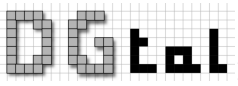


: Digital Geometry Tools and Algorithms Library

`http://liris.cnrs.fr/dgtal`

David Coeurjolly[1] Jacques-Olivier Lachaud[2]
[1] LIRIS (UMR CNRS 5205), Université de Lyon, F-69622
[2] LAMA (UMR CNRS 5127), Université de Savoie, F-73376

DGtal is a generic open source library for Digital Geometry programming for which the main objective is to structure different developments from the digital geometry and topology community. The aims are numerous: to make easier the appropriation of our tools for a neophyte (new PhD students, researchers from other topics, ...), to allow better comparisons from new methods with already existing approaches and to construct a federative project. Another objective of DGtal is to simplify the construction of demonstration tools to share new results with others as well as illustrate the potential efficiency of proposed works.

Overview

The main purpose of the library is to focus on algorithms and data-structures from the digital geometry community. For short, Digital Geometry can be simply characterised as a set of definitions, theorems and algorithmic tools that deal with the topological and geometric properties of subsets of digital pictures. Even if the domain emerged during the second half of the 20th century with the birth of computer graphics and digital image processing, many links have been demonstrated between Digital Geometry results and fundamental theorems in mathematics (arithmetic, geometry, topology, ...), discrete mathematics (word theory, combinatorics, graph theory,...) or computer science (algorithmic, image processing, ...). Hence, `DGtal` package decomposition follows these principles:

Kernel Package : This package contains core concepts, objects and methods which are used in other higher level packages. For example, it defines number types considered in DGtal, fundamental structures such as the digital space, the digital domain, as well as basic linear algebra tools.

Arithmetic Package : This package gathers tools to perform arithmetic computations. Standard arithmetic computations are provided: greatest common divisor, Bézout vectors, continued fractions, convergent, intersection of integer half-spaces. Several representations of irreducible fractions are provided. They are based on the Stern-Brocot tree structure. With these fractions, amortized constant time operations are provided for computing reduced fractions.

Topology Package : This package contains core concepts, objects and methods which are used in other higher level packages. For example, it contains the classical topology tools (à la Rosenfeld), cartesian cellular topology, and digital surface topology (à la

Herman). Generic tools and methods are provided for extracting connected components, identifying simple points, determining the neighborhood over a digital surface, tracking the boundary of a shape, defining cells and incidence operations. High-level classes are provided so that one can represent various types of surfaces and navigate onto them with a common interface. This package is notably used by the geometry package, especially to define curves and surfaces.

Geometry Package : This package contains geometry related concepts, models and algorithms. It provides a generic framework for the segmentation of one-dimensional discrete structures, like strings, contours of 2d digital objects or nd digital curves. It also provides a generic framework for the estimation of geometrical quantities, either global, like length, or local, like normal or curvature. Several estimators are built from some well chosen segmentations. On the other hand, this package contains tools for the analysis of volumes of arbitrary dimension, by the means of separable and incremental distance transforms.

Image Package : This package defines data-structures to represent generic images in arbitrary dimension. We also provide several image containers (linear vector, associative map, pointerless n-D octree-like images, ...). We use specific image containers to define bindings with other existing image processing libraries. For instance, a specific ITK image container allows `DGtal` users to integrate Kiteware's Insight Toolkit filters in their `DGtal` processing pipeline.

IO Package : In this package, we present DGtal tools and utilities to import/export images and visualize digital data using interactive (viewers) and non-interactive (boards) mechanisms.

Mathematical Package : This package gathers various mathematical subpackages and modules. For now, it consists in a module for defining multivariate polynomials.

Implementation Design

On a more technical level, DGtal is developed in C++. Similarly to other classical libraries such as CGAL, it follows the paradigm of genericity with efficiency. This approach is made possible with the now well-known notion of concepts, implemented with template types. More precisely, we use The Boost Concept Check Library (BCCL) to describe concepts in the C++ language. Furthermore, we use `BOOST_CONCEPT_ASSERT` macros to check if a type given as template parameter of a class respect a concept (and is thus a model of this concept) at compile time.

Examples

We give here couple of `DGtal` examples and figures to illustrate the design and some features of the library. First of all, let us define a digital space in dimension 4 in which we will consider the commutative ring associated to `DGtal::int32_t` to approximate computations on $\mathbb{Z}$. On this space, we consider a domain defined as the hyper-rectangular domain constructed on two points of the space. Similarly to many template based C++ code, we start by a series of type definitions before instancing the objects:

```
#include "DGtal/base/Common.h"
#include "DGtal/kernel/SpaceND.h"
#include "DGtal/kernel/domains/HyperRectDomain.h"
...
typedef DGtal::int32_t Integer;
typedef DGtal::SpaceND<4, Integer> Space4;
typedef Space4::Point Point;
typedef HyperRectDomain<Space> Domain;

Point p(12, -34,0, 3);
Point q(2, -2, -1, 19);
if (p < q)
  ...

Domain box(p,q);
....
```

By design, if we finally want to use an exact representation of integer numbers (provided by the GMP - Gnu Multiprecision Arithmetic Library for instance), we just have to change the first typedef and the rest of the code would remain the same. Using the concept programing paradigm, `DGtal` algorithms which use integer numbers first check that the given type is a model of the concept `CCommutativeRing` (both `DGtal::int32_t` and GMP integers are models of this concept). Once the digital space and the arithmetic have been set, we can use higher level structures and algorithms to perform geometrical and topological analysis on digital objects (cf figure).

Project Management & Team

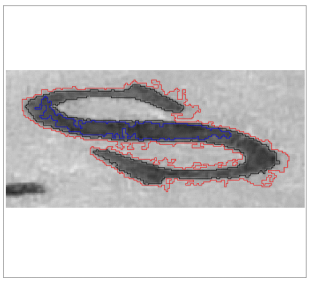
`DGtal` uses a github project (`https://github.com/DGtal-team/DGtal`) to host the code (using `git` as control version system) and to list open/closed issues. The documentation is managed by `doxygen` (both user-guides and technical documentation). The `DGtal` project is composed of several sub-projects:

DGtal: the main library (classes + unit tests + example programs + documentation files)

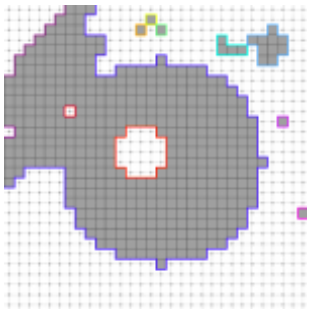
DGtalTools: command line tools built using DGtal (multigrid shape generators, contour analyzers, file format converter,...)

DGtalScripts: scripts for developers, class skeletons,...

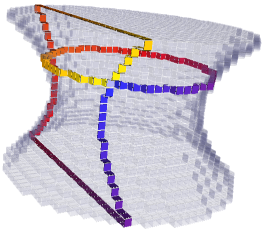
In order to follow and manage `DGtal` developments, several *groups* have been identified. The **Editorial Board** prepares releases, organises DGtal meetings, (*David Coeurjolly, Jacques-Olivier Lachaud*). The **Package Managers** are in-charge of the package design (main concepts, relationships with other packages...), and organise and check package contributions (aka modules). Finally **Contributors** adds new features to DGtal (classes + concept + test files + documentation) as a new module in a DGtal package.



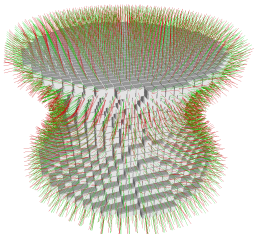
(a) Level set extraction from an image



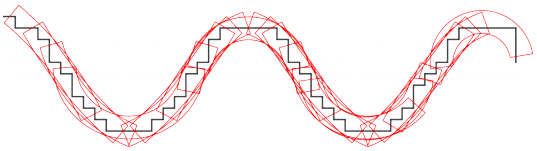
(b) Contour extraction in 2D using a topological cellular model



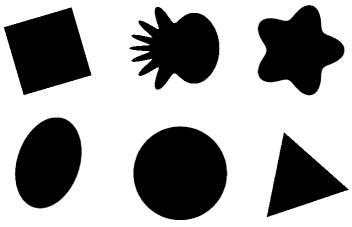
(c) Digital surface extraction and tracking in 3D



(d) Normal vector computation on object surface



(e) Digital curve analysis using digital circular arc covering



(f) Multigrid shape definition for differential estimator evaluation

(g) Volumetric Analysis with Distance transformation