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The Free Software Model of Development in the Area of Medical Informatics

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Abstract
The computerization of medical records is a common goal for modern healthcare systems. The *aim* of this research was to identify the main attributes of the free software development model for health informatics projects used to computerize a medical office or a small clinic, that ensures their success. *Material and methods:* Our study has assessed the benefits that electronics health records can bring to small health care facilities by analyzing a limited number of open source software suites in the area of medical informatics. We have investigated the way in which these benefits may be achieved by implementing the presented software solutions, taking care to highlight the peculiarities of the open source model of development that prove to be differentiating factors against equivalent closed source commercial solutions. *Results:* The paper presents the facts about the projects and the assessment criteria used in the study: developer community, user community, online resources, user interface ergonomy, documentation, hardware requirements. *Conclusion:* The main attributes of the free software development model for health informatics projects used to computerize a medical office or a small clinic that ensures their success, were: clarity, simplicity, extensibility, documentation.

Keywords: Free software; Open source; Medical informatics; Electronic health records.

Introduction

The computerization of medical records is a common goal for modern healthcare systems. It facilitates the archival of data collected by practitioners, its retrieval at a later date and the communication between different medical teams. This study has tracked the potential benefits of electronic health records for small health care facilities, limiting its scope to a qualitative and quantitative analysis of a limited number of open source suites in the area of medical informatics. Towards this goal, we have investigated the software solutions presented in our study not only from a practitioner's point of view but also from the point of view of IT personnel, other support staff from a medical practice office or a clinic and even from the point of view of patients. Because, ultimately, medical records that are correct, complete, and up-to-date constitute one of the main premises on which to base the best possible decisions for the health of the patients. We have investigated the way in which these benefits may be achieved by implementing the presented software solutions, taking care to highlight the peculiarities of the open source model of development that prove to be differentiating factors against equivalent closed source commercial

solutions. Not taking into account the financial aspect (free software solutions have no licensing costs), we have tried to discern the intrinsic advantages of the model of free software development and its particularities in this specific area of investigation: health informatics.

A *free software* [1] program is a software that may be used, studied and modified without restrictions. Such an application may be copied and redistributed (modified or unmodified) without any kind of restrictions, except those that are enforced to assure that there are no restrictions to the rights of future users to use, study and modify it. This hack of the copyright system is commonly referred to as *copyleft*. Alternative terms for free software are *libre software* or *software libre* and they are used to differentiate it more clearly from the broaderterm of gratis software, applications that have no licensing costs. This it easier to distinguish between the two meanings of the English term "free", namely "for zero price" and "without restrictions". A widely used metaphor that summarizes this difference in a slogan is: "Think «free» as in «free speech», not «free beer»."

For an application to qualify as free software, the source code of its components must be available to the user, this being the very definition of open source. Additionally, developers include a legal note that gives the user the rights to copy, modify and redistribute the software. This legal note is either a license such as the GNU Public License (GPL) or a note that specifies that the source code is published in the public domain, in countries that have such a provision. The GPL license is the most common free software license. It was conceived in the early '80s by Richard Stallman for the GNU project. It is the first copyleft license for general use, its particularity being that any derivative work is to be distributed only with the same original license terms. The philosophy of this license is to give the user the rights and liberties associated with a free software program and to impose strict copyleft terms in order to forbid any restrictions of these rights and liberties.

The aim of this research was to identify the main attributes of the free software development model for health informatics projects used to computerize a medical office or a small clinic, that ensures their success.

Material and Method

A prime method of research used in this study is the qualitative method of analyzing the open source movement in the field of medical informatics by empirically evaluating its offsprings. We have gathered data about open source health informatics projects from the world of free software in order to identify and expose here some of the viable projects that can be used to computerize a medical office or a small clinic. We have evaluated this viability first of all from the perspective of long term development of the software in question, trying to follow its evolution in time, from the beginnings to present days, marking its crossroad moments, the difficulties encountered and the means trough which those adversities were overcome. We started by analyzing the oldest free software projects that have succeeded in remaining useful to this day and we ended with the most recent successful projects, the last of which were initiated at the end of 2008.

We have analyzed the successes of those software suites not only by the number of versions launched over the years, but also by the adherence they have created among the developers, users, professional associations, private companies or governmental agencies. Some of the investigated projects have begun as the initiative of an individual and have since conglomerated the support of practitioners associated in a non-governmental organization specially created to back them. Some other projects were initiated by companies, but have since managed to grow an ecosystem of their own and are no longer dependent on their creators. Some of the most successful projects have been adopted by bigger umbrella-type organizations, benefiting not only from their reputation, but also from employing their ready-to-use online technical tools such as code repositories, web sites and mail lists. Two of the investigated projects are now included in the aforementioned GNU project, a major landmark in the field of free software.

We haven't neglected the evaluation of these open source projects in terms of their use in solving practical problems specific to the computerization of a medical office. We have investigated in what ways these software suites were useful to the practitioners (doctors, nurses) but also to the

support staff (receptionists, accountants, administrators) and in some cases even to the patients, because some of the applications make it possible for the patients to securely access some of their private data gathered by the practitioners.

We have collected particular data for every project included in the present research, investigating the chosen solutions: programming languages, database servers, software architectures, additional tools. We have identified the license used for every piece of included software and for all of their dependencies to make sure they, as a whole, qualify as free software solutions.

Finally, in our qualitative evaluation of the analyzed open source products, we have considered the certifications awarded to them by third party evaluators such as governmental programs of certification, for example the annual ONC-ATB Ambulatory EHR from the United States of America, which certifies that a "Meaningful Use" certified electronic health records and medical practice management application has fully integrated electronic health records, practice management, scheduling, electronic billing and interoperability.

One qualitative method used to research the free software projects included in this study was to compare among them those software solutions identified as viable for computerizing a medical office in order to determine which one exposes the most efficient functionality, to see which scenario fits one or the other of the investigated solutions, and to mark the strong and the weak points of every solution. Although the research field in the area of health informatics is rather narrow, we have noticed that some software suites address the needs of a very specific target, for example they are specially conceived for the needs of a family doctor's office. Others try to be useful not only to a medical office, but also to clinics or small hospitals. Many of those software solutions cover not only the professional needs of the practitioner but also help with billing and accounting.

This diversity makes it difficult to objectively compare the analyzed projects. We have tried to define a frame of evaluation that would allow to overcome this problem through a systematic approach of properties common to all investigated software suites. Some of these properties are subjective, harder to evaluate, but some are technical and easily quantifiable in numbers. The following methodological framework has been the cornerstone of our comparative analysis of the open source medical informatics projects analyzed in this study.

First of all, we have listed and compared the development resources of every investigated project, both human (developers, testers, translators, active users, support organizations, associated companies) and technical (free software technologies, associated open source projects, online code repositories, web sites, mail lists for developers and users, online forums, bug reporting systems).

We have also investigated the way in which users and administrators of these software suites interact with its modules, evaluating the ergonomics of the user interface, the efficiency of the work flow, the quality and quantity of the included documentation. We have highlighted included localizations and their completion, investigating how easy it is for users to translate into their native language the user interface or the product's documentation.

More so, we have evaluated the hardware resources needed to implement the investigated solutions, the advantages and disadvantages of the chosen software architecture in this regard. Some solutions may function independently, even without an Internet connection, others require a central online or offline server. Some others may integrate in a modern cloud architecture, taking advantage of the cost reductions made possible by the commoditization of this large scale technology.

Because, in the end, a cost-benefit analysis for the implementation of such a software solution has to take into account not only the costs of the software licenses, but also the cost of the hardware requirements, and implementation and maintenance costs. This cost analysis constitutes by itself a quantitative method of estimating the success of the project of computerizing a medical office, the economical aspect of such an enterprise being of paramount importance.

Free Software Applications for Medical Offices

For this study we have analyzed only those free software projects that offer suitable solutions for medical offices, be them individual, in association, or grouped in a civil medical society,

according to the Romanian law. Therefore, we have not analyzed in this study some of the most well-known open source software suites such as ClearHealth [2], Medintux [3] or SQL Clinic [4], because those are addressing the needs of clinics and hospitals.

Sometimes it is difficult to clearly mark a line of demarcation between the applications dedicated to medical offices and those built for clinics and hospitals, an example from our study being PatientOS, a software suite that suits both scenarios. But, in the end, even in practice, medical offices may be associated or grouped, and this amplifies the complexity of a common informatics solution. More so, a successful medical office may develop in time, attracting more practitioners and morphing into a small private clinic. A certain flexibility is therefore welcome when solving the problem of computerizing a small scale medical entity, be it a medical office or a small clinic.

We started our investigation in the field of free software applications for medical offices with **FreeMED** [5], one of the oldest open source, launched back in 1999, the initial author being Jeffrey Buchbinder from the US. The project has quickly gained an international following, attracting contributions from numerous developers, programmers or translators, the product being localized in French, German, Spanish, Japanese, and Polish. Today, the development of FreeMED is directed by a non-profit American foundation: FreeMED Software Foundation [6]. The FreeMED project uses a suite of free software technologies: the Linux operating system, the Apache web server, the MySQL database, and the PHP programming language. This combination of technologies is commonly abbreviated as LAMP, each part of it being a cornerstone of a typical Web 2.0 solution. Small parts of FreeMED are written in Bash and Perl, other free software technologies. Everything in the FreeMED is licensed under the GPL, version 2.

Another web application for electronic health records, with a history almost as long as FreeMED, is **OpenEMR** [7], a project launched in 2001 by the Synitech company. Presently, OpenEMR development is supervised, as in FreeMED's case, by a non-governmental organization from the US: the OEMR Foundation [8]. We should note that the OpenEMR suite is certified in the ONC-ATB Ambulatory EHR 2011-2012 program [9], as an authorized application for electronic health records and the management of medical practice. As in the case of FreeMED, OpenEMR is a typical LAMP solution that uses the Linux operating system, the Apache web server, the MySQL database server and the PHP programming language. The license used throughout the OpenEMR project is GPL, version 2.

Another example of a free software application built for medical offices is **GNUmed** [10], a project launched in 2001. Unlike the aforementioned web applications, GNUmed has a dedicated desktop client, with versions for Unix-like operating systems such as Linux or BSD, but also for Windows and Mac OS X. The user interface is built using the WxPython libraries and the back-end database is PostgreSQL, both projects being also free software. The license of this project is GPL, version 2 or newer. The goal of the GNUmed's authors is to build a free software solution for the providers of medical services that supports the understanding, documentation, planning, and administration of medical services, for the benefit of their clients, the patients [11]. GNUmed is successfully used for medical records by generalists and physiotherapists, and it may well be the perfect solution for practitioners in remote areas with limited or no Internet connectivity.

PatientOS [12] is an integrated medical system built on Java technology suited for electronic health records both in a hospital and a medical office. However, it wasn't designed to scale much beyond the needs of a small clinic or hospital. It has a modular architecture which includes sections dedicated to scheduling, receipts, medication, pharmacy, and billing. Besides the commercial site of the company that supports this software suite, PatientOS Inc., there is also a site dedicated to the open source development of this GPL 3 licensed application [13].

GNU Health [14] is another free software suite, launched in 2008, which combines the electronic medical records functionality (EHR/EMR) with special provisions for small hospitals and clinics, typically encountered in the field of healthcare information systems (HIS). However, the developers of this software targeted especially family doctors and primary care physicians, placing a special emphasis on investigating social-economical variables: education, housing, substance abuse. Therefore, it may be used not only by practitioners in medical offices, primary care facilities and small hospitals but also by non-governmental organizations that offer related services. The GNU Health project is coded in Python using the PyGTK and GTK+ libraries of the

GNOME project and uses the PostgreSQL database server. The project is licensed under the terms of the GPL license, version 3 or newer.

Other free Software Solutions

The medical informatics applications investigated in our study are not the only free software applications in this field, even if we have limited our investigation to a relatively narrow area: computerization of medical offices. The existence of free software programming languages with a wide following such as Java, Python or PHP and the availability of free software platforms for complex applications such as web servers and database servers have made possible the proliferation of a growing number of programs in the field of medical informatics. Let us enumerate some software suites that could have also been included in our study:

- • FreeMedForms, a modular multi-platform manager of medical records using the XML standard written in C++ by a group of French physicians led by dr. Eric Maeker [16]
- • OSCAR, a web application written in JavaServer Pages, initially developed for the needs of the McMaster University Clinic in Ontario, presently being used in hundreds of medical offices throughout Canada [17]
- • Elexis, a software suite for primary care medical offices written in Java, initially developed by the Swiss physician Gerry Weirich for own use [18]
- • GECAMed, a Java software for administrating medical offices, a project born from the need to continue the support for a commercial product developed by a Luxembourg company that went bankrupt [19]
- • Mountain Meadow EMR, a suite written in C# for the electronic management of medical records that uses a client-server architecture based on the Microsoft .Net technology [20]
- • OpenTAPAS, a Java multi-platform software, which helps primary care physicians to put information technology in the service of medical practice [21]
- • CyDoc, a web application for the management of a medical office, with software-as-a-service support available for a fee [22]
- • OpenDental, a software suite for dental offices written in C#, used by over 2000 practitioners [23]
- • OpenMolar, a promising individual project written in Python by a Scottish dentist: Neil Wallace [24].

And the list could go on... Consulting Internet resources such as online medical communities or the health informatics portals reveals new projects in this field every year. Having no claims to have exhausted the list of all open source software suites that facilitate the computerization of medical offices, we will try to unravel in the following chapter the mechanisms that govern the birth, the development, and the survival of these free software projects.

Results

The Main Free Software Applications for Medical Offices Characteristics

After scrutinizing the available open source applications for health informatics projects used to computerize a medical office or a small clinic, we identified some of the most important ones.

The synthesis of the findings is presented in Table 1. Beside the clear facts about the projects, the table illustrates the qualitative assessment criteria used in the study: developer community, user community, online resources, user interface ergonomy, documentation, hardware requirements.

Table 1 The main characteristics of the most important software applications for medical offices

	FreeMED	OpenEMR	GNUmed	PatientOS	GNU Health
Year of launch	1999	2001	2001	2007	2008
Target	Medical offices	Medical offices	Medical offices	Medical offices, small clinics and hospitals	Medical offices, small clinics and hospitals, NGO's
Strong points	Modularity, lightness	Security, lightness, vibrant community	Security, versatility	Well-defined user interface, good development resources	Easy to use user interface, rapid development
Weak points	Weak user interface, development almost stalled	Weak user interface	Some resources are available only in German	Demanding hardware requirements	Not a fully mature project
Certifications	-	ONC-ATB Ambulatory EHR	-	-	-
License	GPL 2	GPL 2	GPL 2 or newer	GPL 3	GPL 3 or newer
Umbrella organization	FreeMED Software Foundation	OEMR Foundation	GNU Project	Patient OS Inc.	GNU Project
Associated OSS projects	2	-	-	-	-
Number of localizations	4	18	10	0	3
Technical framework	LAMP	LAMP	WxPython / PostgreSQL	Java Swing / PostgreSQL	Python / Tryton / PostgreSQL
Developer community	4 / 10	10 / 10	8 / 10	4 / 10	6 / 10
User community	3 / 10	9 / 10	7 / 10	2 / 10	6 / 10
Online resources	7 / 10	9 / 10	8 / 10	8 / 10	8 / 10
User interface ergonomy	4 / 10	6 / 10	7 / 10	8 / 10	10 / 10
Documentation	6 / 10	9 / 10	8 / 10	7 / 10	7 / 10
Hardware requirements	9 / 10	9 / 10	8 / 10	5 / 10	7 / 10

Attributes of the Free Software Development Model

Investigating these suites of free software applications from the field of medical informatics that may be used to manage the electronic health records in a medical office reveals a prime universal attribute of all these grassroots projects: the fact that they were started in order to solve a personal problem. Colloquially, free software advocates talk about "scratching an itch". That means, first of all, that the motivation of the developers is an intrinsic one. And it additionally means that the developers are also users of their software. Therefore, they have a realistic vision of the typical needs of the users. This is a characteristic of free software projects, but of a special significance in the field of medical informatics, because it means the software developers are also health practitioners.

Another common attribute of the investigated projects is that they were started in order to improve on an already existing software, typically a commercial one. What this means in practice is that the developers have followed an already existing prototype that they have tried to reproduce and possibly surpass. Typically, in the case of commercial software, this process of improvement is the privilege of the authors of the software and users can only generate feedback, signals that may or may not be taken into account by the developers. In the case of a free software project though,

the availability of the source code and its liberal license allow interested users to patch the bugs, to extend the functionality, to complete the documentation, and to localize its interface. In radical cases, users may create a new software project that inherits the code base of the original source, a process known as *forking*.

We have enumerated the premises for the birth of a free software application and the particularities of its genesis. Finally, we will try to synthesize the most important characteristics into the coordinates of a viable model of development for free software applications. The following attributes are essential in the process of developing a successful free software project:

- **Clarity**. A new project must have a clear cause, a main goal, a target doable in a reasonable amount of time that will motivate the initial developers and will lead in time to adherence from potential users. At a more fundamental level, the source code of the project should a have lean design in order to facilitate the accomplishment of easily quantifiable intermediary targets. The software development strategy to follow is that of frequently incremented versions, commonly known as "release soon, release often".
- **Simplicity.** Simple code is easy to understand and improve, a fact that will ease the involvement of new developers. More so, clear code is easy to maintain and debug. This quality is all the more important when the initial author of the code is not available anymore to explain it. The principle that summarizes this is "Keep it simple, stupid" or KISS, a principle shared with commercial software. However, free software projects may push this strategy more aggressively because, having a large amount of open source code at their disposal, developers may avoid reinventing the wheel, a problem known in the software world as the NIH syndrome, NIH being the acronym for "not invented here".
- **Extensibility.** The software's design should allow adding new features, so that future needs of the users are fulfilled without major overhauls of the internal code. A modular architecture and support for scripting languages are ways to attain this goal, easing the addition of more functionality without too many changes to the inner workings of a complex software solution.
- **Documentation**. In order to attract new developers it is necessary to thoroughly document the code functionality, its design and the project's roadmap. In this way, it will be easier for the project to agglutinate new contributors from the ranks of the users or interested programmers. It is of paramount importance that the entry barrier is as low as possible for people that wish to add a suggestion, improve the documentation, translate the interface, report a bug or contribute a patch that solves a certain problem.

These four attributes constitute in our vision the fundamental coordinates of the development of free software applications, common to all successful open source applications in the field of medical informatics, from the most insignificant ones, written to solve specific problems, to comprehensive solutions such as Red Hat Enterprise HealthCare System, platforms that consist of vertically integrated hardware and software solutions.

Discussions

We have tried in our research to decipher the characteristics of successful free software projects in the field of medical informatics that may be used to computerize medical offices. But it is important to emphasize the fact that most open source projects are doomed to fail as most of them do not reach the initial goal of their developers. The failure is most of the times not formally proclaimed, the usual symptom being the absence of any recent updates. More so, investigation of such a project shows the lack of any activity for several years in its code repository, mail list, web site or forum.

In the world of free software, where anyone can help improve an already existent project, such a waste of resources may seem futile at first glance. More so, even when taking into account only successful open source projects, we often encounter concurrent projects that have basically the same goal. We have investigated in our study several software suites that try to accomplish the same: computerizing medical offices. Sometimes it is understandable that some projects were developed using different architectures. Some are web-based applications, others implement a

client-server model where the client is a desktop application. In other cases, the means to achieve the same goal are different, some developers use the LAMP architecture, others build on the Java technology. But even in our very narrow field of medical informatics we have two very similar projects that have all these aspects in common: FreeMED and OpenEMR. Possible explanations for this duplication of the efforts of free software community are: lack of communication, different development rhythms and sometimes the vanity of the developers.

This aspect of the free software movement, which seem to waste resources by developing concurrent software solutions, may give the impression that chaotic development is a peculiarity of the open source applications. But in practice the competition among several projects in the same niche results in improvements in all the projects that manage to survive by continually adapting to the needs of the users. Examples of such pairs of concurrent projects are many in the world of free software: operating systems (Linux and FreeBSD), web servers (Apache and nginx), database servers (PostgreSQL and MySQL), scripting languages (Perl and Python), desktop environments (GNOME and KDE) to name only the most relevant two examples from every category.

This apparently wasteful and chaotic model of development has been described for the first time in 1997 by Eric S. Raymond, who has deciphered its mechanisms in a practical and vivid style in his renowned work "The Cathedral and the Bazaar" [25], in which he compares the apparently chaotic but intrinsically organic development of free software projects with that of an oriental bazaar, in contrast with the carefully ordered and long-term planned development of commercial software, compared to the construction of a Gothic cathedral.

But maybe there is an even better metaphor to put these different models of development in antithesis, a comparison of two systems with related functions, because bazaars and cathedrals do not share the same utility in our society. Let's oppose two systems with identical functions, one from nature, organically developed, and the other conceived and constructed by man. For example, let's compare a butterfly wing with the wing of a plane, components with similar functions, but so unlike each other in their evolution through the ages. In the case of the evolution of the dragonfly wing we speak of phylogenesys, while for the plane's wing development we refer to the history of aeronautical technology. We think this metaphor has a better descriptive value and facilitates discerning the particularities of a free software project when compared to a typical commercial solution.

Organic development, natural adaptation, assiduous competition, these are the attributes describing the evolutionary matrix that constitute the open source archetype of the development of free software projects, a model which proves useful in solving the most common problems encountered in the field of medical informatics. By limiting the area of our investigation to that of electronic health records in a medical office, our study of some of the successful software applications in this field has tried to unravel and decipher the intrinsic mechanisms through which these projects have managed to pass the test of time and viability.

Conclusion

In this study the main attributes of the free software development model for health informatics projects used to computerize a medical office or a small clinic that ensures their success, were: clarity, simplicity, extensibility, documentation.

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