IGSTK: Building High Quality Roads with Open Source Software

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Abstract

This paper is a position statement on the benefits that an Open Source toolkit can bring to the field of image guided surgery. The particular example discussed here is the IGSTK toolkit. IGSTK is an open source software project designed for supporting the development of image guided surgery software applications. It provides functionalities for interfacing with optical and electromagnetic trackers, reading and visualizing DICOM datasets, as well as loading and displaying geometrical models resulting from image segmentation. These functionalities are enveloped by a simplified API implemented in a layer designed with emphasis on patient safety. The Toolkit is designed to ease the development of IGS applications, providing the basic functionalities related to the management of basic components. IGSTK is based on the Insight Toolkit (ITK)[2] and the Visualization Toolkit (VTK)[5], and can be combined with GUI toolkits such as FLTK and Qt. The IGSTK toolkit is distributed under a BSD license.

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1 Introduction

When describing the principles of Open Source Software, an analogy that is commonly used is that Open Source software is the equivalent of public roads while proprietary software is the equivalent of private business that are built and flourish thanks to the services provided by the public roads. In this context, IGSTK is intended to be a public road that will facilitate the rapid development of new endeavors, whether they are academic or commercial.

2 What only Open Source could provide

IGSTK was designed to consolidate in a single, publicly available resource, a body of methodologies that many research groups have developed in the field of image guided surgery. The public availability of IGSTK makes possible the following

- Verification of reproducibility of published work
- Low threshold of investment for commercial start-ups
- Provide a domain standard that serves as a reference
- An educational resource for teaching and training newcomers to the field.

2.1 Verification of reproducibility

How many times have you been confronted with the perspective of finding an interesting paper in the literature and thinking on how long it will take you to write the software that will implement the methodologies described in the paper ?

One of the main reasons why you have been put in such wasteful situation, is that authors do not provide an expedite mechanism for readers to easily reproduce the work that is described in a paper. A commonly brought excuse is that the software used by the authors is zealously kept secret by the academic or commercial institution where they work. The public availability of IGSTK makes possible to break this wasteful vicious circle by allowing authors to use a software platform that will make possible for them to share their finding with the larger community in order to benefit from their collective intelligence by obtaining rapid feedback and therefore quickly verifying the correctness of the described methods, as well as absorbing improvements suggested by experts in the community. The flexibility of Open Source makes possible for this feedback loop to perform a cycle in a matter of days, as opposed to the months or years that the same would have take under the traditional ambiance of secrecy.

The lack of reproducibility verification in the work published on technical journals and conferences hinders the quality of the published works and prevents them from reaching the minimum standards required for them to be considered scientific work [3, 4].

2.2 Economic benefits for Start-Ups

One of the goals of IGSTK is to stimulate the development of new endeavors in the domain of commercial IGS applications. Whether these new applications are initiatives of large commercial groups, or the spark of a small group of entrepreneurs, the public availability of IGSTK along with its correctness verified by the public peer-review of the community, makes possible to lower the threshold of effort required for undertaking a new IGS project. By basing their work on IGSTK, enterprises can build upon the fundamental functionalities available in the toolkit, and focus their efforts on the new functionalities that are going to differentiate their products in the market. Even if IGSTK is used only during the prototyping stages, and discarded later when the final design goes into production, it already provides savings by accelerating the process of bringing an idea to the stage of a proof of concept.

The economic benefit of Open Source is particularly significant in developing countries, where the cost of undertaking commercial enterprises is heavily burdened by prices of products that have been defined for the US and European markets. The availability of Open Source software makes a lot easier for academics and commercial companies in developing countries to participate in the development of IGS systems, with the particular advantage that they are better positioned for customizing and adapting these IGS applications to the specific conditions of their country.

The BSD license used for distributing IGSTK have been selected to facilitate its unencumbered use by academics, researchers and entrepreneurs in both for-profit and non-for-profit organizations. See more on licensing in section 5. Large scale collaboration in the pre-competitive knowledge commons is a powerful way of promoting the advancement of a highly specialized field, and it is a sound business approach to the Digital Age Economy [6].

2.3 Provide a domain reference

The public availability of IGSTK provides a common reference against which many groups can run comparisons. IGSTK developers, despite their careful dedication to the quality of the toolkit, do not claim that IGSTK is the best tool for implementing every possible IGS project. Depending on their context, IGS applications will have very specific requirements that may lead developers to choose tools different from IGSTK. Even in such cases, the fact that IGSTK can be used as a reference against which these other tools and methods can be compared and their advantages can be quantified in an objective manner, provides a service to the community, and helps promote the progress of the field.

2.4 Education Resource

When students and new researchers are introduced to the domain of image guided surgery, it is extremely useful to give them access to a software platform that they can use to experiment. They should have the freedom to inspect its internal implementation, as well as the freedom of making changes to it, and distributing their changes. Only in this way, will students be exposed to the practical details of image guided surgery applications, and will they be able to ask meaningful questions and get answers to them.

It is also very useful for students and trainees to have access to the support provided by a community, where by participating in the public mailing lists and Wikis, productive discussion can be held, and beginner's questions can be posted. The implementation details of software suitable for advanced applications are rarely available in textbooks or published papers, and constitute an extremely valuable body of knowledge that is still transmitted in a way very similar to what the pioneers of enlightenment used during the renaissance: pairing tutors with apprentices. An Open Source minded community, such as the IGSTK one, provides the appropriate environment for transmitting this body of knowledge in an efficient manner that transcends geographical barriers.

3 Toolkit Functionalities

The functionalities of IGSTK can be classified in the following major groups [1]

- Tracking Support
- Scene Representation Support
- Imaging Support

3.1 Trackers

The term "Image Guided Surgery" is an inaccurate description of the clinical practices in this field. A more accurate description would have been "Image and Tracking Guided Surgery". Most practical IGS applications involve a combination of image guidance along with the tracking of position and orientation of physical objects. Tracking provides a fundamental pillar in the context of an IGS application, by providing a connection between the reality of the surgery room and the spatial information contained in images that have been acquired pre-operatively or intra-operatively.

IGSTK acknowledges this reality of the field, and provides support for various tracking devices that are commonly used in clinical practice. The design of the toolkit is extensible and makes easy to add support to new tracking devices.

Currently, the toolkit support the following trackers

- NDI Aurora
- NDI Polaris
- NDI Spectra
- NDI Vicra

- Claron Technologies, Micron Tracker
- Ascencion Technologies, Flock of Birds (in progress)

3.2 Scene Representation

One of the main challenges in IGS applications is to ensure that the images presented to clinicians are consistently reflecting the reality of the surgical scenario. In particular, they must ensure that all the objects displayed are placed in their correct locations and orientations.

In order to support this consistency, IGSTK provides a scene-graph support that makes easy for application developers to specify the relative positions and orientations of objects in the scene. These multiple objects include pre-operative and intra-operative images, surgical instruments, and graphical representations resulting from the segmentation of internal organs and pathologies such as tumors and aneurysms.

Trackers are integrated in the scene graph representation in such a way that object that are being tracked will get their coordinates updated automatically when they are inserted in the scene graph.

3.3 Imaging

IGSTK provides support for reading and displaying medical images that are read from DICOM files. In the context of IGS applications, only images in DICOM format can be considered safe to use in the surgical scenario, since their metadata information (spacing, origin, orientation) can be trusted.

For research and training purposes IGSTK provides support for reading additional image file formats. The use of image file formats different from DICOM in the surgical scenario is strongly discouraged.

The techniques used for displaying images are based on slice extraction and rendering textures on surfaces.

4 Emphasis on Safety

Given that IGSTK is intended to be used in safety-critical software applications, such as the ones used for providing intra-operative guidance during surgical interventions, the design and development of IGSTK has placed a heavy emphasis on the use of quality practices with the goal of improving patient safety during the interventions.

Most toolkit components have been implemented following a State Machine paradigm that strongly restricts their functionalities to the minimum set of features that are strictly needed. Strict code review practices, and high levels of quality control are used in a daily basis. With a 91% of tested lines of code [1], IGSTK has one of the highest levels of code coverage on any software toolkit available today. The values of code coverage are reported on the Nightly dashboard produced by the CDash tool. [2]

A difficult balance has to be maintained between restricting software functionality to protect patient safety, and yet providing enough useful capabilities to facilitate the rapid development of IGS applications. This is a non-trivial effort and requires continuous dialog between IGSTK developers and the developers of IGS applications.

[1] http://www.cdash.org/CDash/index.php?project=IGSTK#Coverage
[2] www.cdash.org

5 The Choice of the BSD license

Starting on March 30th 2008, IGSTK adopted the OSI-approved BSD license [3] with the goal of making sure that users of the toolkit could enjoy a generous Freedom in their use of the software. The BSD license provides a royalty-free, universal permission for using the software in any application, including academia, research (academic or commercial) and commercial applications. The BSD license was selected to encourage the use of IGSTK in any number of fields, regardless of whether the applications are used in the context of for-profit, non-for-profit, academic, research or commercial endeavors.

The fact that a large fraction of the research performed worldwide is privately funded is often overlooked when licenses refer to "research". For example the US Federal budget for research is about $180 Billion a year, while research and development budget of the top 25 corporations is larger than $130 Billion a year. Therefore software licenses the presume that research activities are necessarily non commercial are out of touch with the reality of the economy. Not to mention that the exclusion of a field of endeavor is incompatible with the definition of Open Source [4] as brought forward by the Open Source Initiative [5].

Instead of preventing commercial institutions from using the software, the open source model of IGSTK encourages these commercial institutions to join the community that maintains and improves the software. As part of this community, they share the maintenance cost of the software not by paying royalties and licenses but by providing dedication time from their developers, contributing hardware time and assisting and advising other member of the community on their daily use of the software.

Again, by capitalizing on the principle of building a Commons of pre-competitive knowledge [6], Open Source software provides platforms where industry an academia can collaborate free of the impediments to knowledge sharing that traditionally block the progress of highly technical fields.

6 Acknowledgements

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