The Computational Geometry Algorithms Library CGAL

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Abstract

The Computational Geometry Algorithms Library (CGAL) is an open source software library that provides industrial and academic users with easy access to reliable implementations of efficient geometric algorithms.

Usage. CGAL is used in a diverse range of domains requiring geometric computation such as computer graphics, scientific visualization, computer aided design and modeling, geographic information systems, molecular biology, medical imaging, and many more. Since CGAL provides a wide range of components, we restrict ourselves to mentioning just a few here.
As an example application of CGAL, a series of packages are provided which are useful in robotics and automation: Minkowski sums, offset polygons, Boolean operations on curved regions. The high precision of CGAL allows users to solve geometric problems involving motion in restricted environments, such as those arising in assembly planning.
The robustness and efficiency of components such as the Delaunay triangulation and mesh construction and manipulation packages makes CGAL attractive for simulations, in particular those involving proteins, particle physics, fluid dynamics, medical modeling, biophysics, geophysics, and astronomy. Indeed, the aforementioned components are largely used in these areas.
Some support for manipulations of polynomials and for solving univariate polynomial equations and bivariate polynomial systems is also provided, as well as handling for convex quadratic programs.

History of the CGAL **Open Source Project.** Several European research groups started to develop their own small geometry libraries in the early 90's. In 1996, a consortium of eight sites was created to gather the work of these groups into a single software library, namely CGAL. Their main goal was to promote research in computational geometry and to translate the results into **robust** software suitable for industrial applications.
Around this time the Computational Geometry Impact Task Force Report [C$^+$96, C$^+$99] made a series of recommendations. Amongst these recommendations, the production and distribution of usable (and useful) geometric software, and the need to establish a reward structure for software implementations in academia, were key.
On November 2003, when version 3.0 was released, CGAL officially became an Open Source project, allowing new contributors to join the project.

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License. CGAL is distributed under the GPL license (apart from a few basic parts, which are distributed under the LGPL license). In particular, it is publicly and freely available for academic use. Commercial licenses are offered by GEOMETRY FACTORY, a company founded in 2003 mainly for this purpose.

Editorial board. The CGAL editorial board was created in 2001. It currently consists of thirteen members. The main task of the editorial board is to assure the quality of CGAL. It is also responsible for making decisions about technical matters and coordinating communication and promotion of CGAL.
All new packages must be submitted to the Editorial Board to be reviewed before they can be accepted and integrated into the library, in a process that is very similar to the standard review process for papers published in conference proceedings or journals. More information about the submission process is available at `http://www.cgal.org/review_process_rules.html`.

Style and Techniques. CGAL is a unique library both in general and within the field of computational geometry in particular, as it consists of a large number of components with a homogeneous API (Application Programming Interface). Careful choices in design and programming style have made CGAL the *de facto* standard in the field of applied computational geometry. Its development started whilst the standardization process of C++ and the STL (Standard Template Library) was taking place. Indeed, the programming style is very close to the programming style of STL; it rigorously adheres to the generic programming paradigm—a discipline that consists of the gradual lifting of concrete algorithms abstracting over details, while retaining the algorithm semantics and efficiency. The programming style of CGAL also facilitates the process of interfacing with third party software.
Each package comes with header files consisting not only of the interface, but also the generic implementation of the package code, comprehensive and didactic on-line documentation, a set of non-interactive standalone example programs, and an optional interactive demo with a graphical user interface.

Robustness. CGAL follows the exact geometric-computation paradigm, which simply amounts to ensuring that errors in predicate evaluations do not occur; it guarantees robustness of the applied algorithms.
We additionally remark that every package also includes a collection of function and regression test. [1] The tests provided by each package are combined into one place to form the CGAL test suite. This test suite is run daily and its results are automatically assembled, analyzed, and reported.

Impact. Measuring the impact of software is a difficult task, especially in the Open Source software community. Even if some hard numbers can be found, they can be difficult to interpret. The following facts may shed some light on the impact of CGAL:

- There are roughly 1000 downloads per month from `http://gforge.inria.fr/`
- CGAL is included in various software distribution channels, such as Fedora, Debian/Ubuntu, and Macports.
- The range of uses of CGAL is very broad, as shown by the sample list of projects using CGAL, which is available at `http://www.cgal.org/projects.html`. In addition, many

[1] However these are not distributed as part of the public releases.

projects shown in `http://acg.cs.tau.ac.il/projects` use CGAL or even describe the development of a CGAL component.

- The CGAL triangulation packages were integrated in Matlab 2009a.[2]
- Springer has published a book entitled "CGAL Arrangements and Their Applications" authored by some of the developers of the *2D Arrangements* package and its derivatives.
- Concerning the public mailing lists, there are currently
  - 4000 subscribers to the announcement list `cgal-announce@lists-sop.inria.fr`
  - 1500 to the public discussion list `cgal-discuss@lists-sop.inria.fr`, with high traffic: users are free to ask questions, which are often rapidly answered by the developers or other users.

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References

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[2] Watch the video at `http://www.mathworks.com/products/demos/shipping/matlab/New-MATLAB-Mathematics-Features-in-R2009a.html`