: Check which autotests failed most recently

The following can be noticed:

1. The list is sorted by failure category 1 for all the builds since the selected date
    a. See detailed description for failure categories
2. The top three failed autotests during the last two weeks
3. The tst_qmltest is studied here in more detail because it blocked the latest build
    a. The configuration build that this autotest blocked (dark red); the other on-going or waiting builds were aborted and the autotest itself does not have a result (white)
    b. This autotest blocked the previous configuration build but was successful in the latest one
    c. The autotest failed also in another configuration build but did not block it because the configuration has been flagged as insignificant (red); note that the

configuration build itself may have failed or been successful depending on other criteria

d. The successful configuration builds (green)
e. These builds have been made before the selected date (grey text)
f. See detailed description for the notation used in the table

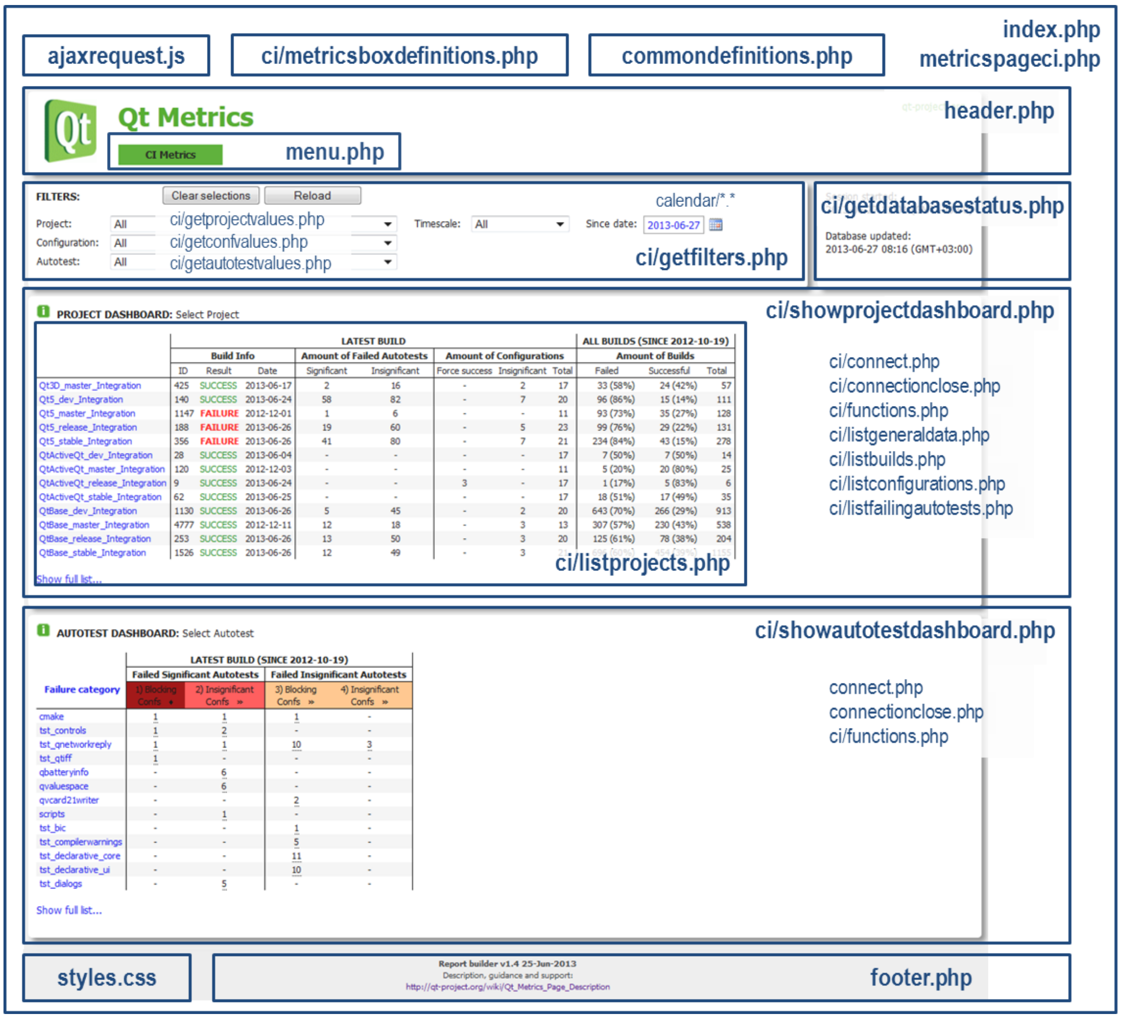
4.6 Implementation

This section discusses the Qt metrics system components and their implementation into a certain level of detail in the developer point of view.

4.6.1 Report Builder

Logically the report builder implementation has two separate components. One is controlling the page layout, including header, footer and metrics pages menu, as well as the AJAX functionality on a single metrics page. The other is the metrics box generating the report or metrics content itself, and it is called by using the AJAX. One metrics page can include several metrics boxes, and the system has been designed so that it is easy to add new metrics boxes, basically just by listing a metrics box source code file into a configuration file.

The initial report builder implementation consists of one metrics page, CI metrics, having a filter box, status box and two metrics boxes, Project dashboard and Autotest dashboard. The file structure of the implementation is illustrated in FIGURE 15 and FIGURE 16.



Project: All
Configuration: All
Autotest: All
Timescale: All
Since date: 2013-06-27

Database updated:
2013-06-27 08:16 (GMT+03:00)

PROJECT DASHBOARD: Select Project

	LATEST BUILD								ALL BUILDS (SINCE 2012-10-19)		
	Build Info			Amount of Failed Autotests		Amount of Configurations			Amount of Builds		
	ID	Result	Date	Significant	Insignificant	Force success	Insignificant	Total	Failed	Successful	Total
Qt3D_master_Integration	425	SUCCESS	2013-06-17	2	16	-	2	17	33 (58%)	24 (42%)	57
Qt5_dev_Integration	140	SUCCESS	2013-06-24	58	82	-	7	20	96 (86%)	15 (14%)	111
Qt5_master_Integration	1147	FAILURE	2012-12-01	1	6	-	-	11	93 (73%)	35 (27%)	128
Qt5_release_Integration	188	FAILURE	2013-06-26	19	60	-	5	23	99 (76%)	29 (22%)	131
Qt5_stable_Integration	356	FAILURE	2013-06-26	41	80	-	7	21	234 (84%)	43 (15%)	278
QtActiveQt_dev_Integration	28	SUCCESS	2013-06-04	-	-	-	-	17	7 (50%)	7 (50%)	14
QtActiveQt_master_Integration	120	SUCCESS	2012-12-03	-	-	-	-	11	5 (20%)	20 (80%)	25
QtActiveQt_release_Integration	9	SUCCESS	2013-06-24	-	-	3	-	17	1 (17%)	5 (83%)	6
QtActiveQt_stable_Integration	62	SUCCESS	2013-06-25	-	-	-	-	17	18 (51%)	17 (49%)	35
QtBase_dev_Integration	1130	SUCCESS	2013-06-26	5	45	-	2	20	643 (70%)	266 (29%)	913
QtBase_master_Integration	4777	SUCCESS	2012-12-11	12	18	-	3	13	307 (57%)	230 (43%)	538
QtBase_release_Integration	253	SUCCESS	2013-06-26	13	50	-	3	20	125 (61%)	78 (38%)	204
QtBase_stable_Integration	1526	SUCCESS	2013-06-26	12	49	-	3	21	696 (60%)	454 (39%)	1155

Show full list...

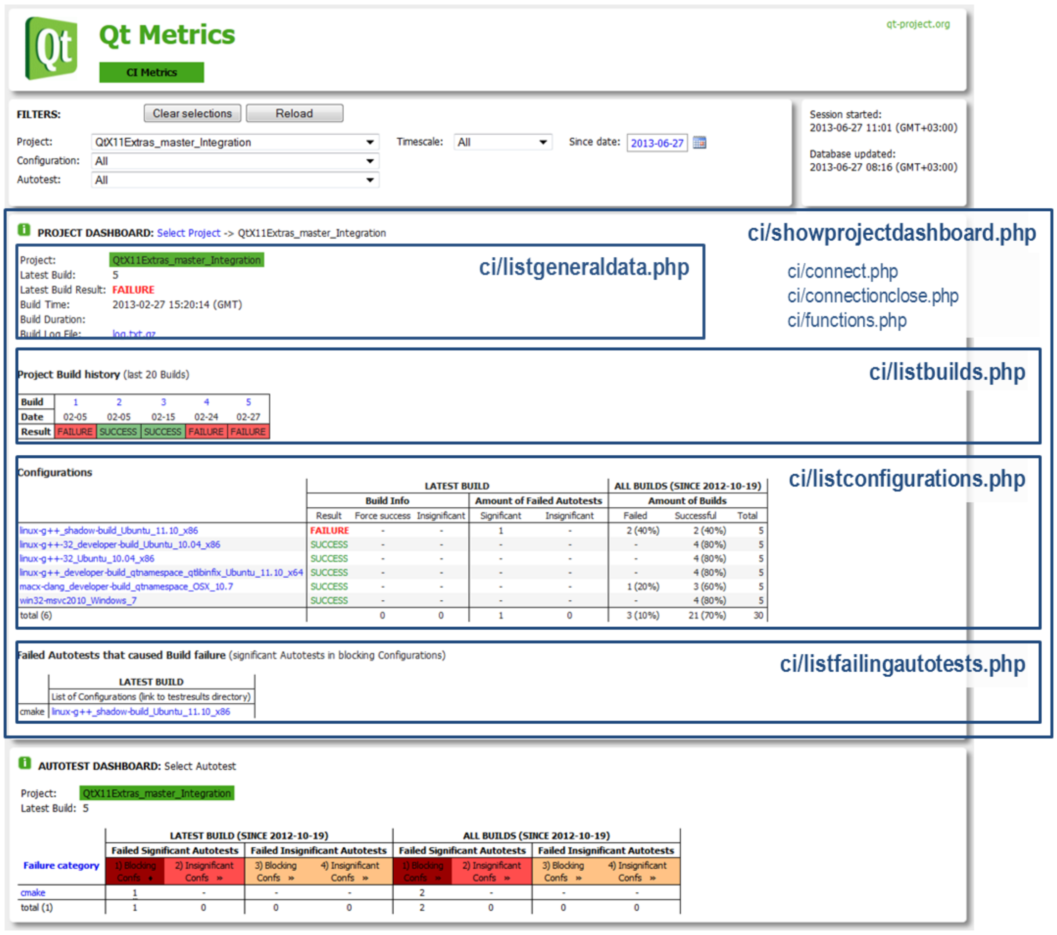
AUTOTEST DASHBOARD: Select Autotest

	LATEST BUILD (SINCE 2012-10-19)			
	Failed Significant Autotests		Failed Insignificant Autotests	
Failure category	1) Blocking Confs	2) Insignificant Confs »	3) Blocking Confs »	4) Insignificant Confs »
cmake	1	1	1	-
tst_controls	1	2	-	-
tst_qnetworkreply	1	1	10	3
tst_qtiff	1	-	-	-
qbatteryinfo	-	6	-	-
qvaluespace	-	6	-	-
qvcard21writer	-	-	2	-
scripts	-	1	-	-
tst_bic	-	-	1	-
tst_compilerwarnings	-	-	5	-
tst_declarative_core	-	-	11	-
tst_declarative_ui	-	-	10	-
tst_dialogs	-	5	-	-

Show full list...

Report builder v1.4 25-Jun-2013
Description, guidance and support:
http://qt-project.org/wiki/Qt_Metrics_Page_Description

FIGURE 15. Report builder file structure, the default web view (level 1)



Qt Metrics

CI Metrics

qt-project.org

FILTERS: Clear selections Reload

Project: QtX11Extras_master_Integration

Configuration: All

Autotest: All

Timescale: All

Since date: 2013-06-27

Session started:
2013-06-27 11:01 (GMT+03:00)

Database updated:
2013-06-27 08:16 (GMT+03:00)

PROJECT DASHBOARD: Select Project -> QtX11Extras_master_Integration

ci/showprojectdashboard.php

ci/connect.php
ci/connectionclose.php
ci/functions.php

ci/listgeneraldata.php

Project: QtX11Extras_master_Integration
Latest Build: 5
Latest Build Result: FAILURE
Build Time: 2013-02-27 15:20:14 (GMT)
Build Duration:
Build Log File: log.txt.gz

ci/listbuilds.php

Project Build history (last 20 Builds)

Build	1	2	3	4	5
Date	02-05	02-05	02-15	02-24	02-27
Result	FAILURE	SUCCESS	SUCCESS	FAILURE	FAILURE

ci/listconfigurations.php

Configurations

	LATEST BUILD					ALL BUILDS (SINCE 2012-10-19)		
	Build Info			Amount of Failed Autotests		Amount of Builds		
	Result	Force success	Insignificant	Significant	Insignificant	Failed	Successful	Total
linux-g++_shadow-build_Ubuntu_11.10_x86	FAILURE	-	-	1	-	2 (40%)	2 (40%)	5
linux-g++-32_developer-build_Ubuntu_10.04_x86	SUCCESS	-	-	-	-	-	4 (80%)	5
linux-g++-32_Ubuntu_10.04_x86	SUCCESS	-	-	-	-	-	4 (80%)	5
linux-g++_developer-build_qtnamespace_qtlibinfix_Ubuntu_11.10_x64	SUCCESS	-	-	-	-	-	4 (80%)	5
macx-clang_developer-build_qtnamespace_OSX_10.7	SUCCESS	-	-	-	-	1 (20%)	3 (60%)	5
win32-msvc2010_Windows_7	SUCCESS	-	-	-	-	-	4 (80%)	5
total (6)		0	0	1	0	3 (10%)	21 (70%)	30

ci/listfailingautotests.php

Failed Autotests that caused Build failure (significant Autotests in blocking Configurations)

	LATEST BUILD
	List of Configurations (link to testresults directory)
cmake	linux-g++_shadow-build_Ubuntu_11.10_x86

AUTOTEST DASHBOARD: Select Autotest

Project: QtX11Extras_master_Integration
Latest Build: 5

	LATEST BUILD (SINCE 2012-10-19)				ALL BUILDS (SINCE 2012-10-19)			
	Failed Significant Autotests		Failed Insignificant Autotests		Failed Significant Autotests		Failed Insignificant Autotests	
Failure category	1) Blocking Confs	2) Insignificant Confs »	3) Blocking Confs »	4) Insignificant Confs »	1) Blocking Confs »	2) Insignificant Confs »	3) Blocking Confs »	4) Insignificant Confs »
cmake	1	-	-	-	2	-	-	-
total (1)	1	0	0	0	2	0	0	0

FIGURE 16. Report builder file structure, a project selected in the Project dashboard (level 2)

4.6.2 Database and Parser

The database is a MySQL database consisting of the tables listed below in TABLE 2. All tables use MyISAM storage engine. The database is running on the Qt testresults server (Solaris) on the qt-project.org domain.

TABLE 2. Database tables

Table	Purpose	Fields	Examples
ci	Project build results	project	QtBase_stable_Integration
		build_number	1182
		result	SUCCESS
		timestamp	2013-05-14 13:01:02 (GMT)
		duration	02:11:33
cfg	Configuration build results for each Project	cfg	linux-g++-32_Ubuntu_10.04_x86
		project	QtBase_stable_Integration
		build_number	1182
		result	SUCCESS
		forcesuccess	0 (= build not forced to succeed)
		insignificant	1 (=build does not fail even in case of autotest failures)
		total_autotests	411
		timestamp	2013-05-14 13:01:02 (GMT)
		duration	00:29:49
test	Failed autotests in each Configuration build	name	tst_qgl
		project	QtBase_stable_Integration
		build_number	1182
		cfg	linux-g++-32_Ubuntu_10.04_x86
		insignificant	1 (= build does not fail if this autotest fails)
		timestamp	2013-05-14 13:01:02 (GMT)
phases	Build phases and time for each Configuration build	project	QtBase_stable_Integration
		build_number	1182
		cfg	linux-g++-32_Ubuntu_10.04_x86
		phase	testing qtbase
		parent	(empty means first level phase)
		start	2013-05-14 14:02:12 (GMT)
		end	2013-05-14 14:30:44 (GMT)
generic	Database update status and date	rebuild	1 (= rebuilding in progress; single scan, full scan or catch up)
		date	2013-05-28 10:40:40 (GMT)
		current	10 (= number of log files parsed)
		total	88 (= number of log files to parse)

The database table fields and their types are shown in FIGURE 17.

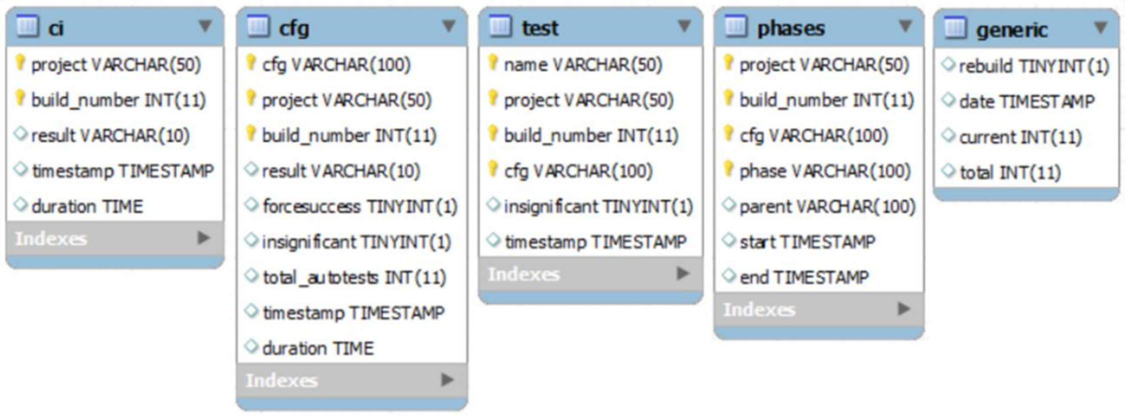


FIGURE 17. Database tables, and their fields and field types

The tables are independent and not linked with each other. This denormalization is done on purpose for performance reasons and for the sake of simplicity. The combination of multiple primary keys in each table uniquely identifies each row in the tables to ensure that there is no duplicate data in the database. The data consistency between the tables is taken care by the parser. The database is not indexed at the moment, apart from the use of the primary keys.

New data is added to the database only by the parser. For CI, data is inserted from the new log files when a new build has completed. This method is called a “single scan”. The data already in the database is never updated since build results never change after a build. However, if there is a need for example to add a new database field or to change a field type, the whole database must be rebuilt from the log files. This method is referred as a “full scan”. There is also a “catch up” method to compare the database against the build log files residing in the server, and to add the possibly missing data. This is needed for example if single scan operations failed for some reason.

4.6.3 Key Functionality

The implementation details for following functionalities are explained below:

- Initial loading of the page
- Selecting a filter to update metrics box(es)

- Database status indication
- Flat vs. nested metrics boxes

More explanations are available at http://qt-project.org/wiki/Qt_Metrics_Page_Description with their code samples.

Initial loading of the page

The initial loading of the page for the first time is processed in the following chronological order:

1. The database status displays a welcome text. If a database update is in progress, it is indicated.
2. Filters are loaded with their values from the database. The project, configuration and autotest filter values are read from the database and stored into session variables. In addition, detailed data is read and stored for each project (for example latest build number, result and timestamp). Session variables are used to improve performance so that it is not required to read all the basic data every time the page is loaded (in other words, when the user selects a filter or item link to update his/her view). If the session variables already exist, the filters are not read from the database again.
3. Metrics boxes are loaded with their content. The metrics boxes are loaded only after the filter box is ready in order to ensure that the project, configuration and autotest values are available in the session variables. Unfortunately this causes some waiting time when loading the page for the first time. However, the subsequent page updates are then faster.
4. The database status is updated with session start time and database update time.

Selecting a filter to update metrics box(es)

The metrics boxes are updated whenever a filter value is changed, without a separate confirmation button. The defined metrics boxes are looped and if set to apply the selected filter, an AJAX request is sent to load the metrics box content.

Content is loaded by content generating PHP files (here ci/showprojectdashboard.php and ci/showautotestdashboard.php) which read the required data from the database and arrange the information into readable report format. The filter parameters (project, configuration, autotest etc.) are passed to the content generating PHP files with the HTML GET method where the variable and its value are sent in the URL with the requested PHP page. The content generating PHP file can use these parameters to scope the database searches. When the content is ready the related metrics box div is updated.

The database status box is updated after every metrics box update to show the possible status change in the database to the user during her or his session.

It is up to the metrics box definition and implementation what data is needed and in what layout and appearance to use. The table format used in the initial dashboard PHP files is recommended for similar type of reports.

Database status indication

The last database update time as well as a possible ongoing update is stored into a generic table in the database. In addition to the welcome text in the database status box three different cases are indicated to the user.

In the normal case the session start time and the database update time are shown. First special case is when the database has been updated after a user session start, for instance a single scan update was done while the user was studying the metrics box information. Here the database update time is compared with the session start time. The session start time and database update time are displayed, together with a “New data available” message.

Second special case is when the database update is in progress, either during the initial loading of the page or when the Qt metrics page is used. Here the generic table holds the flag that an update is in progress, and records the timestamp of the update. The database update progress is shown as a currently ongoing step compared to the total number of steps, with a link to refresh the progress information.

Flat vs. nested metrics boxes

The difference between a “flat” and a “nested” metrics box is mostly about usability. A “flat” box uses filters from the filter box only, while a “nested” box has item links that can be used to drill down to the next level for more detailed information on that specific item. Currently both Project dashboard and Autotest dashboard use the “nested” style where clicking an item link is actually the same as selecting a value from the filter. The only difference is that the filters have all the values listed that are available in the database while the boxes list only a portion of the items that valid only for that specific view. A clickable link is added to the each item name which calls the related filtering function like when using the filter selection boxes.

4.7 Development and Maintenance

As listed in 4.1 Requirements, one important goal for the metrics system was to enable anyone in the Qt developer community to able to create new reports to the metrics pages. The report builder implementation follows that principle in its design, directory and file structure, and in the components that were built, many of which were already described in 4.6.3 Key Functionality. This section describes a few typical development and maintenance cases as a supplement to the detailed implementation description in 4.6 Implementation.

4.7.1 Directory Structure and Naming Conventions

To keep the system manageable the following rules of directory usage and file naming conventions are recommended, as used in FIGURE 15 and FIGURE 16.

The common files like header.php, menu.php, commondefinitions.php and styles.css are located in the main level directory, as well as the metrics page files that collect the page payout (here the metricspageci.php). Images and common components, the calendar for example, use their own subfolders. The files that are specific to a metrics page should be stored into a dedicated subfolder, like “ci” for the CI Metrics page here.

A few file naming conventions should be followed. Metrics page files should use name “metricspageTITLE.php”, where TITLE indicates the page content and purpose. Metrics box files should be named "showBOXNAME.php", where BOXNAME indicates the content and usage of the related metrics box. If the metrics box has been implemented using several files, it may be practical to use files names like "listSECTIONNAME" for those. Files that get the data for the filters from the database are called "getFILTERFIELD.php". The metrics description files use format "msgBOXORDESCRIPTIONNAME.html". Note that all file names are written in lower case. The file extension depends naturally on the implementation of each file.

The detailed list of current directories and files is shown in TABLE 3.

TABLE 3. List of directories and files

Folder/File	**Purpose**
(main folder)	Common implementation files
ajaxrequest.js	JavaScript file for sending and receiving the AJAX requests
commondefinitions.php	Definitions for common flags and values
connect.php	To establish the MySQL connection
connectionclose.php	To close the MySQL connection (code currently commented out)
connectiondefinitions.php	Database server definitions and flags for MySQL API and connection type
footer.php	Footer area
header.php	Header area
index.php	Default file redirecting to metricspageci.php
menu.php	Main menu of metrics pages
metricspageci.php	CI Metrics page implementation
styles.css	Common style definitions
calendar/	Calendar component from http://www.triconsole.com/php/calendar_datepicker.php
ci/	CI Metrics page implementation files
ci/calendar/	Directory for one calendar component image
ci/functions.php	Common functions used in CI Metrics implementation
ci/getautotestvalues.php	To load all the autotest values from database
ci/getconfvalues.php	To load all the configuration values from database
ci/getdatabasestatus.php	To load the database status, for example the time of update, from the database
ci/getfilters.php	To layout the filters and call files to load the filter values
ci/getprojectvalues.php	To load all the project values from database
ci/listbuilds.php	To show the project and configuration build history in project dashboard (level 2 and 3)
ci/listconfigurations.php	To show the configurations in project dashboard (level 2)
ci/listfailingautotests.php	To show the failed autotests in project dashboard (level 2 and 3)
ci/listgeneraldata.php	To show the general data for project and configuration build in project dashboard (level 2 and 3)
ci/listprojects.php	To show the projects in project dashboard (level 1)

ci/metricsboxdefinitions.php	To list the metrics boxes and define their functionality regarding to the filters
ci/msgautotestdashboardlevel1.html	Metrics description for autotest dashboard (level 1)
ci/msgautotestdashboardlevel2.html	Metrics description for autotest dashboard (level 2)
ci/msgautotestresultdescription.html	Description for autotest result history notation used in autotest dashboard (level 2)
ci/msgfailuredescription.html	Description for autotest failure categories used in autotest dashboard (level 1 and 2)
ci/msgprojectdashboardlevel1.html	Metrics description for project dashboard (level 1)
ci/msgprojectdashboardlevel2.html	Metrics description for project dashboard (level 2)
ci/msgprojectdashboardlevel3.html	Metrics description for project dashboard (level 3)
ci/showautotestdashboard.php	Autotest dashboard metrics box implementation (all sections in the same file)
ci/showprojectdashboard.php	Project dashboard metrics box implementation (separate sections implemented in their own files)
images/	Directory for common images like logos and icons

4.7.2 Modifying the Existing Metrics

Cases may arise where the content or the layout of an existing metrics box report needs to be changed. The file to locate the implementation can be found in TABLE 3. Generally, the change may typically be involved with a request to include new or changed information to the data tables, or to include new data from the database. In the first case special attention is needed to keep the resulting HTML script for the data table in order, for example a new column must be added to every row of the table. In the latter case, the MySQL command needs to be changed. A good practice is to test the refined MySQL command with a live database connection first. If metrics box content is changed the affected description HTML file, if any, should be updated accordingly.

The layout of the data is defined by the selection of the columns in the table and by the common CSS style definitions. It is recommended to use the HTML5 approach to make the style definitions in the CSS file instead of in the PHP (or HTML) code. The HTML markup validator (http://validator.w3.org/) and the CSS validator (http://jigsaw.w3.org/css-validator/) should be utilized for the resulting HTML code.

The report builder version in the footer (footer.php) should be updated on every change.

4.7.3 Create New Metrics Box

The current metrics boxes, ci/showprojectdashboard.php or ci/showautotestdashboard.php, can be used as a basis for a new metrics box implementation. The difference between those current implementations is that the project dashboard uses an approach of multiple files, while the autotest dashboard is implemented to a single file.

There are a few recommendations to ensure a common look'n'feel:

1. Close to the title, there should be link to a description window (the "i" icon).
2. The filtered value(s) that affects the content should be shown in the title row in case of a nested metrics box. In addition, the filtered value(s) should appear as table as the first part of the content. This may include also other common information related to the metrics box.
3. It is recommended to use a table format for the information.
4. A nested metrics box should have the values and filter links in the leftmost column.
5. Defined green and red text colors and backgrounds (in styles.css) should be used to indicate "ok" and "not ok" data.
6. Rows in a table are colored differently on every other row for better readability.
7. The length of the content in a box, when initially loading the page, should not be too long, in order not to hide the other metrics boxes. The consequent page loadings may show the full content.

A new metrics box requires only the implementation file(s) and its definition in the ci/metricsboxdefinitions.php. As discussed earlier, the definition includes the behavior regarding the filter changes. Here a new metrics box, implemented in ci/showsomenewbox.php, will be automatically updated when the project filter is changed but will not react to the other filters:

```
$arrayMetricsBoxesCI = array (
   // Fields: File path and name, Applied filters, Filters to clear when other applied ones change
   array("ci/showprojectdashboard.php" ,"Project,Configuration,Timescale", ""),
   array("ci/showautotestdashboard.php", "All", "Autotest"),
   array("ci/showsomenewbox.php", "Project", "")
);
```

4.7.4 Add New Data to Database

Only the parser adds data into the database. If new data fields are needed to the database while specifying or implementing new content of the existing or new metrics boxes or pages, a change request to the parser is needed. The change request should include information as to whether the new data is already available, for example in some log files, or whether the change requires a change to the log files.

One issue for the current MySQL database is the size. The size of the database tables should be kept under control. Change requests should take this into account. In addition, as new data is added to the database on a daily basis, the database size increases continuously. This issue is solved by cleaning old data from the database regularly because the metrics system use cases do not require long history trends as such. In practice, this means that a history of only four months should be kept in the database. The parser takes care of this functionality.

4.7.5 Quality Assurance

The following actions have been identified, and used in the current implementation, to ensure the quality of the change commits.

Qt Commit Policy (http://qt-project.org/wiki/Commit_policy), Qt Coding Style (http://qt-project.org/wiki/Qt_Coding_Style) and Qt Coding Conventions (http://qt-project.org/wiki/Coding-Conventions) should be used where applicable for the PHP, HTML and CSS implementation, and for others if used.

As a general rule for all Qt contributions, it is important to make atomic commits. That means that each commit should contain exactly one self-contained change. Unrelated changes, or new functionality and error corrections, must not be mixed. Likewise, unrelated small fixes, for example to coding style, should not be hidden in bigger commits, but to should be handled in a separate commit. Small changes also make the review process easier so that a single person is able to approve a change to a single component, compared to a change touching multiple parts of code which requires multiple approvers as well because a single person does not feel comfortable to approve the changes that are not in his or her responsibility.

It is recommended to follow the HTML5 standard and use the HTML5/CSS3 approach for example to make the style definitions in the CSS file instead of in the PHP or HTML code. The HTML markup validator (http://validator.w3.org/) and the CSS validator (http://jigsaw.w3.org/css-validator/) by the W3C should be utilized for the resulting HTML code. As the metrics boxes are filled by AJAX functionality, the direct page URL cannot be used in this case. Instead, for the HTML markup validator, the "Validate by Direct Input" option must be used for the resulting HTML code. It must be noted that the validation is made to the exact content visible on the page. Therefore all applicable views must be validated separately to make the validation coverage as high as possible.

The Gerrit early warning system will make certain checks to the code (29). It is a good practice to make the check before pushing the changes to Gerrit to avoid unnecessary fix patches. A sanitizer tool, a script made with Perl, can be used for that.

The development of the Qt metrics system can be done using any available web development environment that supports PHP and MySQL, like XAMPP, LAMP or WAMP via EasyPHP, for example. Sample data should be stored into MySQL database tables. It is important to use different variations of data to cover all the cases and paths in the implementation. This typically requires modifications or additions to the real data to simplify the testing. In addition, the changes can be verified on the Qt testresults server in a specific verification folder before submitting changed code.

Verification in all major browsers is essential for any web based service. The Qt metrics system has been designed for large screen web browsers, although the visible content area has been defined to be as narrow as possible for the content used. All changes should be verified at least with the following browsers: Chrome, Firefox, Opera, IE and Safari. Use of different operating systems and browser versions, as well as mobile browsers, is also recommended. However, it must be noted that the Qt metrics system implementation does not follow responsive design to adjust to different screen resolutions. Hence, still keeping the functionality available, some minor imperfections for instance in the layout may be allowed in small screen browsers. It is proposed to list the verified browsers in the Gerrit commit description.

4.7.6 Submitting Code

The development of the Qt metrics system can be done on any server environment that supports PHP and MySQL. A Qt repository is then used to make the implemented open source code publically available, in this case the master branch of the qtqa/sysadmin repository in the sysadmin/non-puppet/qtmetrics folder. The submissions follow the common Qt contribution guidelines (http://qt-project.org/wiki/Qt-Contribution-Guidelines) including the use of the Gerrit code review tool (https://codereview.qt-project.org). Once the approved changes in a commit have been merged in Git, the changes will be pushed to the Qt testresults server on the qt-project.org by the CI team, and finally become visible to the users of the Qt metrics system. To summarize, the development environment, the controlled source code repository and the server running the Qt metrics system are all isolated from each other. This ensures that only approved changes will be integrated and that the running system remains stable.

The steps to make changes and submit Qt metrics system code to the Gerrit code review tool are as follows (31):

1. Get the latest code from the Qt repository used to local work area
2. Make the changes in the local work area
3. Add files to Git change tracking
4. Make the commit package including a change description
5. Run the sanitizer to check the early warning system messages before pushing the changes forward. Fix the errors, if any, and re-run the sanitizer.
6. Push changes to Gerrit
7. Request contribution feedback by adding reviewers to the change in the Gerrit code review tool. In case corrections are needed, create a fix patch by repeating the steps 2 to 6 until the change is approved and moved to Staged status.

4.7.7 Security and Data Validation

The source data used in the Qt metrics system is publicly available. The log files for the CI metrics page, for example, can be found at http://testresults.qt-project.org/ci/. Hence the data itself does not need any additional user access control. The report builder of the Qt metrics system uses one user id to read the data from the database. This user has only a read access to the database. The parser uses the Qt integrator user id, with a SSH private key, to store the data to the database. The database cannot be accessed outside the Qt testresults server, where both the report builder and the parser reside. Because the data is not confidential and it is never modified by the user, the current level of security is considered sufficient. This could be changed if needs arise.

The parser takes care of the data validation when reading the log files for example by repairing the data to be stored in case of possible errors or corrupted data in the logs. The data consistency between the database tables is taken care of by the parser as well. The MySQL DBMS ensures that duplicate data is not stored into the database by using primary keys in the database tables.

4.8 Project Management Practices

The development team, or pair, consisted of Tony Sarajärvi, the CI Technical Lead in Digia, and Juha Sippola, student at Oulu University of Applied Sciences (Oulu UAS). Tony was responsible for the back-end solutions, including the parser and the database, as well as required server set-ups and configurations. He also introduced the used practices and tools, and acted as the commissioner supervisor of the thesis work. Student Juha Sippola was responsible for the front-end solutions, including the report builder and the web interface, as well as the database structure and its refactoring. In addition, Juha created the required documentation into the Qt Project wiki.

The development process used in the project followed the six-phase approach, described in 3.1.2 Development Process, where applicable. The information gathering phase was mostly already done in the form of target setting for the metrics system. Original idea had been to implement the system by Digia employees, but there was not high enough priority nor budgetary sponsorship available for that plan. The first meeting in Digia focused on sharing the background information, target audience and the resources available. After the official project start the communication methods were agreed to cover discussions, weekly reports via email, and general information sharing towards Digia and the school. However, major part of the work itself planned be done in Digia premises.

In the strategy phase the CI process and the available source data were studied and the possible solutions were brainstormed within the project team. The system architecture was defined and split to front-end and back-end solutions. Finally, the technical solutions were selected (see 4.3 Framework and Tool Selection).

The prototyping phase was done by implementing a live demo system, separately and concurrently for the front-end and back-end. The front-end report builder implementation used the Oulu UAS web and database server environment while the back-end used a local WAMP environment with real data from the CI build log files. Partial real data was exported from the WAMP and imported to Oulu UAS environment to stay in synch with the database table and data structures. The metrics system web interface was publicly available both to the project team and to key stakeholders in Digia for testing as well as for commenting the information design and the interface features. The user controls in the UI and the content of the reports and metrics were refined during the prototyping phase based on the user comments. For example, the concept of nested metrics box was invented. The metrics system was called a “demo” at this phase. The selected solution was evaluated with the key users and it was agreed to proceed and to move the system to the production environment. Further development and improvement needs were listed and prioritized into a change backlog document, which was moved later before the launch to the Qt Project wiki to maintain it there.

The implementation phase started by installing the MySQL database server and PHP support to the Qt testresults server, by creating the MySQL database, and by saving the report builder implementation to a Git repository using the normal Qt contribution process including the use of Gerrit code review tool. The focus moved from showcasing the technical solution to improving the usability and the content of the reports. While the development continued with the agreed items from the change backlog, the Qt metrics system, which now used the complete real-time data from the CI, was already utilized by the key users in their daily operations where possible. In addition, the metrics system was introduced to selected Digia Qt development teams for gathering feedback. The metrics system was called a “pilot” at this phase. A progress review and retrospective meeting was held with the supervisors from the Oulu UAS and Digia to demonstrate the system and to collect feedback about the system and the project execution so far. In addition to the technical solution, another focus area was to document the metrics definitions using a structured approach (see FIGURE 11) derived from the principles of several measurement frameworks, like GQM (goal/question/metric) and MIKKO (mittauskehikko) for example. All in all, green light was shown to start preparations for launching the system.

The launch preparation was started by documenting the Qt metrics system to the Qt Project wiki, and by creating a mechanism into the metrics system itself to show the definitions of each report and metrics visible in the web interface. The purpose was to isolate the metrics system documentation from the metrics documentation so that the definition and implementation of each metric were tied together in the source code files. Final testing was conducted, including data validation testing and overall usability testing by the project team and couple of persons outside the project team. Some minor improvements were made for example regarding how the system indicates the asynchronous AJAX operations. The launch itself was made with an email to the Qt developer community and with a post to the Qt Project announcements forum.

The development continued, and is supposed to continue, in the maintenance phase according to the Qt metrics system change backlog. Some items that were intentionally left out from the launch version, such as database status information and time scale filtering, were implemented, as well as improvements to the autotest dashboard based on the user feedback. The guidelines to add new metrics were also documented to the metrics system description in the Qt Project wiki, to enable and promote community wide contributions.

FIGURE 18 summarizes the development project schedule including the thesis documentation phase. The work was actually started a little earlier than originally estimated. This was because the thesis subject was found early and some preliminary studying was done at the same time when proceeding with the subject approval towards Oulu UAS. On the other hand, finishing the paperwork took some extra calendar time. The prototyping was started early as well, but changing to implementation phase was delayed about a week due to challenges in the target server environment. The launch preparations were started early with the documentation, while the launch itself was delayed a couple of days to follow the common Qt releasing calendar. Thesis documentation started already in May 2013 but was mostly done during the July and August timeframe. The estimates are based on the approved plan in the beginning of April 2013. Overall, the project was kept well on schedule, major reason being that the content and functionality was a variable when managing the project to keep the schedule and quality fixed, with the fixed resources.

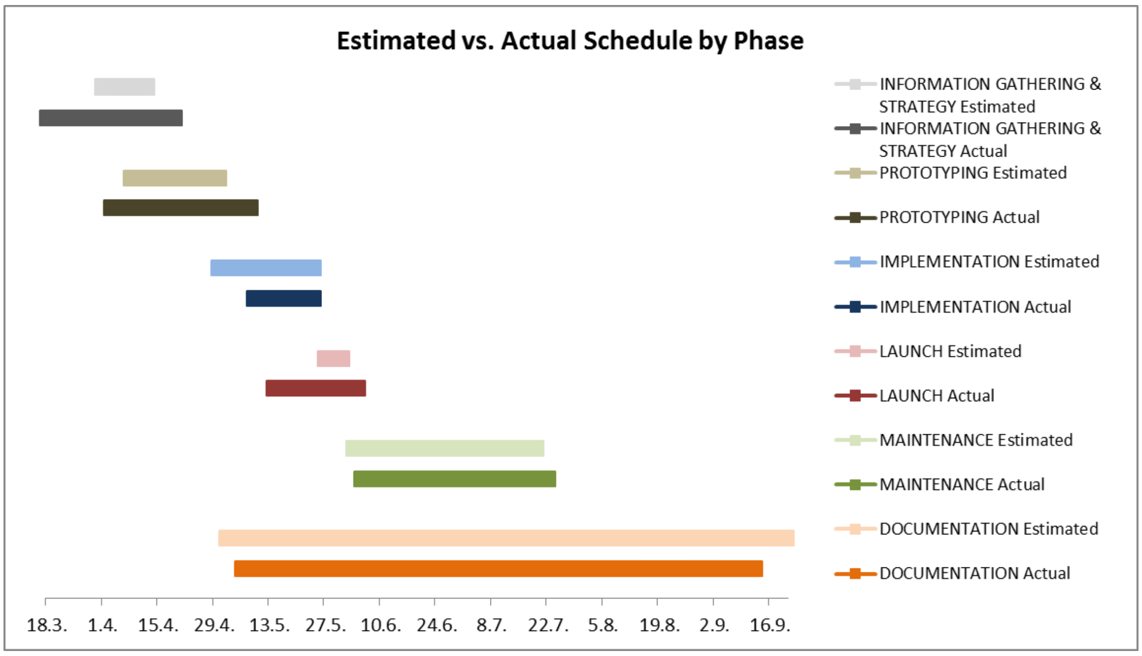


FIGURE 18. Project schedule.

FIGURE 19 shows the effort used in the different project phases. The information gathering and strategy phase did not require as much effort as originally estimated, thanks to the clear and detailed enough target setting. On the other hand, the documentation required more effort than originally anticipated. Like the schedule, the effort was well under control overall.

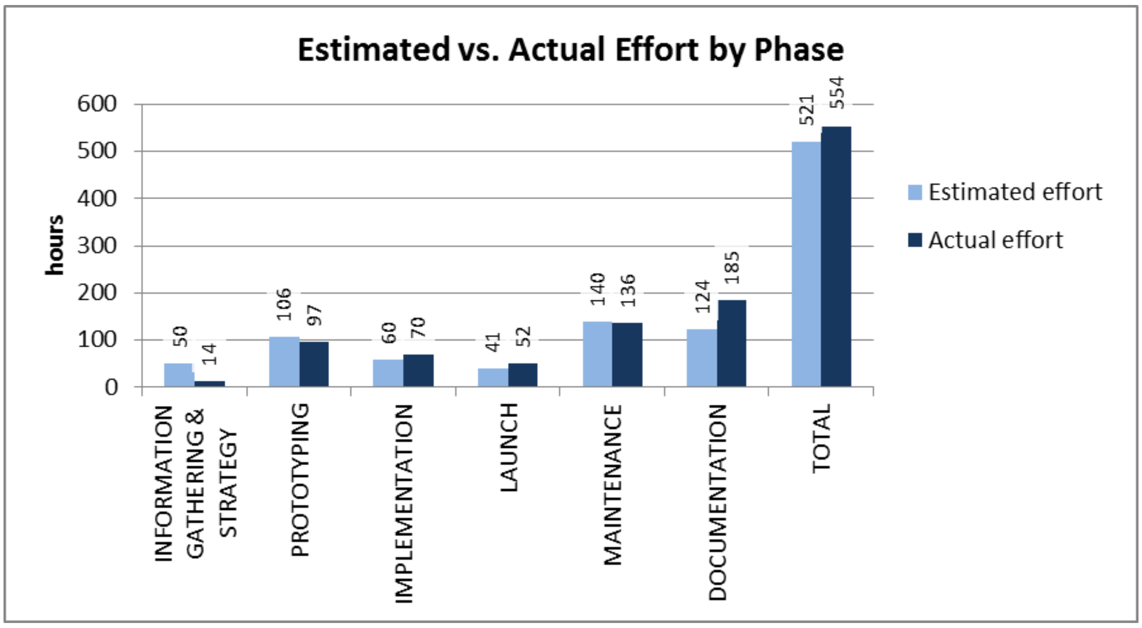


FIGURE 19. Project effort

5 QT METRICS IN USE

This section summarizes the requested and received feedback after the launch of the Qt metrics system, as well as analyzes the requirements set to the system in the beginning of the project. In addition, a few items are listed how to develop and improve the system in the future.

5.1 Feedback

In addition to the instant and continuous feedback from the key users during the development, some feedback was received from Qt development teams in Digia and from Qt community developers. For example, one Qt developer proposed to have the number of builds configurable that are shown in the build history, instead of the current fixed amount. In addition, it was requested to have a mechanism to be able to see what went wrong with the autotests, and then assigning a corrective task to the right person to fix it. Neither of these two cases has been analyzed in detail yet, although the first one would be easy to implement. Another Qt developer requested a simple "fix these autotests to make CI smoother" type of list. The autotest dashboard had been improved at that point so a partial solution could already be provided to that request, including a documentation update to instruct how to use the Qt metrics system in that kind of use case. One Qt developer from the community had noticed that there was some irrelevant data for certain configurations in the system, reason being that the branch structure for a few configurations had been changed at some point making certain branches obsolete for them. A database cleaning operation solved that issue. Another comment was received about infrequent database updates from the build log files. Activating the parser must be done manually in the launch version of the system, and the updates are therefore done only on a daily basis currently. Solution is planned and implementation for automatic frequent updates is already in progress. Another developer highlighted the missing possibility of using URLs and browser back button. Like discussed earlier, the URL does not change when filtering or navigating the data because of the use of AJAX functionality. This is a known issue among the web developers. However, detailed solution has not yet been studied for the Qt metrics system.

All in all, like in many reporting systems, once an answer is found to a certain data oriented question, several new questions appear to be answered. Hence the development of the Qt metrics system should continue based on those new detailed questions and needs.

5.2 Requirements Validation

In general, the validation (coming from the Latin word “valere” meaning “to be worth”) demonstrates that a software or product is fit for purpose and fulfills its operational mission and intended use when placed in its intended environment. It answers the questions like are we building the right product, does the system achieve the business goals, and does the system satisfy the stated and implied needs of the end user. (96) (97)

Validation was actually done throughout the development cycle with the demo and pilot implementation, and therefore it was guiding the development effort all the way. Nevertheless, the requirements set to the system in the beginning of the project, as listed in 4.1 Requirements, are recapped next. The Qt metrics system is hosted under the qt-project.org domain as planned. The system back-end (parser and database) and front-end (report builder) are implemented with free and open source tools and solutions (Perl, MySQL, HTML, CSS, PHP, AJAX and JavaScript) as recommended. It was required that, in addition to the CI reports as the first focus, the selected technologies and technical solutions fit also to the areas that will be implemented later on. Other areas like RTA reports and code coverage reports were not demoed or tested, in that how the implemented system supports large data size or results integrated from third parties in practice, but the selected solutions were evaluated at least not to restrict these features either. A quick trial on showing an external web page in a metrics box was made, and the result was promising although issues like relative directory paths for instance to CSS files should be solved first.

The requirement to enable anyone from the Qt developer community to be able to create new reports to the metrics system was used as the basis in the system design and implementation, and hence resulting to the modular structure of the implementation. How easy this finally is, remains still to be seen.

The user experience related requirements to be able to filter the information based on different criteria and to browse relevant information with high enough performance guided the design and implementation as well. The filtering works well based on the received feedback, although some additional filtering possibilities were identified, some of them were ideas in the original sketches and some were new during the development. The rationale of using an external calendar component in the time scale filter was to make the input validation easy and to ensure the functionality in all browsers; direct input field would have required an extra validation code, and the HTML5 date component is not supported in all browsers yet. However, integrating the component code into Git repository required some minor editorial changes, like replacing tabulator characters with spaces, and unfortunately the component included some HTML5 markup validation errors and warnings. The performance was considered to be mostly on a very good level even though some specific cases were discovered where the response to the user action was not satisfactory as such. One case was when many users opened the initial page simultaneously just after the launch, which made the system to look very slow and maybe giving a wrong first expression of it. Although this was quite as expected, the launch message could have explained that a bit better. In addition, loading the page during database rebuild process appeared to be slow. The quick solution to this was that the possible database update activity is clearly indicated in the status box.

The requirement to document the web site design in such a level that the Qt community can take responsibility of the site maintenance was fulfilled. The site design and implementation is documented into Qt Project wiki, and used also in this document as much as it was found reasonable. In addition, the code is documented in the source files.

5.3 Future Development

The items for future development are related to the new content and functionality in the CI metrics page, the new metrics pages for example for RTA and code coverage, and the overall performance improvement of the system.

The development items to the CI metrics page that were identified during the development cycle are listed in the Qt metrics system change backlog in the Qt Project wiki, see Appendix 1 for an extract. The use of analyzed lists as described in 5.1 Feedback is also a good improvement opportunity. The use cases about which CI build machines failed most often and which CI builds and phases take the longest time to execute, as mentioned in 4.2 Target Audience and Use Cases, are already supported in the parser and the database implementation, and hence the report builder implementation for those could be quite at the top for future development. The build history information in the dashboards is currently shown in a table format. A graphics solution could provide additional readability and improved visual appearance, both in the current build histories and in new trend graphs where needed. Another idea is to detail the results of the autotest sets into test case level, which would make it easier to point out the detailed failure reasons and therefore to get the corrections faster as well. In addition, by analyzing the so-called flaky tests, those autotests or test cases that first fail but then pass on second round without any changes, could help to decrease the overall build times.

The metrics page menu support was not implemented as a part of the project because of the focus only to the CI metrics page. Therefore, when adding new pages to the Qt metrics system, the main menu support must be built as well.

Performance is a vital issue. In order to increase the performance when using the CI metrics page, some key data is read from the database to browser session variables. This, on the other hand, creates a small delay when loading the page for the first time. However, this initial page loading may take more time than loading the page next time even when closing the session or browser in between the usage, which leads to clearing the session variables as well. This performance issue needs further studies. Another performance issue is when loading the page during a database rebuild. The database write operations slow down the read operations. For a quick single scan update this is not a big problem, especially when not done during the office hours. However, the planned automatic database updates may make this issue more visible. The current update progress indication in the status box does not solve the cause of this problem. In addition, the first read operations after a database update may be slow because the DBMS must read the data from the disk instead of from the cache. Again, the planned automatic database updates may make this issue more severe. Hence the performance issues need further analysis regarding the database server and its configurations, the database parameters, structure and possible indexing, as well as the report builder application logic, as discussed in the database performance tuning phase in 3.2.1 Database Design.

6 RESULTS AND CONCLUSIONS

The main objective of this thesis was to improve the visualization and communication of the Qt quality and its progress by creating a web portal to collect and display metrics on required Qt process areas, focusing on continuous integration. The target audience of the portal included the Qt development and continuous integration teams in Digia and the global Qt developer community, i.e. those individuals and teams that develop the Qt library components and the Qt tools. The objective was to automate laborious manual work and to provide real-time information with good performance. It was required that the web portal is hosted on the public Internet under the Qt Project web site, as well as to document the design and implementation into Qt Project wiki. It was required to enable anyone in the Qt developer community to create new metrics or pages to the portal. Because Qt itself is open source, there was a recommendation to use open source solutions in the metrics web portal implementation as well. In addition, there was a specification of some key metrics for the continuous integration to guide the implementation.

The implemented Qt metrics system, running on the existing Qt testresults server on the qt-project.org domain, was launched publicly and taken into use as planned. The system architecture was designed to consist of front-end (report builder) and back-end (parser and database) solutions. The selected technical solutions were Perl for the parser, MySQL for the database, and HTML, CSS, PHP and AJAX for the report builder. Two developers took care of the implementation, me as a thesis worker for the front-end and a Digia employee, who also acted as the thesis supervisor from the commissioner side, for the back-end. All the three components were first implemented in their own development environments and integrated when the required level of maturity was reached. The integration itself to the target server environment was painless, thanks to frequent synchronization of the component implementation and continuous communication between the developers. The Qt metrics system was utilized already during the implementation phase by the key users in their daily operations where possible. The development continued after the public launch according to the prioritized items in the Qt metrics system change backlog. The Qt metrics system functionality as well as the guidelines to further develop the system was documented into Qt Project wiki.

The selected technical solutions, based on the feedback to the functionality and user experience of the implemented system, seem to fit for purpose and are an acknowledged and stable basis for further development. However, it must be recognized that the system is still in its early stages to a complete quality metrics portal on all Qt development process areas, and its ultimate benefit depends on the use and the effort put to its development. During the project there was an idea to be able to show and demonstrate some evidence on improved quality by the aid of using the metrics system, although it soon became apparent that the time the system was in use after the launch, combined with the summer vacation season, was too short for that.

Although the original target setting was clear and detailed enough, there are always cases where the original specification cannot be implemented as such. One example of this with the metrics system implementation was the concept of top-five most often failed autotests. While the CI environment was studied deeper it was realized that the number of autotest failures were not comparable between the builds, and hence identifying the most often failed autotests from the complicated project, configuration and branch structure was not as straightforward as originally thought. The approach was therefore changed to a dashboard solution to first understand current state better, and then to develop the solution later based on the knowledge that will be gained during the use of the dashboard solution. Hence the metrics should be considered dynamic in a sense that they must be adjusted to the needs of a specific moment and situation. And like stated earlier, any metrics reporting solution is only as good as the metrics defined in it.

More detailed feedback, requirements recap and further development proposals to the Qt metrics system are available in 5 QT METRICS IN USE.

7 DISCUSSION

As a student at Oulu UAS I was upgrading my previous B.Sc. degree, after about 25 years of experience in software development in the product development industry. I took courses from the School of Engineering and from the School of Music, Dance and Media. My course selections were based on personal interest to web and database development. Therefore the thesis subject proposed by Digia to build a web portal to visualize CI and other operational data was a perfect match with my studies.

The project started in March 2013 with a couple of meetings regarding the scope of the work and the required competences, resulting to approval from both the Oulu UAS and Digia as the commissioner. The development process followed a common study-prototype-implement-launch-maintain approach. The system architecture was defined and split to front-end and back-end solutions, and the work split to two persons followed the same principle, me as a thesis worker took care of the front-end and a Digia employee, who also acted as the thesis supervisor from the commissioner side, took care of the back-end. The technical solution selection was based mostly on the development competence needs and on easy integration to the existing server environment and to the current processes and practices in the Qt Project. Prototyping the front-end and back-end implementations were done separately and concurrently in their own development environments. Integration of the front-end and back-end implementation to the target server environment was painless. The UI and the content of the CI metrics were improved further, and finally green light was shown to start preparations to launch the system which included documentation to the Qt Project wiki and to the Qt metrics system itself. After final verification, the system was launched publicly to the Qt developer community on 4-Jun-2013. The development continued as a maintenance effort according to the Qt metrics system change backlog.

Part of the success of this thesis comes from the fact that the original target setting was clear and detailed enough but, on the other hand, it allowed freedom in the design and implementation. During the demo prototyping the front-end and backend implementation was synchronized frequently. That, together with continuous communication between the developers, ensured smooth integration to the target server environment. Positive feedback was received for example about the first demo implementation being up-and-running fast, and that the pilot implementation could already be used for production issues, for instance to identify newly failed autotests. The weekly reporting email combined with the report and plan update via the thesis web page in the Oulu UAS environment was also found beneficial. Overall, the schedule and the effort used in the project were kept well compared to the original estimates.

There were also some items that could be improved if repeating a same kind of project in the future. Ramping up the database and the web and PHP support in the target server took more calendar time than first estimated. This was because the target server needed a memory increase and new disk partitioning to ensure good performance. In addition, it was noticed that the PHP support and new Perl version installations were needed before the integration to the target server could happen. These both installation issues should have been identified and requested beforehand. The server environment is taken care of by a third party company in Oslo. The parser implementation took much longer than initially anticipated, although the initial estimate of few hours included only extracting first sample data while the final implementation included also for example data validity checking in addition to parsing itself. The Qt Project releasing process, which defines the releasing cycle and days, should have been investigated already when planning the releases although applied for other kind of deliveries in this case. Therefore the launch date was delayed a few days from its initial plan to follow the weekly Tuesday/Thursday cycle, to ensure office hours for instant feedback and support after a release. The launch itself was not as smooth as it could have been. It should have been realized that an email to a large group of developers would create at least tens or hundreds of simultaneous page loads and therefore a peak in the server usage, which now resulted the system to look very slow and maybe giving a wrong first expression of it. In addition, all the other processes in the same server were slowed down. If nothing else, at least the launch message could have explained that a bit better.

This thesis project provided increased technical knowledge on web and database design, both on high level regarding the development process and different technical solutions, and on detailed level regarding for example PHP and MySQL implementation. One example of the latter is the calculation of local time and time zone with the daylight saving time (DST) which was planned to the status box. Although there are mechanisms in PHP to read the time zone and DST of the user and server, a foolproof solution was not found in reasonable amount of time, and hence the approach was changed to show the local time with the time difference to GMT instead. Apart from the technical knowledge, experience was gained on planning and executing a bachelor's thesis project. By using prior experience on project management, the planning and tracking itself was not a new issue, but to describe what a thesis project is and to investigate the project scope, activities and required deliveries appeared not to be a simple task. A new bachelor's thesis one-slider document was created for the commissioner in order to be able to describe what a thesis project is and what it does require from the commissioner perspective. A need for that kind of document could be investigated. In addition, a clear but detailed enough project planning template does not exist. Although thesis projects vary a lot, a template collected from the experiences of successful projects could help students that may be juniors to project management practices to execute their thesis project better.

More detailed information on the used development process and the project schedule and effort is available in 4.8 Project Management Practices.

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1 The Backlog

STATUS	VERSION	PRIORITY	GROUP	ITEM
Idle		***	Usability	Project dashboard to show the data (general, builds etc.) for any build (by clicking e.g. the build number); now the shows only the latest build
Idle		***	Usability	Enable filtering via URL parameters (e.g. to mail direct link to a specific report)
Idle		***	Filters	Add Branch filter (dev, release, stable) to filter e.g. Project and Autotest list at the 1st level (maybe the current Project filter must be renamed)
Idle		**	Filters	Add ‘search’ filter to Configuration filter (alternative would be a static grouping of Configurations)
Idle		**	Functionality	Add a new metric/page for the build phases data (metric report to be specified first)
Idle		**	Functionality	Project dashboard: When only Conf selected show the Project list for that Conf (instead of a note to select a Project)
Idle		**	Look’n‘feel	The filtered values that appear in green in dashboards is a one big green box, white borders might improve the readability
Idle		**	Security	Store the database login information to a secured file (currently the user has only read access and login is restricted by the server)
Idle		**	Usability	Autotest dashboard to include number of executed autotests (passed/failed)
Idle		**	Usability	Study the slow page loading issues (first load and load during rebuild)
Idle		**	Usability	Browser Back button does not work with nested metrics (you must use the top links in a box instead)
Idle		**	Implementation	Solve the URL encoding issue with correct PHP functions instead of the current string manipulation
Idle		*	Usability	Error handling for cases where e.g. Project, Conf or Autotest drops from the database (due to database rebuild); unsure how frequently these kind of situations would happen
Idle		*	Usability	Project dashboard to include number of significant and insignificant vs. total autotests in latest Build -> both in 1st (Project list) and 2nd (Conf list) level
idle		*	Usability	Check log file availability (it may not always be available)

2 Done Items

STATUS	VERSION	PRIORITY	GROUP	ITEM
DONE	v1.4	***	Usability	Autotest dashboard: Sorting based on any column in the list (in level 1 view)
DONE	v1.3	***	Functionality	Autotest dashboard: Add result history for Project/Conf builds
DONE	v1.2	****	Filters	Add timescale filter (e.g. since a date) and apply it to Project dashboard and Autotest dashboard
DONE	v1.1.1	***	Usability	Change the order in which the boxes are loaded on initial page load to indicate the possible database rebuild progress instead of welcome text when loading the page during rebuild
DONE	v1.1	****	Usability	Show database status (last update time); compare session start time to database rebuild time and show rebuild progress (if ongoing) or reload proposal text (when done) to the user; status is updated when surfing through the filters