HIR
Healthcare Informatics Research

Free/Libre Open Source Software in Health Care: A Review

Thomas Karopka, Dipl.-Ing.[1,2,3]**, Holger Schmuhl, Dipl.-Inf.**[2,3,4]**, Hans Demski, Dipl.-Ing.**[3,4]

[1]BioCon Valley GmbH, Greifswald, Germany; [2]International Medical Informatics Association Open Source Health Informatics Working Group, Geneva, Switzerland; [3]European Federation Medical Informatics Libre/Free and Open Source Software in Health Informatics Working Group, Copenhagen, Denmark; [4]Laboratory for Medical Information Systems, Institute for Biological and Medical Imaging of the Helmholtz Zentrum Munchen, Neuherberg, Germany

Objectives: To assess the current state of the art and the contribution of Free/Libre Open Source Software in health care (FLOSS-HC). **Methods:** The review is based on a narrative review of the scientific literature as well as sources in the context of FLOSS-HC available through the Internet. All relevant available sources have been integrated into the MedFLOSS database and are freely available to the community. **Results:** The literature review reveals that publications about FLOSS-HC are scarce. The largest part of information about FLOSS-HC is available on dedicated websites and not in the academic literature. There are currently FLOSS alternatives available for nearly every specialty in health care. Maturity and quality varies considerably and there is little information available on the percentage of systems that are actually used in health care delivery. **Conclusions:** The global impact of FLOSS-HC is still very limited and no figures on the penetration and usage of FLOSS-HC are available. However, there has been a considerable growth in the last 5 to 10 years. While there where only few systems available a decade ago, in the meantime many systems got available (e.g., more than 300 in the MedFLOSS database). While FLOSS concepts play an important role in most IT related sectors (e.g., telecommunications, embedded devices) the healthcare industry is lagging behind this trend.

Keywords: Software, Medical Informatics, Delivery of Health Care, Sustainable Development

I. Introduction

Today's healthcare systems of most of the developed countries are challenged by an increase of age-related diseases due to demographic ageing as well as a rise of non-communicable diseases. At the same time many of the problems in low resource settings remain unsolved and new challenges arise. Information and communication technologies (ICTs) play a key role in the Internet area and have substantially transformed many domains. Although there is a broad consensus that eHealth plays a key role in modern healthcare delivery, the domain of health care is considerably lagging behind in terms of adoption of modern ICT tools and infrastructure.

Free/Libre Open Source Software (FLOSS) has been successfully adopted across a wide range of different areas and has opened new ways of value creation. Today there are hundreds of examples of successful FLOSS projects and products ranging from Linux to Android, from Open/Libre Office to MySQL, from the Apache Web Server to hundreds of embedded GNU/Linux kernels in different types of systems.

Corresponding Author
Thomas Karopka, Dipl.-Ing.
BioCon Valley GmbH, Walther-Rathenau-Str. 49a, 17489 Greifswald, Germany. Tel: +49-3834-515303, Fax: +49-3834-515102, E-mail: TKaropka@gmail.com

Especially in times of financial crisis and austerity the adoption of FLOSS principles opens interesting alternatives and options to tremendously lower total cost of ownership (TCO) and open the way for a continuous user-driven improvement process.

In this paper the authors review the development of FLOSS in health care (FLOSS-HC) in the last decade and provide an overview of the state of the art in FLOSS-HC. This review considers free and open source software in the area of healthcare delivery and medical research and is based on the MedFLOSS database [1]. The domain of bioinformatics and computational biology is excluded from this review. This domain has a large number of FLOSS tools and projects and a very active and well organized global community with regular meetings. For example, the Bioinformatics Open Source Conference [2] is held yearly since the year 2000 and the Open Bioinformatics Foundation [3] a global non-profit, volunteer-run group is dedicated to promoting the practice and philosophy of Open Source software development and Open Science within the biological research community. However, the situation in health informatics is quite different. In bioinformatics the tools are mainly used in research and not in healthcare delivery, i.e., researchers are programming for research and not for healthcare personnel and patients as end-users.

In the following chapter an introduction to FLOSS in general is given since there are still many misconceptions and lack of knowledge about existing FLOSS concepts on the side of healthcare IT professionals.

II. Open Source and Free Software

The idea of freely sharing software and its underlying source code has been around since the early beginning of computing. Eventually the underlying principles got phrased in the mid-1980s by Richard Stallman. In an effort to write a free Unix alternative called GNU [4], he formulated the so-called Free Software Definition [5] in 1986. Any software conforming to this definition must offer the freedom of using, studying, sharing, and modifying that software to its users. Premise to these principles is the access to its source code. To support the free software movement and promote its ideas Richard Stallman founded the Free Software Foundation [6], a non-profit organization, in 1985. Adjacent to these efforts in 1998 the term Open Source was coined by Eric S. Raymond and Bruce Perens. Instead of sticking to the original notion of Free Software they wanted to have a clear wording for marketing purposes that is not easily mixed up with Freeware—a closed-source software that is given free of

charge but comes with considerable restrictions on its use. In the same year Raymond and Perens founded the Open Source Initiative [7], also a non-profit organization to circularize and promote their definition of Open Source software. Although there have been quite some disagreements between both organizations and its adherers since then about who has the cleaner definition and follows the more genuine and honest intentions, they both accept most software licenses in this field to conform to their definitions. In this paper the term Free/Libre and Open Source Software (FLOSS) is used in an attempt to embrace both communities.

1. Software Licenses

Whilst authorship remains at any time with the originator of the software, re-use, modification, and distribution of software and the access to its source code are regulated by the license under which it is released. Free software and open source licenses can primarily be assigned in one of three categories: permissive, weak and strong copyleft. The main difference between these categories is if the software can be released under a different license than the original in case it is modified and if it can be linked with other software that has a different license. Permissive software licenses permit both options. Popular examples are the Apache License [8], the BSD License [9] and the MIT License [10]. Weak copyleft still permits linking to differently licensed software but requires code changes to be released under the original software license. Popular examples are the Eclipse Public License [11], the Mozilla Public License [12] and the GNU Lesser General Public License [13]. Strong copyleft allows linking as well as releasing code changes only by sticking to the original license. Popular examples are the GNU General Public License [14] and the Affero General Public License (AGPL) [15]. The AGPL is in a way special as it additionally closes the so called "application service provider loophole". The given requirements induced by the corresponding license normally must only be met in case the software is distributed. Nowadays, in the age of cloud computing, access to software's functionalities are more and more offered through Web interfaces according to the software as a service (SaaS) delivery model. As a consequence the users of such software services do not receive the actual software in source or binary form. Due to this providers of such service offerings are not enforced to meet the original license terms. To address this shortcoming the AGPL has been defined to especially include this use case and imply all license terms of the software as if it was distributed in source or binary form.

Numerous guides are available that discuss the differences, advantages and disadvantages of common Free Software and

Open Source licenses. A general in-depth essay has been written by Laurent [16] and is available as open book. Morin et al. [17] published a guide for the academic researcher.

2. Common Misunderstandings

One popular advantage of FLOSS is that the software itself is available at no cost and is normally distributed as unrestricted download via the Internet. Many people infer from this fact that the underlying license terms prohibit any commercial exploitation and that there are no business models available to generate revenue based on FLOSS. Both points are not correct. The only difference to proprietary software and its underlying traditional business model is the absence of license costs. In the Open Source definition the stated clause "Free Redistribution" requires that the "license shall not require a royalty or other fee". Any other sources of revenue, like for example service-based offerings, can be utilized to the same extent and without restrictions. To sum up, FLOSS is not the counterpart to commercial software. There are various business models available that offer convenient ways to generate revenue based on FLOSS [18].

Closely related is also another misconception in respect to costs. As the software itself can be obtained for free, it does not consequently mean that its use and TCO will be cheaper or at no costs. There are experiences that show that after using FLOSS for several years the TCO has been slightly cheaper or similar to proprietary software and that considerable savings could only be achieved by the absence of the license costs. Furthermore there are effects that are quite hard to be expressed in pure monetary terms like prevention of vendor lock-in.

Another misinterpretation of FLOSS principles is related to the release and distribution of the resulting software. A common perception is that as soon as one modifies FLOSS or integrates it in a closed-source product, the resulting software and its source code have to be made publicly available to everyone via the Internet. But what actually is required varies strongly depending on the underlying license as described before. First of all this issue must only be addressed if the result is redistributed. For example source code that is licensed under a permissive FLOSS license can be modified and/or integrated in closed-source software without the need to release the resulting product under similar terms. In contrast strong copyleft FLOSS licenses would require a release under the same license and the provision of the resulting source code, but only to those who receive the software in binary form. Of course a public release on the Internet is highly appreciated by the community and is probably the easiest way to distribute the related source code. However, it

is not demanded by the underlying license terms.

Sometimes FLOSS is falsely lumped together with freeware or shareware. Although the names itself may sound similar, freeware or shareware have nothing in common besides of that they may be gratis or can be shared. Both types are clear closed-source products that come with considerable restrictions on its use and may even contain advertising functionality or more serious threats on the privacy of its user.

III. FLOSS in Health Care

FLOSS-HC is different from FLOSS in other domains. The healthcare domain is very complex. Software solutions often depend on regional and national regulations, final products have to be certified in most countries and health care providers require professional support services for available products.

Many examples for successful FLOSS-HC projects are available today. There are several factors that are indispensable for the sustainability and the success of a product. Some of these factors are: 1) Existence of a developer and user community, 2) Reliable release cycle, 3) FLOSS governance, 4) Modular architecture, 5) Software documentation including handbook, and 6) Professional support services.

Several scientific papers have been published in the last decade about FLOSS-HC [19-42]. An overview of these articles is given in Table 1.

Several researchers have carried out studies to find out reasons for adopting or not adopting FLOSS-HC. Pare et al. [43] have examined the main barriers to open source adoption by interviewing CIOs in Quebec's health care organizations. The three most frequently cited barriers are according to their findings lack of internal IT resources and expertise, internal and external political pressure and lack of reliable information about open source products.

Schmuhl et al. [44] have studied the view of health IT executives on the use of open source software in health care delivery in major hospitals in Germany and other European countries. Significant advantages have been seen in the absence of license costs and the opportunity to actively participate and collaborate on its development. Major disadvantages are lack of professional support and the lack of liability and accountability. The adoption of open source software benefits from executives' dissatisfaction with proprietary vendors and their trust into the power of the community. Hindering factors are seen in the complex and continuously changing legal regulations relevant to health IT and the unpredictable evolvement and outcome of a community-based development approach.

Table 1. Free/Libre Open Source Software in health care reviews from 2003 to 2013

Author	Year	Title
McDonald et al. [19]	2003	Open Source software in medical informatics: why, how and what
Leong et al. [20]	2007	Free and open source enabling technologies for patient-centric, guideline-based clinical decision support: a survey
Munoz-Cornejo [37]	2007	An empirical investigation into the adoption of open source software in hospitals
Nagy [38]	2007	Open source in imaging informatics
Yellowlees [33]	2008	Standards-based, open-source Electronic Health Record systems: a desirable future for the U.S. health industry
Valdes [22]	2008	Free and open source software in healthcare 1.0
Murray et al. [21]	2009	Open source and healthcare in Europe: time to put leading edge ideas into practice
Janamanchi et al. [23]	2009	The state and profile of open source software projects in health and medical informatics
Pare et al. [43]	2009	Barriers to open source software adoption in Quebec's health care organizations
Bhandari and Snowdon [41]	2010	Adoption of open source software in healthcare
Loiterman [24]	2010	Free as in freedom: open source software's role in remaking healthcare in the twenty-first century
Morrison et al. [36]	2010	Report on existing open-source Electronic Medical Records
Atalag and van Huffel [25]	2010	Innovation and openness: Is there room for both
Flores Zuniga et al. [34]	2010	Functionalities of free and open Electronic Health Record systems
Karopka et al. [26]	2011	Towards open collaborative health informatics: the role of free/libre open source principles
Reynolds and Wyatt [27]	2011	Open source, open standards, and health care information systems
Webster [28]	2011	The rise of open-source Electronic Health Records
Ratib et al. [39]	2011	Open Source software and social networks: disruptive alternatives for medical imaging
Millard et al. [29]	2012	Open-source point-of-care Electronic Medical Records for use in resource-limited settings: systematic review and questionnaire surveys
Maglogiannis [30]	2012	Towards the adoption of open source and open access Electronic Health Record systems
Kobayashi [31]	2012	Open source software development on medical domain
Sainz de Abajo and Ballestero [32]	2012	Overview of the most important open source software: analysis of the benefits of OpenMRS, OpenEMR, and VistA
Vasudeva [42]	2012	Open source: an innovation paradigm
Ingram and Arikan [35]	2013	The evolving role of open source software in medicine and health services
Reynolds [40]	2013	Better value digital health: the medium, the market and the role of openness
Vest and Stephens [45]	2013	The use and role of open source software applications in public and not-for-profit hospitals in the United States
Goldwater et al. [46]	2013	The use of open source Electronic Health Records within the federal safety net
Schmuhl et al. [44]	2013	Use of open source software in health care delivery: results of a qualitative field study

Vest and Stephens [45] have questioned CIOs of hospitals in the United States about the use and perception of open source software health information technology. Their central finding is that only general purpose applications are widely used. Main advantage for adoption is seen in cost savings, disadvantages are primarily that available solutions did not sufficiently support the clinical workflows and that relying on these bared to much risk. Furthermore interviewees

stated to still rely heavily on vendor support.

Goldwater et al. [46] have run a study on the use of open source Electronic Medical Records (EMR) within the United States Federal Safety Net. Their main results reveal that users value to be able to utilize a large community of developers and users to optimize the software to their needs and that the acquisition and implementation costs are lower compared to proprietary software. Factors restraining the dissemination and use of open source software are described to be the negative connotation associated with this type of software and the advanced technical skills that are required in-house to assure effectiveness of its application.

1. Information Sources about FLOSS in Health Care on the Web

A decade ago information and knowledge about FLOSS-HC was only available through news groups and limited to a small group of experts. One of the first initiatives to spread the news about the topic of FLOSS-HC was the news portal LinuxMedNews [47] developed by Ignacio Valdes. Linux-MedNews was founded in 2000 and since then nearly 2,000 articles have been published. The main objective of the site is to serve as a platform for medical FLOSS news. LinuxMed-News cover news about FLOSS Electronic Health Records (EHR), medical billing, EMR and practice management systems.

Another source of information is Open Health News (OH-News) [48] which is a combination of news, information, and resource portal on all things related to 'Open Health'—i.e., open source, open access, open data, open architecture, open standards, and open communities in healthcare. OHNews grew out of VistA News, a paper based industry newsletter. In 2010 a team was formed to create the online website which was launched in early 2011. Since then the site had more than 7 million hits and more than 135,000 unique users (data from website October 2013).

In 2010 this portal did not yet exist and information was dispersed over the internet. The open information portal Medfloss.org was created in 2010 out of the need to have a central repository of relevant FLOSS projects for the healthcare sector [26]. The main idea was to offer a structured description, related links and additional information resources on a per project base. Originally this data could only be retrieved by utilizing a search engine, browsing relevant hits for more information or by mining a typical source code repository like sourforge.net or github.com. Medfloss.org

Table 2. Resources for Free/Libre Open Source Software (FLOSS) on the Web

Name	Type	URL	Region served
OpenHealthNews	News/resource	http://www.openhealthnews.com/	World
COSI Open Health	Web-portal	http://sites.google.com/site/cosihealthit/	World
MedFLOSS	Web-portal	http://www.medfloss.org	World
FOSS-for-Health	Web-portal	http://www.foss-for-health.org/portal/	World
LinuxMedNews	News	http://linuxmednews.com/	World
Wikipedia List of Open Source in HC	Wiki	http://en.wikipedia.org/wiki/List_of_open_source_healthcare_software	World
OSEHRA	Foundation	http://www.osehra.org/	North America/World
Open Health Tools	Foundation	http://www.openhealthtools.org	US/World
Open Source Health Informatics in the UK	Blog	http://www.oshi-uk.com/	UK
Open Health Innovation	Blog	http://opensource.com/health	World
eHealth Open Source	Web-portal	http://www.ehealthopensource.org/	UK
eHealth Open Source	LinkedIn Group	http://www.linkedin.com/groups/eHealth-Open-Source-3407265	World
Open Source Software in Health Care	LinkedIn Group	http://www.linkedin.com/groups/Open-Source-Software-in-Health-1849332	World
Fred Trotter	Blog	http://www.fredtrotter.com/	US/World

COSI: Collaboration, Open Solutions & Innovation, FOSS: Free and Open Source Software, HC: health care, OSEHRA: Open Source Electronic Health Record Agent.

now offers a one-stop shop for anyone interested in medical FLOSS. Listed projects are tagged in multiple categories that are specific to the healthcare domain like application type, supported enterprise function, supported interoperability standards as well as in common properties like license, programming language, and supported platform. This guarantees not only easy discovery but also comparability of relevant candidates. Each project entry is enriched with links to the project's homepage and its download, documentation and support sections. Moreover companies that are offering services and scientific publications are included in the database of Medfloss.org and interlinked with the project they are referring to. In numbers currently about 300 projects, 235 publications, and 100 services providers are listed. These are being viewed by about 3,350 unique visitors of Medfloss.org per month.

Foss-for-health.org [49] is a portal that is initiated by Open Source and Standards PCTA (PANACeA Common Thematic Activities) that aims to create awareness of FLOSS in eHealth, promote its use and build both capacity and support for those starting to adopt it. PANACeA is the PAN Asian Collaboration for Evidence-based eHealth Adoption and Application. Table 2 contains an overview of online information sources about FLOSS in health care.

2. Events and Meetings for FLOSS in Health Care
One of the first European Events for FLOSS-HC was the Special Topic Conference of the European Federation for Medical Informatics (EFMI) in 2008 which was organized by the Libre/Free Open Source Working Group (LIFOSS WG) of EFMI. More than 80 people from more than 15 different countries met at the premises of the British Computer Society in London to exchange experience of using FLOSS-HC. The topic of this conference was "Open Source in European Healthcare". This event was the trigger for a series of workshops organized by EFMI LIFOSS WG and International Medical Informatics Association (IMIA) Open Source Health Informatics Working Group (OS WG) [21,26,50]. In 2010 the first FLOSS track at Med-e-Tel [51], the flagship conference of the International Society for Telemedicine and eHealth (ISfTeH) [51] took place followed by tracks in 2011 [53] and 2012 [54]. In 2013 Med-e-Tel featured an "Open Source Village" to give FLOSS initiatives and projects the opportunity to demonstrate their work.

In 2010 O'Reilly decided to integrate a track on healthcare in the O'Reilly Open Source Convention (OSCON) [55], probably the most important FLOSS event in North America. On the website Andy Oram explains why a healthcare track was integrated: "We believe that advances

in APIs, giving data to patients, open source software, and interactive mobile devices will free healthcare IT. We don't know precisely which technologies will win out or how the whole thing will fit together—so we want to use OSCON to help figure that out." [56]. The healthcare track took place at OSCON 2010 [55], OSCON 2011 [57] and OSCON 2012 [58] but was discontinued in 2013. However, other events take over the role. In 2012 the first Open Source Electronic Health Record Agent (OSEHRA) Open Source Summit took place and a second edition followed in 2013 [59].

3. Working Groups and Other Initiatives
In 2002 the IMIA OS WG [60] was founded with the ambition to promote FLOSS among the IMIA community and beyond. The IMIA OS WG aims to: disseminate knowledge about the benefits and prospects of FLOSS-HC among IMIA members and outside of IMIA; provide a neutral collaboration platform for all stakeholders in healthcare in respect to FLOSS; foster collaborations between FLOSS-HC projects; and lower the perceived barriers to the adoption of FLOSS-HC.

The Working Group closely collaborates with other Working Groups and initiatives with similar objectives among them the EFMI LIFOSS WG [61] and the Collaborative Care Team Open Source Working Group of the ISfTeH. Moreover, the American Medical Informatics Association has a working group for open source in healthcare as well [62].

Several Linux distributions have created dedicated projects to assemble medical related FLOSS packages and supply them as a module integrated in their software collections. The most well known are DebianMed [63], OpenSUSE Med [64], and Fedora Medical [65].

In the following paragraph we list some best practice examples from the MedFLOSS database.

IV. Best Practice Examples

One of the best known examples is the Veterans Health Administration VistA software that grew out of the Department of Veterans Affairs (VA) in the United States. The development began in the late 70s and early 80s and is now considered one of the most complex and useful systems covering the needs of a whole hospital. In an article in Health Affairs the potential value of the VA's health IT investments is estimated at $3.09 billion in cumulative benefits net of investment costs [66]. The early pioneers later formed a group called the hardhats and the history of the VistA software can be found on their website [67]. Starting as a bottom-up initiative this has now transformed into an official organisation

created by the VA, the OSEHRA [59] as well as several off-springs like WorldVistA [68] and OpenVista [32,69]. Other useful sources about the history and milestones in FLOSS-HC can be found in Peter Groen's COSI blog [70].

WorldVistA aims to adapt and extend the VA models and the values and principles on which they are based beyond the United States Federal government. "Drawing on experience with medical software going back four decades, the United States Department of Veterans Affairs originally designed VISTA's 1) software structure, 2) support, 3) software lifecycle, 4) community organization, 5) expertise lifecycle, 6) management, and 7) economic relationships to make these things possible. *Only a system based on these principles can fulfill the promise of using computers to improve health for everyone, everywhere.* WorldVistA intends to realize that dream." [68]. An example of WorldVistA's activities is the Hakeem Project. The Hakeem Program was launched 2009 and aims to computerize all of the public hospitals and clinics in Jordan (50 hospitals as well as up to 800 clinics). It is the first national eHealth project in Jordan. Hakeem is based on WorldVistA and is adapted to the needs and requirements of the Jordan health system including translation into Arabic. The customization is done by Electronic Health Solutions (EHS), a non-profit company based in Jordan.

In the UK there exists an initiative to adopt VistA for the UK National Health Service (NHS) called NHS VistA [71]. "As a group of clinicians, IT professionals, NHS managers and patients, we think the NHS needs a high quality, clinically-led, EHR that works across all health and social care settings. Realistically, VistA is the only affordable way for the NHS to achieve this goal." [71].

Another impressive best practice example is the OSCAR system developed at the McMaster University in Canada. The system is now called OSCAREMR [72] and currently supports over 1.5 million patients across Canada by offering an extremely versatile, browser-based, EMR with high clinical functionality and advanced research capabilities. "OSCAR is deeply rooted in its user community as reflected in its motto, 'Connecting Care, Creating Community'. This community is a vital part of the OSCAR ecosystem, with members from academic and research institutions, community practices, hospitals, ambulatory and outreach programs, public health departments, other social service agencies, and the OSCAR Canada User Society." [72].

CONNECT is an open source software and community that promotes IT interoperability in the United States healthcare system. CONNECT enables secure electronic health data exchange among healthcare providers, insurers, government agencies and consumer services [73].

Open Health Tools [74] is a not for profit association that aims to assemble or develop a comprehensive harmonized tool suite to enable the definition, development and deployment of interoperable EHRs. Several projects are supported that cover the life cycle of EHRs in the broadest sense including development of standards, architectures, documentation, and training. For example Open Health Tools provides client side implementations of several key IHE profiles. These implementations were used successfully by over 35 systems in various IHE Connectathons in North America and Europe.

The Japan Medical Association has developed a medical accounting/billing system (Online Receipt Computer Advanced [ORCA]) in 2000 which is now used by more than 10.000 medical providers. ORCA is based on Debian GNU/Linux and Ubuntu and uses PostgreSQL as database system [75].

V. FLOSS in Low Resource Settings

The FLOSS approach is of particular interest for low resource settings. Being available without licensing fees makes these products the only viable solution for many countries. Another important advantage of FLOSS systems is the adaptability to local needs.

OpenMRS is probably the best known and widest deployed system. Based on a clinical database model developed at the Regenstrief Institute in the United States and funded by the Rockefeller Foundation and International Development Research Centre Canada, this project managed to set up a powerful user and developer community including small local companies providing support and customization services for OpenMRS [76-79].

GNU Health is a free health and hospital information system with a focus on low resource settings [80]. Development has started in 2008 under the name 'Medical'. The system is based on a free and open enterprise resource planning program, Tryton [81] and follows the same modular approach like the underlying enterprise resource planning (ERP) software. A big advantage of this approach is that the software "inherits" all modules that are developed in the Tryton ERP community. Despite its short history GNU Health provides extensive functionality and has installations in several countries worldwide, among them Argentina, Jamaica, Paraguay, Kenya, Laos, Philippines, Bangladesh, and Malaysia. Recently the government of Jamaica chose GNU Health as a national health IT system. GNU Health is further developed by a global community of health IT experts, physicians, and other end-users coordinated by GNU Solidario [82], an NGO based in Spain. GNU Health achieved several awards

among them the Free Software Foundation award for projects of social benefit in 2011.

The District Health Information System [83] is a highly flexible, open-source health management information system and data warehouse developed by the Health Information Systems Programme (HISP). "The Health Information Systems Programme has since 1994 expanded from a pilot project in three Cape Town health districts to a global South-South-North network active in around 15 countries/states with over 200 million people in Africa and Asia." [84]. The core development activities are managed and coordinated by the Department of Informatics at the University of Oslo, and supported by The Norwegian Research Council, The Norwegian Agency for Development Cooperation (NORAD), The University of Oslo, and The Norwegian Centre for International Cooperation in Education. The system supports the capture of data linked to any level in an organisational hierarchy, any data collection frequency, a high degree of customisation at both the input and output side. It has been translated into a number of languages. For India there is a dedicated network, HISPIndia [85], a not for profit NGO specializing since more than a decade in designing and implementing solutions in health informatics for the public health sector in Indian states, and also recently in Bangladesh and Sri Lanka.

OpenClinic GA is a FLOSS software for management of hospital information flows. The program has been developed since 2006 by a Belgium company and put in the public domain in 2008. Currently more than 15 country specific localizations are available and more than 2 million patients are served by these installations ranging from small clinics to entire hospitals. The biggest user community is in Burundi, Rwanda, and Mali, and the program features a full billing system for Central African public and private health insurance systems. More details can be found on the wiki site of the project [86].

OpenHIE is a community of FLOSS health IT projects made up of many different organizations and individuals [87]. OpenHIE is comprised of six sub-communities covering the areas of Client Registry, Provider Registry, Facility Registry, Terminology Services, Shared Health Record, and Interoperability Layer. The main objective of the OpenHIE project is to use FLOSS components to build a health information exchange.

VI. Conclusion

FLOSS has gained much attraction in the recent decade. In healthcare it has always been used to some extend in research and academic settings. However, FLOSS-HC delivery is much more demanding and most countries lack a FLOSS ecosystem, including, e.g., professional support services, that is essential for the sustainability of solutions.

North America has the longest tradition in applying FLOSS-HC delivery. It is home of many mature, stable and widely disseminated FLOSS applications. Some of them are even used on a global scale. The deployment of FLOSS systems in healthcare delivery is comparatively low in Europe. Due to the fragmentation of healthcare, with a wide range of different systems run at national level, it is difficult to get a clear picture about FLOSS usage throughout the continent. There is also no organized FLOSS-HC community in Europe as such. However, on a national level the figures vary extensively. The UK has a long tradition of FLOSS-HC and very recently has made considerable progress and has without doubt the most active and vibrant FLOSS-HC community in Europe. In 2012 a series of "NHS Hack Days" [88,89] have been started each bringing together around "120 volunteer doctors, developers, designers and other 'geeks who love the NHS'" [40] with the objective to improve currently available solutions or find solutions for existing problems.

Regarding low resource settings, there are a number of mature and stable systems. Several systems are deployed in different countries and even on different continents. However, compared with the proprietary systems the level of usage is still low.

The objective of an open platform where different modules can be plugged in and where different applications can be assembled to form a highly adaptable and configurable system has yet to be approached. The 'global community', if this exists at all, is still very fragmented. Open Standards, Open Science, Open Data, and FLOSS are the most promising way to create synergies and make healthcare more achievable on a global level. Besides the sharing of knowledge and resources, FLOSS is facilitating health information systems that are sustainable at a long-term, as not only the software but also the data that they contain are accessible and thus allow for migration processes.

The past five years have seen a tremendous growth in global initiatives and collaborative effort among different FLOSS projects. Several sites have been developed to function as a one-stop-shop for news and information around FLOSS-HC (e.g., MedFLOSS, OpenHealthNews, COSI, OSEHRA). It is now time for governments, policy makers, regulators, NGOs, healthcare IT providers, and healthcare providers to create open ecosystems to foster innovation and remove barriers for cross-sectoral, collaborative team-based healthcare research and delivery.

Conflict of Interest

Acknowledgments

References

1. Medical Free/Libre and Open Source Software [Internet]. [place unknown]: Medfloss.org; c2013 [cited at 2013 Jan 28]. Available from: http://www.medfloss.org/.

2. BOSC: Bioinformatics Open Source Conference [Internet]. [place unknown]: Open Bioinformatics Foundation; c2013 [cited at 2013 Dec 15]. Available from: http://www.open-bio.org/wiki/BOSC.

3. Open Bioinformatics Foundation [Internet]. [place unknown]: Open Bioinformatics Foundation; c2013 [cited at 2013 Dec 15]. Available from: http://www.open-bio.org.

4. GNU Operating System [Internet]. Boston (MA): Free Software Foundation; c2013 [cited at 2013 Dec 6]. Available from: http://www.gnu.org/home.en.html.

5. GNU Operating System. The free software definition [Internet]. Boston (MA): Free Software Foundation; c2013 [cited at 2013 Dec 6]. Available from: http://www.gnu.org/philosophy/free-sw.en.html.

6. Free Software Foundation [Internet]. Boston (MA): Free Software Foundation; c2013 [cited at 2013 Dec 2]. Available from: http://www.fsf.org.

7. Open Source Initiative [Internet]. Palo Alto (CA): Open Source Initiative; c2013 [cited at 2013 Dec 6]. Available from: http://opensource.org/.

8. Apache Software Foundation. Apache License [Internet]. [place unknown]: Apache Software Foundation; c2012 [cited at 2013 Dec 17]. Available from: http://www.apache.org/licenses/.

9. Open Source Initiative. The BSD 2-Clause License [Internet]. Palo Alto (CA): Open Source Initiative; c2013 [cited at 2013 Dec 17]. Available from: http://opensource.org/licenses/bsd-license.php.

10. Open Source Initiative. The MIT License [Internet]. Palo Alto (CA): Open Source Initiative; c2013 [cited at 2013 Dec 17]. Available from: http://opensource.org/licenses/MIT.

11. Eclipse Foundation. Eclipse Public License (v 1.0) [Internet]. Ottawa (ON): Eclipse Foundation; c2013 [cited at 2013 Dec 17]. Available from: http://www.eclipse.org/org/documents/epl-v10.php.

12. Mozilla Corporation. Mozilla Public License [Internet]. Mountain View (CA): Mozilla Corporation; c2013 [cited at 2013 Dec 17]. Available from: http://www.mozilla.org/MPL/.

13. GNU Operating System. GNU Lesser General Public License [Internet]. Boston (MA): Free Software Foundation; c2013 [cited at 2013 Dec 17]. Available from: https://www.gnu.org/licenses/lgpl.html.

14. GNU Operating System. GNU General Public License [Internet]. Boston (MA): Free Software Foundation; c2013 [cited at 2013 Dec 17]. Available from: http://www.gnu.org/licenses/gpl.html.

15. GNU Operating System. GNU Affero General Public License [Internet]. Boston (MA): Free Software Foundation; c2013 [cited at 2013 Dec 17]. Available from: http://www.gnu.org/licenses/agpl-3.0.de.html

16. Laurent AM. Understanding open source and free software licensing. Sebastopol (CA): O'Reilly: 2004.

17. Morin A, Urban J, Sliz P. A quick guide to software licensing for the scientist-programmer. PLoS Comput Biol 2012;8(7):e1002598.

18. Riehle D. The commercial open source business model. In: Value creation in e-Business management. Heidelberg, Germany: Springer-Verlag; 2009. p. 18-30.

19. McDonald CJ, Schadow G, Barnes M, Dexter P, Overhage JM, Mamlin B, et al. Open Source software in medical informatics: why, how and what. Int J Med Inform 2003;69(2-3):175-84.

20. Leong TY, Kaiser K, Miksch S. Free and open source enabling technologies for patient-centric, guideline-based clinical decision support: a survey. Yearb Med Inform 2007;2007:74-86.

21. Murray PJ, Wright G, Karopka T, Betts H, Orel A. Open source and healthcare in Europe: time to put leading edge ideas into practice. Stud Health Technol Inform 2009;150:963-7.

22. Valdes I. Free and open source software in Healthcare 1.0. Bethesda (MD): American Medical Informatics Association Open Source Working Group; 2008.

23. Janamanchi B, Katsamakas E, Raghupathi W, Gao W. The state and profile of open source software projects in health and medical informatics. Int J Med Inform

2009;78(7):457-72.

24. Loiterman J. Free as in freedom: open source software's role in remaking healthcare in the twenty-first century. Ann Health Law 2010;19(1 Spec No):259-63.

25. Atalag K, van Huffel W. Innovation and openness: Is there room for both. Health Care Inform Rev Online 2010;14(1):19-23.

26. Karopka T, Schmuhl H, Marcelo A, Molin JD, Wright G. Towards open collaborative health informatics: the role of free/libre open source principles. Contribution of the IMIA Open Source Health Informatics Working Group. Yearb Med Inform 2011;6(1):63-72.

27. Reynolds CJ, Wyatt JC. Open source, open standards, and health care information systems. J Med Internet Res 2011;13(1):e24.

28. Webster PC. The rise of open-source electronic health records. Lancet 2011;377(9778):1641-2.

29. Millard PS, Bru J, Berger CA. Open-source point-of-care electronic medical records for use in resource-limited settings: systematic review and questionnaire surveys. BMJ Open 2012;2(4):e000690.

30. Maglogiannis I. Towards the adoption of open source and open access electronic health record systems. J Healthc Eng 2012;3(1):141-62.

31. Kobayashi S. Open Sourse Software development on medical domain. In: Kalloniatis C, editor. Modern information systems. [place unknown]: InTech; 2012.

32. Sainz de Abajo B, Ballestero AL. Overview of the most important open source software: analysis of the benefits of OpenMRS, OpenEMR, and VistA. In: Rodrigues JJ, de la Torre Diez I, Sainz de Abajo B, editors. Telemedicine and e-Health services, policies, and applications: advancements and developments. Hershey (PA): IGI Global; 2012. p. 315-46.

33. Yellowlees PM, Marks SL, Hogarth M, Turner S. Standards-based, open-source electronic health record systems: a desirable future for the U.S. health industry. Telemed J E Health 2008;14(3):284-8.

34. Flores Zuniga AE, Win KT, Susilo W. Functionalities of free and open electronic health record systems. Int J Technol Assess Health Care 2010;26(4):382-9.

35. Ingram D, Arikan SS. The evolving role of open source software in medicine and health services. Technol Innov Manag Rev 2013;(1):32-9.

36. Morrison C, Iosif A, Danka M. Report on existing open-source electronic medical records. Cambridge, UK: University of Cambridge Computer Laboratory; 2010.

37. Munoz-Cornejo G. An empirical investigation into the adoption of open source software in hospitals [disserta-

tion]. Catonsville (MD): University of Maryland at Baltimore County; 2007.

38. Nagy P. Open source in imaging informatics. J Digit Imaging 2007;20 Suppl 1:1-10.

39. Ratib O, Rosset A, Heuberger J. Open Source software and social networks: disruptive alternatives for medical imaging. Eur J Radiol 2011;78(2):259-65.

40. Reynolds CJ. Better value digital health: the medium, the market and the role of openness. Clin Med 2013;13(4):336-9.

41. Bhandari G, Snowdon A. Adoption of open source software in healthcare. In: Advances in intelligent dicision technologies. Heidelberg, Germany: Springer-Verlag; 2010. p. 365-72.

42. Vasudeva VN. Open source: an innovation paradigm. Med Leg Update 2012;12(2):220-4.

43. Pare G, Wybo MD, Delannoy C. Barriers to open source software adoption in Quebec's health care organizations. J Med Syst 2009;33(1):1-7.

44. Schmuhl H, Heinze O, Bergh B. Use of open source software in health care delivery: results of a qualitative field study. Contribution of the EFMI LIFOSS Working Group. Yearb Med Inform 2013;8(1):107-13.

45. Vest JR, Stephens JH. The use and role of open source software applications in public and not-for-profit hospitals in the United States. Health Care Manage Rev 2013;38(4):361-70.

46. Goldwater JC, Kwon NJ, Nathanson A, Muckle AE, Brown A, Cornejo K. The use of open source electronic health records within the federal safety net. J Am Med Inform Assoc 2013 Jun 6 [Epub]. http://dx.doi.org/10.1136/amiajnl-2013-001671.

47. LinuxMedNews: revolutionizing medical education and practice [Internet]. [place unknown]: LinuxMedNews.com; c2013 [cited at 2013 Nov 26]. Available from: http://linuxmednews.com/.

48. Open Health News: the voice for the open health community [Internet]. [place unknown]: Open Health News; c2013 [cited at 2013 Nov 26]. Available from: http://www.openhealthnews.com.

49. Free and Open Source Software for Health [Internet]. [place unknown]: foss-for-health.org; c2009 [cited at 2013 Dec 15]. Available from: http://www.foss-for-health.org/portal/.

50. Karopka T, Cruz Correia RJ, editors. Proceedings of the 1st International Workshop on Open Source in European Health Care: The Time is Ripe; 2009 Jan 16-17; Porto, Portugal. [place unknown]: INSTICC Press; 2009.

51. International Society for Telemedicine & eHealth (IS-

fTeH). Proceedings of the 8th Annual Med-e-Tel Conference on Benefits of Free/Libre Open Source Software in Health Care 2010; 2010 Apr 14-16; Luxembourg.

52. International Society for Telemedicine and eHealth (ISfTeH) [Internet]. Luzern, Switzerland: ISfTeH; c2013 [cited at 2013 Dec 16]. Available from: http://www.isfteh.org.

53. International Society for Telemedicine & eHealth (ISfTeH). Proceedings of the 9th Annual Med-e-Tel Conference on Benefits of Free/Libre Open Source Software in Health Care 2011; 2011 Apr 6-8; Luxembourg.

54. International Society for Telemedicine & eHealth (ISfTeH). Proceedings of the 10th Annual Med-e-Tel Conference on Benefits of Free/Libre Open Source Software in Health Care 2012; 2012 Apr 18-20; Luxembourg.

55. OSCON 2010 Healthcare track [Internet]. Sebastopol (CA): O'Reilly Media; c2010 [cited at 2013 Dec 5]. Available from: http://www.oscon.com/oscon2010/public/schedule/topic/Health.

56. Oram A. Why health care is coming to the Open Source convention [Internet]. Sebastopol (CA): O'Reilly Programming; c2010 [cited at 2013 Dec 5]. Available from: http://programming.oreilly.com/2010/03/why-health-care-is-coming-to-t.html.

57. OSCON 2011 Healthcare track [Internet]. Sebastopol (CA): O'Reilly Media; c2011 [cited at 2013 Dec 5]. Available from: http://www.oscon.com/oscon2011/public/schedule/topic/Healthcare.

58. OSCON 2012 Healthcare track [Internet]. Sebastopol (CA): O'Reilly Media; c2012 [cited at 2013 Dec 5]. Available from: http://www.oscon.com/oscon2012/public/schedule/topic/808.

59. Open Source Electronic Health Record Agent (OSEHRA) [Internet]. Arlington (VA): OSEHRA; c2013 [cited at 2013 Nov 26]. Available from: http://www.osehra.org.

60. International Medical Informatics Association. IMIA Open Source Health Informatics Working Group [Internet]. Geneva, Switzerland: IMIA; c2013 [cited at 2013 Nov 26]. Available from: http://www.imia-medinfo.org/new2/node/147.

61. European Federation Medical Informatics. EFMI Working Group LIFOSS [Internet]. Copenhagen, Denmark: EFMI; c2013 [cited at 2013 Nov 26]. Available from: http://www.helmholtz-muenchen.de/ibmi/efmi/index.php?option=com_content&task=view&id=1076&Itemid=260.

62. American Medical Informatics Association. AMIA Open Source Working Group [Internet]. Bethesda (MD): AMIA; c2013 [cited at 2013 Dec 17]. Available

from: http://www.amia.org/programs/working-groups/open-source.

63. DebianMed [Internet]. [place unknown]: DebianMed; c2013 [cited at 2013 Dec 15]. Available from: https://wiki.debian.org/DebianMed.

64. OpenSUSE: Medical team [Internet]. [place unknown]: openSUSE.org; c2013 [cited at 2013 Dec 15]. Available from: http://en.opensuse.org/openSUSE:Medical_team.

65. Fedora medical group [Internet]. Raleigh (NC): Red Hat Inc.; c2013 [cited at 2013 Dec 15]. Available from: http://fedoraproject.org/wiki/SIGs/FedoraMedical.

66. Byrne CM, Mercincavage LM, Pan EC, Vincent AG, Johnston DS, Middleton B. The value from investments in health information technology at the U.S. Department of Veterans Affairs. Health Aff (Millwood) 2010;29(4):629-38.

67. Hardhats [Internet]. [place unknown]: hardhats.org; c2013 [cited at 2013 Nov 26]. Available from: http://www.hardhats.org.

68. WorldVistA [Internet]. [place unknown]: WorldVistA.org; c2013 [cited at 2013 Nov 26]. Available from: http://www.worldvista.org/.

69. OpenVista EHR solution [Internet]. Carlsbad (CA): Medsphere; c2013 [cited at 2013 Dec 15]. Available from: http://www.medsphere.com/commercial/openvista-for-the-enterprise.

70. Groen P. Collaboration, Open Solutions & Innovation (COSI) in healthcare [Internet]. [place unknown: publisher unknown]; c2013 [cited at 2013 Dec 15]. Available from: https://sites.google.com/site/cosihealthit/.

71. Campaign for NHS VistA [Internet]. [place unknown]: nhsvista.net; c2013 [cited at 2013 Nov 26]. Available from: http://nhsvista.net.

72. OSCAR EMR [Internet]. [place unknown]: OSCAR; c2013 [cited at 2013 Nov 26]. Available from: http://oscar-emr.com/.

73. CONNECT [Internet]. Washington (DC): U.S. Department of Health and Human Services; c2013 [cited at 2013 Nov 26]. Available from: www.connectopensource.org.

74. Open Health Tools [Internet]. Vienna (VA): Open Health Tools; c2013 [cited at 2013 Nov 26]. Available from: http://www.openhealthtools.org/.

75. Kobayashi S, Yahata K, Goudge M, Okada M, Nakahara T, Ishihara K. Open source software in medicine and its implementation in Japan. J Inf Technol Healthc 2009;7(2);95-101.

76. Mamlin BW, Biondich PG, Wolfe BA, Fraser H, Jazayeri D, Allen C, et al. Cooking up an open source EMR for

developing countries: OpenMRS: a recipe for successful collaboration. AMIA Annu Symp Proc 2006;2006:529-33.

77. Seebregts CJ, Mamlin BW, Biondich PG, Fraser HS, Wolfe BA, Jazayeri D, et al. The OpenMRS implementers network. Int J Med Inform 2009;78(11):711-20.

78. Seebregts CJ, Mamlin BW, Biondich PG, Fraser HS, Wolfe BA, Jazayeri D, et al. Human factors for capacity building: lessons learned from the OpenMRS implementers network. Yearb Med Inform 2010;2010:13-20.

79. Kanter AS, Negin J, Olayo B, Bukachi F, Johnson E, Sachs SE. Millennium Global Village-Net: bringing together Millennium Villages throughout sub-Saharan Africa. Int J Med Inform 2009;78(12):802-7.

80. GNU Health [Internet]. [place unknown]: GNU Solidario; c2011 [cited at 2013 Dec 15]. Available from: http://health.gnu.org/.

81. Tryton [Internet]. [place unknown]: Tryton; c2013 [cited at 2013 Dec 15]. Available from: http://www.tryton.org/.

82. GNU Solidario [Internet]. [place unknown]: GNU Solidario; c2011 [cited at 2013 Dec 15]. Available from: http://www.gnusolidario.org

83. District Health Information System [Internet]. [place unknown]: Wikimedia Foundation Inc.; c2013 [cited at Dec 15]. Available from: http://en.wikipedia.org/wiki/DHIS.

84. Health Information Systems Programme (HISP) [Internet]. [place unknown]: HISP; c2013 [cited at 2013 Nov 26]. Available from: http://www.hisp.org/.

85. HISP India [Internet]. [place unknown]: HISPindia.org; c2013 [cited at 2013 Nov 26]. Available from: http://hispindia.org/.

86. OpenClinic GA [Internet]. [place unknown: publisher unknown]; c2013 [cited at 2013 Dec 16]. Available from: http://sourceforge.net/projects/open-clinic/.

87. Open Health Information Exchange (OpenHIE) [Internet]. [place unknown]: OpenHIE; c2013 [cited at 2013 Nov 26]. Available from: http://ohie.org/.

88. NHS Hack Day [Internet]. [place unknown]; nhshackday.com; c2013 [cited at 2013 Dec 15]. Available from: http://nhshackday.com.

89. Tavare A. NHS "hack day" will reward apps and software tools that help patients and doctors. BMJ 2012;344:e3609.