Open Source Software - The future of medical imaging?

June Henriksen[1], Johan Gustav Bellika[2] , Cathal Gurrin[3] , Gunnar Hartvigsen[1,2]
[1]University of Tromsø, Tromsø, Norway
[2]Norwegian Centre of Telemedicine, Tromsø, Norway
[3]Dublin City University, Dublin, Ireland
Corresponding author: June Henriksen, Institutt for informatikk, mat-nat. fakultetet, UiT 9037 Tromsø. E-mail: juneih@stud.cs.uit.no

Medical imaging and Picture Archiving and Communication Systems (PACS) in particular, have appeared to be one of the promising areas for Open Source Software (OSS). Open source medical imaging solutions do exist, including PACS, but are not widely deployed at hospitals and health care establishments, which prevents them from achieving their full potential. In most cases where medical OSS systems exist (i.e. not necessarily PACS), it is to a very limited degree, and typically out of sight of the common user. Research we have conducted on medical software companies in North Norway and three hospitals in Europe suggests that if open source medical software is to become a useful alternative to proprietary software, that firstly, the initiative must be taken by the public health services and secondly, that it will require a shift from software companies (from sale-value oriented to service oriented). However, it would be naïve to rely on existing proprietary companies to initiate such a change. Interviews revealed that some companies considered the possibilities of developing using an OSS model, but did not deem it to be profitable, whereas others stated that it was simply out of the question. They are not willing to risk their successful business models, because historically (and perhaps at the cost of quality) it pays to keep the inner workings of their software secret. Other reasons revealed for not using OSS were: poor support, prejudices and the unwillingness of proprietary companies to accept a new business model. We suggest that these problems can be overcome with the emergence of competence centers for OSS, and that if open source medical imaging, PACS projects in particular, are to get started, they are more likely to succeed if a hospital is involved. However, our suggestions can only be tested thoroughly if more implementations are done.

INTRODUCTION

Ever since medical imaging software emerged in health care the goal has been to improve diagnostic value. In the late eighties medical imaging was improved further, by the slow uptake of digital imaging. It proved to be safer for the patient with regards to radiation exposure, it removed expensive film rolls and the need for enormous storage rooms from the budget, and also allowed for digital enhancement of the images.

In any improvements to digital medical imaging in the future, OSS should be an important approach to consider. It can help medical environments get functionality they want when they need it, and effectively avoid difficult dialogs with proprietary vendors. A large-scale OSS deployment at Beaumont hospital in Dublin proves that in the long run it is also a cost-saving exercise ([1]). OSS should not be underestimated as a means to enable continued use of new and old open standards.

This has not gone unnoticed by European governments. Through the foundation of competence centres for OSS ([2]), they have taken active steps towards the increased deployment of OSS in the public sector. Medical imaging, and PACS in particular, has appeared to be one of the promising areas for OSS. Current proprietary PACS solutions, when compared with typical open source solutions, place many restrictions on customers. As mentioned, when additional functionality is required, the health care sector must depend on the software manufacturers, both for reasonable costs and for timely delivery.

Medical imaging and open source software are highly compatible with each other. Primarily because medical imaging already has a history with open standards in the DICOM format, but also because OSS has collaboration and standards as its cornerstones, which makes it ideal for developing medical software.

In general it is safe to say that open standards promote OSS. However, this is not the case with medical imaging, where the take-up of OSS has been limited, even with the extended use of the DICOM open standard. OSS solutions do exist, but few of them are widely deployed at hospitals and health care establishments, which prevents them from evolving to their full potential. Thus the root of the problem stems from the fact that, although the standards PACSs are based on are open, the systems themselves are not.

In this paper, we report on research we conducted at several hospitals and medical software companies, and identify why open source software has rarely been applied in health care environments to date. Our conclusions suggest that if free medical software is to become a useful alternative to proprietary software in the near future, the initiative has to be taken by the public health services. As a minimum they need to provide extensive help and support.

WHY OSS AND MEDICAL IMAGING?

Within the field of medical informatics, medical imaging is one of the best placed to adapt to an OSS model. We can identify two reasons for this. Firstly because it has a history with open standards through the DICOM format ([3]). Secondly, when examining E. Raymond's ([4]) five checkpoints (discussed below) to assess the pay-off of open sourcing a piece of software, we find that they are all valid for PACS:

Reliable, Scalable and Stable Software

Any software that needs to be reliable, scalable and stable, will benefit from being open source, because peer-review is an exceptionally successful method of achieving this. These qualities are all essential for a PACS system, however, few health care executives will agree that they have access to accurate, reliable, and relevant information today ([5]). It is safe to say that PACS will have a high pay-off from going open source when looking at this criterion.

Peer-Review

One of the main advantages of keeping source code open is the presence of large-scale, free, software bug detection and removal by willing contributors. It helps validate the correctness of both code and design, and similar to the previous criterion, it produces reliable, scalable and stable software. If there is another, easier way to do this than peer-review, the payoff from going open source logically decreases. However, such an alternative method for peer-review does not exist for PACS, which fulfills this criterion also. Medical software in general is by nature as complex as the environment it operates in; bugs can not always be easily located and remedied during the development phase.

Critical Software

The dangers of software monopoly become more harmful as the software becomes more important to the users' business. Monopoly limits choices, and the more critical the software is, the more control the software companies have. Based on these contentions it makes sense to open source the software if it is critical to the customer's business. Requiring 24 hour up-time per day, PACS systems are certainly critical to hospitals, which can be confirmed by all hospitals that have had their PACS malfunction.

This danger was recognised by F. Murgia, and his team, when working on their project *lumen reconstruction and manufacturing replicas by RP technique* ([6]). The tool they developed was released as OSS because to them it meant versatility, and independence from manufacturing companies.

Network Effect

Network effect is a term that describes how a service, or product, becomes more useful as its deployment increases. For example, telephones have high network effect ([7]), because the more telephones there are, the more useful each telephone actually becomes.

If the software helps contribute to the network effect of a standard that is not controlled by a single company, making it open source can be defended also from this perspective. The more software on the market enabling a standard, the more useful each product is, which is exactly the point of having standards.

Network effect was the main reason for making the DPACS project ([8]) OSS in 2004. The developers stated that it would give the flexibility to promote information and communication system solutions in hospital environments.

Sometimes going open source has not only been helpful, but utterly necessary to prevent a proprietary company from gaining a monopoly, and the opportunity to close standards so they only work with their software ([4]). Thanks to the widely used DICOM standard this criterion is also met for PACS.

Known Knowledge

Raymond's last criterion says that software should be based on accepted software engineering knowledge and practices. The software itself should not be private; rather the data that the software operates on should be private.

If the algorithms are well known, open sourcing it will not give away secrets that competitors can take advantage of. This final criterion is also met, all parts of a PACS require the implementation of

key procedural methods and algorithms, which are well known and in the public domain in the field of medical imaging. In fact, most of the components of a PACS can be found open source already, including sophisticated databases like PostgreSQL, and quality DICOM viewers like Mac's OsiriX.

If the algorithms deployed in PACS are known, what makes a PACS unique? The answer is the workflow it will enable at a hospital, an important consideration for hospitals competing for patients. If there is no competition, that is, if an environment will not lose funding or costs by helping others solving their problems, this is not an issue. If there does exist an element of competition, the medical establishments will have to evaluate if competing on the basis of human competence is good enough, if it means getting a better system in return.

We have now assessed the five checkpoints by Raymond, and move on to discuss economic models.

ECONOMIC MODELS

In addition to the five checkpoints above, Raymond ([4]) argues that the economic model used to make money on software today, has been unhealthy for a long time. It has survived the only way it can, through monopoly, and "fear, uncertainty, doubt" tactics. What he claims is wrong is that proprietary software companies tend to fund an ongoing service by charging a fixed price. Service is, as mentioned, what OSS tends to lack. However, in some cases it does exist, and in those cases it makes for a better economic model where the customer is one of the winners. We will discuss three economic models here, cost-sharing, risk-spreading and service oriented.

Cost-Sharing

Imagine a scenario in which ten hospitals are paying €1 million each, to one company, or a number of companies, to keep their PACS system operational. Were these ten hospitals to combine their funding, they would have €10 million, which could easily fund the development of a state-of-the-art and extremely reliable PACS system for all ten hospitals to use, and for a fraction of the original price. In addition, yearly maintenance and support contracts will be a lot less than the €1 million (as would be previously needed) for the following years. This approach would provide a good foundation of co-developers and users to begin with, which is important to attain peer-review. It also captures the advantage of building a PACS system particularly adapted to the hospitals' needs. In other words, the hospital will not have to adapt to suit an existing PACS system, rather the PACS system will adapt to the hospital's unique and individual requirements.

One of the most successful examples in OSS, the Apache Web server, follows this model (2). The Apache web server is the most widely used web server according to Netcraft, it had 62% of the market share in April, 2006 ([9]).

Spreading of any Risk

Were a hospital to decide to develop their very own, tailored, PACS system, it is very likely that the cost of maintenance will require that the hospital release the code, and encourage a community to form out of users, and co-developers from other hospitals. The community would help keep the code up to date, and thus effectively spread the risk of maintaining it. The risk lies in ability to keep maintaining the code after the original developers change jobs, and protect the code from growing old. This is a good model for public services in general, as they rarely lose money from others having their problems solved. The most prominent OSS example using this model is Cisco Print ([4,10]).

Service-Oriented

The first two models describe how use-value alone can fund full-time developers, based on prior experiences with the Apache and Cisco projects ([4]). However, many of the main successes within open source are third party companies, charging clients for support and service contracts, and nothing else. Examples of this include RedHat, MySQL and OpenOffice. These companies succeeded by providing services for projects developed by standalone communities, but naturally still have high interests in keeping the OSS projects they need running, and can thus afford to give something back to the community responsible for doing so. Service is in this case what funds some full-time developers in the community for further innovation and maintenance.

This OSS economic model has become a very lucrative business. So much so that many proprietary companies have decided to embrace such OSS projects. IBM has donated millions of dollars worth of funding to the Eclipse project, Netscape released their browser as open source under the name Mozilla Firefox, and Apple's Mac OS X is based on the FreeBSD project. The common point for all the previous examples' decision to turn to open source, was that their positions were being threatened by a single dominant company in the market-

place. Thus, these examples clearly illustrate that many major companies recognise the potential of open source, but also that OSS could be an effective tool to fight monopoly. It is important to note that, as of yet, few companies are willing to rake this risk of embracing a wholly OSS development strategy, unless they have to.

The latter model in particular will create more competition in the market, which is something the typical software vendors will not appreciate, however some key participants will benefit hugely from increased competition, these participants are the hospital environment stakeholders.

STAKEHOLDERS

From the five checkpoints considered in the first section, it seems to make sense to have an open source PACS solution, yet the question remains, why are open source solutions not in widespread use at hospital and medical establishments, or even considered as a valid option? There are only a few known, large-scale, open source implementations or medical imaging solutions in use today, why is this?

To answer this question, a good place to start is to identify the stakeholders. They are the patients, the administration, the vendor, the IT-support personnel, and the users of the software (i.e. the medical and office personnel). For OSS to be considered successful, all stakeholders must be satisfied in some way:

- Patients will benefit from OSS, if it manages to encourage more cooperation between medical environments, and produce high-quality software faster. More cooperation will lead to better software, and faster developed software is always needed in the ever changing settings that is the medical environment ([11]).
- The vendors will need to undergo a change, from sale-value oriented to service-oriented business models, much like we discussed in a previous section.
- Physicians, radiologists, radiographers and other users, will have more influence in how the software operates, such as demands for interoperability, or better human-computer interfaces. Suggestions by physicians, no matter how beneficial, may never find their way into commercial software; however, in OSS there exists a clear path from stakeholder to developers to final software delivery. This is dependent on whether there is a close connection between developers and users or not. This interest is especially taken care of in cases where developers are working on site at the hospital. If all OSS development is outsourced, the clear path will fade, and this benefit will vanish.
- IT-support personnel will want a support contract that frees them from too much responsibility. Support services can be outsourced to third-party local companies, acknowledging the personnel's demand, and allowing them to suggest changes or maybe even apply some changes to the OSS solution if they so wish.
- This leaves the administration, which will be reluctant to try new solutions, unless they have a very good reason. The cost of OSS will inevitably be less than for proprietary software, and thus therein might lie the legitimate reason for administration to choose OSS over proprietary software. Additional, needed functionality could also be one of those reasons.

A criticism often levelled at OSS providers is the lack of extensive support deals, which, in an environment such as a medical institution, would be a vital aspect of any software deployment. Extensive and reliable support is what hospitals need and want, and is where vendors could, and should, make money. This issue needs to be resolved, if OSS is to stand a chance as a valid option for hospitals and healthcare establishments. If a client has problems with software from any given company, having someone to call when things go wrong means the responsibility lies elsewhere, which creates a feeling of security. This security is comforting, and is highly appreciated on all levels, from technicians to administrators ([12],[13]). Knowing that the company who created the software, which probably also have the better experience with it, are the ones to fix the problem, heightens this feeling even more.

Most OSS projects can not compete with this type of service, only the few very successful projects can compete. Traditional vendors are in charge of both development and support, where in the OSS equivalent, a community will take care of development and bug-fixing, and let service be in the form of forums, e-mail lists etc. This position is, in the most successful cases, also aided by third party service companies, where RedHat ([14]) is the most prominent example. This is, however, the exception rather than the rule. As mentioned previously, these service providing vendors are also often highly involved in the development community.

If such third party outsourcing is avoided, for example to keep the closeness between the develop-

ment and the users, there is no other way, but to realise that with the control and freedom that OSS brings, comes also responsibility ([15]).

INTERVIEWS WITH STAKEHOLDER DECISION MAKERS

Interviews with the different stakeholders uncovered some of the problems behind lack of OSS implementation in medical informatics. Of the five stakeholders we have identified, the administration level was the most sceptical, and they will undoubtedly be the more difficult to convince. Prejudices, lack of support deals and fear of non-traditional solutions were given as answers to why it was not considered. IT-maintenance personnel on the other hand, want the best solution regardless of whether the software is proprietary or free. From the viewpoint of the medical environment, we summarise that the software has to be of high quality, and the administration must be convinced that choosing OSS solutions is a valid option and one that could bring a significant monetary saving.

From the other point of view, that is, the companies producing the software, the situation is quite different. When proprietary medical software companies where asked if they considered releasing OSS, the answers were all negative. Three proprietary medical software companies were questioned about this issue: RisCo ([16]), Well Diagnostics ([17]) and DIPS ([18]). Typically, the answers they gave ranged were: *we have looked at it, but did not deem it to be a better business-model than the one we are currently using*, to *releasing our code as open-source would be like giving away our family silver*. The business model referred to is so thoroughly worked into company standards, that the wait for proprietary software companies to try it out, might be an indefinite one.

It seems like the missing link is often the third party service vendor between users (i.e. hospitals) and the OSS developers (i.e. the OSS community). However, waiting for an OSS company like this to appear and provide service for such software, is not very likely. They usually emerge after the software projects have started and become successful. Waiting for an existing proprietary software company to open source their solutions, is, judging by their answers, an equally unlikely option.

The question remains, what are the unique ingredients for a successful OSS implementation for the medical imaging environment?

SUGGESTED APPROACH FOR DEPLOYMENT

The development method used by OSS is merely a method for improving existing software. Which means that in order to get an OSS up and running in the first place, a core base of executable source code is required. Firstly, this requires a substantial amount of funding and person-years, and secondly, a proper environment in which testing can be carried out. This can, in most cases, only be done in a real-world healthcare environment. Which means the first step of an OSS project is likely to come from an organisation in the healthcare sector, or from a close cooperation with such organisations.

There are many possible solutions to this problem. There are many qualified technicians in larger healthcare environments, and university hospitals with connections to academia will provide an excellent source of qualified personnel and advice.

After the initial code has been established, in typical OSS development, the contributors for further development will typically consist of both companies investing time and money because it benefits them somehow, to single-standing individuals who find it interesting and also beneficial to them in some way. With open source in medical informatics there would still be interested individuals, but companies could be replaced by hospital technical staff in addition to medical software companies who support the OSS product.

This leads us back to the missing link between OSS communities, and the users. Who will provide support for open source medical software? At the University hospital of North Norway (UNN) in Tromsø, the emergence of the nearby, competence centre for OSS, and the outsourcing of the IT-department could be the key. The competence centre will provide guidance in this new territory, help avoiding pitfalls, and the means to address the inherent reservations of administration to embrace the OSS solutions. In addition, the outsourcing of aspects of the IT-department might let the department be less restricted and be in a better position to join the development and maintenance team for such projects. It is important that they maintain the closeness they have.

Thus far, only one large-scale open source implementation has been thoroughly documented. At Beaumont Hospital (an acute 620 bed general hospital) in Dublin, Ireland, they are anticipating a huge cost savings of over €8 million over five years, and in most cases also document extra functionality ([1]) based on a recent deployment of an

OSS system. Beaumont hospital, as a use case, illustrates the considerable cost savings of OSS deployment within the health care sector. Perhaps such success stories might be enough to convince decision makers at administration level to change their view of OSS and embrace this new methodology of high-quality software development.

CONCLUSIONS

If a shift for software companies is required, from sale-value oriented, to service oriented, one cannot rely on proprietary companies to make this change. Interviews revealed that some considered it, but did not deem it to be profitable, whereas others stated that is was out of the question. They simply are not willing to risk their successful business models, because historically, at the cost of quality, it pays off to keep things secret ([4]). One can not rely on OSS companies alone either, as they tend to emerge after the success of an open source project.

OSS is, in spite of these difficulties, already in use in medical environments. Though in most cases, this is to a very limited degree, and typically out of sight of the common user. The question we address is; why is it not more equally deployed, when compared to proprietary software, or compared to non-medical OSS? This paper has uncovered some of the issues: poor support, prejudices and the unwillingness of proprietary companies to accept a new business model.

All of these problems could be overcome in the near future, with the emergence of competence centres for OSS. That these problems have a solution is important, because if open source projects are to get started, the chances are much better if a hospital environment is involved. They are, after all, the stakeholder with the most to gain.

The anticipated benefits of OSS in medical environments only be confirmed, if tested thoroughly, and this relies on real-world implementations like the one at Beaumont Hospital in Dublin. When this is accomplished, perhaps then, medical informatics can reap the same benefits from open source as the rest of the world.

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