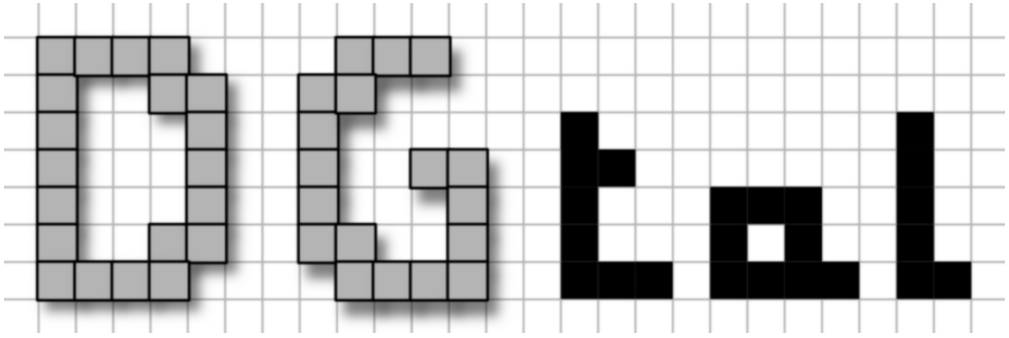


Introduction to DGtal and its Concepts

http://liris.cnrs.fr/dgtal

David Coeurjolly

DGtal: why

Digital Geometry

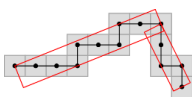
Objectives

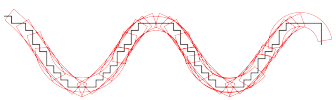
- to make digital geometry easier for the neophyte (student, researcher from another field, ...)
- to quickly test new ideas, with objective comparison wrt existing works
- to make easier the implementation of demonstrators
- to help spread our research results to other domains

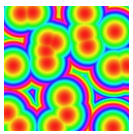
DGtal: what for ?

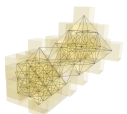
Main features

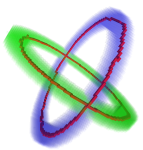
- to define digital objects in arbitrary dimension
- to propose algorithms for topological and geometric analysis
- to provide I/O mechanisms and visualization tools

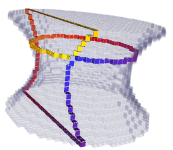

DSS

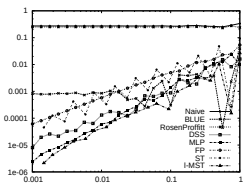

DCA


DT

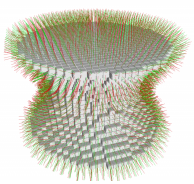

Objects

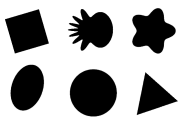

Thinning

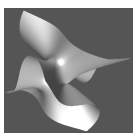

Cellular model



Estimators


normal vectors


Shape DB


polynomial surfaces


Contours

...

DGtal philosophy and structure

- Genericity and efficiency: C++ library, concepts
- LGPL
- cmake build system (linux/macOS/MSwindows), CDash test-suite, doxygen documentation, git, github project, ...
- user friendly, not necessarily kernel-developer friendly

Kernel Package

- Digital space
- Point, vectors
- Digital domains and digital sets
- ...

Arithmetic Package

- Fractions
- Irreducible fractions
- DSS Pattern..
- ...

DGtal philosophy and structure

Topology Package

- Digital Topology: connectedness, border, simple points (*á la* Rosenfeld)
- Cartesian Cellular Topology: cells, surfaces and contours (*á la* Herman), tracking algorithms
- Digital Surface concepts and models

Geometry Package

- Primitives (*a.k.a.* SEGMENTCOMPUTERS): DSS, DCA,...
- Contour analysis: decomposition, convexity, estimators
- Volumetric analysis: area/volume, distance transforms, reverse distance transforms, Fast-marching methods.
- Implicit/parametric shape generator for multigrid analysis

Math Package

- Representation of polynoms
- ...

DGtal philosophy and structure

Image Package

Image concept and Image containers, e.g.

- Image by STL `vector` (linearized nD image)
- Image by STL `map` (mapping points↔values)
- HashTree image container (generalized octree with hashing functions)

IO Package

- `Boards`: export to illustrate objects/algorithms (eps,pdf,svg,png,tikz...)
- `Viewers`: simple 3D viewer (Qt/QGlViewer)
- Readers/writers for various image formats

DGtal 0.5.1

- Project started in Jan 2010
- 200k lines of code
- *env*. 557 C++ classes
- Used in couple of research projects (ANR digitalSnow, collaboration with Chemical lab in Lyon, collaboration INRA at Nancy,...)

DGtal principles

Generic Programming

- Data structures $\perp$ Algorithms
- Concepts, models of concepts and concept checking

$\Rightarrow$ C++ with template programming

Concepts ?

Way to ensure (or to describe) that a type (class) satisfies some constraints (syntactically or semantically).

- At design level: very helpful to enhance separability data/algorithms
- At implementation level: concept checking tools to verify that a given type validates a concept

DGtal program skeleton

```
1
2       #include "DGtal/base/Common.h"
3       #include "DGtal/kernel/SpaceND.h"
4       #include "DGtal/kernel/domains/HyperRectDomain.h"
5       ...
6       typedef DGtal::int32_t Integer;
7       typedef DGtal::SpaceND<3, Integer> Space3;
8       typedef Space3::Point Point;
9       typedef HyperRectDomain<Space3> Domain;
10
11      Point p(12, -34,0);
12      Point q(2, -2, -1);
13      if (p < q)
14        ...
15
16      Domain box(p,q);
17      ....
```

DGtal program skeleton

or even simpler with standard definitions:

```
1
2       #include "DGtal/base/Common.h"
3       #include "DGtal/helpers/StdDefs.h"
4       ...
5       DGtal::Z3i::Point p(12, -34,0);
6       DGtal::Z3i::Point q(2, -2, -1);
7       if (p < q)
8         ...
9
10      DGtal::Z3i::Domain box(p,q);
11      ....
```

DGtal program skeleton (again)

Things to do

1. Fix the dimension
2. Fix the Integer type (commutative ring (+,-,*))
3. Define the digital space DGtal::SpaceND

```
1    #include "DGtal/base/Common.h"
2    #include "DGtal/kernel/SpaceND.h"
3    {...}
4    typedef DGtal::int32_t Integer;
5    typedef DGtal::SpaceND<6, Integer> Space6;
6
7    typedef mpz_class IntegerGMP;  //mpz_class == DGtal::↩
         BigInteger
8    typedef DGtal::SpaceND<6, IntegerGMP> Space6GMP;
```

Q: what's wrong with ?

```
1  typedef DGtal::SpaceND<2, unsigned char> MySpaceUChar;
```

[DETAILS] Concept & Models

Answer

`unsigned char` does not define a ring !

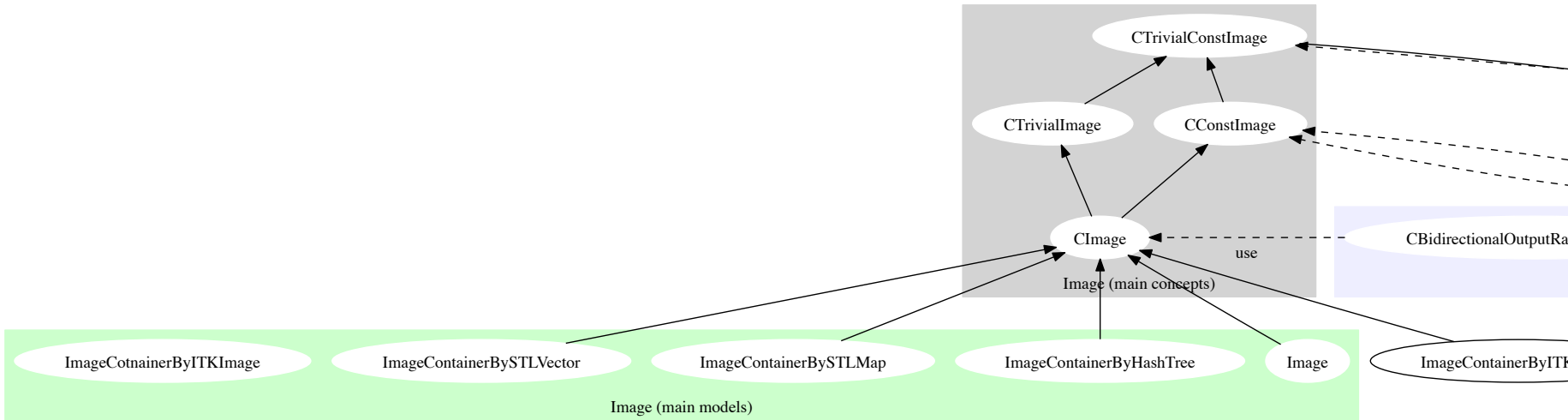
Constraints on types and template parameters are defined with **Concepts**

`Integer` in `SpaceND` should be a model of `DGtal::CCommutativeRing`.

Concept Checking with `boost`

```
1    ...
2    //Integer must be signed to characterize a ring.
3    BOOST_CONCEPT_ASSERT(( CCommutativeRing<TInteger> ) );
4    ...
```

Example using Image concepts



liris.cnrs.fr/dgtal/doc/nightly/structDGtal_1_1CCommutativeRing.html

DGtal::CCommutativeRing< T >

[legend]

Public Member Functions

BOOST_CONCEPT_USAGE (CCommutativeRing)

Private Attributes

T a
T b
T c

Detailed Description

template<typename T>
struct DGtal::CCommutativeRing< T >

Aim: Defines the mathematical concept equivalent to a unitary commutative ring.

Description of **concept** 'CCommutativeRing'

Refinement of boost::Assignable<T>,

boost::EqualityComparable<T>, boost::LessThanComparable<T>

Associated types :

Notation

- X : A type that is a model of CCommutativeRing
- x, y : Object of type Integer

Definitions

Valid expressions and

Name	Expression	Type requirements	Return type	Precondition	Semantics	Postcondition	Complexity
Construction from basic integer type	X(i)				X represents the integer i		
Addition	x + y		X		addition of two numbers		
Subtraction	x - y		X		subtraction of two numbers		
Multiplication	x - y		X		subtraction of two numbers		
Opposite operator	- x		X		defines the opposite of x (x + -x = 0)		
X should have a 0 (neutral element for addition)	X(0)		X		the value 0		
X should have a 1 (neutral element for multiplication)	X (1)		X		the value 1		

Invariants

Main DGtal objects/concepts in one slide

CSpace : where all your computations lie, provides you an algebra

CPositiveIrreducibleFraction : well.. you get the idea...

CDomain : provides you ways iterate on points (classical model: `HyperRectDomain`)

CDigitalSet : containers of a collection of digital points, provides you iterators, insert/delation methods,...

Object : union of a digital topology and a digital set (neighborhood , connected components, simple points test, ...)

CDigitalSurface{Container,Tracker} : models to construct/track digital surfaces

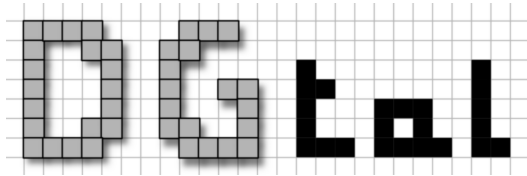
CSegment : given a 2D generic contour, models which associate a “property” to a part of it

CSegmentComputer : refinement of CSegment whose models provides methods to “recognize” part of the curve satisfying the “property” (*e.g.* DSS, DCA, ...)

CImage : models which associate values to point in a domain.

Board2D, Viewer3D, Board3DTo2D : viewers, exporters,...

DGtal Team



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