Open Source software and social networks: Disruptive alternatives for medical imaging

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Abstract

In recent decades several major changes in computer and communication technology have pushed the limits of imaging informatics and PACS beyond the traditional system architecture providing new perspectives and innovative approach to a traditionally conservative medical community. Disruptive technologies such as the world-wide-web, wireless networking, Open Source software and recent emergence of cyber communities and social networks have imposed an accelerated pace and major quantum leaps in the progress of computer and technology infrastructure applicable to medical imaging applications.

Methods: This paper reviews the impact and potential benefits of two major trends in consumer market software development and how they will influence the future of medical imaging informatics. Open Source software is emerging as an attractive and cost effective alternative to traditional commercial software developments and collaborative social networks provide a new model of communication that is better suited to the needs of the medical community.

Observations: Evidence shows that successful Open Source software tools have penetrated the medical market and have proven to be more robust and cost effective than their commercial counterparts. Developed by developers that are themselves part of the user community, these tools are usually better adapted to the user's need and are more robust than traditional software programs being developed and tested by a large number of contributing users. This context allows a much faster and more appropriate development and evolution of the software platforms. Similarly, communication technology has opened up to the general public in a way that has changed the social behavior and habits adding a new dimension to the way people communicate and interact with each other. The new paradigms have also slowly penetrated the professional market and ultimately the medical community. Secure social networks allowing groups of people to easily communicate and exchange information is a new model that is particularly suitable for some specific groups of healthcare professional and for physicians. It has also changed the expectations of how patients wish to communicate with their physicians.

Conclusion: Emerging disruptive technologies and innovative paradigm such as Open Source software are leading the way to a new generation of information systems that slowly will change the way physicians and healthcare providers as well as patients will interact and communicate in the future. The impact of these new technologies is particularly effective in image communication, PACS and teleradiology.

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1. Introduction

The increasing volume of medical images and imaging procedures that are becoming part of clinical practice and patient workup represent a significant challenge for IT infrastructure and data management and communication systems. Furthermore, users such as physicians, care providers and even patients have increasingly higher expectations regarding wider distribution and faster access to all medical imaging data anywhere anytime. Physicians tend to rely exclusively on evidence of imaging procedures for patient management and clinical decision-making. A growing number of surgical interventions as well as minimally invasive interventional procedures rely extensively on morphological and anatomical information obtained by imaging procedures as well as on image guidance for performing those procedures [1]. This constant growth in demand for faster and broader distribution of large volumes of imaging data puts a serious burden on traditional PACS architecture and image management systems. New and more flexible communication paradigms are emerging in general consumer market and will strongly influence the evolution of medical information systems. With increasing bandwidth of wireless networks and rapid expansion of services accessible through cellular net-
works for phones and portable devices, communication paradigm have shifted toward real-time interactive and continuous data communication and seamless access to information at any time. This trend slowly penetrates professional community and medical institutions.

Under restrictive financial constrains and new rules of cost-effectiveness in healthcare a pressure for higher efficiency and better performance have led to increase demand for information systems that provide better access to medical data but particularly to medical imaging data [2]. Also, with increasing complexity of imaging modalities a trend toward more objective and quantitative evaluation of images require sophisticated image processing and analysis tools [3]. Emergence of new molecular imaging techniques provides additional metabolic and functional information that adds to the morphological and anatomical findings. Adequate representation and visualization of such complex multidimensional data require sophisticated rendering tools and image processing software. Ironically, where these tools are needed the most is not in radiology departments but in clinical services and in areas where clinical decisions and patient management choices are being made. They are also becoming a communication means for radiologists to communicate their findings. The availability of these tools are however very limited outside radiology departments due to their high cost and complex setups.

Development of commercial systems driven by medical imaging manufacturers lags behind the increasing demand for advanced processing tools. They usually follow research and clinical validation and require several years before releasing new products on the market (Fig. 1). These are the reasons why Open Source and free software is becoming more widely adopted in the medical community. Open Source not only provides a cost effective alternative, but, because they are being developed by a community of developers from the field, the software tools can be customized to match the needs and specific usage in clinical setups outside radiology. Also Open Source have less restrictions on providing new innovative and challenging viewing and analysis tools that respond to users demands even before industry and commercial vendors identify these new trends as potential source of revenue (Fig. 2).

2. Impact of emerging new technologies

Disruptive technologies have triggered radical changes in system design and IT infrastructures in often-unpredictable ways. There is no doubt that the rapid development of the world-wide web has taken the IT community by surprise and has significantly changed the way information and communications are being handled today. These technologies have also rapidly penetrated more traditional professional environments such as medicine and shaped the way medical applications are being developed today with a massive shift toward web-based implementations. The subsequent development of high bandwidth communication networks and new quantum leaps in system performance such as the recent adoption of Internet II initiatives have also gone beyond the original expectations. Fueled by the explosion of needs for storage of multimedia data such as music and video, driven by a high demand from the consumer market for personal storage space has driven the unprecedented development of network storage services with incredible storage capacities that dwarf the storage requirements for medical imaging. As of today it is already cheaper to outsource large capacity storage on secure online storage services in the “cloud” than to implement a local storage infrastructure. Wide availability and low cost of high capacity network and unlim-
Advanced image display and analysis tools adapted to multimodality imaging techniques such as hybrid PET-CT images showing multiplanar reformatting of fused images (back window) as well as volume rendering and segmentation of tumor outline from PET images (front window).

The revolution of Open Source software

The concept of Open Source software (OSS) promotes the development and sharing of software source code under special licensing agreements that protects author's copyrights while maintaining the distribution of free and open derivative work based on the original code. The most successful example of Open Source development is Linux Operating system. Numerous other Open Source software products have recently been successfully deployed and widely adopted such as Apache web server software that has exceeded by far the number of implementation sites of competing commercial products.

The rationale behind Open Source is very simple: when several programmers can read, redistribute, and modify the source code for a piece of software, the software evolves. Developers and users will contribute to improve it, adapt it and help fix the bugs. Open Source software can thereby evolve at a much higher speed than conventional software and will be better adapted to users needs. The main characteristic of the Open Software is that it is being peer reviewed and evaluated by the user community, and only the best will gather enough momentum and be widely adopted. To be successful, an Open Source program must have a strong development momentum with a leading team or preferably a single leader that ensures the consistency and quality of the software that is being distributed. Given that most Open Source project cannot be funded by traditional channels such as grants or industry support, most of the work is provided by benevolent contributors.

Several non-profit organizations have emerged to support and help the development of Open Source initiatives. Open Source Initiative (OSI) is a non-profit corporation dedicated to managing and promoting the Open Source Definition for the good of the community, specifically through the OSI Certified Open Source Software certification mark and program (http://www.opensource.org/). In healthcare several smaller organizations have emerged such as the Open Source in Health Care (OSHCA) association (http://www.oshca.org/), and Open Source in Healthcare (http://www.openhealth.org/), and more specifically for Medical Imaging the OpenRad initiative (http://www.openrad.com/). This is certainly not a comprehensive list and there are numerous small associations and users groups that are active in the domain of Open Source software development in medicine. Of interest are on-line “Journal of Free and Open Source Medical Computing” http://www.josmc.org/ and “LINUX Medical News” http://www.linuxmednews.com/ where news and information about Open Source developments in medicine can be found.

Open Source in medicine

Numerous Open Source initiatives in medicine leading to innovative and cost effective information systems supporting electronic patient record applications and medical imaging and PACS have emerged in the recent years. Recent reports showed that adoption of computerized medical records and medical informatics in medicine have significantly lagged behind expectations due to three major barriers: excessive cost, the transience of vendors, and
the lack of common standards and adequate models. Many authors suggested however that Open Source software reduces these barriers by reducing ownership and development costs and facilitating the adaptation of customized tools for clinical practice [4]. Open Source offers freedom from software licensing costs. The medical informatics community welcomes Open Source model, which fits naturally its scientific model of shared, peer-reviewed knowledge. Distributors of Open Source applications can share development costs with the users community and focus on implementation and support services. The resulting paradigm shift is that Open Source medical system vendors can become professional service providers, competing on service quality rather than on the basis of software secrets.

The impact of open source is even greater in specialized areas of medicine such medical imaging [5]. These vertical markets have always been a challenge for vendors and manufacturers due to the small size of specialized users and high expectations in terms of complexity and performance of the tools required. This has naturally driven the market to high-end and high-cost developments and marketing strategies that also try to cope with very rapid evolution of computer technologies and software developments that make most products obsolete in very short time interval, which does not allow the manufacturers to generate sustainable return on investment [6]. In very specialized niches such as in medical imaging it is almost impossible to maintain profitable business models that are self-sustained. Most manufacturers will cover the cost through revenues from other business avenues such as sales of imaging modalities, scanners and imaging devices, or by providing expensive global solutions and charging high costs for implementation and support and maintenance contracts of complex integrated information systems [3].

A list of recent Open Source initiatives in Medical Imaging Software can be found at [http://www.idoimaging.com/]. In the scientific community, a new set of Open Source libraries have emerged for the visualization of multidimensional data. The most successful set of tools is provided by Insight Software Consortium ([http://www.insightsoftwareconsortium.org/]). The Visualization Toolkit or VTK ([http://public.kitware.com/VTK/]) is a well recognized and widely adopted software library that runs on multiple platforms and has been used for numerous scientific and medical applications so far [7]. The recent adjunction of the Insight Toolkit or ITK ([http://www.itk.org/]), mostly funded by the US National Library of Medicine as part of the Visible Human Project, adds a wealth of additional rendering and image processing tools for medical applications. More information on VTK and ITK applications can be found in the “Insight Journal” [http://www.insight-journal.org/]. There is also an emerging effort to consolidate multiple projects into larger community of non-profit associations that can have a stronger core momentum for fund raising and sharing of development resources. Among such initiatives one should mention a consortium of academic groups that recently launched a concerted effort for the development of Open Source components for PACS and Image Management in Medicine and holding its first general conference on “Open Source Strategy for Multi-Center Image Management” ([http://www.mcim.georgetown.edu]) in March 2006. The first objective of this new consortium is to regroup its partners efforts in Open Source development under a common framework called Image Management Tool Kit (IMTK).

Another example of successful Open Source software development in medical imaging is the OsiriX software platform [8]. Developed at the University of Geneva, this program aimed for image analysis and visualization of complex multidimensional medical imaging modalities has gained an impressive momentum around the world. Designed by radiologists and specialists in medical imaging it is tailored to be used by radiologists but also by non-expert physicians that need to access and review complex imaging data generated by today’s scanners and digital modalities [9]. One of the most attractive features of OSIRIX remains its ability to manipulate and visualize large sets of image data using advanced volume rendering and three dimensional navigation tools. OSIRIX user interface was designed to allow physicians to rapidly become familiar with the manipulation of 3D objects and navigating through large sets of images [1]. All the traditional visualizations tools such as multiplanar reformatting, volume and surface rendering, transparency and intensity projects are available at a click of a mouse. It also supports dynamic time/varying data sets that can be manipulated in 3D while being displayed in cine motion essentially showing a 4D rendered image (where time is referred to as the fourth dimension). With the advent of multimodality imaging and molecular imaging devices such as hybrid PET/CT scanners, it is possible now to generate functional images that represent metabolic and biological dimension superimposed over morphological and anatomical data. OSIRIX was designed to conveniently handle the fusion of metabolic images and anatomical images in essential a 5D image rendering mode (where the anatomical information is referred to as the fifth dimension). OSIRIX is probably among the very few software platforms available today allowing users to display and manipulate 3D image sets in a convenient and user-friendly navigation environment (see Fig. 2).

Advanced image processing and analysis tools are being added to the program everyday. Developers from all around the world have contributed to the extension of OSIRIX by adding innovative and specialized image processing features. Furthermore, the OSIRIX software architecture allows for separate processing modules to be added to the program as plug-ins (Fig. 3). Such plug-ins will be imbedded in the program when it is launched but they do not have to be integrated in the core of the main program. These external plug-ins could also be components that are not shared as Open Source software but could be protected as binary modules or even sold as commercial extensions to the OSIRIX platform.

Currently, according to our latest surveys we have estimated a number over 45,000 active users that correspond with us on a regular basis around the world. This number does not account for users that have simply downloaded the software and are using it on their own workstation with no interaction with the rest of the user community (Fig. 4). Industry has also started to adopt OSIRIX as a base for new business models where they provide the support and integration services as well as training and customization of the generic platforms. Several certified versions for Europe and for FDA in the US have already appeared on the market recently. And finally, and probably most importantly, the academic community has started to regroup its efforts to support and promote
Fig. 4. Image distribution workflow extends beyond the tradition DICOM-based workflow where peer-to-peer data distribution provides additional distribution paths for a community of physicians over a variety of hardware platforms.

5. Legal and regulatory constrains

Professional Open Source applications fall short of legal framework in current highly regulated medical market. Heated debates have emerged regarding the lack of clear legal regulations on Open Source software certifications. Medical certifications such as FDA in the US and CE marking in Europe do not apply to Open Source software. These certifications require a legal commercial entity to be identified as the owner of the product and warrant the legal liability of its distribution and commercial support. Open Source software being often developed outside commercial enterprises; such as academic groups or university research labs, they do not have the proper legal structure to apply for such certifications. Also, most Open Source products being distributed free of charge they lack the legal binding between the provider and the user that is required for software distribution under FDA and CE certification. Such certifications require a documented and legal agreement between the provider and the user to ensure adequate follow-up and notification in case of software dysfunction or software upgrades for errors and bug fixes.

However it is important to remind the users that FDA certifications or CE certification are in no mean a warranty of quality and accuracy of the software. It only insures that there is a due process and a well document workflow as well as good manufacturing practice of development and documentation of the software with proper follow-up and documentation of its flaws and enhancements with adequate notifications to the registered users. None of these regulatory certifications have any rules on the accuracy or validation of the features and processes performed by the software. Being FDA certified does not mean that the calculations or quantitative analysis features applied by the program provide accurate or validated results. Unlike drugs and medical treatment devices, software products are not required to be clinically validated in clinical trials. Actually it is well established that Open Source software programs are more robust and less prone to errors than commercial proprietary programs because they are more widely scrutinized by users and developers that can test and evaluate the source code and the algorithms used. Open Source platforms have much wider and more thorough evaluation and testing by a broader community of users. Vendors of closed proprietary solution often have to invest in selected beta sites to get their software tested and evaluated by a limited number of users. Also, legal certification such as FDA does not establish any criteria regarding the quality of the program and its performance. Some proprietary commercial solutions may have very convoluted and complex user interface that often require extensive training of the users who are at risk of making mistakes and getting inadequate results from the image data being processed. Open Source software on another hand offer easier and better users interfaces and are often much easier to use with less risk of making mistakes, simply because if an Open Source program is not well designed it simply does not get adopted by the users. Open Source programs are under unforgiving user scrutiny and natural selection where only the best programs survive and are used by a large community.
It is also important to center the debate on the specific use and applications of such software programs. Some vendors have launched aggressive campaigns against Open Source software by promoting unfounded claims that users of Open Source programs are at risk of legal actions and law suits for using non-certified programs. While some payors and insurance companies will require radiologists to use certified workstations for image interpretation in order to be reimbursed for the study performed, there is no restrictions on other tools that they may use to assist them in their work. Besides, if the program is not used for primary diagnosis, such as when a surgeon uses the program to review results of a scan, there are no restrictions on software certification used by non-radiologists for their daily practice. In essence, if a physician wants to use a non-medical software such as Photoshop to review medical images he is legally allowed to do so. There is also no legal ground for suing a doctor for malpractice in case of medical errors if he or she used a non-certified software program to gather patient’s information. The responsibility of making the right decision and getting adequate representation of the clinical data remains on the physician and his judgment call.

6. New paradigms in networking and communication

With the rapid expansion of wide area and metropolitan networks a new generation of communication paradigms have emerged providing community of users with new tools for social networking. Initial interactive tools for chatting and for exchanging short messages (SMS) over the network or by cellular phones have slowly replaced more traditional Emails. Social networking is just one of many consumer technologies, including blogs, wikis and virtual worlds, to cross over into the corporate world. Moreover, social networking systems such as Facebook, MySpace and other free communication forums have completely changed the way people communicate and exchange information. Popularized by teens sharing information with their friends online these new web-based social network platforms are now blooming in the business world, thanks to new social networks that enable professionals, doctors and executives in industries such as advertising and finance to create private discussion forums and exchange opinions and ideas [10]. For a variety of reasons, social networking has been slower to take off in the business world. Employees are wary of disclosing too much to potential competitors, and loose-lipped executives can easily embarrass themselves and their companies online. Policing these services’ memberships to weed out impostors can be difficult, and the sites are still in the early stages of turning their networks into sustainable and secure businesses. Professional social networking services are trying to broaden their appeal with new ways of making sure their members are who they say they are. For example, Sermo (http://www.sermo.com), a medical networking service founded by a surgeon from Boston, authenticates each of its members by checking their credentials against several of the 10,000 databases they have access to. A recent report from Manhattan Research (http://www.manhattanresearch.com) discusses the adoption of social networks by physicians. The survey showed about 60% of physicians were interested in social networks and 40% not. Sermo and Medscape Physician Connect have 100,000 each but it is unclear how many of these are duplicates or active users. With any social network, the effectiveness can be measured by the activity rather than shear numbers of members.

A major limitation in exchanging medical imaging information is the size of the image files that tend to be very large and require high bandwidth or long time to transfer. Downloading large multimedia files such as music and videos from high performance servers can usually be optimized by data streaming, there are no specific optimization techniques that were specifically developed for medical images usually available in DICOM format. While the general public is usually comfortable with the long delays required for downloading entertainment movies, radiologists and physicians in
general are not willing to wait long to transfer or receive large medical image files. In most standard wide area network infrastructure, sending a large file (upload) is even an order of magnitude slower than receiving (download) a file. This requires files to be posted in advance on high bandwidth servers to be subsequently downloaded to the recipients. Sending these files on an online server usually requires long transfer times and are not quite suitable for physicians that want to exchange data on demand with limited advance notice. In most cases images are therefore transferred in compressed format or viewed through web-based viewers that avoid having to transfer all the native images. But these solutions will not allow the recipient to process or manipulate the images locally. Remote processing through thin client application are usually required to process the images remotely without having to transfer them.

Innovative solutions for rapid and robust transfer of very large data files are emerging and will probably change significantly the current limitations in the next few years (Fig. 5). Online free file transfer providers such as yousendit (http://www.yousendit.com) have already become very popular for convenient transfer of large files, notifying the recipient by Email when the file is available for him to download. These public services lack the performance and security that would be required for transferring large medical image files. Similarly, some professional social networks are now specializing in storage and sharing of very large data files. Professional social networks such as “Linkedin” (http://www.linkedin.com) have gained popularity among professionals and executives for exchanging data and information. Whether commercial medical software programs. On another hand it is quite compelling because it provides a means for development of innovative solutions designed by the users themselves and better suited for their specific needs.

Electronic communication tools have penetrated our daily environment in a way that changed radically our social behaviors and daily life. Social networking is just one of many consumer technologies such as blogs, SMS, and Wikis to penetrate into corporate world. It is happening, as social networking is moving into the mainstream. While most of these services are free of charge for members, revenue comes from advertising or charging outside businesses access to data and member discussions, some new professional businesses offer similar services for paying registered members limiting access to identified professional groups. Offers for better management of medical images and compliance with IHE profiles will also bring more appropriate solutions to the specific needs of the medical community and will ensure a better interoperability. Only such customized solution will be able to penetrate vertical markets such as medical imaging and allow broader adoption. With the additional challenge of managing very large datasets, online services adapted to medical imaging will have to adopt new innovative technology to overcome the current limitations of network bandwidth. What seems today as an impossible dream will soon become our everyday reality allowing users to exchange large data sets in a secure and convenient way that does not require expensive and complex IT infrastructure.

7. Discussion and conclusion

Information technology is evolving in directions that are hardly predictable and will affect the way professional applications such as medical imaging and PACS will change in the future. User expectations have also changed rapidly with the emergence of innovative communication paradigms in general public and consumer products. Open Source software is an alternative to conventional software market that has matured and finally acquired sufficient credential to be widely adopted. Now it is breaking out into the commercial world and into vertical markets such as medical applications, and that's changing all the rules. It is particularly promising in advanced image display and analysis applications where the rapid increase in demand cannot be matched by traditional expensive commercial solutions. To allow radiologists and clinicians to conveniently and efficiently interpret these large exams, traditional image viewers have to be re-designed and adapted to a new paradigm of multidimensional image navigation, visualization and manipulation. By combining multiple new technologies and Open Source projects it is today possible to develop a new generation of high-performance 3D and 4D visualization tools that were traditionally only accessible on expensive commercial workstations restricting their use to specialist radiologists. Open Source software also challenges the established medical imaging market but also raises the question of the integrity and quality assurance of software that is developed by a community of users and does not follow the traditional conformance and certification required for commercial medical software programs. On another hand it is quite compelling because it provides a means for development of innovative solutions designed by the users themselves and better suited for their specific needs.