Signal/Geometry Processing Library (SPL)

2.0.6

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Contents

Chapter 1

Signal/Geometry Processing Library (SPL) Reference Manual (Version 2.0.6)

1.1 Introduction

The Signal Processing Library (SPL) provides several classes and associated code that are useful for various signal/geometry processing applications. The SPL was developed by Michael Adams from the Department of Electrical and Computer Engineering at the University of Victoria, Victoria, BC, Canada.

1.2 License

1.3 Reporting Bugs

Please send any bug reports to mdadams@ece.uvic.ca.

Chapter 2

Getting Started

The following sections are useful for getting started with the SPL:

- Installation. Describes how to install the SPL.
- Organization of the Manual. Briefly explains the organization of the manual (e.g., where to find things).

2.1 Installation

```
Installing the SPL Software
===========================

The SPL software should build on most Linux systems with a C++ compiler that
supports C++14.

Installation Steps
------------------

In what follows, $SOURCE_DIR denotes the top-level directory of the SPL
software distribution (i.e., the directory containing the INSTALL file that
you are currently reading), $BUILD_DIR denote denotes a directory (which is
either empty or to be newly created) to be used for building the software,
and $INSTALL_DIR denotes the directory under which the software should
be installed.

Note that in-source builds are not supported.  So, $BUILD_DIR must be
different from $SOURCE_DIR.

To build the software, the following steps are required (in order):

1. Install the prerequisite libraries.

Ensure that all of the libraries needed by the SPL software are installed
on your system.  This includes the following libraries:

    1) Computational Geometry Algorithms Library (CGAL)
    http://www.cgal.org

    2) OpenGL Utility Toolkit (GLUT)
    http://www.opengl.org/resources/libraries/glut/
    http://freeglut.sourceforge.net
```

```
    3) Sndfile Library
    http://www.mega-nerd.com/libsndfile
```

Some platforms provide a package manager for installing software packages and their dependencies. For example, Fedora provides the DNF package manager, which is accessed via the dnf command, and Ubuntu provides the Apt package manager, which is accessed via the apt-get command. If a package manager is available on your system, it can likely be used to simplify the process of installing some of the above prerequisite libraries. For example, on a Fedora system with the DNF package manager, some of the above libraries could be installed by using a sequence of commands resembling the following:

```
    dnf install CGAL CGAL-devel CGAL-demos-source mpfr-devel
    dnf install freeglut freeglut-devel
    dnf install libsndfile libsndfile-devel
```

Note that the specific package names required by the package manager will vary from one version of Fedora to another and may not exactly match those appearing above.

2. Generate the native build files.

If the build directory $BUILD_DIR does not exist, create it by using the command:

```
    mkdir -p $BUILD_DIR
```

Generate the build files for the native build tool on your system using the command:

```
    cd $BUILD_DIR
    cmake -DCMAKE_INSTALL_PREFIX=$INSTALL_DIR $OPTIONS $SOURCE_DIR
```

where $OPTIONS corresponds to zero or more -D options as described in the later section titled "Cmake Options".

3. Build the software.

To build the software, use the command:

```
    cmake --build $BUILD_DIR --clean-first
```

4. Test the software (prior to installation).

Run some basic sanity checks on the software, prior to installation. Although this step is not strictly required, it is strongly recommended that this step not be skipped. The test the software, use the command:

```
    cd $BUILD_DIR
    ctest --output-on-failure
```

Some tests may require considerable time to complete. So, be prepared to go for a coffee break. After all of the tests have run, a message should be printed that indicates how many tests passed of those that were run. If any of the tests failed, this is an indication that something is wrong and the SPL software is not working reliably. If such a situation arises, it is likely due to either an error made by the person installing the software or a bug in the software itself.

Some of the tests may require graphics capabilities. If the graphics display is not on the local machine, this can sometimes cause problems. For example, some tests may fail due to bugs in the graphics libraries that handle remote displays. In such cases, it may be desirable to disable tests that require graphics capabilities. To do this, set the environment variable SPL_MAKE_CHECK_ENABLE_GRAPHICS to 0 (before running ctest).

5. Install the software.

```
The actual installation of the software may require special administrator
privileges depending on the target directory for installation (i.e.,
$INSTALL_DIR).  To install the executables, libraries, include files, and
other auxiliary data, use the command:

    cmake --build $BUILD_DIR --target install

Cmake Options
-------------

The option OPTION can be set to the value VALUE with a command-line option
of the form -DOPTION=VALUE
The following options are supported:

CMAKE_INSTALL_PREFIX
    Specify the installation directory.
        Value: A directory name.

CMAKE_BUILD_TYPE
    Specify the build type (i.e., release or debug).
    Valid values: Debug or Release

SPL_ENABLE_ASAN
        Enable the Address Sanitizer.
        Valid values: true or false

SPL_ENABLE_USAN
        Enable the Undefined-Behavior Sanitizer.
        Valid values: true or false

SPL_ENABLE_LSAN
        Enable the Leak Sanitizer.
        Valid values: true or false

SPL_ENABLE_MSAN
        Enable the Memory Sanitizer.
        Valid values: true or false
```

2.2 Organization of the Manual

The library is partitioned into groups of related code called modules. The documentation is also parititioned in this way. The documentation for each of the various modules can be found in the modules page.

Chapter 3

Frequently Asked Questions (FAQ)

The following is a list of common questions/problems encountered when using the library.

- I would like to avoid many stressful days and sleepless nights debugging my code that uses the SPL library. Do you have any suggestions on how I can avoid needless mistakes? Are there any common pitfalls that I should be particularly careful to avoid?

  Sadly, one of the most common sources of problems is not reading the documentation and making incorrect assumptions about how the library works. Unfortunately, an incorrect assumption about how the library works can be quite costly, leading to hours of unnecessary debugging time.

- My code is triggering a failed assertion in the SPL library. What does this mean?

  The SPL library makes frequent use of assertions in order to assist in the detection of bugs. If an assertion fails, the code has encountered a situation that should never occur in correct code. The most likely cause is that you are using the library incorrectly. Be sure that you have read the documentation for the parts of the library that you are using in order to ensure that you are using it correctly.

Chapter 4

Known Bugs

Currently, there are no known bugs in the library.

Chapter 5

Module Index

5.1 Modules

Here is a list of all modules:

Chapter 6

Hierarchical Index

6.1 Class Hierarchy

This inheritance list is sorted roughly, but not completely, alphabetically:

Chapter 7

Class Index

7.1 Class List

Here are the classes, structs, unions and interfaces with brief descriptions:

Chapter 8

File Index

8.1 File List

Here is a list of all documented files with brief descriptions:

Chapter 9

Module Documentation

9.1 Arrays and Sequences

One- and two-dimensional arrays and sequences.

Modules

- One-Dimensional Arrays

  One-dimensional arrays.
- Two-Dimensional Arrays

  Two-dimensional arrays.
- One-Dimensional Sequences

  One-dimensional sequences.
- Two-Dimensional Sequences

  Two-dimensional sequences.

9.1.1 Detailed Description

One- and two-dimensional arrays and sequences.

9.2 One-Dimensional Arrays

One-dimensional arrays.

Classes

- class SPL::Array1< T >

  A one-dimensional array class with lazy copying and reference counting.

Typedefs

- typedef Array1< double > SPL::RealArray1

  A one-dimensional array with real elements.
- typedef Array1< int > SPL::IntArray1

  A one-dimensional array with integer elements.

Functions

- template<class T >
  std::ostream & SPL::operator<< (std::ostream &out, const Array1< T > &a)

  Output an array to the specified stream.
- template<class T >
  std::istream & SPL::operator>> (std::istream &in, Array1< T > &a)

  Input an array from the specified stream.
- template<class T >
  bool SPL::operator== (const Array1< T > &a, const Array1< T > &b)

  Test two arrays for equality.
- template<class T >
  SPL_ARRAY1_INLINE bool SPL::operator!= (const Array1< T > &a, const Array1< T > &b)

  Test two arrays for inequality.
- SPL::Array1< T >::Array1 ()

  Create an empty array.
- SPL::Array1< T >::Array1 (int size)

  Create an array of the specified size.
- SPL::Array1< T >::Array1 (const Array1 &a)

  Create a copy of an array.
- SPL::Array1< T >::Array1 (int size, const T &value)

  Create an array of the given size with all elements initialized to the specified value.
- SPL::Array1< T >::~Array1 ()

  Destroy an array.
- Array1 & SPL::Array1< T >::operator= (const Array1 &a)

  Assign one array to another.
- template<class OtherType >
  Array1< T > & SPL::Array1< T >::operator= (const Array1< OtherType > &a)

  Assign an array with elements of arbitrary type to another array.

- Array1 & SPL::Array1< T >::operator+= (const Array1 &a)

  Add another array (elementwise) to this array.
- Array1 & SPL::Array1< T >::operator-= (const Array1 &a)

  Subtract another array (elementwise) from this array.
- Array1 & SPL::Array1< T >::operator*= (const Array1 &a)

  Multiply another array (elementwise) by this array.
- Array1 & SPL::Array1< T >::operator/= (const Array1 &a)

  Divide this array (elementwise) by another array.
- Array1 & SPL::Array1< T >::operator+= (const T &value)

  Add the specified value to each element in the array.
- Array1 & SPL::Array1< T >::operator-= (const T &value)

  Subtract the specified value from each element in the array.
- Array1 & SPL::Array1< T >::operator*= (const T &value)

  Multiply each element in the array by the specified value.
- Array1 & SPL::Array1< T >::operator/= (const T &value)

  Divide each element in the array by the specified value.
- int SPL::Array1< T >::getSize () const

  Get the number of elements in the array.
- bool SPL::Array1< T >::isShared () const

  Is the data for this array shared with another array?
- bool SPL::Array1< T >::isSharedWith (const Array1 &a) const

  Is the data for this array shared with the specified array?
- T & SPL::Array1< T >::operator() (int i)

  Get a mutable reference to the specified element in the array.
- const T & SPL::Array1< T >::operator() (int i) const

  Get a const reference to the specified element in the array.
- Iterator SPL::Array1< T >::begin ()

  Get a mutable iterator referring to the first element in the array.
- Iterator SPL::Array1< T >::end ()

  Get a mutable iterator referring to one past the last element in the array.
- ConstIterator SPL::Array1< T >::begin () const

  Get a const iterator referring to the first element in the array.
- ConstIterator SPL::Array1< T >::end () const

  Get a const iterator referring to one past the last element in the array.
- void SPL::Array1< T >::resize (int size)

  Change the size of the array.
- template<class InputIterator >
  void SPL::Array1< T >::resize (int size, InputIterator data)

  Change the size of the array, initializing the resized array with the data obtained from the specified input iterator.
- T SPL::Array1< T >::max () const

  Get the maximum of the elements in the array.
- T SPL::Array1< T >::min () const

  Get the minimum of the elements in the array.
- T SPL::Array1< T >::sum () const

  Get the sum of the elements in the array.
- std::ostream & SPL::Array1< T >::output (std::ostream &out, int fieldWidth) const

  Output an array to a stream with a particular field width to be used for each element.

- int SPL::Array1< T >::load (const char *fileName)

  Load an array from the file with the specified name.
- int SPL::Array1< T >::save (const char *fileName) const

  Save an array to the file with the specified name.
- void SPL::Array1< T >::swap (Array1 &a)

  Swap the contents of the array with the contents of another array.
- void SPL::Array1< T >::fill (const T &value=T(0))

  Set all elements in the array to the specified value.
- void SPL::Array1< T >::dump (std::ostream &out) const

  Output information about an array to a stream for debugging.

9.2.1 Detailed Description

One-dimensional arrays.

9.2.2 Typedef Documentation

9.2.2.1 IntArray1

```
typedef Array1<int> SPL::IntArray1
```

A one-dimensional array with integer elements.

9.2.2.2 RealArray1

```
typedef Array1<double> SPL::RealArray1
```

A one-dimensional array with real elements.

9.2.3 Function Documentation

9.2.3.1 Array1() [1/4]

```
template<class T >
SPL_ARRAY1_INLINE SPL::Array1< T >::Array1 ( )
```

Create an empty array.

9.2.3.2 Array1() [2/4]

```
template<class T >
SPL_ARRAY1_INLINE SPL::Array1< T >::Array1 (
            int size )  [explicit]
```

Create an array of the specified size.

9.2.3.3 Array1() [3/4]

```
template<class T >
SPL_ARRAY1_INLINE SPL::Array1< T >::Array1 (
            int size,
            const T & value )
```

Create an array of the given size with all elements initialized to the specified value.

9.2.3.4 Array1() [4/4]

```
template<class T >
SPL_ARRAY1_INLINE SPL::Array1< T >::Array1 (
            const Array1< T > & a )
```

Create a copy of an array.

9.2.3.5 begin() [1/2]

```
template<class T >
SPL_ARRAY1_INLINE Array1< T >::ConstIterator SPL::Array1< T >::begin ( ) const
```

Get a const iterator referring to the first element in the array.

9.2.3.6 begin() [2/2]

```
template<class T >
SPL_ARRAY1_INLINE Array1< T >::Iterator SPL::Array1< T >::begin ( )
```

Get a mutable iterator referring to the first element in the array.

9.2.3.7 dump()

```
template<class T >
void SPL::Array1< T >::dump (
            std::ostream & out ) const
```

Output information about an array to a stream for debugging.

9.2.3.8 end() [1/2]

```
template<class T >
SPL_ARRAY1_INLINE Array1< T >::ConstIterator SPL::Array1< T >::end ( ) const
```

Get a const iterator referring to one past the last element in the array.

9.2.3.9 end() [2/2]

```
template<class T >
SPL_ARRAY1_INLINE Array1< T >::Iterator SPL::Array1< T >::end ( )
```

Get a mutable iterator referring to one past the last element in the array.

9.2.3.10 fill()

```
template<class T >
SPL_ARRAY1_INLINE void SPL::Array1< T >::fill (
            const T & value = T(0) )
```

Set all elements in the array to the specified value.

9.2.3.11 getSize()

```
template<class T >
SPL_ARRAY1_INLINE int SPL::Array1< T >::getSize ( ) const
```

Get the number of elements in the array.

9.2.3.12 isShared()

```
template<class T >
SPL_ARRAY1_INLINE bool SPL::Array1< T >::isShared ( ) const
```

Is the data for this array shared with another array?

Under most normal circumstances, one should never need to call this function. In some instances, however, it might be necessary to know whether data is shared in order to write more optimal code.

9.2.3.13 isSharedWith()

```
template<class T >
SPL_ARRAY1_INLINE bool SPL::Array1< T >::isSharedWith (
            const Array1< T > & a ) const
```

Is the data for this array shared with the specified array?

9.2.3.14 load()

```
template<class T >
int SPL::Array1< T >::load (
            const char * fileName )
```

Load an array from the file with the specified name.

9.2.3.15 max()

```
template<class T >
SPL_ARRAY1_INLINE T SPL::Array1< T >::max ( ) const
```

Get the maximum of the elements in the array.

The array must contain at least one element.

9.2.3.16 min()

```
template<class T >
SPL_ARRAY1_INLINE T SPL::Array1< T >::min ( ) const
```

Get the minimum of the elements in the array.

The array must contain at least one element.

9.2.3.17 operator"!=()

```
template<class T >
SPL_ARRAY1_INLINE bool SPL::operator!= (
            const Array1< T > & a,
            const Array1< T > & b )
```

Test two arrays for inequality.

9.2.3.18 operator()() [1/2]

```
template<class T >
SPL_ARRAY1_INLINE T & SPL::Array1< T >::operator() (
            int i )
```

Get a mutable reference to the specified element in the array.

9.2.3.19 operator()() [2/2]

```
template<class T >
SPL_ARRAY1_INLINE const T & SPL::Array1< T >::operator() (
            int i ) const
```

Get a const reference to the specified element in the array.

9.2.3.20 operator*=() [1/2]

```
template<class T >
SPL_ARRAY1_INLINE Array1< T > & SPL::Array1< T >::operator*= (
            const Array1< T > & a )
```

Multiply another array (elementwise) by this array.

9.2.3.21 operator*=() [2/2]

```
template<class T >
SPL_ARRAY1_INLINE Array1< T > & SPL::Array1< T >::operator*= (
            const T & value )
```

Multiply each element in the array by the specified value.

9.2.3.22 operator+=() [1/2]

```
template<class T >
SPL_ARRAY1_INLINE Array1< T > & SPL::Array1< T >::operator+= (
            const Array1< T > & a )
```

Add another array (elementwise) to this array.

9.2.3.23 operator+=() [2/2]

```
template<class T >
SPL_ARRAY1_INLINE Array1< T > & SPL::Array1< T >::operator+= (
            const T & value )
```

Add the specified value to each element in the array.

9.2.3.24 operator-=() [1/2]

```
template<class T >
SPL_ARRAY1_INLINE Array1< T > & SPL::Array1< T >::operator-= (
            const Array1< T > & a )
```

Subtract another array (elementwise) from this array.

9.2.3.25 operator-=() [2/2]

```
template<class T >
SPL_ARRAY1_INLINE Array1< T > & SPL::Array1< T >::operator-= (
            const T & value )
```

Subtract the specified value from each element in the array.

9.2.3.26 operator/=() [1/2]

```
template<class T >
SPL_ARRAY1_INLINE Array1< T > & SPL::Array1< T >::operator/= (
            const Array1< T > & a )
```

Divide this array (elementwise) by another array.

9.2.3.27 operator/=() [2/2]

```
template<class T >
SPL_ARRAY1_INLINE Array1< T > & SPL::Array1< T >::operator/= (
            const T & value )
```

Divide each element in the array by the specified value.

9.2.3.28 operator<<()

```
template<class T >
std::ostream& SPL::operator<< (
            std::ostream & out,
            const Array1< T > & a )
```

Output an array to the specified stream.

9.2.3.29 operator=() [1/2]

```
template<class T >
SPL_ARRAY1_INLINE Array1< T > & SPL::Array1< T >::operator= (
            const Array1< T > & a )
```

Assign one array to another.

9.2.3.30 operator=() [2/2]

```
template<class T >
template<class OtherType >
Array1< T > & SPL::Array1< T >::operator= (
            const Array1< OtherType > & a )
```

Assign an array with elements of arbitrary type to another array.

9.2.3.31 operator==()

```
template<class T >
bool SPL::operator== (
            const Array1< T > & a,
            const Array1< T > & b )
```

Test two arrays for equality.

9.2.3.32 operator>>()

```
template<class T >
std::istream& SPL::operator>> (
             std::istream & in,
             Array1< T > & a )
```

Input an array from the specified stream.

9.2.3.33 output()

```
template<class T >
std::ostream & SPL::Array1< T >::output (
             std::ostream & out,
             int fieldWidth ) const
```

Output an array to a stream with a particular field width to be used for each element.

9.2.3.34 resize() [1/2]

```
template<class T >
void SPL::Array1< T >::resize (
             int size )
```

Change the size of the array.

Effects: The array size is changed to the specified size. If the new size is the same as the old size, this function does nothing.

9.2.3.35 resize() [2/2]

```
template<class T >
template<class InputIterator >
void SPL::Array1< T >::resize (
             int size,
             InputIterator data )
```

Change the size of the array, initializing the resized array with the data obtained from the specified input iterator.

9.2.3.36 save()

```
template<class T >
int SPL::Array1< T >::save (
            const char * fileName ) const
```

Save an array to the file with the specified name.

9.2.3.37 sum()

```
template<class T >
SPL_ARRAY1_INLINE T SPL::Array1< T >::sum ( ) const
```

Get the sum of the elements in the array.

9.2.3.38 swap()

```
template<class T >
SPL_ARRAY1_INLINE void SPL::Array1< T >::swap (
            Array1< T > & a )
```

Swap the contents of the array with the contents of another array.

9.2.3.39 ~Array1()

```
template<class T >
SPL_ARRAY1_INLINE SPL::Array1< T >::~Array1 ( )
```

Destroy an array.

9.3 Two-Dimensional Arrays

Two-dimensional arrays.

Classes

- class SPL::Array2< T >

  A two-dimensional array class with lazy copying and reference counting.

Typedefs

- typedef Array2< double > SPL::RealArray2

  A two-dimensional array with real elements.
- typedef Array2< int > SPL::IntArray2

  A two-dimensional array with integer elements.

Functions

- template<class T >
  std::ostream & SPL::operator<< (std::ostream &out, const Array2< T > &a)

  Output an array to the specified stream.
- template<class T >
  std::istream & SPL::operator>> (std::istream &in, Array2< T > &a)

  Input an array from the specified stream.
- template<class T >
  Array2< T > SPL::transpose (const Array2< T > &a)

  Get the transpose of the array.
- template<class T >
  bool SPL::operator== (const Array2< T > &a, const Array2< T > &b)

  Test two arrays for equality.
- template<class T >
  bool SPL::operator!= (const Array2< T > &a, const Array2< T > &b)

  Test two arrays for inequality.
- SPL::Array2< T >::Array2 ()

  Create an empty array.
- SPL::Array2< T >::Array2 (int width, int height)

  Create an array of the specified width and height.
- SPL::Array2< T >::Array2 (const Array2 &a)

  The copy constructor.
- SPL::Array2< T >::Array2 (int width, int height, const T &value)

  Create an array of the specified width and height with the elements of the array initialized to the specified value.
- SPL::Array2< T >::~Array2 ()

  The destructor.
- Array2 & SPL::Array2< T >::operator= (const Array2 &a)

  The assignment operator.

- Array2 & SPL::Array2< T >::operator+= (const Array2 &a)

  Add another array (elementwise) to this array.
- Array2 & SPL::Array2< T >::operator-= (const Array2 &a)

  Subtract another array (elementwise) from this array.
- Array2 & SPL::Array2< T >::operator*= (const Array2 &a)

  Multiply another array (elementwise) by this array.
- Array2 & SPL::Array2< T >::operator/= (const Array2 &a)

  Divide this array (elementwise) by another array.
- Array2 & SPL::Array2< T >::operator+= (const T &a)

  Add the specified value to each element in the array.
- Array2 & SPL::Array2< T >::operator-= (const T &a)

  Subtract the specified value from each element in the array.
- Array2 & SPL::Array2< T >::operator*= (const T &a)

  Multiply each element in the array by the specified value.
- Array2 & SPL::Array2< T >::operator/= (const T &a)

  Divide each element in the array by the specified value.
- int SPL::Array2< T >::getWidth () const

  Get the width of the array.
- int SPL::Array2< T >::getHeight () const

  Get the height of the array.
- int SPL::Array2< T >::getSize () const

  Get the number of elements in the array.
- bool SPL::Array2< T >::isShared () const

  Is the data for this array shared with another array?
- bool SPL::Array2< T >::isSharedWith (const Array2 &a) const

  Is the data for this array shared with the specified array?
- T & SPL::Array2< T >::operator() (int x, int y)

  Get a mutable reference to the (x,y)-th element in the array.
- const T & SPL::Array2< T >::operator() (int x, int y) const

  Get a const reference to the (x,y)-th element in the array.
- T & SPL::Array2< T >::operator() (int i)

  Get a mutable reference to the i-th element in the array.
- const T & SPL::Array2< T >::operator() (int i) const

  Get a const reference to the i-th element in the array.
- ConstIterator SPL::Array2< T >::begin () const

  Get a const iterator for the first element in the array.
- Iterator SPL::Array2< T >::begin ()

  Get a mutable iterator for the first element in the array.
- ConstIterator SPL::Array2< T >::end () const

  Get a const iterator for one past the last element in the array.
- Iterator SPL::Array2< T >::end ()

  Get a mutable iterator for one past the last element in the array.
- ConstXIterator SPL::Array2< T >::rowBegin (int y) const

  Get a const iterator for the first element in the specified row of the array.
- XIterator SPL::Array2< T >::rowBegin (int y)

  Get a mutable iterator for the first element in the specified row of the array.
- ConstXIterator SPL::Array2< T >::rowEnd (int y) const

Get a const iterator for one past the end in the specified row of the array.

- XIterator SPL::Array2< T >::rowEnd (int y)

  Get a mutable iterator for one past the end in the specified row of the array.

- ConstYIterator SPL::Array2< T >::colBegin (int x) const

  Get a const iterator for the first element in the specified column of the array.

- YIterator SPL::Array2< T >::colBegin (int x)

  Get a mutable iterator for the first element in the specified column of the array.

- ConstYIterator SPL::Array2< T >::colEnd (int x) const

  Get a const iterator for one past the end in the specified column of the array.

- YIterator SPL::Array2< T >::colEnd (int x)

  Get a mutable iterator for one past the end in the specified column of the array.

- void SPL::Array2< T >::resize (int width, int height)

  Change the size of the array.

- template<class InputIterator >
  void SPL::Array2< T >::resize (int width, int height, InputIterator data)

  Change the size of the array, initializing the resized array with the data obtained from the specified input iterator.

- T SPL::Array2< T >::max () const

  Get the maximum of the elements in the array.

- T SPL::Array2< T >::min () const

  Get the minimum of the elements in the array.

- T SPL::Array2< T >::sum () const

  Get the sum of the elements in the array.

- std::ostream & SPL::Array2< T >::output (std::ostream &out, int fieldWidth) const

  Output an array to a stream using the specified field width for each array element.

- int SPL::Array2< T >::load (const char *fileName)

  Load an array from the file with the specified name.

- int SPL::Array2< T >::save (const char *fileName) const

  Save an array to the file with the specified name.

- void SPL::Array2< T >::swap (Array2 &a)

  Swap the array data with the data of the specified array.

- void SPL::Array2< T >::fill (const T &value=T(0))

  Set all elements in the array to the specified value.

- Array2 & SPL::Array2< T >::flipud ()

  Flip the array upside down.

- Array2 & SPL::Array2< T >::fliplr ()

  Flip the array left to right.

- void SPL::Array2< T >::dump (std::ostream &out) const

  Output information about an array to a stream for debugging.

- void SPL::Array2< T >::unshare () const

  Force the underlying data to be copied if the data is shared.

9.3.1 Detailed Description

Two-dimensional arrays.

9.3.2 Typedef Documentation

9.3.2.1 IntArray2

```
typedef Array2<int> SPL::IntArray2
```

A two-dimensional array with integer elements.

9.3.2.2 RealArray2

```
typedef Array2<double> SPL::RealArray2
```

A two-dimensional array with real elements.

9.3.3 Function Documentation

9.3.3.1 Array2() [1/4]

```
template<class T >
SPL_ARRAY2_INLINE SPL::Array2< T >::Array2 ( )
```

Create an empty array.

9.3.3.2 Array2() [2/4]

```
template<class T >
SPL_ARRAY2_INLINE SPL::Array2< T >::Array2 (
            int width,
            int height )
```

Create an array of the specified width and height.

9.3.3.3 Array2() [3/4]

```
template<class T >
SPL_ARRAY2_INLINE SPL::Array2< T >::Array2 (
            int width,
            int height,
            const T & value )
```

Create an array of the specified width and height with the elements of the array initialized to the specified value.

9.3.3.4 Array2() [4/4]

```
template<class T >
SPL_ARRAY2_INLINE SPL::Array2< T >::Array2 (
            const Array2< T > & a )
```

The copy constructor.

9.3.3.5 begin() [1/2]

```
template<class T >
SPL_ARRAY2_INLINE Array2< T >::ConstIterator SPL::Array2< T >::begin ( ) const
```

Get a const iterator for the first element in the array.

9.3.3.6 begin() [2/2]

```
template<class T >
SPL_ARRAY2_INLINE Array2< T >::Iterator SPL::Array2< T >::begin ( )
```

Get a mutable iterator for the first element in the array.

9.3.3.7 colBegin() [1/2]

```
template<class T >
SPL_ARRAY2_INLINE Array2< T >::ConstYIterator SPL::Array2< T >::colBegin (
            int x ) const
```

Get a const iterator for the first element in the specified column of the array.

9.3.3.8 colBegin() [2/2]

```
template<class T >
SPL_ARRAY2_INLINE Array2< T >::YIterator SPL::Array2< T >::colBegin (
            int x )
```

Get a mutable iterator for the first element in the specified column of the array.

9.3.3.9 colEnd() [1/2]

```
template<class T >
SPL_ARRAY2_INLINE Array2< T >::ConstYIterator SPL::Array2< T >::colEnd (
            int x ) const
```

Get a const iterator for one past the end in the specified column of the array.

9.3.3.10 colEnd() [2/2]

```
template<class T >
SPL_ARRAY2_INLINE Array2< T >::YIterator SPL::Array2< T >::colEnd (
            int x )
```

Get a mutable iterator for one past the end in the specified column of the array.

9.3.3.11 dump()

```
template<class T >
void SPL::Array2< T >::dump (
            std::ostream & out ) const
```

Output information about an array to a stream for debugging.

Ouput information about an array to the specified stream for debugging purposes.

9.3.3.12 end() [1/2]

```
template<class T >
SPL_ARRAY2_INLINE Array2< T >::ConstIterator SPL::Array2< T >::end ( ) const
```

Get a const iterator for one past the last element in the array.

9.3.3.13 end() [2/2]

```
template<class T >
SPL_ARRAY2_INLINE Array2< T >::Iterator SPL::Array2< T >::end ( )
```

Get a mutable iterator for one past the last element in the array.

9.3.3.14 fill()

```
template<class T >
SPL_ARRAY2_INLINE void SPL::Array2< T >::fill (
            const T & value = T(0) )
```

Set all elements in the array to the specified value.

9.3.3.15 fliplr()

```
template<class T >
Array2< T > & SPL::Array2< T >::fliplr ( )
```

Flip the array left to right.

9.3.3.16 flipud()

```
template<class T >
Array2< T > & SPL::Array2< T >::flipud ( )
```

Flip the array upside down.

9.3.3.17 getHeight()

```
template<class T >
SPL_ARRAY2_INLINE int SPL::Array2< T >::getHeight ( ) const
```

Get the height of the array.

9.3.3.18 getSize()

```
template<class T >
SPL_ARRAY2_INLINE int SPL::Array2< T >::getSize ( ) const
```

Get the number of elements in the array.

9.3.3.19 getWidth()

```
template<class T >
SPL_ARRAY2_INLINE int SPL::Array2< T >::getWidth ( ) const
```

Get the width of the array.

9.3.3.20 isShared()

```
template<class T >
SPL_ARRAY2_INLINE bool SPL::Array2< T >::isShared ( ) const
```

Is the data for this array shared with another array?

Under most normal circumstances, one should never need to call this function. In some instances, however, it might be necessary to know whether data is shared in order to write more optimal code.

9.3.3.21 isSharedWith()

```
template<class T >
SPL_ARRAY2_INLINE bool SPL::Array2< T >::isSharedWith (
            const Array2< T > & a ) const
```

Is the data for this array shared with the specified array?

9.3.3.22 load()

```
template<class T >
int SPL::Array2< T >::load (
            const char * fileName )
```

Load an array from the file with the specified name.

9.3.3.23 max()

```
template<class T >
SPL_ARRAY2_INLINE T SPL::Array2< T >::max ( ) const
```

Get the maximum of the elements in the array.

The array must contain at least one element.

9.3.3.24 min()

```
template<class T >
SPL_ARRAY2_INLINE T SPL::Array2< T >::min ( ) const
```

Get the minimum of the elements in the array.

The array must contain at least one element.

9.3.3.25 operator"!=()

```
template<class T >
bool SPL::operator!= (
            const Array2< T > & a,
            const Array2< T > & b )
```

Test two arrays for inequality.

9.3.3.26 operator()() [1/4]

```
template<class T >
SPL_ARRAY2_INLINE T & SPL::Array2< T >::operator() (
            int x,
            int y )
```

Get a mutable reference to the (x,y)-th element in the array.

9.3.3.27 operator()() [2/4]

```
template<class T >
SPL_ARRAY2_INLINE const T & SPL::Array2< T >::operator() (
            int x,
            int y ) const
```

Get a const reference to the (x,y)-th element in the array.

9.3.3.28 operator()() [3/4]

```
template<class T >
SPL_ARRAY2_INLINE T & SPL::Array2< T >::operator() (
            int i )
```

Get a mutable reference to the i-th element in the array.

The array must have either a width or height of one.

9.3.3.29 operator()() [4/4]

```
template<class T >
SPL_ARRAY2_INLINE const T & SPL::Array2< T >::operator() (
            int i ) const
```

Get a const reference to the i-th element in the array.

The array must have either a width or height of one.

9.3.3.30 operator*=() [1/2]

```
template<class T >
SPL_ARRAY2_INLINE Array2< T > & SPL::Array2< T >::operator*= (
            const Array2< T > & a )
```

Multiply another array (elementwise) by this array.

9.3.3.31 operator*=() [2/2]

```
template<class T >
SPL_ARRAY2_INLINE Array2< T > & SPL::Array2< T >::operator*= (
            const T & a )
```

Multiply each element in the array by the specified value.

9.3.3.32 operator+=() [1/2]

```
template<class T >
SPL_ARRAY2_INLINE Array2< T > & SPL::Array2< T >::operator+= (
            const Array2< T > & a )
```

Add another array (elementwise) to this array.

9.3.3.33 operator+=() [2/2]

```
template<class T >
SPL_ARRAY2_INLINE Array2< T > & SPL::Array2< T >::operator+= (
            const T & a )
```

Add the specified value to each element in the array.

9.3.3.34 operator-=() [1/2]

```
template<class T >
SPL_ARRAY2_INLINE Array2< T > & SPL::Array2< T >::operator-= (
            const Array2< T > & a )
```

Subtract another array (elementwise) from this array.

9.3.3.35 operator-=() [2/2]

```
template<class T >
SPL_ARRAY2_INLINE Array2< T > & SPL::Array2< T >::operator-= (
            const T & a )
```

Subtract the specified value from each element in the array.

9.3.3.36 operator/=() [1/2]

```
template<class T >
SPL_ARRAY2_INLINE Array2< T > & SPL::Array2< T >::operator/= (
            const Array2< T > & a )
```

Divide this array (elementwise) by another array.

9.3.3.37 operator/=() [2/2]

```
template<class T >
SPL_ARRAY2_INLINE Array2< T > & SPL::Array2< T >::operator/= (
            const T & a )
```

Divide each element in the array by the specified value.

9.3.3.38 operator<<()

```
template<class T >
std::ostream& SPL::operator<< (
            std::ostream & out,
            const Array2< T > & a )
```

Output an array to the specified stream.

9.3.3.39 operator=()

```
template<class T >
SPL_ARRAY2_INLINE Array2< T > & SPL::Array2< T >::operator= (
            const Array2< T > & a )
```

The assignment operator.

9.3.3.40 operator==()

```
template<class T >
bool SPL::operator== (
            const Array2< T > & a,
            const Array2< T > & b )
```

Test two arrays for equality.

9.3.3.41 operator>>()

```
template<class T >
std::istream& SPL::operator>> (
            std::istream & in,
            Array2< T > & a )
```

Input an array from the specified stream.

9.3.3.42 output()

```
template<class T >
std::ostream & SPL::Array2< T >::output (
            std::ostream & out,
            int fieldWidth ) const
```

Output an array to a stream using the specified field width for each array element.

9.3.3.43 resize() [1/2]

```
template<class T >
void SPL::Array2< T >::resize (
            int width,
            int height )
```

Change the size of the array.

Effects: The array size is changed to the specified size. If the new size is the same as the old size, this function does nothing.

9.3.3.44 resize() [2/2]

```
template<class T >
template<class InputIterator >
void SPL::Array2< T >::resize (
            int width,
            int height,
            InputIterator data )
```

Change the size of the array, initializing the resized array with the data obtained from the specified input iterator.

9.3.3.45 rowBegin() [1/2]

```
template<class T >
SPL_ARRAY2_INLINE Array2< T >::ConstXIterator SPL::Array2< T >::rowBegin (
            int y ) const
```

Get a const iterator for the first element in the specified row of the array.

9.3.3.46 rowBegin() [2/2]

```
template<class T >
SPL_ARRAY2_INLINE Array2< T >::XIterator SPL::Array2< T >::rowBegin (
            int y )
```

Get a mutable iterator for the first element in the specified row of the array.

9.3.3.47 rowEnd() [1/2]

```
template<class T >
SPL_ARRAY2_INLINE Array2< T >::ConstXIterator SPL::Array2< T >::rowEnd (
            int y ) const
```

Get a const iterator for one past the end in the specified row of the array.

9.3.3.48 rowEnd() [2/2]

```
template<class T >
SPL_ARRAY2_INLINE Array2< T >::XIterator SPL::Array2< T >::rowEnd (
            int y )
```

Get a mutable iterator for one past the end in the specified row of the array.

9.3.3.49 save()

```
template<class T >
int SPL::Array2< T >::save (
            const char * fileName ) const
```

Save an array to the file with the specified name.

9.3.3.50 sum()

```
template<class T >
SPL_ARRAY2_INLINE T SPL::Array2< T >::sum ( ) const
```

Get the sum of the elements in the array.

9.3.3.51 swap()

```
template<class T >
void SPL::Array2< T >::swap (
             Array2< T > & a )
```

Swap the array data with the data of the specified array.

9.3.3.52 transpose()

```
template<class T >
Array2<T> SPL::transpose (
             const Array2< T > & a )
```

Get the transpose of the array.

9.3.3.53 unshare()

```
template<class T >
SPL_ARRAY2_INLINE void SPL::Array2< T >::unshare ( ) const
```

Force the underlying data to be copied if the data is shared.

9.3.3.54 ~Array2()

```
template<class T >
SPL_ARRAY2_INLINE SPL::Array2< T >::~Array2 ( )
```

The destructor.

9.4 One-Dimensional Sequences

One-dimensional sequences.

Classes

- class SPL::Sequence1< T >

  A one-dimensional sequence class with lazy copying and reference counting.

Typedefs

- typedef Sequence1< double > SPL::RealSequence1

  Real sequence.
- typedef Sequence1< int > SPL::IntSequence1

  Integer sequence.

Functions

- template<class T >
  std::ostream & SPL::operator<< (std::ostream &out, const Sequence1< T > &f)

  Output a sequence to a stream.
- template<class T >
  std::istream & SPL::operator>> (std::istream &in, Sequence1< T > &f)

  Input a sequence from a stream.
- template<class T >
  SPL_SEQUENCE1_INLINE Sequence1< T > SPL::operator+ (const Sequence1< T > &f, const Sequence1< T > &g)

  Compute the sum of two sequences.
- template<class T >
  SPL_SEQUENCE1_INLINE Sequence1< T > SPL::operator- (const Sequence1< T > &f, const Sequence1< T > &g)

  Compute the difference of two sequences.
- template<class T >
  SPL_SEQUENCE1_INLINE Sequence1< T > SPL::operator* (const Sequence1< T > &f, const Sequence1< T > &g)

  Compute the (element-wise) product of two sequences.
- template<class T >
  SPL_SEQUENCE1_INLINE Sequence1< T > SPL::operator/ (const Sequence1< T > &f, const Sequence1< T > &g)

  Compute the (element-wise) quotient of two sequences.
- template<class T >
  Sequence1< T > SPL::add (const Sequence1< T > &f, const Sequence1< T > &g)

  Compute the sum of two sequences with potentially differing domains.
- template<class T >
  SPL_SEQUENCE1_INLINE Sequence1< T > SPL::operator+ (const T &a, const Sequence1< T > &f)

  Add a value to a sequence.

- template<class T >
  SPL_SEQUENCE1_INLINE Sequence1< T > SPL::operator+ (const Sequence1< T > &f, const T &a)

  Add a value to a sequence.
- template<class T >
  SPL_SEQUENCE1_INLINE Sequence1< T > SPL::operator- (const Sequence1< T > &f, const T &a)

  Subtract a value from a sequence.
- template<class T >
  SPL_SEQUENCE1_INLINE Sequence1< T > SPL::operator* (const T &a, const Sequence1< T > &f)

  Compute a scalar multiple of a sequence.
- template<class T >
  SPL_SEQUENCE1_INLINE Sequence1< T > SPL::operator* (const Sequence1< T > &f, const T &a)

  Compute a scalar multiple of a sequence.
- template<class T >
  SPL_SEQUENCE1_INLINE Sequence1< T > SPL::operator/ (const Sequence1< T > &f, const T &a)

  Divide a sequence by a scalar.
- template<class T >
  SPL_SEQUENCE1_INLINE bool SPL::operator== (const Sequence1< T > &f, const Sequence1< T > &g)

  Test two sequences for equality.
- template<class T >
  SPL_SEQUENCE1_INLINE bool SPL::operator!= (const Sequence1< T > &f, const Sequence1< T > &g)

  Test two sequences for inequality.
- template<class T >
  SPL_SEQUENCE1_INLINE bool SPL::approxEqual (const Sequence1< T > &f, const Sequence1< T > &g, T threshold=1e-9)

  Test two sequences for approximate equality.
- template<class T >
  Sequence1< T > SPL::subsequence (const Sequence1< T > &f, int startInd, int size)

  Extract a subsequence from a sequence.
- template<class T >
  SPL_SEQUENCE1_INLINE Sequence1< T > SPL::translate (const Sequence1< T > &f, int delta)

  Translate a sequence by the specified amount.
- template<class T >
  Sequence1< T > SPL::convolve (const Sequence1< T > &f, const Sequence1< T > &g, int mode=ConvolveMode::full)

  Compute the convolution of two sequences.
- template<class T >
  Sequence1< T > SPL::downsample (const Sequence1< T > &f, int factor)

  Downsample a sequence by the specified factor.
- template<class T >
  Sequence1< T > SPL::upsample (const Sequence1< T > &f, int factor, int pad=0)

  Upsample a sequence by the specified factor.
- template<class T >
  Array1< Sequence1< T > > SPL::polyphaseSplit (const Sequence1< T > &seq, int type, int numPhases)

  Split a sequence into its polyphase components.
- template<class T >
  Sequence1< T > SPL::polyphaseJoin (const Array1< Sequence1< T > > &comps, int type)

  Reassemble a sequence from its polyphase components.
- SPL::Sequence1< T >::Sequence1 ()

  The default constructor.

- SPL::Sequence1< T >::Sequence1 (int startInd, int size)

  Construct a sequence with the specified start index and size.
- SPL::Sequence1< T >::Sequence1 (int startInd, int size, const T &value)

  Construct a sequence with the specified start index and size, with all elements set to the given value.
- SPL::Sequence1< T >::Sequence1 (const Array1< T > &data)

  Create a sequence from an array.
- SPL::Sequence1< T >::Sequence1 (int startInd, const Array1< T > &data)

  Create a sequence from an array using the given starting index.
- SPL::Sequence1< T >::Sequence1 (const Sequence1 &f)

  The copy constructor.
- SPL::Sequence1< T >::~Sequence1 ()

  The destructor.
- Sequence1 & SPL::Sequence1< T >::operator= (const Sequence1 &f)

  The assignment operator.
- Sequence1 & SPL::Sequence1< T >::operator+= (const Sequence1 &f)

  Add another sequence to this one.
- Sequence1 & SPL::Sequence1< T >::operator-= (const Sequence1 &f)

  Subtract another sequence from this one.
- Sequence1 & SPL::Sequence1< T >::operator*= (const Sequence1 &f)

  Multiply elementwise this sequence by another one.
- Sequence1 & SPL::Sequence1< T >::operator/= (const Sequence1 &f)

  Divide elementwise this sequence by another one.
- Sequence1 & SPL::Sequence1< T >::operator+= (const T &value)

  Add a value to each element of this sequence.
- Sequence1 & SPL::Sequence1< T >::operator-= (const T &value)

  Subtract a value from each element of this sequence.
- Sequence1 & SPL::Sequence1< T >::operator*= (const T &value)

  Multiply each element of this sequence by the specified value.
- Sequence1 & SPL::Sequence1< T >::operator/= (const T &value)

  Divide each element of the sequence by the given value.
- int SPL::Sequence1< T >::getStartInd () const

  Get the start index for the sequence.
- int SPL::Sequence1< T >::getEndInd () const

  Get the end index for the sequence.
- int SPL::Sequence1< T >::getSize () const

  Get the length of the sequence.
- bool SPL::Sequence1< T >::isShared () const

  Is the array for this sequence shared with another array?
- const T & SPL::Sequence1< T >::operator() (int i) const

  Get the specified element in the sequence.
- T & SPL::Sequence1< T >::operator() (int i)

  Get the specified element in the sequence.
- ConstIterator SPL::Sequence1< T >::begin () const

  Get an iterator referencing the first element in the sequence.
- ConstIterator SPL::Sequence1< T >::end () const

  Get an iterator referencing just after the last element in the sequence.
- Iterator SPL::Sequence1< T >::begin ()

Get an iterator referencing the first element in the sequence.

- Iterator SPL::Sequence1< T >::end ()

  Get an iterator referencing just after the last element in the sequence.

- T SPL::Sequence1< T >::min () const

  Get the minimum element in the sequence.

- T SPL::Sequence1< T >::max () const

  Get the maximum element in the sequence.

- T SPL::Sequence1< T >::sum () const

  Get the sum of the elements in the sequence.

- void SPL::Sequence1< T >::swapArray (Array1< T > &data)

  Swap the data for the underlying array and the specified array.

- void SPL::Sequence1< T >::fill (const T &value)

  Set all of the elements in the sequence to the specified value.

- Array1< T > SPL::Sequence1< T >::getArray () const

  Get a copy of the underlying array.

- Sequence1 & SPL::Sequence1< T >::translate (int delta)

  Translate (i.e., shift) a sequence by the specified displacement.

9.4.1 Detailed Description

One-dimensional sequences.

9.4.2 Typedef Documentation

9.4.2.1 IntSequence1

```
typedef Sequence1<int> SPL::IntSequence1
```

Integer sequence.

9.4.2.2 RealSequence1

```
typedef Sequence1<double> SPL::RealSequence1
```

Real sequence.

9.4.3 Function Documentation

9.4.3.1 add()

```
template<class T >
Sequence1<T> SPL::add (
            const Sequence1< T > & f,
            const Sequence1< T > & g )
```

Compute the sum of two sequences with potentially differing domains.

Effects: The sum of the sequences f and g is computed. The domain of the sum is taken to be the smallest domain that contains the domains of both of the sequences being summed.

Returns: The sum is returned.

9.4.3.2 approxEqual()

```
template<class T >
SPL_SEQUENCE1_INLINE bool SPL::approxEqual (
            const Sequence1< T > & f,
            const Sequence1< T > & g,
            T threshold = 1e-9 )
```

Test two sequences for approximate equality.

9.4.3.3 begin() [1/2]

```
template<class T >
SPL_SEQUENCE1_INLINE Sequence1< T >::ConstIterator SPL::Sequence1< T >::begin ( ) const
```

Get an iterator referencing the first element in the sequence.

Returns: An iterator referencing the first element in the sequence (i.e., the element with index getStartInd()) is returned.

9.4.3.4 begin() [2/2]

```
template<class T >
SPL_SEQUENCE1_INLINE Sequence1< T >::Iterator SPL::Sequence1< T >::begin ( )
```

Get an iterator referencing the first element in the sequence.

Returns: An iterator referencing the first element in the sequence (i.e., the element with index getStartInd()) is returned.

9.4.3.5 convolve()

```
template<class T >
Sequence1<T> SPL::convolve (
             const Sequence1< T > & f,
             const Sequence1< T > & g,
             int mode = ConvolveMode::full )
```

Compute the convolution of two sequences.

Effects: The convolution of the sequences f and g is computed. The domain of the resulting sequence (as well as how boundaries are handled) depends on the convolution mode mode. The "full" mode is the same as the "full" mode in MATLAB. The "sameDomainZeroExt" mode is the same as the "same" mode in MATLAB.

Returns: A sequence containing the convolution result is returned.

9.4.3.6 downsample()

```
template<class T >
Sequence1<T> SPL::downsample (
             const Sequence1< T > & f,
             int factor )
```

Downsample a sequence by the specified factor.

Effects: The sequence f is downsampled by the factor factor.

Returns: The downsampled sequence is returned.

9.4.3.7 end() [1/2]

```
template<class T >
SPL_SEQUENCE1_INLINE Sequence1< T >::ConstIterator SPL::Sequence1< T >::end ( ) const
```

Get an iterator referencing just after the last element in the sequence.

Returns: An iterator for the end of the sequence (i.e., one past the last element) is returned.

9.4.3.8 end() [2/2]

```
template<class T >
SPL_SEQUENCE1_INLINE Sequence1< T >::Iterator SPL::Sequence1< T >::end ( )
```

Get an iterator referencing just after the last element in the sequence.

Returns: An iterator for the end of the sequence (i.e., one past the last element) is returned.

9.4.3.9 fill()

```
template<class T >
SPL_SEQUENCE1_INLINE void SPL::Sequence1< T >::fill (
            const T & value )
```

Set all of the elements in the sequence to the specified value.

Effects: Each elements in the sequence is set to the value value.

9.4.3.10 getArray()

```
template<class T >
SPL_SEQUENCE1_INLINE Array1< T > SPL::Sequence1< T >::getArray ( ) const
```

Get a copy of the underlying array.

9.4.3.11 getEndInd()

```
template<class T >
SPL_SEQUENCE1_INLINE int SPL::Sequence1< T >::getEndInd ( ) const
```

Get the end index for the sequence.

Returns: The ending index (i.e., one past the last valid index) is returned.

9.4.3.12 getSize()

```
template<class T >
SPL_SEQUENCE1_INLINE int SPL::Sequence1< T >::getSize ( ) const
```

Get the length of the sequence.

Returns: The number of elements in the sequence is returned. This value is equivalent to getEndInd() - getStartInd().

9.4.3.13 getStartInd()

```
template<class T >
SPL_SEQUENCE1_INLINE int SPL::Sequence1< T >::getStartInd ( ) const
```

Get the start index for the sequence.

Returns: The starting index for the sequence is returned.

9.4.3.14 isShared()

```
template<class T >
SPL_SEQUENCE1_INLINE bool SPL::Sequence1< T >::isShared ( ) const
```

Is the array for this sequence shared with another array?

9.4.3.15 max()

```
template<class T >
SPL_SEQUENCE1_INLINE T SPL::Sequence1< T >::max ( ) const
```

Get the maximum element in the sequence.

The sequence must contain at least one element.

9.4.3.16 min()

```
template<class T >
SPL_SEQUENCE1_INLINE T SPL::Sequence1< T >::min ( ) const
```

Get the minimum element in the sequence.

The sequence must contain at least one element.

9.4.3.17 operator"!=()

```
template<class T >
SPL_SEQUENCE1_INLINE bool SPL::operator!= (
            const Sequence1< T > & f,
            const Sequence1< T > & g )
```

Test two sequences for inequality.

9.4.3.18 operator()() [1/2]

```
template<class T >
SPL_SEQUENCE1_INLINE const T & SPL::Sequence1< T >::operator() (
            int i ) const
```

Get the specified element in the sequence.

Returns: A reference to the i-th element in the sequence is returned.

9.4.3.19 operator()() [2/2]

```
template<class T >
SPL_SEQUENCE1_INLINE T & SPL::Sequence1< T >::operator() (
            int i )
```

Get the specified element in the sequence.

Returns: A reference to the i-th element in the sequence is returned.

9.4.3.20 operator*() [1/3]

```
template<class T >
SPL_SEQUENCE1_INLINE Sequence1<T> SPL::operator* (
            const Sequence1< T > & f,
            const Sequence1< T > & g )
```

Compute the (element-wise) product of two sequences.

Returns: The element-wise product of the sequences f and g is returned. Both sequences must have the same domain.

9.4.3.21 operator*() [2/3]

```
template<class T >
SPL_SEQUENCE1_INLINE Sequence1<T> SPL::operator* (
            const T & a,
            const Sequence1< T > & f )
```

Compute a scalar multiple of a sequence.

Returns: The sequence f multiplied by the value a is returned.

9.4.3.22 operator*() [3/3]

```
template<class T >
SPL_SEQUENCE1_INLINE Sequence1<T> SPL::operator* (
            const Sequence1< T > & f,
            const T & a )
```

Compute a scalar multiple of a sequence.

Returns: The sequence f multiplied by the value a is returned.

9.4.3.23 operator*=() [1/2]

```
template<class T >
SPL_SEQUENCE1_INLINE Sequence1< T > & SPL::Sequence1< T >::operator*= (
            const Sequence1< T > & f )
```

Multiply elementwise this sequence by another one.

Effects: This sequence is multiplied (element-wise) by the sequence f. Both sequences must have the same domain.

9.4.3.24 operator*=() [2/2]

```
template<class T >
SPL_SEQUENCE1_INLINE Sequence1< T > & SPL::Sequence1< T >::operator*= (
            const T & value )
```

Multiply each element of this sequence by the specified value.

Effects: This sequence is multiplied by the element value value.

9.4.3.25 operator+() [1/3]

```
template<class T >
SPL_SEQUENCE1_INLINE Sequence1<T> SPL::operator+ (
            const Sequence1< T > & f,
            const Sequence1< T > & g )
```

Compute the sum of two sequences.

Returns: The sum of the sequences f and g is returned. Both sequences must have the same domain.

9.4.3.26 operator+() [2/3]

```
template<class T >
SPL_SEQUENCE1_INLINE Sequence1<T> SPL::operator+ (
            const T & a,
            const Sequence1< T > & f )
```

Add a value to a sequence.

Returns: The sequence f with a added to each of its elements is returned.

9.4.3.27 operator+() [3/3]

```
template<class T >
SPL_SEQUENCE1_INLINE Sequence1<T> SPL::operator+ (
            const Sequence1< T > & f,
            const T & a )
```

Add a value to a sequence.

Returns: The sequence f with a added to each of its elements is returned.

9.4.3.28 operator+=() [1/2]

```
template<class T >
SPL_SEQUENCE1_INLINE Sequence1< T > & SPL::Sequence1< T >::operator+= (
            const Sequence1< T > & f )
```

Add another sequence to this one.

Effects: The sequence f is added to this sequence. Both sequences must have the same domain.

9.4.3.29 operator+=() [2/2]

```
template<class T >
SPL_SEQUENCE1_INLINE Sequence1< T > & SPL::Sequence1< T >::operator+= (
            const T & value )
```

Add a value to each element of this sequence.

Effects: The value value is added to each element of the sequence.

9.4.3.30 operator-() [1/2]

```
template<class T >
SPL_SEQUENCE1_INLINE Sequence1<T> SPL::operator- (
            const Sequence1< T > & f,
            const Sequence1< T > & g )
```

Compute the difference of two sequences.

Returns: The difference between the sequence f and sequence g (i.e., f - g) is returned. Both sequences must have the same domain.

9.4.3.31 operator-() [2/2]

```
template<class T >
SPL_SEQUENCE1_INLINE Sequence1<T> SPL::operator- (
            const Sequence1< T > & f,
            const T & a )
```

Subtract a value from a sequence.

Returns: The sequence f with a subtracted from each of its elements is returned.

9.4.3.32 operator-=() [1/2]

```
template<class T >
SPL_SEQUENCE1_INLINE Sequence1< T > & SPL::Sequence1< T >::operator-= (
            const Sequence1< T > & f )
```

Subtract another sequence from this one.

Effects: The sequence f is subtracted from this sequence. Both sequences must have the same domain.

9.4.3.33 operator-=() [2/2]

```
template<class T >
SPL_SEQUENCE1_INLINE Sequence1< T > & SPL::Sequence1< T >::operator-= (
            const T & value )
```

Subtract a value from each element of this sequence.

Effects: The value value is subtracted from each element of the sequence.

9.4.3.34 operator/() [1/2]

```
template<class T >
SPL_SEQUENCE1_INLINE Sequence1<T> SPL::operator/ (
            const Sequence1< T > & f,
            const Sequence1< T > & g )
```

Compute the (element-wise) quotient of two sequences.

Returns: The element-wise quotient of the sequences f and g is returned. Both sequences must have the same domain.

9.4.3.35 operator/() [2/2]

```
template<class T >
SPL_SEQUENCE1_INLINE Sequence1<T> SPL::operator/ (
            const Sequence1< T > & f,
            const T & a )
```

Divide a sequence by a scalar.

Returns: The sequence f divided by the value a is returned.

9.4.3.36 operator/=() [1/2]

```
template<class T >
SPL_SEQUENCE1_INLINE Sequence1< T > & SPL::Sequence1< T >::operator/= (
            const Sequence1< T > & f )
```

Divide elementwise this sequence by another one.

Effects: This sequence is divided (element-wise) by the sequence f. Both sequences must have the same domain.

9.4.3.37 operator/=() [2/2]

```
template<class T >
SPL_SEQUENCE1_INLINE Sequence1< T > & SPL::Sequence1< T >::operator/= (
            const T & value )
```

Divide each element of the sequence by the given value.

Effects: Each element of the sequence is divided by the value value.

9.4.3.38 operator<<()

```
template<class T >
std::ostream& SPL::operator<< (
            std::ostream & out,
            const Sequence1< T > & f )
```

Output a sequence to a stream.

Effects: The sequence f is written to the output stream out. The output consists of the following information in order: 1) the starting index of the sequence 2) the size of the sequence 3) the elements of the sequence in increasing order of index

Returns: A reference to the stream out is returned.

9.4.3.39 operator=()

```
template<class T >
SPL_SEQUENCE1_INLINE Sequence1< T > & SPL::Sequence1< T >::operator= (
            const Sequence1< T > & f )
```

The assignment operator.

9.4.3.40 operator==()

```
template<class T >
SPL_SEQUENCE1_INLINE bool SPL::operator== (
            const Sequence1< T > & f,
            const Sequence1< T > & g )
```

Test two sequences for equality.

In order for two sequences to be deemed equal, they must be defined on the same domain and have their element values match everywhere in this domain.

9.4.3.41 operator>>()

```
template<class T >
std::istream& SPL::operator>> (
            std::istream & in,
            Sequence1< T > & f )
```

Input a sequence from a stream.

Effects: The sequence f is read from the input stream in. The data is read in a format consistent with that used by operator<<.

Returns: A reference to the stream in is returned.

9.4.3.42 polyphaseJoin()

```
template<class T >
Sequence1<T> SPL::polyphaseJoin (
            const Array1< Sequence1< T > > & comps,
            int type )
```

Reassemble a sequence from its polyphase components.

Effects: A sequence is recomposed from its polyphase components comps. A polyphase decomposition of type type is assumed.

Returns: The recomposed sequence is returned.

9.4.3.43 polyphaseSplit()

```
template<class T >
Array1<Sequence1<T> > SPL::polyphaseSplit (
            const Sequence1< T > & seq,
            int type,
            int numPhases )
```

Split a sequence into its polyphase components.

Effects: The polyphase decomposition of the sequence seq is computed. In particular, the polyphase decomposition with numPhases phases and type type is computed.

Returns: An array containing the polyphase components is returned.

9.4.3.44 Sequence1() [1/6]

```
template<class T >
SPL_SEQUENCE1_INLINE SPL::Sequence1< T >::Sequence1 ( )
```

The default constructor.

9.4.3.45 Sequence1() [2/6]

```
template<class T >
SPL_SEQUENCE1_INLINE SPL::Sequence1< T >::Sequence1 (
            int startInd,
            int size )
```

Construct a sequence with the specified start index and size.

Effects: A sequence with a starting index of startInd and size size is created. The elements in the sequence are default constructed!

9.4.3.46 Sequence1() [3/6]

```
template<class T >
SPL_SEQUENCE1_INLINE SPL::Sequence1< T >::Sequence1 (
            int startInd,
            int size,
            const T & value )
```

Construct a sequence with the specified start index and size, with all elements set to the given value.

Effects: A sequence with a starting index of startInd and size size is created, with all elements initialized to the value value.

9.4.3.47 Sequence1() [4/6]

```
template<class T >
SPL_SEQUENCE1_INLINE SPL::Sequence1< T >::Sequence1 (
            const Sequence1< T > & f )
```

The copy constructor.

9.4.3.48 Sequence1() [5/6]

```
template<class T >
SPL_SEQUENCE1_INLINE SPL::Sequence1< T >::Sequence1 (
            const Array1< T > & data )
```

Create a sequence from an array.

9.4.3.49 Sequence1() [6/6]

```
template<class T >
SPL_SEQUENCE1_INLINE SPL::Sequence1< T >::Sequence1 (
            int startInd,
            const Array1< T > & data )
```

Create a sequence from an array using the given starting index.

9.4.3.50 subsequence()

```
template<class T >
Sequence1<T> SPL::subsequence (
            const Sequence1< T > & f,
            int startInd,
            int size )
```

Extract a subsequence from a sequence.

Effects: The subsequence with start index startInd and size size is extracted from the sequence f.

Returns: The extracted subsequence is returned.

9.4.3.51 sum()

```
template<class T >
SPL_SEQUENCE1_INLINE T SPL::Sequence1< T >::sum ( ) const
```

Get the sum of the elements in the sequence.

9.4.3.52 swapArray()

```
template<class T >
SPL_SEQUENCE1_INLINE void SPL::Sequence1< T >::swapArray (
            Array1< T > & data )
```

Swap the data for the underlying array and the specified array.

9.4.3.53 translate() [1/2]

```
template<class T >
SPL_SEQUENCE1_INLINE Sequence1< T > & SPL::Sequence1< T >::translate (
            int delta )
```

Translate (i.e., shift) a sequence by the specified displacement.

9.4.3.54 translate() [2/2]

```
template<class T >
SPL_SEQUENCE1_INLINE Sequence1<T> SPL::translate (
            const Sequence1< T > & f,
            int delta )
```

Translate a sequence by the specified amount.

Effects: The sequence f is translated (i.e., time shifted) by i. For example, if the sequence f is defined on the domain a, a+1, ..., b, then the translated sequence will be defined on the domain a+i, a+i+1, ..., b+i.

Returns: The translated sequence is returned.

9.4.3.55 upsample()

```
template<class T >
Sequence1<T> SPL::upsample (
            const Sequence1< T > & f,
            int factor,
            int pad = 0 )
```

Upsample a sequence by the specified factor.

Effects: The sequence f is upsampled by the factor factor. If pad is zero, new samples will only be added between the first and last sample. Up to (factor - 1) extra new samples can be added at the end of the new sequence, by specifying a nonzero value for pad. The default is no padding.

Returns: The upsampled sequence is returned.

9.4.3.56 ~Sequence1()

```
template<class T >
SPL_SEQUENCE1_INLINE SPL::Sequence1< T >::~Sequence1 ( )
```

The destructor.

9.5 Two-Dimensional Sequences

Two-dimensional sequences.

Classes

- class SPL::Sequence2< T >

  A two-dimensional sequence class with lazy copying and reference counting.

Typedefs

- typedef Sequence2< double > SPL::RealSequence2

  Real sequence.
- typedef Sequence2< int > SPL::IntSequence2

  Integer sequence.

Functions

- template<class T >
  std::ostream & SPL::operator<< (std::ostream &out, const Sequence2< T > &f)

  Output a sequence to a stream.
- template<class T >
  std::istream & SPL::operator>> (std::istream &in, Sequence2< T > &f)

  Input a sequence from a stream.
- template<class T >
  SPL_SEQUENCE2_INLINE Sequence2< T > SPL::operator+ (const Sequence2< T > &f, const Sequence2< T > &g)

  Compute the sum of two sequences.
- template<class T >
  SPL_SEQUENCE2_INLINE Sequence2< T > SPL::operator- (const Sequence2< T > &f, const Sequence2< T > &g)

  Compute the difference of two sequences.
- template<class T >
  SPL_SEQUENCE2_INLINE Sequence2< T > SPL::operator* (const Sequence2< T > &f, const Sequence2< T > &g)

  Compute the (element-wise) product of two sequences.
- template<class T >
  SPL_SEQUENCE2_INLINE Sequence2< T > SPL::operator/ (const Sequence2< T > &f, const Sequence2< T > &g)

  Compute the (element-wise) quotient of two sequences.
- template<class T >
  Sequence2< T > SPL::add (const Sequence2< T > &f, const Sequence2< T > &g)

  Compute the sum of two sequences with potentially differing domains.
- template<class T >
  SPL_SEQUENCE2_INLINE Sequence2< T > SPL::operator+ (const T &value, const Sequence2< T > &f)

  Add a value to a sequence.

- template<class T >
  SPL_SEQUENCE2_INLINE Sequence2< T > SPL::operator+ (const Sequence2< T > &f, const T &value)

  Add a value to a sequence.
- template<class T >
  SPL_SEQUENCE2_INLINE Sequence2< T > SPL::operator- (const Sequence2< T > &f, const T &value)

  Subtract a value from a sequence.
- template<class T >
  SPL_SEQUENCE2_INLINE Sequence2< T > SPL::operator* (const T &value, const Sequence2< T > &f)

  Compute a scalar multiple of a sequence.
- template<class T >
  SPL_SEQUENCE2_INLINE Sequence2< T > SPL::operator* (const Sequence2< T > &f, const T &value)

  Compute a scalar multiple of a sequence.
- template<class T >
  SPL_SEQUENCE2_INLINE Sequence2< T > SPL::operator/ (const Sequence2< T > &f, const T &value)

  Divide a sequence by a scalar.
- template<class T >
  bool SPL::operator== (const Sequence2< T > &f, const Sequence2< T > &g)

  Test two sequences for equality.
- template<class T >
  SPL_SEQUENCE2_INLINE bool SPL::operator!= (const Sequence2< T > &f, const Sequence2< T > &g)

  Test two sequences for inequality.
- template<class T >
  SPL_SEQUENCE2_INLINE bool SPL::approxEqual (const Sequence2< T > &f, const Sequence2< T > &g, T threshold=1e-9)

  Test two sequences for approximate equality.
- template<class T >
  Sequence2< T > SPL::subsequence (const Sequence2< T > &f, int startX, int startY, int width, int height)

  Extract a subsequence from a sequence.
- template<class T >
  SPL_SEQUENCE2_INLINE Sequence2< T > SPL::translate (const Sequence2< T > &f, int deltaX, int deltaY)

  Translate a sequence by the specified amount.
- template<class T >
  Sequence2< T > SPL::convolve (const Sequence2< T > &f, const Sequence2< T > &g, int mode)

  Compute the convolution of two sequences.
- template<class T >
  Sequence2< T > SPL::convolveSeparable (const Sequence2< T > &f, const Sequence1< T > &horzFilt, const Sequence1< T > &vertFilt, int mode=ConvolveMode::full)

  Compute the convolution of a sequence with two 1-D filters (i.e., convolution with a separable filter).
- template<class T >
  Sequence2< T > SPL::downsample (const Sequence2< T > &f, int factorX, int factorY)

  Downsample a sequence in each of the horizontal and vertical directions by the specified factors.
- template<class T >
  Sequence2< T > SPL::upsample (const Sequence2< T > &f, int factorX, int factorY)

  Upsample a sequence in each of the horizontal and vertical directions by the specified factors.
- template<class T >
  Sequence2< T > SPL::upsample (const Sequence2< T > &f, int factorX, int factorY, int padX, int padY)

  Upsample a sequence in each of the horizontal and vertical directions by the specified factors.
- template<class T >
  Array2< Sequence2< T > > SPL::polyphaseSplit (const Sequence2< T > &seq, int typeX, int numPhasesX, int typeY, int numPhasesY)

Split a sequence into its polyphase components.

- template<class T >
  Sequence2< T > SPL::polyphaseJoin (const Array2< Sequence2< T > > &comps, int typeX, int typeY)

  Reassemble a sequence from its polyphase components.
- SPL::Sequence2< T >::Sequence2 ()

  The default constructor.
- SPL::Sequence2< T >::Sequence2 (int startX, int startY, int width, int height)

  Construct a sequence with the specified start index and size.
- SPL::Sequence2< T >::Sequence2 (int startX, int startY, int width, int height, const T &data)

  Construct a sequence with the specified start index and size, with all elements set to the given value.
- SPL::Sequence2< T >::Sequence2 (const Sequence2 &f)

  The copy constructor.
- SPL::Sequence2< T >::Sequence2 (const Array2< T > &data)

  Create a sequence from an array.
- SPL::Sequence2< T >::Sequence2 (int startX, int startY, const Array2< T > &data)

  Create a sequence from an array using the given starting index.
- SPL::Sequence2< T >::~Sequence2 ()

  The destructor.
- Sequence2 & SPL::Sequence2< T >::operator= (const Sequence2 &f)

  The assignment operator.
- Sequence2 & SPL::Sequence2< T >::operator+= (const Sequence2 &f)

  Add another sequence to this one.
- Sequence2 & SPL::Sequence2< T >::operator-= (const Sequence2 &f)

  Subtract another sequence from this one.
- Sequence2 & SPL::Sequence2< T >::operator*= (const Sequence2 &f)

  Multiply elementwise this sequence by another one.
- Sequence2 & SPL::Sequence2< T >::operator/= (const Sequence2 &f)

  Divide elementwise this sequence by another one.
- Sequence2 & SPL::Sequence2< T >::operator+= (const T &value)

  Add a value to each element of this sequence.
- Sequence2 & SPL::Sequence2< T >::operator-= (const T &value)

  Subtract a value from each element of this sequence.
- Sequence2 & SPL::Sequence2< T >::operator*= (const T &value)

  Multiply each element of this sequence by the specified value.
- Sequence2 & SPL::Sequence2< T >::operator/= (const T &value)

  Divide each element of the sequence by the given value.
- int SPL::Sequence2< T >::getStartX () const

  Get the x-coordinate of the start index for the sequence.
- int SPL::Sequence2< T >::getStartY () const

  Get the y-coordinate of the start index for the sequence.
- int SPL::Sequence2< T >::getEndX () const

  Get the x-coordinate of the end index for the sequence.
- int SPL::Sequence2< T >::getEndY () const

  Get the y-coordinate of the end index for the sequence.
- int SPL::Sequence2< T >::getWidth () const

  Get the width of the sequence.
- int SPL::Sequence2< T >::getHeight () const

Get the height of the sequence.

- int SPL::Sequence2< T >::getSize () const

  Get the number of elements in the sequence.

- bool SPL::Sequence2< T >::isShared () const

  Is the array for this sequence shared with another array?

- const T & SPL::Sequence2< T >::operator() (int x, int y) const

  Get a const reference to the specified element in the sequence.

- T & SPL::Sequence2< T >::operator() (int x, int y)

  Get a mutable reference to the specified element in the sequence.

- ConstIterator SPL::Sequence2< T >::begin () const

  Get a const iterator for the first element in the sequence.

- Iterator SPL::Sequence2< T >::begin ()

  Get a mutable iterator for the first element in the sequence.

- ConstIterator SPL::Sequence2< T >::end () const

  Get a const iterator for one past the last element in the sequence.

- Iterator SPL::Sequence2< T >::end ()

  Get a mutable iterator for one past the last element in the sequence.

- ConstXIterator SPL::Sequence2< T >::rowBegin (int y) const

  Get a const iterator for the first element in the specified row of the sequence.

- XIterator SPL::Sequence2< T >::rowBegin (int y)

  Get a mutable iterator for the first element in the specified row of the sequence.

- ConstXIterator SPL::Sequence2< T >::rowEnd (int y) const

  Get a const iterator for one past the end in the specified row of the sequence.

- XIterator SPL::Sequence2< T >::rowEnd (int y)

  Get a mutable iterator for one past the end in the specified row of the sequence.

- ConstYIterator SPL::Sequence2< T >::colBegin (int x) const

  Get a const iterator for the first element in the specified column of the sequence.

- YIterator SPL::Sequence2< T >::colBegin (int x)

  Get a mutable iterator for the first element in the specified column of the sequence.

- ConstYIterator SPL::Sequence2< T >::colEnd (int x) const

  Get a const iterator for one past the end in the specified column of the sequence.

- YIterator SPL::Sequence2< T >::colEnd (int x)

  Get a mutable iterator for one past the end in the specified column of the sequence.

- T SPL::Sequence2< T >::min () const

  Get the minimum element in the sequence.

- T SPL::Sequence2< T >::max () const

  Get the maximum element in the sequence.

- T SPL::Sequence2< T >::sum () const

  Get the sum of the elements in the sequence.

- std::ostream & SPL::Sequence2< T >::output (std::ostream &out, int fieldWidth) const

  Output a sequence to the specified stream using the given field width for each sequence element.

- void SPL::Sequence2< T >::fill (const T &value)

  Get a copy of the underlying array.

- void SPL::Sequence2< T >::swapArray (Array2< T > &data)

  Swap the data for the underlying array and the specified array.

- Array2< T > SPL::Sequence2< T >::getArray () const

  Get a copy of the underlying array.

- Sequence2 & SPL::Sequence2< T >::translate (int x, int y)

  Translate (i.e., shift) a sequence by the specified displacement.

9.5.1 Detailed Description

Two-dimensional sequences.

9.5.2 Typedef Documentation

9.5.2.1 IntSequence2

```
typedef Sequence2<int> SPL::IntSequence2
```

Integer sequence.

9.5.2.2 RealSequence2

```
typedef Sequence2<double> SPL::RealSequence2
```

Real sequence.

9.5.3 Function Documentation

9.5.3.1 add()

```
template<class T >
Sequence2<T> SPL::add (
            const Sequence2< T > & f,
            const Sequence2< T > & g )
```

Compute the sum of two sequences with potentially differing domains.

Effects: The sum of the sequences f and g is computed. The domain of the sum is taken to be the smallest domain that contains the domains of both of the sequences being summed.

Returns: The sum is returned.

9.5.3.2 approxEqual()

```
template<class T >
SPL_SEQUENCE2_INLINE bool SPL::approxEqual (
            const Sequence2< T > & f,
            const Sequence2< T > & g,
            T threshold = 1e-9 )
```

Test two sequences for approximate equality.

9.5.3.3 begin() [1/2]

```
template<class T >
SPL_SEQUENCE2_INLINE Sequence2< T >::ConstIterator SPL::Sequence2< T >::begin ( ) const
```

Get a const iterator for the first element in the sequence.

9.5.3.4 begin() [2/2]

```
template<class T >
SPL_SEQUENCE2_INLINE Sequence2< T >::Iterator SPL::Sequence2< T >::begin ( )
```

Get a mutable iterator for the first element in the sequence.

9.5.3.5 colBegin() [1/2]

```
template<class T >
SPL_SEQUENCE2_INLINE Sequence2< T >::ConstYIterator SPL::Sequence2< T >::colBegin (
            int x ) const
```

Get a const iterator for the first element in the specified column of the sequence.

9.5.3.6 colBegin() [2/2]

```
template<class T >
SPL_SEQUENCE2_INLINE Sequence2< T >::YIterator SPL::Sequence2< T >::colBegin (
            int x )
```

Get a mutable iterator for the first element in the specified column of the sequence.

9.5.3.7 colEnd() [1/2]

```
template<class T >
SPL_SEQUENCE2_INLINE Sequence2< T >::ConstYIterator SPL::Sequence2< T >::colEnd (
            int x ) const
```

Get a const iterator for one past the end in the specified column of the sequence.

9.5.3.8 colEnd() [2/2]

```
template<class T >
SPL_SEQUENCE2_INLINE Sequence2< T >::YIterator SPL::Sequence2< T >::colEnd (
            int x )
```

Get a mutable iterator for one past the end in the specified column of the sequence.

9.5.3.9 convolve()

```
template<class T >
Sequence2<T> SPL::convolve (
            const Sequence2< T > & f,
            const Sequence2< T > & g,
            int mode )
```

Compute the convolution of two sequences.

9.5.3.10 convolveSeparable()

```
template<class T >
Sequence2<T> SPL::convolveSeparable (
            const Sequence2< T > & f,
            const Sequence1< T > & horzFilt,
            const Sequence1< T > & vertFilt,
            int mode = ConvolveMode::full )
```

Compute the convolution of a sequence with two 1-D filters (i.e., convolution with a separable filter).

9.5.3.11 downsample()

```
template<class T >
Sequence2<T> SPL::downsample (
            const Sequence2< T > & f,
            int factorX,
            int factorY )
```

Downsample a sequence in each of the horizontal and vertical directions by the specified factors.

9.5.3.12 end() [1/2]

```
template<class T >
SPL_SEQUENCE2_INLINE Sequence2< T >::ConstIterator SPL::Sequence2< T >::end ( ) const
```

Get a const iterator for one past the last element in the sequence.

9.5.3.13 end() [2/2]

```
template<class T >
SPL_SEQUENCE2_INLINE Sequence2< T >::Iterator SPL::Sequence2< T >::end ( )
```

Get a mutable iterator for one past the last element in the sequence.

9.5.3.14 fill()

```
template<class T >
SPL_SEQUENCE2_INLINE void SPL::Sequence2< T >::fill (
            const T & value )
```

Get a copy of the underlying array.

9.5.3.15 getArray()

```
template<class T >
SPL_SEQUENCE2_INLINE Array2< T > SPL::Sequence2< T >::getArray ( ) const
```

Get a copy of the underlying array.

9.5.3.16 getEndX()

```
template<class T >
SPL_SEQUENCE2_INLINE int SPL::Sequence2< T >::getEndX ( ) const
```

Get the x-coordinate of the end index for the sequence.

9.5.3.17 getEndY()

```
template<class T >
SPL_SEQUENCE2_INLINE int SPL::Sequence2< T >::getEndY ( ) const
```

Get the y-coordinate of the end index for the sequence.

9.5.3.18 getHeight()

```
template<class T >
SPL_SEQUENCE2_INLINE int SPL::Sequence2< T >::getHeight ( ) const
```

Get the height of the sequence.

9.5.3.19 getSize()

```
template<class T >
SPL_SEQUENCE2_INLINE int SPL::Sequence2< T >::getSize ( ) const
```

Get the number of elements in the sequence.

9.5.3.20 getStartX()

```
template<class T >
SPL_SEQUENCE2_INLINE int SPL::Sequence2< T >::getStartX ( ) const
```

Get the x-coordinate of the start index for the sequence.

9.5.3.21 getStartY()

```
template<class T >
SPL_SEQUENCE2_INLINE int SPL::Sequence2< T >::getStartY ( ) const
```

Get the y-coordinate of the start index for the sequence.

9.5.3.22 getWidth()

```
template<class T >
SPL_SEQUENCE2_INLINE int SPL::Sequence2< T >::getWidth ( ) const
```

Get the width of the sequence.

9.5.3.23 isShared()

```
template<class T >
SPL_SEQUENCE2_INLINE bool SPL::Sequence2< T >::isShared ( ) const
```

Is the array for this sequence shared with another array?

9.5.3.24 max()

```
template<class T >
SPL_SEQUENCE2_INLINE T SPL::Sequence2< T >::max ( ) const
```

Get the maximum element in the sequence.

The sequence must contain at least one element.

9.5.3.25 min()

```
template<class T >
SPL_SEQUENCE2_INLINE T SPL::Sequence2< T >::min ( ) const
```

Get the minimum element in the sequence.

The sequence must contain at least one element.

9.5.3.26 operator"!=()

```
template<class T >
SPL_SEQUENCE2_INLINE bool SPL::operator!= (
            const Sequence2< T > & f,
            const Sequence2< T > & g )
```

Test two sequences for inequality.

9.5.3.27 operator()() [1/2]

```
template<class T >
SPL_SEQUENCE2_INLINE T & SPL::Sequence2< T >::operator() (
            int x,
            int y )
```

Get a mutable reference to the specified element in the sequence.

9.5.3.28 operator()() [2/2]

```
template<class T >
SPL_SEQUENCE2_INLINE const T & SPL::Sequence2< T >::operator() (
            int x,
            int y ) const
```

Get a const reference to the specified element in the sequence.

9.5.3.29 operator∗() [1/3]

```
template<class T >
SPL_SEQUENCE2_INLINE Sequence2<T> SPL::operator* (
            const Sequence2< T > & f,
            const Sequence2< T > & g )
```

Compute the (element-wise) product of two sequences.

Returns: The element-wise product of the sequences f and g is returned. Both sequences must have the same domain.

9.5.3.30 operator∗() [2/3]

```
template<class T >
SPL_SEQUENCE2_INLINE Sequence2<T> SPL::operator* (
            const T & value,
            const Sequence2< T > & f )
```

Compute a scalar multiple of a sequence.

Returns: The sequence f multiplied by the value a is returned.

9.5.3.31 operator∗() [3/3]

```
template<class T >
SPL_SEQUENCE2_INLINE Sequence2<T> SPL::operator* (
            const Sequence2< T > & f,
            const T & value )
```

Compute a scalar multiple of a sequence.

Returns: The sequence f multiplied by the value a is returned.

9.5.3.32 operator∗=() [1/2]

```
template<class T >
SPL_SEQUENCE2_INLINE Sequence2< T > & SPL::Sequence2< T >::operator*= (
            const Sequence2< T > & f )
```

Multiply elementwise this sequence by another one.

9.5.3.33 operator∗=() [2/2]

```
template<class T >
SPL_SEQUENCE2_INLINE Sequence2< T > & SPL::Sequence2< T >::operator*= (
            const T & value )
```

Multiply each element of this sequence by the specified value.

9.5.3.34 operator+() [1/3]

```
template<class T >
SPL_SEQUENCE2_INLINE Sequence2<T> SPL::operator+ (
            const Sequence2< T > & f,
            const Sequence2< T > & g )
```

Compute the sum of two sequences.

Returns: The sum of the sequences f and g is returned. Both sequences must have the same domain.

9.5.3.35 operator+() [2/3]

```
template<class T >
SPL_SEQUENCE2_INLINE Sequence2<T> SPL::operator+ (
            const T & value,
            const Sequence2< T > & f )
```

Add a value to a sequence.

Returns: The sequence f with a added to each of its elements is returned.

9.5.3.36 operator+() [3/3]

```
template<class T >
SPL_SEQUENCE2_INLINE Sequence2<T> SPL::operator+ (
            const Sequence2< T > & f,
            const T & value )
```

Add a value to a sequence.

Returns: The sequence f with a added to each of its elements is returned.

9.5.3.37 operator+=() [1/2]

```
template<class T >
SPL_SEQUENCE2_INLINE Sequence2< T > & SPL::Sequence2< T >::operator+= (
            const Sequence2< T > & f )
```

Add another sequence to this one.

9.5.3.38 operator+=() [2/2]

```
template<class T >
SPL_SEQUENCE2_INLINE Sequence2< T > & SPL::Sequence2< T >::operator+= (
            const T & value )
```

Add a value to each element of this sequence.

9.5.3.39 operator-() [1/2]

```
template<class T >
SPL_SEQUENCE2_INLINE Sequence2<T> SPL::operator- (
            const Sequence2< T > & f,
            const Sequence2< T > & g )
```

Compute the difference of two sequences.

Returns: The difference between the sequence f and sequence g (i.e., f - g) is returned. Both sequences must have the same domain.

9.5.3.40 operator-() [2/2]

```
template<class T >
SPL_SEQUENCE2_INLINE Sequence2<T> SPL::operator- (
            const Sequence2< T > & f,
            const T & value )
```

Subtract a value from a sequence.

Returns: The sequence f with a subtracted from each of its elements is returned.

9.5.3.41 operator-=() [1/2]

```
template<class T >
SPL_SEQUENCE2_INLINE Sequence2< T > & SPL::Sequence2< T >::operator-= (
            const Sequence2< T > & f )
```

Subtract another sequence from this one.

9.5.3.42 operator-=() [2/2]

```
template<class T >
SPL_SEQUENCE2_INLINE Sequence2< T > & SPL::Sequence2< T >::operator-= (
            const T & value )
```

Subtract a value from each element of this sequence.

9.5.3.43 operator/() [1/2]

```
template<class T >
SPL_SEQUENCE2_INLINE Sequence2<T> SPL::operator/ (
            const Sequence2< T > & f,
            const Sequence2< T > & g )
```

Compute the (element-wise) quotient of two sequences.

Returns: The element-wise quotient of the sequences f and g is returned. Both sequences must have the same domain.

9.5.3.44 operator/() [2/2]

```
template<class T >
SPL_SEQUENCE2_INLINE Sequence2<T> SPL::operator/ (
            const Sequence2< T > & f,
            const T & value )
```

Divide a sequence by a scalar.

Returns: The sequence f divided by the value a is returned.

9.5.3.45 operator/=() [1/2]

```
template<class T >
SPL_SEQUENCE2_INLINE Sequence2< T > & SPL::Sequence2< T >::operator/= (
            const Sequence2< T > & f )
```

Divide elementwise this sequence by another one.

9.5.3.46 operator/=() [2/2]

```
template<class T >
SPL_SEQUENCE2_INLINE Sequence2< T > & SPL::Sequence2< T >::operator/= (
            const T & value )
```

Divide each element of the sequence by the given value.

9.5.3.47 operator<<()

```
template<class T >
std::ostream& SPL::operator<< (
            std::ostream & out,
            const Sequence2< T > & f )
```

Output a sequence to a stream.

Effects: The sequence f is written to the output stream out. The output consists of the following information in order: 1) the x-coordinate of the start index of the sequence 2) the y-coordinate of the start index of the sequence 3) the width of the sequence 4) the height of the sequence 5) the elements of the sequence in row-major order

Returns: A reference to the stream out is returned.

9.5.3.48 operator=()

```
template<class T >
SPL_SEQUENCE2_INLINE Sequence2< T > & SPL::Sequence2< T >::operator= (
            const Sequence2< T > & f )
```

The assignment operator.

9.5.3.49 operator==()

```
template<class T >
bool SPL::operator== (
            const Sequence2< T > & f,
            const Sequence2< T > & g )
```

Test two sequences for equality.

In order for two sequences to be deemed equal, they must be defined on the same domain and have their element values match everywhere in this domain.

9.5.3.50 operator>>()

```
template<class T >
std::istream& SPL::operator>> (
            std::istream & in,
            Sequence2< T > & f )
```

Input a sequence from a stream.

Effects: The sequence f is read from the input stream in. The data is read in a format consistent with that used by operator<<.

Returns: A reference to the stream in is returned.

9.5.3.51 output()

```
template<class T >
std::ostream & SPL::Sequence2< T >::output (
            std::ostream & out,
            int fieldWidth ) const
```

Output a sequence to the specified stream using the given field width for each sequence element.

9.5.3.52 polyphaseJoin()

```
template<class T >
Sequence2<T> SPL::polyphaseJoin (
            const Array2< Sequence2< T > > & comps,
            int typeX,
            int typeY )
```

Reassemble a sequence from its polyphase components.

Effects: A sequence is recomposed from its polyphase components comps. A polyphase decomposition of type type is assumed.

Returns: The recomposed sequence is returned.

9.5.3.53 polyphaseSplit()

```
template<class T >
Array2<Sequence2<T> > SPL::polyphaseSplit (
            const Sequence2< T > & seq,
            int typeX,
            int numPhasesX,
            int typeY,
            int numPhasesY )
```

Split a sequence into its polyphase components.

Effects: The polyphase decomposition of the sequence seq is computed. In particular, the polyphase decomposition with numPhase phases and type type is computed.

Returns: An array containing the polyphase components is returned.

9.5.3.54 rowBegin() [1/2]

```
template<class T >
SPL_SEQUENCE2_INLINE Sequence2< T >::ConstXIterator SPL::Sequence2< T >::rowBegin (
            int y ) const
```

Get a const iterator for the first element in the specified row of the sequence.

9.5.3.55 rowBegin() [2/2]

```
template<class T >
SPL_SEQUENCE2_INLINE Sequence2< T >::XIterator SPL::Sequence2< T >::rowBegin (
            int y )
```

Get a mutable iterator for the first element in the specified row of the sequence.

9.5.3.56 rowEnd() [1/2]

```
template<class T >
SPL_SEQUENCE2_INLINE Sequence2< T >::ConstXIterator SPL::Sequence2< T >::rowEnd (
            int y ) const
```

Get a const iterator for one past the end in the specified row of the sequence.

9.5.3.57 rowEnd() [2/2]

```
template<class T >
SPL_SEQUENCE2_INLINE Sequence2< T >::XIterator SPL::Sequence2< T >::rowEnd (
            int y )
```

Get a mutable iterator for one past the end in the specified row of the sequence.

9.5.3.58 Sequence2() [1/6]

```
template<class T >
SPL_SEQUENCE2_INLINE SPL::Sequence2< T >::Sequence2 ( )
```

The default constructor.

9.5.3.59 Sequence2() [2/6]

```
template<class T >
SPL_SEQUENCE2_INLINE SPL::Sequence2< T >::Sequence2 (
            int startX,
            int startY,
            int width,
            int height )
```

Construct a sequence with the specified start index and size.

9.5.3.60 Sequence2() [3/6]

```
template<class T >
SPL_SEQUENCE2_INLINE SPL::Sequence2< T >::Sequence2 (
            int startX,
            int startY,
            int width,
            int height,
            const T & data )
```

Construct a sequence with the specified start index and size, with all elements set to the given value.

9.5.3.61 Sequence2() [4/6]

```
template<class T >
SPL_SEQUENCE2_INLINE SPL::Sequence2< T >::Sequence2 (
            const Sequence2< T > & f )
```

The copy constructor.

9.5.3.62 Sequence2() [5/6]

```
template<class T >
SPL_SEQUENCE2_INLINE SPL::Sequence2< T >::Sequence2 (
            const Array2< T > & data )
```

Create a sequence from an array.

9.5.3.63 Sequence2() [6/6]

```
template<class T >
SPL_SEQUENCE2_INLINE SPL::Sequence2< T >::Sequence2 (
            int startX,
            int startY,
            const Array2< T > & data )
```

Create a sequence from an array using the given starting index.

9.5.3.64 subsequence()

```
template<class T >
Sequence2<T> SPL::subsequence (
            const Sequence2< T > & f,
            int startX,
            int startY,
            int width,
            int height )
```

Extract a subsequence from a sequence.

Effects: The subsequence with start index startInd and size size is extracted from the sequence f.

Returns: The extracted subsequence is returned.

9.5.3.65 sum()

```
template<class T >
SPL_SEQUENCE2_INLINE T SPL::Sequence2< T >::sum ( ) const
```

Get the sum of the elements in the sequence.

9.5.3.66 swapArray()

```
template<class T >
SPL_SEQUENCE2_INLINE void SPL::Sequence2< T >::swapArray (
            Array2< T > & data )
```

Swap the data for the underlying array and the specified array.

9.5.3.67 translate() [1/2]

```
template<class T >
SPL_SEQUENCE2_INLINE Sequence2< T > & SPL::Sequence2< T >::translate (
            int x,
            int y )
```

Translate (i.e., shift) a sequence by the specified displacement.

9.5.3.68 translate() [2/2]

```
template<class T >
SPL_SEQUENCE2_INLINE Sequence2<T> SPL::translate (
             const Sequence2< T > & f,
             int deltaX,
             int deltaY )
```

Translate a sequence by the specified amount.

Effects: The sequence f is translated by (deltaX, deltaY).

Returns: The translated sequence is returned.

9.5.3.69 upsample() [1/2]

```
template<class T >
Sequence2<T> SPL::upsample (
             const Sequence2< T > & f,
             int factorX,
             int factorY )
```

Upsample a sequence in each of the horizontal and vertical directions by the specified factors.

The following condition should always be true: downsample(upsample(f, factorX, factorY), factorX, factorY) == f.

9.5.3.70 upsample() [2/2]

```
template<class T >
Sequence2<T> SPL::upsample (
             const Sequence2< T > & f,
             int factorX,
             int factorY,
             int padX,
             int padY )
```

Upsample a sequence in each of the horizontal and vertical directions by the specified factors.

The following condition should always be true: downsample(upsample(f, factorX, factorY), factorX, factorY) == f.

9.5.3.71 ~Sequence2()

```
template<class T >
SPL_SEQUENCE2_INLINE SPL::Sequence2< T >::~Sequence2 ( )
```

The destructor.

9.6 Bit Stream I/O

Bit streams.

Classes

- class SPL::BitStream

  A common base class for the input and output bit stream classes.
- class SPL::InputBitStream

  Input bit stream class.
- class SPL::OutputBitStream

  Output bit stream class.

Functions

- bool SPL::BitStream::isOkay () const

  Test if the bitstream in an okay (i.e., non-error) state.
- bool SPL::BitStream::isEof () const

  Test if the bitstream has encountered end-of-file (EOF).
- bool SPL::BitStream::isLimit () const

  Test if the bitstream has encountered a read/write limit.
- void SPL::BitStream::setIoState (IoState state)

  Set the I/O state of a bit stream.
- IoState SPL::BitStream::getIoState () const

  Get the I/O state of a bit stream.
- void SPL::BitStream::clearIoStateBits (IoState state=allIoBits)

  Clear the specified bits in the I/O state of a bit stream.
- void SPL::BitStream::setIoStateBits (IoState state)

  Set the specified bits in the I/O state of a bit stream.
- void SPL::InputBitStream::clearReadCount ()

  Set the read count to zero.
- Size SPL::InputBitStream::getReadCount () const

  Get the number of bits read from the bit stream so far.
- void SPL::InputBitStream::setReadLimit (Offset readLimit)

  Specify the maximum allowable number of bits that may be read from the bit stream.
- Offset SPL::InputBitStream::getReadLimit () const

  Get the number of bits that still may be read from the bit stream before the read limit is reached.
- Size SPL::OutputBitStream::getWriteCount () const

  Get the number of bits written to the bit stream.
- void SPL::OutputBitStream::clearWriteCount ()

  Clear the count of the number of bits written to the bit stream.
- Offset SPL::OutputBitStream::getWriteLimit () const

  Get the number of bits that may still be written to the underlying (character) stream.
- void SPL::OutputBitStream::setWriteLimit (Offset writeLimit)

  Set the number of bits that may still be written to the bit stream.

9.6.1 Detailed Description

Bit streams.

9.6.2 Function Documentation

9.6.2.1 clearIoStateBits()

```
void SPL::BitStream::clearIoStateBits (
            BitStream::IoState mask = allIoBits )  [inline]
```

Clear the specified bits in the I/O state of a bit stream.

If no parameter is provided, all bits are cleared.

9.6.2.2 clearReadCount()

```
void SPL::InputBitStream::clearReadCount ( )  [inline]
```

Set the read count to zero.

9.6.2.3 clearWriteCount()

```
void SPL::OutputBitStream::clearWriteCount ( )  [inline]
```

Clear the count of the number of bits written to the bit stream.

9.6.2.4 getIoState()

```
BitStream::IoState SPL::BitStream::getIoState ( ) const  [inline]
```

Get the I/O state of a bit stream.

(This is similar in spirit to basic_ios::rdstate.)

9.6.2.5 getReadCount()

```
InputBitStream::Size SPL::InputBitStream::getReadCount ( ) const  [inline]
```

Get the number of bits read from the bit stream so far.

9.6.2.6 getReadLimit()

```
InputBitStream::Offset SPL::InputBitStream::getReadLimit ( ) const  [inline]
```

Get the number of bits that still may be read from the bit stream before the read limit is reached.

If read-limit checking is enabled, the function returns the number of bits that can still be read before the read limit is reached. If read-limit checking is disabled, a negative value is returned.

9.6.2.7 getWriteCount()

```
OutputBitStream::Size SPL::OutputBitStream::getWriteCount ( ) const  [inline]
```

Get the number of bits written to the bit stream.

9.6.2.8 getWriteLimit()

```
OutputBitStream::Offset SPL::OutputBitStream::getWriteLimit ( ) const  [inline]
```

Get the number of bits that may still be written to the underlying (character) stream.

If write-limit checking is enabled, the function returns the number of bits that can still be written before the write limit is reached. If write-limit checking is disabled, a negative value is returned.

9.6.2.9 isEof()

```
bool SPL::BitStream::isEof ( ) const  [inline]
```

Test if the bitstream has encountered end-of-file (EOF).

(This is similar in spirit to basic_ios::eof.)

9.6.2.10 isLimit()

```
bool SPL::BitStream::isLimit ( ) const  [inline]
```

Test if the bitstream has encountered a read/write limit.

9.6.2.11 isOkay()

```
bool SPL::BitStream::isOkay ( ) const  [inline]
```

Test if the bitstream in an okay (i.e., non-error) state.

(This is similar in spirit to !basic_ios::fail.)

9.6.2.12 setIoState()

```
void SPL::BitStream::setIoState (
            BitStream::IoState state )  [inline]
```

Set the I/O state of a bit stream.

(This is similar in spirit to basic_ios::clear.)

9.6.2.13 setIoStateBits()

```
void SPL::BitStream::setIoStateBits (
            BitStream::IoState mask )  [inline]
```

Set the specified bits in the I/O state of a bit stream.

(This is similar in spirit to basic_ios::setstate.)

9.6.2.14 setReadLimit()

```
void SPL::InputBitStream::setReadLimit (
            InputBitStream::Offset readLimit )  [inline]
```

Specify the maximum allowable number of bits that may be read from the bit stream.

If readLimit is nonnegative, read-limit checking is enabled and the current read limit is set to readLimit. If readLimit is negative, read-limit checking is disabled.

9.6.2.15 setWriteLimit()

```
void SPL::OutputBitStream::setWriteLimit (
            OutputBitStream::Offset writeLimit )  [inline]
```

Set the number of bits that may still be written to the bit stream.

If writeLimit is nonnegative, write-limit checking is enabled and the current write limit is set to writeLimit. If writeLimit is negative, write-limit checking is disabled.

9.7 Audio and Image Codecs

Audio and image codecs.

Modules

- Audio Codecs

  Audio file I/O support.
- Image Codecs

  Image file I/O support.

9.7.1 Detailed Description

Audio and image codecs.

9.8 Audio Codecs

Audio file I/O support.

Functions

- int SPL::loadAudioFile (const std::string &fileName, int &samplingRate, RealArray1 &samples)
  Read audio data from a file in WAV format.
- int SPL::saveAudioFile (const std::string &fileName, int samplingRate, const RealArray1 &samples)
  Write a sequence to a file in WAV format.

9.8.1 Detailed Description

Audio file I/O support.

9.8.2 Function Documentation

9.8.2.1 loadAudioFile()

```
int SPL::loadAudioFile (
            const std::string & fileName,
            int & samplingRate,
            RealArray1 & samples )
```

Read audio data from a file in WAV format.

Effects: The audio signal from the file named fileName in WAV format is read. The sample data is placed in the array samples and the sampling rate is placed in samplingRate. If the file has more than one channel, only the first channel is read. The sample data will always lie in the range [-1.0, 1.0].

Returns: On success, zero is returned. On failure, a nonzero value is returned.

9.8.2.2 saveAudioFile()

```
int SPL::saveAudioFile (
            const std::string & fileName,
            int samplingRate,
            const RealArray1 & samples )
```

Write a sequence to a file in WAV format.

Effects: The sequence seq with sampling rate samplingRate is written to the file named fileName in WAV format. The sample data must lie in the range [-1.0, 1.0].

Returns: On success, zero is returned. On failure, a nonzero value is returned.

9.9 Image Codecs

Image file I/O support.

Functions

- template<class T >
  int SPL::encodePnm (std::ostream &outStream, const std::vector< Array2< T > > &comps, int maxVal, bool sgnd, bool binaryFormat=true)

  Output the array as an image in the PNM format.
- template<class T >
  int SPL::encodePbm (std::ostream &outStream, const Array2< T > &bits, bool binaryFormat=true)

  Output the array as an image in the PNM format (PBM type).
- template<class T >
  int SPL::encodePgm (std::ostream &outStream, const Array2< T > &gray, int maxVal, bool sgnd, bool binary↩ Format=true)

  Output the array as an image in the PNM format (PGM type).
- template<class T >
  int SPL::encodePpm (std::ostream &outStream, const Array2< T > &red, const Array2< T > &green, const Array2< T > &blue, int maxVal, bool sgnd, bool binaryFormat=true)

  Output the array as an image in the PNM format (PPM type).
- template<class T >
  int SPL::decodePnm (std::istream &inStream, std::vector< Array2< T > > &comps, int &maxVal, bool &sgnd)

  Input an array as an image in the PNM format.
- template<class T >
  int SPL::decodePbm (std::istream &inStream, Array2< T > &bits)

  Input an array as an image in the PNM format.
- template<class T >
  int SPL::decodePgm (std::istream &inStream, Array2< T > &gray, int &maxVal, bool &sgnd)

  Input an array as an image in the PNM format.
- template<class T >
  int SPL::decodePpm (std::istream &inStream, Array2< T > &red, Array2< T > &green, Array2< T > &blue, int &maxVal, bool &sgnd)

  Input an array as an image in the PNM format.

9.9.1 Detailed Description

Image file I/O support.

9.9.2 Function Documentation

9.9.2.1 decodePbm()

```
template<class T >
int SPL::decodePbm (
            std::istream & inStream,
            Array2< T > & bits )
```

Input an array as an image in the PNM format.

Effects: A binary image in the PBM format is read from the stream inStream. The parameter bits is set to the image read. The image to be read must be of the PBM type (i.e., binary).

Returns: Upon success, zero is returned; otherwise, a nonzero value is returned.

9.9.2.2 decodePgm()

```
template<class T >
int SPL::decodePgm (
            std::istream & inStream,
            Array2< T > & gray,
            int & maxVal,
            bool & sgnd )
```

Input an array as an image in the PNM format.

Effects: A grayscale image in the PGM format is read from the stream inStream. The parameter gray is updated to hold the image read. The parameter maxVal is set to the maximum value for the image sample data. The parameter sgnd is set to indicate whether the image data is signed. The image to be read must be of the PGM type (i.e., grayscale).

Returns: Upon success, zero is returned; otherwise, a nonzero value is returned.

9.9.2.3 decodePnm()

```
template<class T >
int SPL::decodePnm (
            std::istream & inStream,
            std::vector< Array2< T > > & comps,
            int & maxVal,
            bool & sgnd )
```

Input an array as an image in the PNM format.

Effects: An image in the PNM format is read from the stream inStream. The parameter comps is updated to hold the components of the image read, where the red, green, and blue color components are placed in comps[0], comps[1], and comps[2], respectively. The parameter maxVal is set to the maximum value for the image sample data. The parameter sgnd is set to indicate whether the image data is signed.

Returns: Upon success, zero is returned; otherwise, a nonzero value is returned.

9.9.2.4 decodePpm()

```
template<class T >
int SPL::decodePpm (
            std::istream & inStream,
            Array2< T > & red,
            Array2< T > & green,
            Array2< T > & blue,
            int & maxVal,
            bool & sgnd )
```

Input an array as an image in the PNM format.

Effects: A color image in the PPM format is read from the stream inStream. The parameters red, green, and blue are set to RGB components of the image read. The parameter maxVal is set to the maximum value for the image sample data. The parameter sgnd is set to indicate whether the image data is signed. The image to be read must be of the PPM type (i.e., RGB color).

Returns: Upon success, zero is returned; otherwise, a nonzero value is returned.

9.9.2.5 encodePbm()

```
template<class T >
int SPL::encodePbm (
            std::ostream & outStream,
            const Array2< T > & bits,
            bool binaryFormat = true )
```

Output the array as an image in the PNM format (PBM type).

Effects: The binary image in the array bits is written to the stream outStream. If the parameter binaryFormat is true, the binary variant of the PBM format is used; otherwise, the text variant is employed.

Returns: Upon success, zero is returned; otherwise, a nonzero value is returned.

9.9.2.6 encodePgm()

```
template<class T >
int SPL::encodePgm (
            std::ostream & outStream,
            const Array2< T > & gray,
            int maxVal,
            bool sgnd,
            bool binaryFormat = true )
```

Output the array as an image in the PNM format (PGM type).

Effects: The grayscale image in the array gray is written to the stream outStream. If the parameter binaryFormat is true, the binary variant of the PBM format is used; otherwise, the text variant is employed. The parameter maxVal specifies the maximum value for sample data. The parameter sgnd specified if the sample data is signed.

Returns: Upon success, zero is returned; otherwise, a nonzero value is returned.

9.9.2.7 encodePnm()

```
template<class T >
int SPL::encodePnm (
             std::ostream & outStream,
             const std::vector< Array2< T > > & comps,
             int maxVal,
             bool sgnd,
             bool binaryFormat = true )
```

Output the array as an image in the PNM format.

Effects: The image components comps are written to the stream outStream in the PNM format, where the red, green, and blue color componenets are given by comps[0], comps[1], and comps[2], respectively. If the parameter binary↩ Format is true, the binary variant of the PNM format is used; otherwise, the text variant is used. The parameter maxVal specifies the maximum value for sample data. The parameter sgnd specified if the sample data is signed.

Returns: Upon success, zero is returned; otherwise, a nonzero value is returned.

9.9.2.8 encodePpm()

```
template<class T >
int SPL::encodePpm (
             std::ostream & outStream,
             const Array2< T > & red,
             const Array2< T > & green,
             const Array2< T > & blue,
             int maxVal,
             bool sgnd,
             bool binaryFormat = true )
```

Output the array as an image in the PNM format (PPM type).

Effects: The color image with RGB color planes in the arrays red, green, and blue, respectively, is written to the stream outStream. If the parameter binaryFormat is true, the binary variant of the PBM format is used; otherwise, the text variant is employed. The parameter maxVal specifies the maximum value for sample data. The parameter sgnd specified if the sample data is signed.

Returns: Upon success, zero is returned; otherwise, a nonzero value is returned.

9.10 Filter Design

Filter design.

Functions

- RealSequence1 SPL::lowpassFilter (double cutoffFreq, double transWidth, double maxPassbandRipple=0.1, double minStopbandAtten=20.0)

  Design a zero-phase FIR lowpass filter.
- RealSequence1 SPL::highpassFilter (double cutoffFreq, double transWidth, double maxPassbandRipple=0.1, double minStopbandAtten=20.0)

  Design a zero-phase FIR highpass filter.
- RealSequence1 SPL::bandpassFilter (double cutoffFreq0, double cutoffFreq1, double transWidth0, double transWidth1, double maxPassbandRipple=0.1, double minStopbandAtten=20.0)

  Design a zero-phase FIR bandpass filter.

9.10.1 Detailed Description

Filter design.

9.10.2 Function Documentation

9.10.2.1 bandpassFilter()

```
RealSequence1 SPL::bandpassFilter (
            double cutoffFreq0,
            double cutoffFreq1,
            double transWidth0,
            double transWidth1,
            double maxPassbandRipple = 0.1,
            double minStopbandAtten = 20.0 )
```

Design a zero-phase FIR bandpass filter.

Effects: A linear-phase FIR filter with zero group delay is designed with the (normalized) lower cutoff frequency cutoffFreq0, (normalized) upper cutoff frequency cutoffFreq1, (normalized) lower transition width transWidth0, (normalized) upper transition width transWidth1, maximum peak-to-peak passband ripple maxPassbandRipple (in dB), and minimum stopband attenuation minStopbandAtten (in dB). Note: Frequencies are normalized such that a value of one corresponds to the Nyquist frequency.

The cutoff frequencies cannot be 0 or 1. In other words, this function cannot be used to design a lowpass or highpass filter.

Returns: The impulse response of the designed filter is returned.

9.10.2.2 highpassFilter()

```
RealSequence1 SPL::highpassFilter (
             double cutoffFreq,
             double transWidth,
             double maxPassbandRipple = 0.1,
             double minStopbandAtten = 20.0 )
```

Design a zero-phase FIR highpass filter.

Effects: A linear-phase FIR filter with zero group delay is designed with the (normalized) cutoff frequency cutoffFreq, (normalized) transition width transWidth, maximum peak-to-peak passband ripple maxPassbandRipple (in dB), and minimum stopband attenuation minStopbandAtten (in dB). Note: Frequencies are normalized such that a value of one corresponds to the Nyquist frequency.

Returns: The impulse response of the designed filter is returned.

9.10.2.3 lowpassFilter()

```
RealSequence1 SPL::lowpassFilter (
             double cutoffFreq,
             double transWidth,
             double maxPassbandRipple = 0.1,
             double minStopbandAtten = 20.0 )
```

Design a zero-phase FIR lowpass filter.

Effects: A linear-phase FIR filter with zero group delay is designed with the (normalized) cutoff frequency cutoffFreq, (normalized) transition width transWidth, maximum peak-to-peak passband ripple maxPassbandRipple (in dB), and minimum stopband attenuation minStopbandAtten (in dB). Note: Frequencies are normalized such that a value of one corresponds to the Nyquist frequency.

Returns: The impulse response of the designed filter is returned.

9.11 CPU and Memory Utilization

Support for measuring CPU and memory utilization.

Classes

- class SPL::Timer

  A class for making timing measurements.

Functions

- double SPL::getCurrentMemUsage ()

  Get the amount of memory currently being used by the process.
- double SPL::getPeakMemUsage ()

  Get the peak memory usage for the process.

9.11.1 Detailed Description

Support for measuring CPU and memory utilization.

9.11.2 Function Documentation

9.11.2.1 getCurrentMemUsage()

```
double SPL::getCurrentMemUsage ( )
```

Get the amount of memory currently being used by the process.

Effects: Query the total amount of memory currently being used by the process.

Returns: The amount of memory (in bytes) currently being used by the process is returned.

9.11.2.2 getPeakMemUsage()

```
double SPL::getPeakMemUsage ( )
```

Get the peak memory usage for the process.

Effects: Query the peak memory usage for the process.

Returns: The peak memory usage for the process (in bytes) is returned.

9.12 Math Utilities

Math utilities.

Functions

- template<class T >
  T SPL::absVal (T x)

  The absolute value function.
- template<class T >
  T SPL::signum (T x)

  The signum function.
- template<class T >
  T SPL::sqr (const T &x)

  The square function.
- template<class T >
  T SPL::clip (T x, T min, T max)

  The clip function.
- double SPL::sinc (double x)

  The cardinal sine function.
- long SPL::roundTowardZeroDiv (long x, long y)

  Compute a quotient with the result rounded towards zero.
- long SPL::floorDiv (long x, long y)

  Compute the floor of a quotient.
- template<class T >
  T SPL::mod (T x, T y)

  Compute the remainder after division.
- long SPL::ceilDiv (long x, long y)

  Compute the ceiling of a quotient.
- double SPL::radToDeg (double x)

  Convert from radians to degrees.
- double SPL::degToRad (double x)

  Convert from degrees to radians.

9.12.1 Detailed Description

Math utilities.

9.12.2 Function Documentation

9.12.2.1 absVal()

```
template<class T >
T SPL::absVal (
            T x )  [inline]
```

The absolute value function.

Returns: The absolute value of the quantity x is returned.

9.12.2.2 ceilDiv()

```
long SPL::ceilDiv (
            long x,
            long y )  [inline]
```

Compute the ceiling of a quotient.

Returns: The ceiling of x divided by y is returned.

9.12.2.3 clip()

```
template<class T >
T SPL::clip (
            T x,
            T min,
            T max )  [inline]
```

The clip function.

9.12.2.4 degToRad()

```
double SPL::degToRad (
            double x )  [inline]
```

Convert from degrees to radians.

Returns: The quantity x converted (from degrees) to radians is returned.

9.12.2.5 floorDiv()

```
long SPL::floorDiv (
            long x,
            long y )  [inline]
```

Compute the floor of a quotient.

Returns: The floor of x divided by y is returned.

9.12.2.6 mod()

```
template<class T >
T SPL::mod (
            T x,
            T y )  [inline]
```

Compute the remainder after division.

9.12.2.7 radToDeg()

```
double SPL::radToDeg (
            double x )  [inline]
```

Convert from radians to degrees.

Returns: The quantity x converted (from radians) to degrees is returned.

9.12.2.8 roundTowardZeroDiv()

```
long SPL::roundTowardZeroDiv (
            long x,
            long y )  [inline]
```

Compute a quotient with the result rounded towards zero.

Returns: The floor of x divided by y is returned.

9.12.2.9 signum()

```
template<class T >
T SPL::signum (
            T x )  [inline]
```

The signum function.

Returns: The signum of the quantity x is returned.

9.12.2.10 sinc()

```
double SPL::sinc (
            double x )  [inline]
```

The cardinal sine function.

Returns: The sinc of x is returned.

9.12.2.11 sqr()

```
template<class T >
T SPL::sqr (
            const T & x )  [inline]
```

The square function.

Returns: The square of the quantity x is returned.

9.13 CGAL Utilities

CGAL utilities.

Classes

- class SPL::Arcball< T >

  Arcball.
- struct SPL::Rotation_3< T >

  A 3-D rotation.
- struct SPL::Quaternion< T >

  A quaternion represented in terms of its scalar and vector parts.

Functions

- template<class T >
  T::Point_3 SPL::closestPointOnRay (const typename CGAL::Point_3< T > &rayOrigin, const typename CGAL↩
  ::Vector_3< T > &rayDir, const typename CGAL::Point_3< T > &point)

  Compute the closest point on a ray to the specified point.
- template<class T >
  std::pair< bool, typename T::Point_3 > SPL::findRaySphereIntersection (const typename CGAL::Point_3< T > &sphereCenter, typename T::FT sphereRadius, const typename CGAL::Point_3< T > &rayOrigin, const typename CGAL::Vector_3< T > &rayDir)

  Compute the intersection of a ray and a sphere.
- template<class T >
  std::pair< bool, typename T::Point_3 > SPL::findRayPlaneIntersection (const typename CGAL::Point_3< T > &planePoint, const typename CGAL::Vector_3< T > &planeNormal, const typename CGAL::Point_3< T > &rayOrigin, const typename CGAL::Vector_3< T > &rayDir)

  Compute the intersection of a ray and a plane.
- template<class T >
  T::FT SPL::norm (const typename CGAL::Vector_3< T > &v)

  Compute the norm of a vector.
- template<class T >
  T::Vector_3 SPL::normalize (const typename CGAL::Vector_3< T > &v)

  Compute a unit vector.
- template<class T >
  T::FT SPL::angleBetweenVectors (const typename CGAL::Vector_3< T > &u, const CGAL::Vector_3< T > &v)

  Compute the angle between two vectors.
- template<class T >
  Quaternion< T > SPL::operator∗ (const Quaternion< T > &q, const Quaternion< T > &r)

  Compute the product of two quaternions.
- template<class T >
  Quaternion< T > SPL::operator/ (const Quaternion< T > &q, const Quaternion< T > &r)

  Compute the quotient of two quaternions.
- template<class T >
  Quaternion< T > SPL::rotationToQuaternion (const Rotation_3< T > &rot)

  Convert a rotation into its corresponding quaternion.

- template<class T >
  Rotation_3< T > SPL::quaternionToRotation (const Quaternion< T > &q)

  Convert a unit-norm quaternion into its corresponding rotation.
- SPL::Arcball< T >::Arcball ()

  Create an arcball.
- void SPL::Arcball< T >::initialize (double arcBallRadius, const Point &eyePos, const Vector &eyeDir, const Vector &eyeUp, const Point &sceneCenter)

  Initialize the state of an arcball.
- void SPL::Arcball< T >::setMode (int mode)

  Set the arcball rotation mode.
- void SPL::Arcball< T >::start (const Point &pos)

  Set the starting position for arcball movement.
- void SPL::Arcball< T >::move (const Point &pos)

  Set the current position for arcball movement.
- void SPL::Arcball< T >::clear ()

  Clear the starting and current positions for the arcball.
- Rotation SPL::Arcball< T >::getRotation () const

  Get the rotation required to turn the arcball from the starting position to the current position.
- static Rotation SPL::Arcball< T >::combineRotations (const Rotation &, const Rotation &)

  Combine two rotations.

9.13.1 Detailed Description

CGAL utilities.

9.13.2 Function Documentation

9.13.2.1 angleBetweenVectors()

```
template<class T >
T::FT SPL::angleBetweenVectors (
            const typename CGAL::Vector_3< T > & u,
            const CGAL::Vector_3< T > & v )  [inline]
```

Compute the angle between two vectors.

9.13.2.2 Arcball()

```
template<class T >
SPL::Arcball< T >::Arcball ( )
```

Create an arcball.

9.13.2.3 clear()

```
template<class T >
void SPL::Arcball< T >::clear ( )
```

Clear the starting and current positions for the arcball.

9.13.2.4 closestPointOnRay()

```
template<class T >
T::Point_3 SPL::closestPointOnRay (
            const typename CGAL::Point_3< T > & rayOrigin,
            const typename CGAL::Vector_3< T > & rayDir,
            const typename CGAL::Point_3< T > & point )
```

Compute the closest point on a ray to the specified point.

9.13.2.5 combineRotations()

```
template<class T>
Arcball< T >::Rotation SPL::Arcball< T >::combineRotations (
            const Rotation & ,
            const Rotation &  )  [static]
```

Combine two rotations.

9.13.2.6 findRayPlaneIntersection()

```
template<class T >
std::pair<bool, typename T::Point_3> SPL::findRayPlaneIntersection (
            const typename CGAL::Point_3< T > & planePoint,
            const typename CGAL::Vector_3< T > & planeNormal,
            const typename CGAL::Point_3< T > & rayOrigin,
            const typename CGAL::Vector_3< T > & rayDir )
```

Compute the intersection of a ray and a plane.

Compute the intersection of a ray and a plane. The return value is a pair. The first element of the pair is a boolean. This value is true if an intersection point was found, and is false otherwise. The second element in the pair is the intersection point closest to the ray's origin. If no intersection point was found, the ray's origin is returned.

9.13.2.7 findRaySphereIntersection()

```
template<class T >
std::pair<bool, typename T::Point_3> SPL::findRaySphereIntersection (
             const typename CGAL::Point_3< T > & sphereCenter,
             typename T::FT sphereRadius,
             const typename CGAL::Point_3< T > & rayOrigin,
             const typename CGAL::Vector_3< T > & rayDir )
```

Compute the intersection of a ray and a sphere.

Compute the intersection of a ray and a sphere. The return value is a pair. The first element in the pair is a boolean value. This value is true if an intersection point was found, and is false otherwise. The second element in the pair is the intersection point closest to the ray's origin. If no intersection was found, the point on the sphere that is closest to the ray is returned.

9.13.2.8 getRotation()

```
template<class T >
Arcball< T >::Rotation SPL::Arcball< T >::getRotation ( ) const
```

Get the rotation required to turn the arcball from the starting position to the current position.

9.13.2.9 initialize()

```
template<class T>
void SPL::Arcball< T >::initialize (
             double arcBallRadius,
             const Point & eyePos,
             const Vector & eyeDir,
             const Vector & eyeUp,
             const Point & sceneCenter )
```

Initialize the state of an arcball.

9.13.2.10 move()

```
template<class T>
void SPL::Arcball< T >::move (
             const Point & pos )
```

Set the current position for arcball movement.

9.13.2.11 norm()

```
template<class T >
T::FT SPL::norm (
            const typename CGAL::Vector_3< T > & v )  [inline]
```

Compute the norm of a vector.

9.13.2.12 normalize()

```
template<class T >
T::Vector_3 SPL::normalize (
            const typename CGAL::Vector_3< T > & v )  [inline]
```

Compute a unit vector.

Compute a unit vector in the direction of the given vector. If the zero vector is given, the zero vector is returned.

9.13.2.13 operator*()

```
template<class T >
Quaternion<T> SPL::operator* (
            const Quaternion< T > & q,
            const Quaternion< T > & r )
```

Compute the product of two quaternions.

9.13.2.14 operator/()

```
template<class T >
Quaternion<T> SPL::operator/ (
            const Quaternion< T > & q,
            const Quaternion< T > & r )
```

Compute the quotient of two quaternions.

9.13.2.15 quaternionToRotation()

```
template<class T >
Rotation_3<T> SPL::quaternionToRotation (
            const Quaternion< T > & q )
```

Convert a unit-norm quaternion into its corresponding rotation.

9.13.2.16 rotationToQuaternion()

```
template<class T >
Quaternion<T> SPL::rotationToQuaternion (
             const Rotation_3< T > & rot )
```

Convert a rotation into its corresponding quaternion.

9.13.2.17 setMode()

```
template<class T >
void SPL::Arcball< T >::setMode (
             int mode )
```

Set the arcball rotation mode.

9.13.2.18 start()

```
template<class T>
void SPL::Arcball< T >::start (
             const Point & pos )
```

Set the starting position for arcball movement.

9.14 Arithmetic Coders

Arithmetic coders.

Modules

- M-Coder

  M-Coder (binary arithmetic coder).
- Binary and m-ary Arithmetic Coders

  Binary and m-ary arithmetic coders.

9.14.1 Detailed Description

Arithmetic coders.

9.15 M-Coder

M-Coder (binary arithmetic coder).

Classes

- class SPL::MEncoder

  The M-Coder (binary) arithmetic encoder class.
- class SPL::MDecoder

  The M-Coder (binary) arithmetic decoder class.

Functions

- long SPL::MEncoder::getSymCount () const

  Get the number of symbols that have been encoded so far.
- long SPL::MEncoder::getBitCount () const

  Get the number of bits (of encoded data) that have been output to the underlying bit stream so far.
- int SPL::MEncoder::getNumContexts () const

  Get the number of contexts.
- OutputBitStream * SPL::MEncoder::getOutput () const

  Get the bit stream being used for output.
- void SPL::MEncoder::setOutput (OutputBitStream *out)

  Set the bit stream to use for output.
- long SPL::MDecoder::getBitCount () const

  Get the number of bits read so far.
- long SPL::MDecoder::getSymCount () const

  Get the number of symbols decoded so far.
- int SPL::MDecoder::getNumContexts () const

  Get the number of contexts.
- InputBitStream * SPL::MDecoder::getInput () const

  Get the input bit stream (i.e., the bit stream from which encoded data is to be read).
- void SPL::MDecoder::setInput (InputBitStream *in)

  Set the input bit stream (i.e., the bit stream from which encoded data is to be read).

9.15.1 Detailed Description

M-Coder (binary arithmetic coder).

9.15.2 Function Documentation

9.15.2.1 getBitCount() [1/2]

```
long SPL::MEncoder::getBitCount ( ) const  [inline]
```

Get the number of bits (of encoded data) that have been output to the underlying bit stream so far.

9.15.2.2 getBitCount() [2/2]

```
long SPL::MDecoder::getBitCount ( ) const  [inline]
```

Get the number of bits read so far.

9.15.2.3 getInput()

```
InputBitStream * SPL::MDecoder::getInput ( ) const  [inline]
```

Get the input bit stream (i.e., the bit stream from which encoded data is to be read).

9.15.2.4 getNumContexts() [1/2]

```
int SPL::MEncoder::getNumContexts ( ) const  [inline]
```

Get the number of contexts.

9.15.2.5 getNumContexts() [2/2]

```
int SPL::MDecoder::getNumContexts ( ) const  [inline]
```

Get the number of contexts.

9.15.2.6 getOutput()

```
OutputBitStream * SPL::MEncoder::getOutput ( ) const  [inline]
```

Get the bit stream being used for output.

9.15.2.7 getSymCount() [1/2]

```
long SPL::MEncoder::getSymCount ( ) const  [inline]
```

Get the number of symbols that have been encoded so far.

9.15.2.8 getSymCount() [2/2]

```
long SPL::MDecoder::getSymCount ( ) const  [inline]
```

Get the number of symbols decoded so far.

9.15.2.9 setInput()

```
void SPL::MDecoder::setInput (
            InputBitStream * in )  [inline]
```

Set the input bit stream (i.e., the bit stream from which encoded data is to be read).

9.15.2.10 setOutput()

```
void SPL::MEncoder::setOutput (
            OutputBitStream * out )  [inline]
```

Set the bit stream to use for output.

9.16 Binary and m-ary Arithmetic Coders

Binary and m-ary arithmetic coders.

Classes

- class SPL::MultiArithEncoder

  M-ary arithmetic encoder class.
- class SPL::MultiArithDecoder

  M-ary arithmetic decoder class.
- struct SPL::BinArithCoderContextStat

  Binary Arithmetic Coder Context Statistics Class.
- class SPL::BinArithEncoder

  Binary arithmetic encoder class.
- class SPL::BinArithDecoder

  Binary arithmetic decoder class.

Functions

- static std::ostream & SPL::MultiArithEncoder::getDebugStream ()

  Get the stream for debugging output.
- OutputBitStream * SPL::MultiArithEncoder::getOutput ()

  Get the bit stream used for output.
- void SPL::MultiArithEncoder::setOutput (OutputBitStream *out)

  Set the bit stream used for output.
- SPL_ArithCoder_ulong SPL::MultiArithEncoder::getSymCount () const

  Get the number of symbols encoded so far.
- SPL_ArithCoder_ulong SPL::MultiArithEncoder::getBitCount () const

  Get the number of bits of output generated so far including bits awaiting output.
- static void SPL::MultiArithEncoder::setDebugLevel (int debugLevel)

  Set the debug level.
- static void SPL::MultiArithEncoder::setDebugStream (std::ostream &out)

  Set the stream for debugging output.
- int SPL::MultiArithEncoder::getMaxContexts () const

  Get the maximum number of contexts.
- static std::ostream & SPL::MultiArithDecoder::getDebugStream ()

  Get the stream used for debugging output.
- InputBitStream * SPL::MultiArithDecoder::getInput () const

  Get the bit stream from which to read encoded data.
- void SPL::MultiArithDecoder::setInput (InputBitStream *in)

  Set the bit stream from which to read encoded data.
- SPL_ArithCoder_ulong SPL::MultiArithDecoder::getBitCount () const

  Get the number of bits read so far.
- SPL_ArithCoder_ulong SPL::MultiArithDecoder::getSymCount () const

  Get the number of symbols decoded so far.

- static void SPL::MultiArithDecoder::setDebugLevel (int debugLevel)

  Set the debug level.
- static void SPL::MultiArithDecoder::setDebugStream (std::ostream &out)

  Set the stream to use for debugging output.
- int SPL::MultiArithDecoder::getMaxContexts () const

  Get the maximum number of contexts.
- SPL_ArithCoder_ulong SPL::BinArithEncoder::getSymCount () const

  Get the number of symbols output so far.
- SPL_ArithCoder_ulong SPL::BinArithEncoder::getBitCount () const

  Get the number of bits output so far.
- OutputBitStream * SPL::BinArithEncoder::getOutput () const

  Get the bit stream to which encoded data should be written.
- int SPL::BinArithEncoder::getNumContexts () const

  Get the number of contexts.
- static void SPL::BinArithEncoder::setDebugStream (std::ostream &out)

  Set the stream to use for debugging output.
- static std::ostream & SPL::BinArithEncoder::getDebugStream ()

  Get the stream used for debugging output.
- static void SPL::BinArithEncoder::setDebugLevel (int debugLevel)

  Set the debug level.
- void SPL::BinArithEncoder::setOutput (OutputBitStream *out)

  Set the bit stream to which encoded data should be written.
- SPL_ArithCoder_ulong SPL::BinArithDecoder::getSymCount () const

  Get the number of symbols decoded so far.
- SPL_ArithCoder_ulong SPL::BinArithDecoder::getBitCount () const

  Get the number of bits read so far.
- InputBitStream * SPL::BinArithDecoder::getInput () const

  Get the bit stream from which to read encoded data.
- int SPL::BinArithDecoder::getNumContexts () const

  Get the number of contexts.
- static void SPL::BinArithDecoder::setDebugStream (std::ostream &out)

  Set the stream to be used for debugging output.
- static std::ostream & SPL::BinArithDecoder::getDebugStream ()

  Get the stream used for debugging output.
- static void SPL::BinArithDecoder::setDebugLevel (int debugLevel)

  Set the debug level.
- void SPL::BinArithDecoder::setInput (InputBitStream *in)

  Set the bit stream from which to read encoded data.

9.16.1 Detailed Description

Binary and m-ary arithmetic coders.

9.16.2 Function Documentation

9.16.2.1 getBitCount() [1/4]

```
SPL_ArithCoder_ulong SPL::MultiArithEncoder::getBitCount ( ) const  [inline]
```

Get the number of bits of output generated so far including bits awaiting output.

9.16.2.2 getBitCount() [2/4]

```
SPL_ArithCoder_ulong SPL::MultiArithDecoder::getBitCount ( ) const  [inline]
```

Get the number of bits read so far.

9.16.2.3 getBitCount() [3/4]

```
SPL_ArithCoder_ulong SPL::BinArithEncoder::getBitCount ( ) const  [inline]
```

Get the number of bits output so far.

This function gets the number of bits output so far by the arithmetic encoder.

Returns

The number of bits output so far is returned.

9.16.2.4 getBitCount() [4/4]

```
SPL_ArithCoder_ulong SPL::BinArithDecoder::getBitCount ( ) const  [inline]
```

Get the number of bits read so far.

This function gets the number of bits read so far by the arithmetic decoder.

Returns

The number of bits read so far is returned.

9.16.2.5 getDebugStream() [1/4]

```
std::ostream & SPL::MultiArithEncoder::getDebugStream ( )  [inline], [static]
```

Get the stream for debugging output.

9.16.2.6 getDebugStream() [2/4]

```
std::ostream & SPL::MultiArithDecoder::getDebugStream ( )  [inline], [static]
```

Get the stream used for debugging output.

9.16.2.7 getDebugStream() [3/4]

```
std::ostream & SPL::BinArithEncoder::getDebugStream ( )  [inline], [static]
```

Get the stream used for debugging output.

9.16.2.8 getDebugStream() [4/4]

```
std::ostream & SPL::BinArithDecoder::getDebugStream ( )  [inline], [static]
```

Get the stream used for debugging output.

9.16.2.9 getInput() [1/2]

```
InputBitStream * SPL::MultiArithDecoder::getInput ( ) const  [inline]
```

Get the bit stream from which to read encoded data.

9.16.2.10 getInput() [2/2]

```
InputBitStream * SPL::BinArithDecoder::getInput ( ) const  [inline]
```

Get the bit stream from which to read encoded data.

This function gets the bit stream from which to read encoded data.

Returns

A pointer to the bit stream is returned.

9.16.2.11 getMaxContexts() [1/2]

```
int SPL::MultiArithEncoder::getMaxContexts ( ) const  [inline]
```

Get the maximum number of contexts.

9.16.2.12 getMaxContexts() [2/2]

```
int SPL::MultiArithDecoder::getMaxContexts ( ) const  [inline]
```

Get the maximum number of contexts.

9.16.2.13 getNumContexts() [1/2]

```
int SPL::BinArithEncoder::getNumContexts ( ) const  [inline]
```

Get the number of contexts.

This function gets the number of contexts employed by the arithmetic encoder.

Returns

The number of contexts is returned.

9.16.2.14 getNumContexts() [2/2]

```
int SPL::BinArithDecoder::getNumContexts ( ) const  [inline]
```

Get the number of contexts.

This function gets the number of contexts employed by the arithmetic decoder.

Returns

The number of contexts is returned.

9.16.2.15 getOutput() [1/2]

```
OutputBitStream * SPL::MultiArithEncoder::getOutput ( )  [inline]
```

Get the bit stream used for output.

9.16.2.16 getOutput() [2/2]

```
OutputBitStream * SPL::BinArithEncoder::getOutput ( ) const  [inline]
```

Get the bit stream to which encoded data should be written.

This function gets the bit stream to which encoded data should be written.

Returns

A pointer to the output bit stream is returned.

9.16.2.17 getSymCount() [1/4]

```
SPL_ArithCoder_ulong SPL::MultiArithEncoder::getSymCount ( ) const  [inline]
```

Get the number of symbols encoded so far.

9.16.2.18 getSymCount() [2/4]

```
SPL_ArithCoder_ulong SPL::MultiArithDecoder::getSymCount ( ) const  [inline]
```

Get the number of symbols decoded so far.

9.16.2.19 getSymCount() [3/4]

```
SPL_ArithCoder_ulong SPL::BinArithEncoder::getSymCount ( ) const  [inline]
```

Get the number of symbols output so far.

This function gets the number of symbols output so far by the arithmetic encoder.

Returns

The number of symbols output so far is returned.

9.16.2.20 getSymCount() [4/4]

```
SPL_ArithCoder_ulong SPL::BinArithDecoder::getSymCount ( ) const  [inline]
```

Get the number of symbols decoded so far.

This function gets the number of symbols decoded so far by the arithmetic decoder.

Returns

The number of symbols decoded so far is returned.

9.16.2.21 setDebugLevel() [1/4]

```
void SPL::MultiArithEncoder::setDebugLevel (
            int debugLevel )  [inline], [static]
```

Set the debug level.

9.16.2.22 setDebugLevel() [2/4]

```
void SPL::MultiArithDecoder::setDebugLevel (
            int debugLevel )  [inline], [static]
```

Set the debug level.

9.16.2.23 setDebugLevel() [3/4]

```
void SPL::BinArithEncoder::setDebugLevel (
            int debugLevel )  [inline], [static]
```

Set the debug level.

9.16.2.24 setDebugLevel() [4/4]

```
void SPL::BinArithDecoder::setDebugLevel (
            int debugLevel )  [inline], [static]
```

Set the debug level.

9.16.2.25 setDebugStream() [1/4]

```
void SPL::MultiArithEncoder::setDebugStream (
            std::ostream & out )  [inline], [static]
```

Set the stream for debugging output.

9.16.2.26 setDebugStream() [2/4]

```
void SPL::MultiArithDecoder::setDebugStream (
            std::ostream & out )  [inline], [static]
```

Set the stream to use for debugging output.

9.16.2.27 setDebugStream() [3/4]

```
void SPL::BinArithEncoder::setDebugStream (
            std::ostream & out )  [inline], [static]
```

Set the stream to use for debugging output.

9.16.2.28 setDebugStream() [4/4]

```
void SPL::BinArithDecoder::setDebugStream (
            std::ostream & out )  [inline], [static]
```

Set the stream to be used for debugging output.

9.16.2.29 setInput() [1/2]

```
void SPL::MultiArithDecoder::setInput (
            InputBitStream * in )  [inline]
```

Set the bit stream from which to read encoded data.

9.16.2.30 setInput() [2/2]

```
void SPL::BinArithDecoder::setInput (
            InputBitStream * in )  [inline]
```

Set the bit stream from which to read encoded data.

Parameters

in	The input bit stream.

This function sets the bit stream from which to read encoded data to `in`.

9.16.2.31 setOutput() [1/2]

```
void SPL::MultiArithEncoder::setOutput (
            OutputBitStream * out )  [inline]
```

Set the bit stream used for output.

9.16.2.32 setOutput() [2/2]

```
void SPL::BinArithEncoder::setOutput (
            OutputBitStream * out )  [inline]
```

Set the bit stream to which encoded data should be written.

Parameters

out	The output bit stream.

This function sets the bit stream to which encoded data should be written.

Chapter 10

Class Documentation

10.1 SPL::Arcball< T > Class Template Reference

Arcball.

`#include <Arcball.hpp>`

Public Types

- typedef T Kernel

  The CGAL kernel.
- typedef Kernel::Point_3 Point

  The point type.
- typedef Kernel::Vector_3 Vector

  The vector type.
- typedef Rotation_3< Kernel > Rotation

  The representation of a rotation.

Public Member Functions

- Arcball ()

  Create an arcball.
- void initialize (double arcBallRadius, const Point &eyePos, const Vector &eyeDir, const Vector &eyeUp, const Point &sceneCenter)

  Initialize the state of an arcball.
- void setMode (int mode)

  Set the arcball rotation mode.
- void start (const Point &pos)

  Set the starting position for arcball movement.
- void move (const Point &pos)

  Set the current position for arcball movement.
- void clear ()

  Clear the starting and current positions for the arcball.
- Rotation getRotation () const

  Get the rotation required to turn the arcball from the starting position to the current position.
- void setDebugLevel (int debugLevel) const

  For debugging...

Static Public Member Functions

- static Rotation combineRotations (const Rotation &, const Rotation &)

  Combine two rotations.

10.1.1 Detailed Description

template<class T>
class SPL::Arcball< T >

Arcball.

References: K. Shoemake, Arcball Rotation Control, Graphics Gems IV, 1994, pp. 175-192.

10.1.2 Member Typedef Documentation

10.1.2.1 Kernel

```
template<class T>
typedef T SPL::Arcball< T >::Kernel
```

The CGAL kernel.

10.1.2.2 Point

```
template<class T>
typedef Kernel::Point_3 SPL::Arcball< T >::Point
```

The point type.

10.1.2.3 Rotation

```
template<class T>
typedef Rotation_3<Kernel> SPL::Arcball< T >::Rotation
```

The representation of a rotation.

10.1.2.4 Vector

```
template<class T>
typedef Kernel::Vector_3 SPL::Arcball< T >::Vector
```

The vector type.

10.1.3 Member Function Documentation

10.1.3.1 setDebugLevel()

```
template<class T>
void SPL::Arcball< T >::setDebugLevel (
            int debugLevel ) const
```

For debugging...

The documentation for this class was generated from the following file:

- Arcball.hpp

10.2 SPL::Array1< T > Class Template Reference

A one-dimensional array class with lazy copying and reference counting.

```
#include <Array1.hpp>
```

Public Types

- typedef T ElemType

  The type of the elements in the array.
- typedef std::vector< T >::iterator Iterator

  A mutable iterator for the array elements.
- typedef std::vector< T >::const_iterator ConstIterator

  A constant iterator for the array elements.

Public Member Functions

- Array1 ()

  Create an empty array.
- Array1 (int size)

  Create an array of the specified size.
- Array1 (int size, const T &value)

  Create an array of the given size with all elements initialized to the specified value.
- template<class InputIterator >
  Array1 (int size, InputIterator data)

  Create an array of the specified size with the elements initialized to the data obtained from the given input iterator.
- Array1 (const Array1 &a)

  Create a copy of an array.
- template<class OtherType >
  Array1 (const Array1< OtherType > &a)

  Create a copy of an array with elements of arbitrary type.
- ~Array1 ()

  Destroy an array.
- Array1 & operator= (const Array1 &a)

  Assign one array to another.
- template<class OtherType >
  Array1< T > & operator= (const Array1< OtherType > &a)

  Assign an array with elements of arbitrary type to another array.
- Array1 & operator+= (const Array1 &a)

  Add another array (elementwise) to this array.
- Array1 & operator-= (const Array1 &a)

  Subtract another array (elementwise) from this array.
- Array1 & operator*= (const Array1 &a)

  Multiply another array (elementwise) by this array.
- Array1 & operator/= (const Array1 &a)

  Divide this array (elementwise) by another array.
- Array1 & operator+= (const T &value)

  Add the specified value to each element in the array.
- Array1 & operator-= (const T &value)

  Subtract the specified value from each element in the array.
- Array1 & operator*= (const T &value)

  Multiply each element in the array by the specified value.
- Array1 & operator/= (const T &value)

  Divide each element in the array by the specified value.
- int getSize () const

  Get the number of elements in the array.
- bool isShared () const

  Is the data for this array shared with another array?
- bool isSharedWith (const Array1 &a) const

  Is the data for this array shared with the specified array?
- T & operator() (int i)

  Get a mutable reference to the specified element in the array.
- const T & operator() (int i) const

Get a const reference to the specified element in the array.

- ConstIterator begin () const

  Get a const iterator referring to the first element in the array.
- Iterator begin ()

  Get a mutable iterator referring to the first element in the array.
- ConstIterator end () const

  Get a const iterator referring to one past the last element in the array.
- Iterator end ()

  Get a mutable iterator referring to one past the last element in the array.
- void resize (int size)

  Change the size of the array.
- template<class InputIterator >
  void resize (int size, InputIterator data)

  Change the size of the array, initializing the resized array with the data obtained from the specified input iterator.
- T max () const

  Get the maximum of the elements in the array.
- T min () const

  Get the minimum of the elements in the array.
- T sum () const

  Get the sum of the elements in the array.
- std::ostream & output (std::ostream &out, int fieldWidth) const

  Output an array to a stream with a particular field width to be used for each element.
- int load (const char *fileName)

  Load an array from the file with the specified name.
- int save (const char *fileName) const

  Save an array to the file with the specified name.
- void fill (const T &value=T(0))

  Set all elements in the array to the specified value.
- void swap (Array1 &a)

  Swap the contents of the array with the contents of another array.
- void dump (std::ostream &out) const

  Output information about an array to a stream for debugging.

10.2.1 Detailed Description

template<class T>
class SPL::Array1< T >

A one-dimensional array class with lazy copying and reference counting.

10.2.2 Member Typedef Documentation

10.2.2.1 ConstIterator

```
template<class T>
typedef std::vector<T>::const_iterator SPL::Array1< T >::ConstIterator
```

A constant iterator for the array elements.

10.2.2.2 ElemType

```
template<class T>
typedef T SPL::Array1< T >::ElemType
```

The type of the elements in the array.

10.2.2.3 Iterator

```
template<class T>
typedef std::vector<T>::iterator SPL::Array1< T >::Iterator
```

A mutable iterator for the array elements.

10.2.3 Constructor & Destructor Documentation

10.2.3.1 Array1() [1/2]

```
template<class T>
template<class InputIterator >
SPL::Array1< T >::Array1 (
            int size,
            InputIterator data )
```

Create an array of the specified size with the elements initialized to the data obtained from the given input iterator.

10.2.3.2 Array1() [2/2]

```
template<class T>
template<class OtherType >
SPL::Array1< T >::Array1 (
            const Array1< OtherType > & a )
```

Create a copy of an array with elements of arbitrary type.

Note: The type OtherType must be assignable to the type T.

The documentation for this class was generated from the following file:

- Array1.hpp

10.3 SPL::Array2< T > Class Template Reference

A two-dimensional array class with lazy copying and reference counting.

```
#include <Array2.hpp>
```

Public Types

- typedef T ElemType

  The type of the elements in the array.
- typedef std::vector< T >::iterator Iterator

  A mutable iterator for all elements in the array.
- typedef std::vector< T >::const_iterator ConstIterator

  A constant iterator for all elements in the array.
- typedef Iterator XIterator

  A mutable iterator for elements of a row in the array.
- typedef std::vector< T >::const_iterator ConstXIterator

  A constant iterator for elements of a row in the array.
- typedef YIter< T > YIterator

  A mutable iterator for elements of a column in the array.
- typedef YIter< const T > ConstYIterator

  A constant iterator for elements of a column in the array.

Public Member Functions

- Array2 ()

  Create an empty array.
- Array2 (int width, int height)

  Create an array of the specified width and height.
- Array2 (int width, int height, const T &value)

  Create an array of the specified width and height with the elements of the array initialized to the specified value.
- template<class InputIter >
  Array2 (int width, int height, InputIter data)

  Create an array of the specified width and height with the elements of the array initialized to the specified data.
- ~Array2 ()

  The destructor.
- Array2 (const Array2 &a)

  The copy constructor.
- template<class OtherType >
  Array2 (const Array2< OtherType > &a)

  Create an array from an array having elements of a different type.
- Array2 & operator= (const Array2 &a)

  The assignment operator.
- template<class OtherType >
  Array2 & operator= (const Array2< OtherType > &a)

  Assign another array with elements of a different type to this array.
- Array2 & operator+= (const Array2 &a)

  Add another array (elementwise) to this array.
- Array2 & operator-= (const Array2 &a)

  Subtract another array (elementwise) from this array.
- Array2 & operator*= (const Array2 &a)

  Multiply another array (elementwise) by this array.
- Array2 & operator/= (const Array2 &a)

  Divide this array (elementwise) by another array.
- Array2 & operator+= (const T &a)

  Add the specified value to each element in the array.
- Array2 & operator-= (const T &a)

  Subtract the specified value from each element in the array.
- Array2 & operator*= (const T &a)

  Multiply each element in the array by the specified value.
- Array2 & operator/= (const T &a)

  Divide each element in the array by the specified value.
- int getWidth () const

  Get the width of the array.
- int getHeight () const

  Get the height of the array.
- int getSize () const

  Get the number of elements in the array.
- bool isShared () const

  Is the data for this array shared with another array?
- bool isSharedWith (const Array2 &a) const

Is the data for this array shared with the specified array?

- T & operator() (int x, int y)

  Get a mutable reference to the (x,y)-th element in the array.
- const T & operator() (int x, int y) const

  Get a const reference to the (x,y)-th element in the array.
- T & operator() (int i)

  Get a mutable reference to the i-th element in the array.
- const T & operator() (int i) const

  Get a const reference to the i-th element in the array.
- ConstIterator begin () const

  Get a const iterator for the first element in the array.
- Iterator begin ()

  Get a mutable iterator for the first element in the array.
- ConstIterator end () const

  Get a const iterator for one past the last element in the array.
- Iterator end ()

  Get a mutable iterator for one past the last element in the array.
- ConstXIterator rowBegin (int y) const

  Get a const iterator for the first element in the specified row of the array.
- XIterator rowBegin (int y)

  Get a mutable iterator for the first element in the specified row of the array.
- ConstXIterator rowEnd (int y) const

  Get a const iterator for one past the end in the specified row of the array.
- XIterator rowEnd (int y)

  Get a mutable iterator for one past the end in the specified row of the array.
- ConstYIterator colBegin (int x) const

  Get a const iterator for the first element in the specified column of the array.
- YIterator colBegin (int x)

  Get a mutable iterator for the first element in the specified column of the array.
- ConstYIterator colEnd (int x) const

  Get a const iterator for one past the end in the specified column of the array.
- YIterator colEnd (int x)

  Get a mutable iterator for one past the end in the specified column of the array.
- void resize (int width, int height)

  Change the size of the array.
- template<class InputIterator >
  void resize (int width, int height, InputIterator data)

  Change the size of the array, initializing the resized array with the data obtained from the specified input iterator.
- T max () const

  Get the maximum of the elements in the array.
- T min () const

  Get the minimum of the elements in the array.
- T sum () const

  Get the sum of the elements in the array.
- std::ostream & output (std::ostream &out, int fieldWidth) const

  Output an array to a stream using the specified field width for each array element.
- int load (const char *fileName)

Load an array from the file with the specified name.

- int save (const char *fileName) const

  Save an array to the file with the specified name.

- void fill (const T &value=T(0))

  Set all elements in the array to the specified value.

- Array2 & flipud ()

  Flip the array upside down.

- Array2 & fliplr ()

  Flip the array left to right.

- void swap (Array2 &a)

  Swap the array data with the data of the specified array.

- void dump (std::ostream &out) const

  Output information about an array to a stream for debugging.

- void unshare () const

  Force the underlying data to be copied if the data is shared.

10.3.1 Detailed Description

template<class T>
class SPL::Array2< T >

A two-dimensional array class with lazy copying and reference counting.

10.3.2 Member Typedef Documentation

10.3.2.1 ConstIterator

```
template<class T>
typedef std::vector<T>::const_iterator SPL::Array2< T >::ConstIterator
```

A constant iterator for all elements in the array.

10.3.2.2 ConstXIterator

```
template<class T>
typedef std::vector<T>::const_iterator SPL::Array2< T >::ConstXIterator
```

A constant iterator for elements of a row in the array.

10.3.2.3 ConstYIterator

```
template<class T>
typedef YIter<const T> SPL::Array2< T >::ConstYIterator
```

A constant iterator for elements of a column in the array.

10.3.2.4 ElemType

```
template<class T>
typedef T SPL::Array2< T >::ElemType
```

The type of the elements in the array.

10.3.2.5 Iterator

```
template<class T>
typedef std::vector<T>::iterator SPL::Array2< T >::Iterator
```

A mutable iterator for all elements in the array.

10.3.2.6 XIterator

```
template<class T>
typedef Iterator SPL::Array2< T >::XIterator
```

A mutable iterator for elements of a row in the array.

10.3.2.7 YIterator

```
template<class T>
typedef YIter<T> SPL::Array2< T >::YIterator
```

A mutable iterator for elements of a column in the array.

10.3.3 Constructor & Destructor Documentation

10.3.3.1 Array2() [1/2]

```
template<class T>
template<class InputIter >
SPL::Array2< T >::Array2 (
            int width,
            int height,
            InputIter data )
```

Create an array of the specified width and height with the elements of the array initialized to the specified data.

10.3.3.2 Array2() [2/2]

```
template<class T>
template<class OtherType >
SPL::Array2< T >::Array2 (
            const Array2< OtherType > & a )
```

Create an array from an array having elements of a different type.

10.3.4 Member Function Documentation

10.3.4.1 operator=()

```
template<class T>
template<class OtherType >
Array2& SPL::Array2< T >::operator= (
            const Array2< OtherType > & a )
```

Assign another array with elements of a different type to this array.

The documentation for this class was generated from the following file:

- Array2.hpp

10.4 SPL::BinArithCoderContextStat Struct Reference

Binary Arithmetic Coder Context Statistics Class.

`#include <arithCoder.hpp>`

10.4.1 Detailed Description

Binary Arithmetic Coder Context Statistics Class.

The documentation for this struct was generated from the following file:

- include/SPL/arithCoder.hpp

10.5 SPL::BinArithDecoder Class Reference

Binary arithmetic decoder class.

`#include <arithCoder.hpp>`

Public Member Functions

- BinArithDecoder (int numContexts, InputBitStream *in=nullptr)

  Create a decoder with the specified number of contexts that receives input from the given bit stream.
- ~BinArithDecoder ()

  Destroy a decoder.
- SPL_ArithCoder_ulong getSymCount () const

  Get the number of symbols decoded so far.
- SPL_ArithCoder_ulong getBitCount () const

  Get the number of bits read so far.
- void setInput (InputBitStream *in)

  Set the bit stream from which to read encoded data.
- InputBitStream * getInput () const

  Get the bit stream from which to read encoded data.
- int getNumContexts () const

  Get the number of contexts.
- void setContextState (int contextId, ArithCoder::Freq oneFreq, ArithCoder::Freq totalFreq, ArithCoder::Freq max↩ Freq, bool adaptive)

  Set the symbol probabilities and adaptivity for the specified context.
- void getContextState (int contextId, ArithCoder::Freq &oneFreq, ArithCoder::Freq &totalFreq, ArithCoder::Freq &maxFreq, bool &adaptive)

  Get the symbol probabilities and adaptivity for the specified context.
- int start ()

  Start a code word.
- int terminate ()

  Terminate the code word (for synchonization with the encoder).
- int decodeRegular (int contextId)

  Decode a symbol in the specified context.
- int decodeBypass ()

  Decode a symbol in bypass mode (i.e., using a fixed probability distribution with all symbols being equiprobable).
- void dump (std::ostream &out) const

  Dump the internal decoder state to the specified stream for debugging purposes.

Static Public Member Functions

- static void setDebugLevel (int debugLevel)

  Set the debug level.
- static void setDebugStream (std::ostream &out)

  Set the stream to be used for debugging output.
- static std::ostream & getDebugStream ()

  Get the stream used for debugging output.

10.5.1 Detailed Description

Binary arithmetic decoder class.

10.5.2 Constructor & Destructor Documentation

10.5.2.1 BinArithDecoder()

```
SPL::BinArithDecoder::BinArithDecoder (
            int numContexts,
            InputBitStream * in = nullptr )
```

Create a decoder with the specified number of contexts that receives input from the given bit stream.

Parameters

numContexts	The number of contexts.
in	The input bit stream.

This function creates an arithmetic decoder with the number of contexts being `numContexts` that receives input from the bit stream `in`.

10.5.2.2 ~BinArithDecoder()

```
SPL::BinArithDecoder::~BinArithDecoder ( )
```

Destroy a decoder.

This function destroys an arithmetic decoder.

10.5.3 Member Function Documentation

10.5.3.1 decodeBypass()

```
int SPL::BinArithDecoder::decodeBypass ( )
```

Decode a symbol in bypass mode (i.e., using a fixed probability distribution with all symbols being equiprobable).

This function decodes a symbol in bypass mode (i.e., using a fixed probability distribution with all symbols being equiprobable).

Returns

Upon success, the decoded symbol is returned (which is either 0 or 1); otherwise, a negative value is returned.

10.5.3.2 decodeRegular()

```
int SPL::BinArithDecoder::decodeRegular (
            int contextId )
```

Decode a symbol in the specified context.

Parameters

contextId	The ID of the context to be used for decoding.

The function decodes a symbol using the context specified by `contextId`. The value of `contextId` must be from 0 to n - 1 (inclusive), where n is the number of contexts employed by the arithmetic decoder.

Returns

Upon success, the decoded symbol is returned (which is either 0 or 1); otherwise, a negative value is returned.

10.5.3.3 dump()

```
void SPL::BinArithDecoder::dump (
            std::ostream & out ) const
```

Dump the internal decoder state to the specified stream for debugging purposes.

10.5.3.4 getContextState()

```
void SPL::BinArithDecoder::getContextState (
            int contextId,
            ArithCoder::Freq & oneFreq,
            ArithCoder::Freq & totalFreq,
            ArithCoder::Freq & maxFreq,
            bool & adaptive )
```

Get the symbol probabilities and adaptivity for the specified context.

Parameters

	contextId	The ID of the context to query.
out	*oneFreq*	The frequency count for a one symbol.
out	*totalFreq*	The normalizing frequency count for all symbols.
out	*maxFreq*	The maximum normalizing frequency count.
out	*adaptive*	The adaptivity flag.

This function queries the state of the context with the context ID `contextId`, and sets the parameters `oneFreq`, `totalFreq`, `maxFreq`, and `adaptive` appropriately. The probability of a one symbol is given by `oneFreq` / `totalFreq`, while the probability of a zero symbol is given by 1 - `oneFreq` / `totalFreq`.

10.5.3.5 setContextState()

```
void SPL::BinArithDecoder::setContextState (
            int contextId,
            ArithCoder::Freq oneFreq,
            ArithCoder::Freq totalFreq,
            ArithCoder::Freq maxFreq,
            bool adaptive )
```

Set the symbol probabilities and adaptivity for the specified context.

10.5.3.6 start()

```
int SPL::BinArithDecoder::start ( )
```

Start a code word.

This function starts the decoding of a new arithmetic code word. This function must be called before attempting to decode any symbols.

Returns

Upon success, zero is returned; otherwise, a nonzero value is returned.

10.5.3.7 terminate()

```
int SPL::BinArithDecoder::terminate ( )
```

Terminate the code word (for synchonization with the encoder).

This function terminates the decoding of the current arithmetic code word.

Returns

Upon success, zero is returned; otherwise, a nonzero value is returned.

The documentation for this class was generated from the following files:

- include/SPL/arithCoder.hpp
- arithCoder.cpp

10.6 SPL::BinArithEncoder Class Reference

Binary arithmetic encoder class.

```
#include <arithCoder.hpp>
```

Public Member Functions

- BinArithEncoder (int numContexts, OutputBitStream *out=nullptr)
  Create an arithmetic encoder with the specified number of contexts that sends output to the given bit stream.
- ~BinArithEncoder ()
  Destroy an arithmetic encoder.
- int getNumContexts () const
  Get the number of contexts.
- SPL_ArithCoder_ulong getSymCount () const
  Get the number of symbols output so far.
- SPL_ArithCoder_ulong getBitCount () const
  Get the number of bits output so far.
- void setOutput (OutputBitStream *out)
  Set the bit stream to which encoded data should be written.
- OutputBitStream * getOutput () const
  Get the bit stream to which encoded data should be written.
- void setContextState (int contextId, ArithCoder::Freq oneFreq, ArithCoder::Freq totalFreq, ArithCoder::Freq maxFreq, bool adaptive)
  Set the symbol probabilities and adaptivity for the specified context.
- void getContextState (int contextId, ArithCoder::Freq &oneFreq, ArithCoder::Freq &totalFreq, ArithCoder::Freq &maxFreq, bool &adaptive)
  Get the symbol probabilities and adaptivity for the specified context.
- int start ()

Start a code word.

- int encodeRegular (int contextId, int binVal)

  Encode the specified symbol in the given context.
- int encodeBypass (int binVal)

  Encode the specified symbol in bypass mode (i.e., using a fixed probability distribution with all symbols being equiprobable).
- int terminate ()

  Terminate the code word.
- void dump (std::ostream &out) const

  Dump the internal encoder state to the specified output stream for debugging purposes.
- void dumpModels (std::ostream &out) const

  Dump the internal encoder context state to the specified output stream for debugging purposes.

Static Public Member Functions

- static void setDebugLevel (int debugLevel)

  Set the debug level.
- static void setDebugStream (std::ostream &out)

  Set the stream to use for debugging output.
- static std::ostream & getDebugStream ()

  Get the stream used for debugging output.

10.6.1 Detailed Description

Binary arithmetic encoder class.

10.6.2 Constructor & Destructor Documentation

10.6.2.1 BinArithEncoder()

```
SPL::BinArithEncoder::BinArithEncoder (
            int numContexts,
            OutputBitStream * out = nullptr )
```

Create an arithmetic encoder with the specified number of contexts that sends output to the given bit stream.

Parameters

numContexts	The number of contexts.
out	The output bit stream.

This constructor creates an arithmetic encoder with the number of contexts being `numContexts` that sends output to the bit stream `out`.

10.6.2.2 ~BinArithEncoder()

```
SPL::BinArithEncoder::~BinArithEncoder ( )
```

Destroy an arithmetic encoder.

This destructor destroys an arithmetic encoder.

10.6.3 Member Function Documentation

10.6.3.1 dump()

```
void SPL::BinArithEncoder::dump (
            std::ostream & out ) const
```

Dump the internal encoder state to the specified output stream for debugging purposes.

10.6.3.2 dumpModels()

```
void SPL::BinArithEncoder::dumpModels (
            std::ostream & out ) const
```

Dump the internal encoder context state to the specified output stream for debugging purposes.

10.6.3.3 encodeBypass()

```
int SPL::BinArithEncoder::encodeBypass (
            int binVal )
```

Encode the specified symbol in bypass mode (i.e., using a fixed probability distribution with all symbols being equiprobable).

Parameters

binVal	The symbol to be encoded.

This function encodes the symbol `binVal` in bypass mode (i.e., using a fixed probability distribution with all symbols being equiprobable). The symbol to be encoded must be either 0 or 1.

Returns

Upon success, zero is returned; otherwise, a nonzero value is returned.

10.6.3.4 encodeRegular()

```
int SPL::BinArithEncoder::encodeRegular (
            int contextId,
            int binVal )
```

Encode the specified symbol in the given context.

Parameters

contextId	The ID of the context to be used for encoding.
binVal	The symbol to be encoded.

This function encodes the symbol `binVal` using the context specified by `contextId`. The value of `contextId` must be from 0 to n - 1 (inclusive), where n is the number of contexts employed by the arithmetic encoder. The symbol to be encoded must be either 0 or 1.

Returns

Upon success, zero is returned; otherwise, a nonzero value is returned.

10.6.3.5 getContextState()

```
void SPL::BinArithEncoder::getContextState (
            int contextId,
            ArithCoder::Freq & oneFreq,
            ArithCoder::Freq & totalFreq,
            ArithCoder::Freq & maxFreq,
            bool & adaptive )
```

Get the symbol probabilities and adaptivity for the specified context.

Parameters

	contextId	The ID of the context to query.
out	*oneFreq*	The frequency count for a one symbol.
out	*totalFreq*	The normalizing frequency count for all symbols.
out	*maxFreq*	The maximum normalizing frequency count.
out	*adaptive*	The adaptivity flag.

This function queries the state of the context with the context ID `contextId`, and sets the parameters `oneFreq`, `totalFreq`, `maxFreq`, and `adaptive` appropriately. The probability of a one symbol is given by `oneFreq` / `totalFreq`, while the probability of a zero symbol is given by 1 - `oneFreq` / `totalFreq`.

10.6.3.6 setContextState()

```
void SPL::BinArithEncoder::setContextState (
            int contextId,
            ArithCoder::Freq oneFreq,
            ArithCoder::Freq totalFreq,
            ArithCoder::Freq maxFreq,
            bool adaptive )
```

Set the symbol probabilities and adaptivity for the specified context.

10.6.3.7 start()

```
int SPL::BinArithEncoder::start ( )
```

Start a code word.

This function starts the encoding of a new code word. This function must be called before attempting to encode any symbols.

Returns

Upon success, zero is returned; otherwise, a nonzero value is returned.

10.6.3.8 terminate()

```
int SPL::BinArithEncoder::terminate ( )
```

Terminate the code word.

This function terminates the encoding of the current arithmetic code word.

Returns

Upon success, zero is returned; otherwise, a nonzero value is returned.

The documentation for this class was generated from the following files:

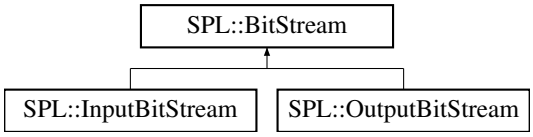
- include/SPL/arithCoder.hpp
- arithCoder.cpp

10.7 SPL::BitStream Class Reference

A common base class for the input and output bit stream classes.

```
#include <bitStream.hpp>
```

Inheritance diagram for SPL::BitStream:



Public Types

- typedef unsigned IoState

  The type used for the error state for a stream.
- typedef unsigned long long Size

  An unsigned integral type (used for sizes/counts).
- typedef long long Offset

  A signed integral type (used for differences).

Public Member Functions

- bool isOkay () const

  Test if the bitstream in an okay (i.e., non-error) state.
- bool isEof () const

  Test if the bitstream has encountered end-of-file (EOF).
- bool isLimit () const

  Test if the bitstream has encountered a read/write limit.
- IoState getIoState () const

  Get the I/O state of a bit stream.
- void setIoState (IoState state)

  Set the I/O state of a bit stream.
- void setIoStateBits (IoState state)

  Set the specified bits in the I/O state of a bit stream.
- void clearIoStateBits (IoState state=allIoBits)

  Clear the specified bits in the I/O state of a bit stream.

Static Public Attributes

- static const IoState eofBit = 1

  end of file (EOF) reached on input
- static const IoState limitBit = 2

  read/write limit exceeded
- static const IoState badBit = 4

  I/O error.
- static const IoState allIoBits = eofBit | limitBit | badBit

  all error bits

10.7.1 Detailed Description

A common base class for the input and output bit stream classes.

This class provides some error handling functionality common to the input and output bit stream classes.

10.7.2 Member Typedef Documentation

10.7.2.1 IoState

```
typedef unsigned SPL::BitStream::IoState
```

The type used for the error state for a stream.

10.7.2.2 Offset

```
typedef long long SPL::BitStream::Offset
```

A signed integral type (used for differences).

10.7.2.3 Size

```
typedef unsigned long long SPL::BitStream::Size
```

An unsigned integral type (used for sizes/counts).

10.7.3 Member Data Documentation

10.7.3.1 allIoBits

```
const IoState SPL::BitStream::allIoBits = eofBit | limitBit | badBit  [static]
```

all error bits

10.7.3.2 badBit

```
const IoState SPL::BitStream::badBit = 4  [static]
```

I/O error.

10.7.3.3 eofBit

```
const IoState SPL::BitStream::eofBit = 1  [static]
```

end of file (EOF) reached on input

10.7.3.4 limitBit

```
const IoState SPL::BitStream::limitBit = 2  [static]
```

read/write limit exceeded

The documentation for this class was generated from the following file:

- bitStream.hpp

10.8 SPL::ConvolveMode Struct Reference

Constants identifying various convolution modes.

```
#include <Sequence.hpp>
```

Static Public Attributes

- static const int full = 0
  The full convolution result (i.e., the same as "full" in MATLAB)
- static const int sameDomainZeroExt = 1
  The same as "same" in MATLAB.
- static const int sameDomainConstExt = 3
  Constant extension.
- static const int sameDomainPerExt = 2
  Periodic extension.
- static const int sameDomainSymExt0 = 4
  Symmetric periodic extension.

10.8.1 Detailed Description

Constants identifying various convolution modes.

10.8.2 Member Data Documentation

10.8.2.1 full

```
const int SPL::ConvolveMode::full = 0  [static]
```

The full convolution result (i.e., the same as "full" in MATLAB)

10.8.2.2 sameDomainConstExt

```
const int SPL::ConvolveMode::sameDomainConstExt = 3  [static]
```

Constant extension.

10.8.2.3 sameDomainPerExt

```
const int SPL::ConvolveMode::sameDomainPerExt = 2  [static]
```

Periodic extension.

10.8.2.4 sameDomainSymExt0

```
const int SPL::ConvolveMode::sameDomainSymExt0 = 4  [static]
```

Symmetric periodic extension.

10.8.2.5 sameDomainZeroExt

```
const int SPL::ConvolveMode::sameDomainZeroExt = 1  [static]
```

The same as "same" in MATLAB.

The documentation for this struct was generated from the following file:

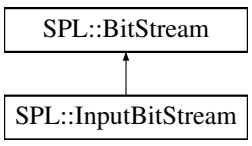
- Sequence.hpp

10.9 SPL::InputBitStream Class Reference

Input bit stream class.

```
#include <bitStream.hpp>
```

Inheritance diagram for SPL::InputBitStream:



Public Types

- typedef unsigned IoState

  The type used for the error state for a stream.
- typedef unsigned long long Size

  An unsigned integral type (used for sizes/counts).
- typedef long long Offset

  A signed integral type (used for differences).

Public Member Functions

- InputBitStream ()

  Create a bit stream that is not initially bound to any (character) stream.
- InputBitStream (std::istream &in)

  Create a bit stream that reads data from the specified (character) stream.
- ~InputBitStream ()

  Destroy a bit stream.
- std::istream * getInput () const

  Get the (character) stream from which data is read.
- void setInput (std::istream *in)

  Set the (character) stream from which data is read.
- Offset getReadLimit () const

  Get the number of bits that still may be read from the bit stream before the read limit is reached.
- void setReadLimit (Offset readLimit)

  Specify the maximum allowable number of bits that may be read from the bit stream.
- Size getReadCount () const

  Get the number of bits read from the bit stream so far.
- void clearReadCount ()

  Set the read count to zero.
- long getBits (int numBits)

  Read the specified number of bits from the bit stream.
- void align ()

  Force byte-alignment of the bit stream.
- void dump (std::ostream &out) const

  Dump the internal state of the bit stream to a (character) stream for debugging purposes.
- bool isOkay () const

  Test if the bitstream in an okay (i.e., non-error) state.
- bool isEof () const

  Test if the bitstream has encountered end-of-file (EOF).
- bool isLimit () const

  Test if the bitstream has encountered a read/write limit.
- IoState getIoState () const

  Get the I/O state of a bit stream.
- void setIoState (IoState state)

  Set the I/O state of a bit stream.
- void setIoStateBits (IoState state)

  Set the specified bits in the I/O state of a bit stream.
- void clearIoStateBits (IoState state=allIoBits)

  Clear the specified bits in the I/O state of a bit stream.

Static Public Attributes

- static const IoState eofBit = 1

  end of file (EOF) reached on input
- static const IoState limitBit = 2

  read/write limit exceeded
- static const IoState badBit = 4

  I/O error.
- static const IoState allIoBits = eofBit | limitBit | badBit

  all error bits

10.9.1 Detailed Description

Input bit stream class.

10.9.2 Member Typedef Documentation

10.9.2.1 IoState

```
typedef unsigned SPL::BitStream::IoState  [inherited]
```

The type used for the error state for a stream.

10.9.2.2 Offset

```
typedef long long SPL::BitStream::Offset  [inherited]
```

A signed integral type (used for differences).

10.9.2.3 Size

```
typedef unsigned long long SPL::BitStream::Size  [inherited]
```

An unsigned integral type (used for sizes/counts).

10.9.3 Constructor & Destructor Documentation

10.9.3.1 InputBitStream() [1/2]

```
SPL::InputBitStream::InputBitStream ( )
```

Create a bit stream that is not initially bound to any (character) stream.

10.9.3.2 InputBitStream() [2/2]

```
SPL::InputBitStream::InputBitStream (
            std::istream & in )
```

Create a bit stream that reads data from the specified (character) stream.

10.9.3.3 ~InputBitStream()

```
SPL::InputBitStream::~InputBitStream ( )
```

Destroy a bit stream.

10.9.4 Member Function Documentation

10.9.4.1 align()

```
void SPL::InputBitStream::align ( )
```

Force byte-alignment of the bit stream.

The bit stream position is moved forward to the nearest byte (i.e., multiple of 8 bits) boundary.

10.9.4.2 dump()

```
void SPL::InputBitStream::dump (
            std::ostream & out ) const
```

Dump the internal state of the bit stream to a (character) stream for debugging purposes.

10.9.4.3 getBits()

```
long SPL::InputBitStream::getBits (
            int numBits )
```

Read the specified number of bits from the bit stream.

The bits that are read from the bit stream are assigned to the returned integer value in most-significant to least-significant order.

10.9.4.4 getInput()

```
std::istream* SPL::InputBitStream::getInput ( ) const
```

Get the (character) stream from which data is read.

10.9.4.5 setInput()

```
void SPL::InputBitStream::setInput (
            std::istream * in )
```

Set the (character) stream from which data is read.

10.9.5 Member Data Documentation

10.9.5.1 allIoBits

```
const IoState SPL::BitStream::allIoBits = eofBit | limitBit | badBit  [static], [inherited]
```

all error bits

10.9.5.2 badBit

```
const IoState SPL::BitStream::badBit = 4  [static], [inherited]
```

I/O error.

10.9.5.3 eofBit

```
const IoState SPL::BitStream::eofBit = 1  [static], [inherited]
```

end of file (EOF) reached on input

10.9.5.4 limitBit

```
const IoState SPL::BitStream::limitBit = 2  [static], [inherited]
```

read/write limit exceeded

The documentation for this class was generated from the following files:

- bitStream.hpp
- bitStream.cpp

10.10 SPL::MDecoder Class Reference

The M-Coder (binary) arithmetic decoder class.

```
#include <mCoder.hpp>
```

Inherits SPL::MCoder.

Public Member Functions

- MDecoder (int numContexts=0, InputBitStream *in=0)

  Create a decoder with the specified number of contexts that reads input from the given bit stream.
- ~MDecoder ()

  Destroy a decoder.
- void setNumContexts (int numContexts)

  Set the number of contexts.
- int getNumContexts () const

  Get the number of contexts.
- void setInput (InputBitStream *in)

  Set the input bit stream (i.e., the bit stream from which encoded data is to be read).
- InputBitStream * getInput () const

  Get the input bit stream (i.e., the bit stream from which encoded data is to be read).
- void clearContexts ()

  Clear the state of all of the contexts.
- long getBitCount () const

  Get the number of bits read so far.
- long getSymCount () const

  Get the number of symbols decoded so far.
- int start ()

  Prepare to decode an arithmetic code word.
- int terminate ()

  Terminate the arithmetic code word.
- int decodeRegular (int contextId)

  Decode a symbol in the specified context.
- int decodeBypass ()

  Decode a symbol in bypass mode (i.e., assuming both symbols are equiprobable).
- void dump (std::ostream &out) const

  Dump the internal state information for the decoder to a stream (for debugging).

Static Public Member Functions

- static void setDebugLevel (int debugLevel)

  Set the debug level.
- static void setDebugStream (std::ostream &debugStream)

  Set the stream to use for debugging output.
- static std::ostream & getDebugStream ()

  Get the stream used for debugging output.

10.10.1 Detailed Description

The M-Coder (binary) arithmetic decoder class.

10.10.2 Constructor & Destructor Documentation

10.10.2.1 MDecoder()

```
SPL::MDecoder::MDecoder (
            int numContexts = 0,
            InputBitStream * in = 0 )
```

Create a decoder with the specified number of contexts that reads input from the given bit stream.

10.10.2.2 ~MDecoder()

```
SPL::MDecoder::~MDecoder ( )
```

Destroy a decoder.

10.10.3 Member Function Documentation

10.10.3.1 clearContexts()

```
void SPL::MDecoder::clearContexts ( )
```

Clear the state of all of the contexts.

10.10.3.2 decodeBypass()

```
int SPL::MDecoder::decodeBypass ( )
```

Decode a symbol in bypass mode (i.e., assuming both symbols are equiprobable).

10.10.3.3 decodeRegular()

```
int SPL::MDecoder::decodeRegular (
            int contextId )
```

Decode a symbol in the specified context.

10.10.3.4 dump()

```
void SPL::MDecoder::dump (
            std::ostream & out ) const
```

Dump the internal state information for the decoder to a stream (for debugging).

10.10.3.5 getDebugStream()

```
std::ostream & SPL::MDecoder::getDebugStream ( )  [static]
```

Get the stream used for debugging output.

10.10.3.6 setDebugLevel()

```
void SPL::MDecoder::setDebugLevel (
            int debugLevel )  [static]
```

Set the debug level.

10.10.3.7 setDebugStream()

```
void SPL::MDecoder::setDebugStream (
            std::ostream & debugStream )  [static]
```

Set the stream to use for debugging output.

10.10.3.8 setNumContexts()

```
void SPL::MDecoder::setNumContexts (
            int numContexts )
```

Set the number of contexts.

10.10.3.9 start()

```
int SPL::MDecoder::start ( )
```

Prepare to decode an arithmetic code word.

Note: This function must be called before attempting to decode any symbols.

10.10.3.10 terminate()

```
int SPL::MDecoder::terminate ( )
```

Terminate the arithmetic code word.

The documentation for this class was generated from the following files:

- mCoder.hpp
- mCoder.cpp

10.11 SPL::MEncoder Class Reference

The M-Coder (binary) arithmetic encoder class.

```
#include <mCoder.hpp>
```

Inherits SPL::MCoder.

Public Member Functions

- MEncoder (int numContexts=0, OutputBitStream *out=0)

  Create an encoder with a specified number of contexts that sends output to a given bit stream.
- ~MEncoder ()

  Destroy an encoder.
- void setNumContexts (int numContexts)

  Set the number of contexts.
- int getNumContexts () const

  Get the number of contexts.
- void clearContexts ()

  Clear the state of all of the contexts.
- void setOutput (OutputBitStream *out)

  Set the bit stream to use for output.
- OutputBitStream * getOutput () const

  Get the bit stream being used for output.
- long getSymCount () const

  Get the number of symbols that have been encoded so far.
- long getBitCount () const

  Get the number of bits (of encoded data) that have been output to the underlying bit stream so far.
- void start ()

  Start the arithmetic code word.
- int terminate ()

  Terminate the arithmetic code word.
- int encodeRegular (int contextId, int binVal)

  Encode a symbol in the specified context.
- int encodeBypass (int binVal)

  Encode a symbol in bypass mode (i.e., assuming that both symbols are equiprobable).
- void dump (std::ostream &out) const

  Dump the internal state of the encoder for debugging.

Static Public Member Functions

- static void setDebugLevel (int debugLevel)

  Set the debug level.
- static void setDebugStream (std::ostream &debugStream)

  Set the stream for debugging output.
- static std::ostream & getDebugStream ()

  Get the stream used for debugging output.

10.11.1 Detailed Description

The M-Coder (binary) arithmetic encoder class.

10.11.2 Constructor & Destructor Documentation

10.11.2.1 MEncoder()

```
SPL::MEncoder::MEncoder (
            int numContexts = 0,
            OutputBitStream * out = 0 )
```

Create an encoder with a specified number of contexts that sends output to a given bit stream.

10.11.2.2 ~MEncoder()

```
SPL::MEncoder::~MEncoder ( )
```

Destroy an encoder.

10.11.3 Member Function Documentation

10.11.3.1 clearContexts()

```
void SPL::MEncoder::clearContexts ( )
```

Clear the state of all of the contexts.

10.11.3.2 dump()

```
void SPL::MEncoder::dump (
            std::ostream & out ) const
```

Dump the internal state of the encoder for debugging.

10.11.3.3 encodeBypass()

```
int SPL::MEncoder::encodeBypass (
            int binVal )
```

Encode a symbol in bypass mode (i.e., assuming that both symbols are equiprobable).

10.11.3.4 encodeRegular()

```
int SPL::MEncoder::encodeRegular (
            int contextId,
            int binVal )
```

Encode a symbol in the specified context.

The symbol binVal is encoded using context contextId.

10.11.3.5 getDebugStream()

```
std::ostream & SPL::MEncoder::getDebugStream ( )  [static]
```

Get the stream used for debugging output.

10.11.3.6 setDebugLevel()

```
void SPL::MEncoder::setDebugLevel (
            int debugLevel )  [static]
```

Set the debug level.

10.11.3.7 setDebugStream()

```
void SPL::MEncoder::setDebugStream (
            std::ostream & debugStream )  [static]
```

Set the stream for debugging output.

10.11.3.8 setNumContexts()

```
void SPL::MEncoder::setNumContexts (
            int numContexts )
```

Set the number of contexts.

10.11.3.9 start()

```
void SPL::MEncoder::start ( )
```

Start the arithmetic code word.

10.11.3.10 terminate()

```
int SPL::MEncoder::terminate ( )
```

Terminate the arithmetic code word.

The documentation for this class was generated from the following files:

- mCoder.hpp
- mCoder.cpp

10.12 SPL::MultiArithDecoder Class Reference

M-ary arithmetic decoder class.

```
#include <arithCoder.hpp>
```

Public Member Functions

- MultiArithDecoder (int maxContexts, InputBitStream *in=nullptr)

  Create a decoder with the specified maximum number of contexts that sends output to the given bit stream.
- ~MultiArithDecoder ()

  Destroy the decoder.
- InputBitStream * getInput () const

  Get the bit stream from which to read encoded data.
- void setInput (InputBitStream *in)

  Set the bit stream from which to read encoded data.
- SPL_ArithCoder_ulong getBitCount () const

  Get the number of bits read so far.
- SPL_ArithCoder_ulong getSymCount () const

  Get the number of symbols decoded so far.
- int getMaxContexts () const

  Get the maximum number of contexts.
- void setContext (int contextId, int numSyms)

  Set the specified context to have the given number of symbols which are initially equiprobable.
- void setContext (int contextId, const std::vector< ArithCoder::Freq > &symFreqs, bool adaptive)

  Set the specified context to have symbols with the given frequencies and the given adaptivity.
- int start ()

  Start a code word.
- int terminate ()

  Terminate a code word (for synchronization with encoder).
- int decodeRegular (int contextId)

  Decode a symbol using the given context.
- int decodeBypass (int numSyms)

  Decode a symbol in bypass mode (i.e., all symbols equiprobable).
- void dump (std::ostream &out) const

  Dump the internal state of the decoder to the specified stream for debugging purposes.

Static Public Member Functions

- static void setDebugLevel (int debugLevel)

  Set the debug level.
- static void setDebugStream (std::ostream &out)

  Set the stream to use for debugging output.
- static std::ostream & getDebugStream ()

  Get the stream used for debugging output.

10.12.1 Detailed Description

M-ary arithmetic decoder class.

10.12.2 Constructor & Destructor Documentation

10.12.2.1 MultiArithDecoder()

```
SPL::MultiArithDecoder::MultiArithDecoder (
            int maxContexts,
            InputBitStream * in = nullptr )
```

Create a decoder with the specified maximum number of contexts that sends output to the given bit stream.

10.12.2.2 ~MultiArithDecoder()

```
SPL::MultiArithDecoder::~MultiArithDecoder ( )
```

Destroy the decoder.

10.12.3 Member Function Documentation

10.12.3.1 decodeBypass()

```
int SPL::MultiArithDecoder::decodeBypass (
            int numSyms )
```

Decode a symbol in bypass mode (i.e., all symbols equiprobable).

10.12.3.2 decodeRegular()

```
int SPL::MultiArithDecoder::decodeRegular (
            int contextId )
```

Decode a symbol using the given context.

10.12.3.3 dump()

```
void SPL::MultiArithDecoder::dump (
            std::ostream & out ) const
```

Dump the internal state of the decoder to the specified stream for debugging purposes.

10.12.3.4 setContext() [1/2]

```
void SPL::MultiArithDecoder::setContext (
            int contextId,
            int numSyms )
```

Set the specified context to have the given number of symbols which are initially equiprobable.

10.12.3.5 setContext() [2/2]

```
void SPL::MultiArithDecoder::setContext (
            int contextId,
            const std::vector< ArithCoder::Freq > & symFreqs,
            bool adaptive )
```

Set the specified context to have symbols with the given frequencies and the given adaptivity.

10.12.3.6 start()

```
int SPL::MultiArithDecoder::start ( )
```

Start a code word.

This function must be called before attempting to decode any symbols.

10.12.3.7 terminate()

```
int SPL::MultiArithDecoder::terminate ( )
```

Terminate a code word (for synchronization with encoder).

The documentation for this class was generated from the following files:

- include/SPL/arithCoder.hpp
- arithCoder.cpp

10.13 SPL::MultiArithEncoder Class Reference

M-ary arithmetic encoder class.

`#include <arithCoder.hpp>`

Public Member Functions

- MultiArithEncoder (int maxContexts, OutputBitStream *out=nullptr)
  Create an encoder with the specified number of contexts that sends output to the given bit stream.
- ~MultiArithEncoder ()
  Destroy an encoder.
- OutputBitStream * getOutput ()
  Get the bit stream used for output.
- void setOutput (OutputBitStream *out)
  Set the bit stream used for output.
- SPL_ArithCoder_ulong getSymCount () const
  Get the number of symbols encoded so far.
- SPL_ArithCoder_ulong getBitCount () const
  Get the number of bits of output generated so far including bits awaiting output.
- int getMaxContexts () const
  Get the maximum number of contexts.
- void setContext (int contextId, int numSyms)
  Set the specified context to have the given number of symbols which are initially equiprobable.
- void setContext (int contextId, const std::vector< ArithCoder::Freq > &symFreqs, bool adaptive)
  Set the specified context to have symbols with the given frequencies and the given adaptivity.
- int start ()
  Start a code word.
- int terminate ()
  Terminate the code word.
- int encodeRegular (int contextId, int sym)
  Encode the given symbol in the specified context.
- int encodeBypass (int numSyms, int sym)
  Encode the given symbol in bypass mode (i.e., a fixed probablity distribution where all symbols are equiprobable).
- void dump (std::ostream &out) const
  Dump the internal state of the encoder to the specified stream for debugging purposes.

Static Public Member Functions

- static void setDebugLevel (int debugLevel)
  Set the debug level.
- static void setDebugStream (std::ostream &out)
  Set the stream for debugging output.
- static std::ostream & getDebugStream ()
  Get the stream for debugging output.

10.13.1 Detailed Description

M-ary arithmetic encoder class.

10.13.2 Constructor & Destructor Documentation

10.13.2.1 MultiArithEncoder()

```
SPL::MultiArithEncoder::MultiArithEncoder (
            int maxContexts,
            OutputBitStream * out = nullptr )
```

Create an encoder with the specified number of contexts that sends output to the given bit stream.

10.13.2.2 ~MultiArithEncoder()

```
SPL::MultiArithEncoder::~MultiArithEncoder ( )
```

Destroy an encoder.

10.13.3 Member Function Documentation

10.13.3.1 dump()

```
void SPL::MultiArithEncoder::dump (
            std::ostream & out ) const
```

Dump the internal state of the encoder to the specified stream for debugging purposes.

10.13.3.2 encodeBypass()

```
int SPL::MultiArithEncoder::encodeBypass (
            int numSyms,
            int sym )
```

Encode the given symbol in bypass mode (i.e., a fixed probablity distribution where all symbols are equiprobable).

10.13.3.3 encodeRegular()

```
int SPL::MultiArithEncoder::encodeRegular (
            int contextId,
            int sym )
```

Encode the given symbol in the specified context.

10.13.3.4 setContext() [1/2]

```
void SPL::MultiArithEncoder::setContext (
            int contextId,
            int numSyms )
```

Set the specified context to have the given number of symbols which are initially equiprobable.

10.13.3.5 setContext() [2/2]

```
void SPL::MultiArithEncoder::setContext (
            int contextId,
            const std::vector< ArithCoder::Freq > & symFreqs,
            bool adaptive )
```

Set the specified context to have symbols with the given frequencies and the given adaptivity.

10.13.3.6 start()

```
int SPL::MultiArithEncoder::start ( )
```

Start a code word.

This function must be called before attempting to encode any symbols.

10.13.3.7 terminate()

```
int SPL::MultiArithEncoder::terminate ( )
```

Terminate the code word.

The documentation for this class was generated from the following files:

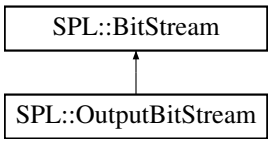
- include/SPL/arithCoder.hpp
- arithCoder.cpp

10.14 SPL::OutputBitStream Class Reference

Output bit stream class.

`#include <bitStream.hpp>`

Inheritance diagram for SPL::OutputBitStream:



Public Types

- typedef unsigned IoState

  The type used for the error state for a stream.
- typedef unsigned long long Size

  An unsigned integral type (used for sizes/counts).
- typedef long long Offset

  A signed integral type (used for differences).

Public Member Functions

- OutputBitStream ()

  Create a bit stream that is not initially bound to any (character) stream.
- OutputBitStream (std::ostream &out)

  Create a bit stream that sends its output to the specified (character) stream.
- ~OutputBitStream ()

  Destroy a bit stream.
- std::ostream * getOutput () const

  Get the output (character) stream associated with the bit stream.
- void setOutput (std::ostream *out)

  Set the output (character) stream associated with the bit stream.
- void clearWriteCount ()

  Clear the count of the number of bits written to the bit stream.
- Size getWriteCount () const

  Get the number of bits written to the bit stream.
- void setWriteLimit (Offset writeLimit)

  Set the number of bits that may still be written to the bit stream.
- Offset getWriteLimit () const

  Get the number of bits that may still be written to the underlying (character) stream.
- int putBits (long data, int numBits)

  Output the specified number of bits to the bit stream.
- void align ()

Align the bit stream output position to the nearest byte boundary.

- void flush ()

  Flush any pending output to the underlying (character) stream.
- void dump (std::ostream &out) const

  Dump the internal state of the bit stream to the specified (character) stream for debugging purposes.
- bool isOkay () const

  Test if the bitstream in an okay (i.e., non-error) state.
- bool isEof () const

  Test if the bitstream has encountered end-of-file (EOF).
- bool isLimit () const

  Test if the bitstream has encountered a read/write limit.
- IoState getIoState () const

  Get the I/O state of a bit stream.
- void setIoState (IoState state)

  Set the I/O state of a bit stream.
- void setIoStateBits (IoState state)

  Set the specified bits in the I/O state of a bit stream.
- void clearIoStateBits (IoState state=allIoBits)

  Clear the specified bits in the I/O state of a bit stream.

Static Public Attributes

- static const IoState eofBit = 1

  end of file (EOF) reached on input
- static const IoState limitBit = 2

  read/write limit exceeded
- static const IoState badBit = 4

  I/O error.
- static const IoState allIoBits = eofBit | limitBit | badBit

  all error bits

10.14.1 Detailed Description

Output bit stream class.

10.14.2 Member Typedef Documentation

10.14.2.1 IoState

```
typedef unsigned SPL::BitStream::IoState  [inherited]
```

The type used for the error state for a stream.

10.14.2.2 Offset

```
typedef long long SPL::BitStream::Offset  [inherited]
```

A signed integral type (used for differences).

10.14.2.3 Size

```
typedef unsigned long long SPL::BitStream::Size  [inherited]
```

An unsigned integral type (used for sizes/counts).

10.14.3 Constructor & Destructor Documentation

10.14.3.1 OutputBitStream() [1/2]

```
SPL::OutputBitStream::OutputBitStream ( )
```

Create a bit stream that is not initially bound to any (character) stream.

10.14.3.2 OutputBitStream() [2/2]

```
SPL::OutputBitStream::OutputBitStream (
            std::ostream & out )
```

Create a bit stream that sends its output to the specified (character) stream.

10.14.3.3 ~OutputBitStream()

```
SPL::OutputBitStream::~OutputBitStream ( )
```

Destroy a bit stream.

10.14.4 Member Function Documentation

10.14.4.1 align()

```
void SPL::OutputBitStream::align ( )
```

Align the bit stream output position to the nearest byte boundary.

10.14.4.2 dump()

```
void SPL::OutputBitStream::dump (
            std::ostream & out ) const
```

Dump the internal state of the bit stream to the specified (character) stream for debugging purposes.

10.14.4.3 flush()

```
void SPL::OutputBitStream::flush ( )
```

Flush any pending output to the underlying (character) stream.

The bit stream is aligned to the nearest byte boundary and any pending output is flushed to the underlying (character) stream.

10.14.4.4 getOutput()

```
std::ostream * SPL::OutputBitStream::getOutput ( ) const
```

Get the output (character) stream associated with the bit stream.

10.14.4.5 putBits()

```
int SPL::OutputBitStream::putBits (
            long data,
            int numBits )
```

Output the specified number of bits to the bit stream.

This function returns a nonnegative value upon success and a negative value if an error is encountered.

10.14.4.6 setOutput()

```
void SPL::OutputBitStream::setOutput (
            std::ostream * out )
```

Set the output (character) stream associated with the bit stream.

10.14.5 Member Data Documentation

10.14.5.1 allIoBits

```
const IoState SPL::BitStream::allIoBits = eofBit | limitBit | badBit  [static], [inherited]
```

all error bits

10.14.5.2 badBit

```
const IoState SPL::BitStream::badBit = 4  [static], [inherited]
```

I/O error.

10.14.5.3 eofBit

```
const IoState SPL::BitStream::eofBit = 1  [static], [inherited]
```

end of file (EOF) reached on input

10.14.5.4 limitBit

```
const IoState SPL::BitStream::limitBit = 2  [static], [inherited]
```

read/write limit exceeded

The documentation for this class was generated from the following files:

- bitStream.hpp
- bitStream.cpp

10.15 SPL::PnmHeader Struct Reference

The header information for PNM data.

`#include <pnmCodec.hpp>`

Public Attributes

- PnmMagic magic
  The magic number.
- int width
  The image width.
- int height
  The image height.
- int maxVal
  The maximum sample value.
- bool sgnd
  The signedness of the sample data.

10.15.1 Detailed Description

The header information for PNM data.

10.15.2 Member Data Documentation

10.15.2.1 height

`int SPL::PnmHeader::height`

The image height.

10.15.2.2 magic

`PnmMagic SPL::PnmHeader::magic`

The magic number.

10.15.2.3 maxVal

```
int SPL::PnmHeader::maxVal
```

The maximum sample value.

10.15.2.4 sgnd

```
bool SPL::PnmHeader::sgnd
```

The signedness of the sample data.

10.15.2.5 width

```
int SPL::PnmHeader::width
```

The image width.

The documentation for this struct was generated from the following file:

- pnmCodec.hpp

10.16 SPL::Quaternion< T > Struct Template Reference

A quaternion represented in terms of its scalar and vector parts.

```
#include <cgalUtil.hpp>
```

Public Types

- typedef T::FT Real
  The field type for the CGAL kernel.
- typedef CGAL::Vector_3< T > Vector_3
  The 3-dimensional vector type.

Public Member Functions

- Quaternion ()
- Quaternion (Real scalar_, const Vector_3 &vector_)

Public Attributes

- Real scalar

  The scalar part of the quaternion.
- Vector_3 vector

  The vector part of the quaternion.

10.16.1 Detailed Description

template<class T>
struct SPL::Quaternion< T >

A quaternion represented in terms of its scalar and vector parts.

10.16.2 Member Typedef Documentation

10.16.2.1 Real

```
template<class T>
typedef T::FT SPL::Quaternion< T >::Real
```

The field type for the CGAL kernel.

10.16.2.2 Vector_3

```
template<class T>
typedef CGAL::Vector_3<T> SPL::Quaternion< T >::Vector_3
```

The 3-dimensional vector type.

10.16.3 Constructor & Destructor Documentation

10.16.3.1 Quaternion() [1/2]

```
template<class T>
SPL::Quaternion< T >::Quaternion ( )  [inline]
```

Create a quaternion.

10.16.3.2 Quaternion() [2/2]

```
template<class T>
SPL::Quaternion< T >::Quaternion (
            Real scalar_,
            const Vector_3 & vector_ )  [inline]
```

Create a quaternion with the specified scalar and vector parts.

10.16.4 Member Data Documentation

10.16.4.1 scalar

```
template<class T>
Real SPL::Quaternion< T >::scalar
```

The scalar part of the quaternion.

10.16.4.2 vector

```
template<class T>
Vector_3 SPL::Quaternion< T >::vector
```

The vector part of the quaternion.

The documentation for this struct was generated from the following file:

- cgalUtil.hpp

10.17 SPL::Rotation_3< T > Struct Template Reference

A 3-D rotation.

`#include <cgalUtil.hpp>`

Public Types

- typedef T::FT Real
  The field type for the CGAL kernel.
- typedef T::Vector_3 Vector_3
  The 3-dimensional vector type.

Public Member Functions

- Rotation_3 (const Vector_3 &axis_, Real angle_)

  Create a rotation.

Public Attributes

- Vector_3 axis

  The axis of rotation.
- Real angle

  The angle of rotation.

10.17.1 Detailed Description

template<class T>
struct SPL::Rotation_3< T >

A 3-D rotation.

10.17.2 Member Typedef Documentation

10.17.2.1 Real

```
template<class T>
typedef T::FT SPL::Rotation_3< T >::Real
```

The field type for the CGAL kernel.

10.17.2.2 Vector_3

```
template<class T>
typedef T::Vector_3 SPL::Rotation_3< T >::Vector_3
```

The 3-dimensional vector type.

10.17.3 Constructor & Destructor Documentation

10.17.3.1 Rotation_3()

```
template<class T>
SPL::Rotation_3< T >::Rotation_3 (
            const Vector_3 & axis_,
            Real angle_ )  [inline]
```

Create a rotation.

10.17.4 Member Data Documentation

10.17.4.1 angle

```
template<class T>
Real SPL::Rotation_3< T >::angle
```

The angle of rotation.

10.17.4.2 axis

```
template<class T>
Vector_3 SPL::Rotation_3< T >::axis
```

The axis of rotation.

The documentation for this struct was generated from the following file:

- cgalUtil.hpp

10.18 SPL::Sequence1< T > Class Template Reference

A one-dimensional sequence class with lazy copying and reference counting.

```
#include <Sequence1.hpp>
```

Public Types

- typedef T ElemType

  The type of the element in the sequence.
- typedef Array1< T >::ConstIterator ConstIterator

  The const iterator for the sequence.
- typedef Array1< T >::Iterator Iterator

  The mutable iterator for the sequence.

Public Member Functions

- Sequence1 ()

  The default constructor.
- Sequence1 (int startInd, int size)

  Construct a sequence with the specified start index and size.
- Sequence1 (int startInd, int size, const T &value)

  Construct a sequence with the specified start index and size, with all elements set to the given value.
- template<class InputIterator >
  Sequence1 (int startInd, int size, InputIterator data)

  Construct a sequence with the specified start index and size, with the elements initialized to the data read from the given iterator.
- Sequence1 (const Sequence1 &f)

  The copy constructor.
- template<class OtherT >
  Sequence1 (const Sequence1< OtherT > &f)

  Create a sequence from another sequence having elements of a different type.
- Sequence1 (const Array1< T > &data)

  Create a sequence from an array.
- Sequence1 (int startInd, const Array1< T > &data)

  Create a sequence from an array using the given starting index.
- ~Sequence1 ()

  The destructor.
- Sequence1 & operator= (const Sequence1 &f)

  The assignment operator.
- template<class OtherT >
  Sequence1 & operator= (const Sequence1< OtherT > &f)

  Assign another sequence with elements of a different type to this sequence.
- Sequence1 & operator+= (const Sequence1 &f)

  Add another sequence to this one.
- Sequence1 & operator-= (const Sequence1 &f)

  Subtract another sequence from this one.
- Sequence1 & operator*= (const Sequence1 &f)

  Multiply elementwise this sequence by another one.
- Sequence1 & operator/= (const Sequence1 &f)

  Divide elementwise this sequence by another one.
- Sequence1 & operator+= (const T &value)

  Add a value to each element of this sequence.
- Sequence1 & operator-= (const T &value)

  Subtract a value from each element of this sequence.
- Sequence1 & operator*= (const T &value)

  Multiply each element of this sequence by the specified value.
- Sequence1 & operator/= (const T &value)

  Divide each element of the sequence by the given value.
- int getStartInd () const

  Get the start index for the sequence.
- int getEndInd () const

  Get the end index for the sequence.

- int getSize () const

  Get the length of the sequence.
- bool isShared () const

  Is the array for this sequence shared with another array?
- const T & operator() (int i) const

  Get the specified element in the sequence.
- T & operator() (int i)

  Get the specified element in the sequence.
- ConstIterator begin () const

  Get an iterator referencing the first element in the sequence.
- Iterator begin ()

  Get an iterator referencing the first element in the sequence.
- ConstIterator end () const

  Get an iterator referencing just after the last element in the sequence.
- Iterator end ()

  Get an iterator referencing just after the last element in the sequence.
- T min () const

  Get the minimum element in the sequence.
- T max () const

  Get the maximum element in the sequence.
- T sum () const

  Get the sum of the elements in the sequence.
- Array1< T > getArray () const

  Get a copy of the underlying array.
- void swapArray (Array1< T > &data)

  Swap the data for the underlying array and the specified array.
- void fill (const T &value)

  Set all of the elements in the sequence to the specified value.
- Sequence1 & translate (int delta)

  Translate (i.e., shift) a sequence by the specified displacement.

10.18.1 Detailed Description

template<class T>
class SPL::Sequence1< T >

A one-dimensional sequence class with lazy copying and reference counting.

10.18.2 Member Typedef Documentation

10.18.2.1 ConstIterator

```
template<class T>
typedef Array1<T>::ConstIterator SPL::Sequence1< T >::ConstIterator
```

The const iterator for the sequence.

10.18.2.2 ElemType

```
template<class T>
typedef T SPL::Sequence1< T >::ElemType
```

The type of the element in the sequence.

10.18.2.3 Iterator

```
template<class T>
typedef Array1<T>::Iterator SPL::Sequence1< T >::Iterator
```

The mutable iterator for the sequence.

10.18.3 Constructor & Destructor Documentation

10.18.3.1 Sequence1() [1/2]

```
template<class T>
template<class InputIterator >
SPL::Sequence1< T >::Sequence1 (
            int startInd,
            int size,
            InputIterator data )
```

Construct a sequence with the specified start index and size, with the elements initialized to the data read from the given iterator.

Effects: A sequence with a starting index of startInd and size size is created, with the elements being initialized by the data pointed to by data.

10.18.3.2 Sequence1() [2/2]

```
template<class T>
template<class OtherT >
SPL::Sequence1< T >::Sequence1 (
            const Sequence1< OtherT > & f )
```

Create a sequence from another sequence having elements of a different type.

10.18.4 Member Function Documentation

10.18.4.1 operator=()

```
template<class T>
template<class OtherT >
Sequence1& SPL::Sequence1< T >::operator= (
            const Sequence1< OtherT > & f )
```

Assign another sequence with elements of a different type to this sequence.

The type OtherT must be assignable to the type T.

The documentation for this class was generated from the following file:

- Sequence1.hpp

10.19 SPL::Sequence2< T > Class Template Reference

A two-dimensional sequence class with lazy copying and reference counting.

`#include <Sequence2.hpp>`

Public Types

- typedef T ElemType
  The type of the element in the sequence.
- typedef Array2< T >::ConstIterator ConstIterator
  The const iterator for all elements in the sequence.
- typedef Array2< T >::Iterator Iterator
  The mutable iterator for all elements in the sequence.
- typedef Array2< T >::ConstXIterator ConstXIterator
  The const iterator for the elements in a row of the sequence.
- typedef Array2< T >::XIterator XIterator
  The mutable iterator for the elements in a row of the sequence.
- typedef Array2< T >::ConstYIterator ConstYIterator
  The const iterator for the elements in a column of the sequence.
- typedef Array2< T >::YIterator YIterator
  The mutable iterator for the elements in a column of the sequence.

Public Member Functions

- Sequence2 ()

  The default constructor.
- Sequence2 (int startX, int startY, int width, int height)

  Construct a sequence with the specified start index and size.
- Sequence2 (int startX, int startY, int width, int height, const T &data)

  Construct a sequence with the specified start index and size, with all elements set to the given value.
- template<class InputIterator >
  Sequence2 (int startX, int startY, int width, int height, InputIterator data)

  Construct a sequence with the specified start index and size, with the elements initialized to the data read from the given iterator.
- Sequence2 (const Sequence2 &f)

  The copy constructor.
- template<class OtherT >
  Sequence2 (const Sequence2< OtherT > &f)

  Create a sequence from another sequence having elements of a different type.
- Sequence2 (const Array2< T > &data)

  Create a sequence from an array.
- Sequence2 (int startX, int startY, const Array2< T > &data)

  Create a sequence from an array using the given starting index.
- ~Sequence2 ()

  The destructor.
- Sequence2 & operator= (const Sequence2 &f)

  The assignment operator.
- template<class OtherT >
  Sequence2 & operator= (const Sequence2< OtherT > &f)

  Assign another sequence with elements of a different type to this sequence.
- Sequence2 & operator+= (const Sequence2 &f)

  Add another sequence to this one.
- Sequence2 & operator-= (const Sequence2 &f)

  Subtract another sequence from this one.
- Sequence2 & operator*= (const Sequence2 &f)

  Multiply elementwise this sequence by another one.
- Sequence2 & operator/= (const Sequence2 &f)

  Divide elementwise this sequence by another one.
- Sequence2 & operator+= (const T &value)

  Add a value to each element of this sequence.
- Sequence2 & operator-= (const T &value)

  Subtract a value from each element of this sequence.
- Sequence2 & operator*= (const T &value)

  Multiply each element of this sequence by the specified value.
- Sequence2 & operator/= (const T &value)

  Divide each element of the sequence by the given value.
- int getStartX () const

  Get the x-coordinate of the start index for the sequence.
- int getStartY () const

  Get the y-coordinate of the start index for the sequence.

- int getEndX () const

  Get the x-coordinate of the end index for the sequence.
- int getEndY () const

  Get the y-coordinate of the end index for the sequence.
- int getWidth () const

  Get the width of the sequence.
- int getHeight () const

  Get the height of the sequence.
- int getSize () const

  Get the number of elements in the sequence.
- bool isShared () const

  Is the array for this sequence shared with another array?
- T & operator() (int x, int y)

  Get a mutable reference to the specified element in the sequence.
- const T & operator() (int x, int y) const

  Get a const reference to the specified element in the sequence.
- ConstIterator begin () const

  Get a const iterator for the first element in the sequence.
- Iterator begin ()

  Get a mutable iterator for the first element in the sequence.
- ConstIterator end () const

  Get a const iterator for one past the last element in the sequence.
- Iterator end ()

  Get a mutable iterator for one past the last element in the sequence.
- ConstXIterator rowBegin (int y) const

  Get a const iterator for the first element in the specified row of the sequence.
- XIterator rowBegin (int y)

  Get a mutable iterator for the first element in the specified row of the sequence.
- ConstXIterator rowEnd (int y) const

  Get a const iterator for one past the end in the specified row of the sequence.
- XIterator rowEnd (int y)

  Get a mutable iterator for one past the end in the specified row of the sequence.
- ConstYIterator colBegin (int x) const

  Get a const iterator for the first element in the specified column of the sequence.
- YIterator colBegin (int x)

  Get a mutable iterator for the first element in the specified column of the sequence.
- ConstYIterator colEnd (int x) const

  Get a const iterator for one past the end in the specified column of the sequence.
- YIterator colEnd (int x)

  Get a mutable iterator for one past the end in the specified column of the sequence.
- T min () const

  Get the minimum element in the sequence.
- T max () const

  Get the maximum element in the sequence.
- T sum () const

  Get the sum of the elements in the sequence.
- std::ostream & output (std::ostream &out, int fieldWidth) const

Output a sequence to the specified stream using the given field width for each sequence element.

- Array2< T > getArray () const

  Get a copy of the underlying array.
- void swapArray (Array2< T > &data)

  Swap the data for the underlying array and the specified array.
- void fill (const T &value)

  Get a copy of the underlying array.
- Sequence2 & translate (int x, int y)

  Translate (i.e., shift) a sequence by the specified displacement.

10.19.1 Detailed Description

template<class T>
class SPL::Sequence2< T >

A two-dimensional sequence class with lazy copying and reference counting.

10.19.2 Member Typedef Documentation

10.19.2.1 ConstIterator

```
template<class T>
typedef Array2<T>::ConstIterator SPL::Sequence2< T >::ConstIterator
```

The const iterator for all elements in the sequence.

10.19.2.2 ConstXIterator

```
template<class T>
typedef Array2<T>::ConstXIterator SPL::Sequence2< T >::ConstXIterator
```

The const iterator for the elements in a row of the sequence.

10.19.2.3 ConstYIterator

```
template<class T>
typedef Array2<T>::ConstYIterator SPL::Sequence2< T >::ConstYIterator
```

The const iterator for the elements in a column of the sequence.

10.19.2.4 ElemType

```
template<class T>
typedef T SPL::Sequence2< T >::ElemType
```

The type of the element in the sequence.

10.19.2.5 Iterator

```
template<class T>
typedef Array2<T>::Iterator SPL::Sequence2< T >::Iterator
```

The mutable iterator for all elements in the sequence.

10.19.2.6 XIterator

```
template<class T>
typedef Array2<T>::XIterator SPL::Sequence2< T >::XIterator
```

The mutable iterator for the elements in a row of the sequence.

10.19.2.7 YIterator

```
template<class T>
typedef Array2<T>::YIterator SPL::Sequence2< T >::YIterator
```

The mutable iterator for the elements in a column of the sequence.

10.19.3 Constructor & Destructor Documentation

10.19.3.1 Sequence2() [1/2]

```
template<class T>
template<class InputIterator >
SPL::Sequence2< T >::Sequence2 (
            int startX,
            int startY,
            int width,
            int height,
            InputIterator data )
```

Construct a sequence with the specified start index and size, with the elements initialized to the data read from the given iterator.

10.19.3.2 Sequence2() [2/2]

```
template<class T>
template<class OtherT >
SPL::Sequence2< T >::Sequence2 (
            const Sequence2< OtherT > & f )
```

Create a sequence from another sequence having elements of a different type.

10.19.4 Member Function Documentation

10.19.4.1 operator=()

```
template<class T>
template<class OtherT >
Sequence2& SPL::Sequence2< T >::operator= (
            const Sequence2< OtherT > & f )
```

Assign another sequence with elements of a different type to this sequence.

The type OtherT must be assignable to the type T.

The documentation for this class was generated from the following file:

- Sequence2.hpp

10.20 SPL::Timer Class Reference

A class for making timing measurements.

`#include <Timer.hpp>`

Public Member Functions

- void start ()
  Start the timer.
- void stop ()
  Stop the timer.
- double get () const
  Get the timer value.

10.20.1 Detailed Description

A class for making timing measurements.

10.20.2 Member Function Documentation

10.20.2.1 get()

`double SPL::Timer::get ( ) const`

Get the timer value.

Effects: Query the elapsed time measured by the timer.

Returns: The elapsed time in seconds is returned. The resolution of the timer depends on the particular platform (e.g., operating system, hardware, etc.). For most mainstream platforms, the resolution of the timer is typically microseconds.

10.20.2.2 start()

`void SPL::Timer::start ( )`

Start the timer.

Effects: Starts the timer. The timer should not already be running.

10.20.2.3 stop()

`void SPL::Timer::stop ( )`

Stop the timer.

Effects: Stops the timer. The timer should already be running.

The documentation for this class was generated from the following file:

- Timer.hpp

Chapter 11

File Documentation

11.1 Arcball.hpp File Reference

This file contains the Arcball class and related code.

```
#include <SPL/config.hpp>
#include <CGAL/Plane_3.h>
#include <CGAL/Ray_3.h>
#include "cgalUtil.hpp"
```

Classes

- class SPL::Arcball< T >

  Arcball.

Functions

- template<class T >
  T::Point_3 SPL::closestPointOnRay (const typename CGAL::Point_3< T > &rayOrigin, const typename CGAL::Vector_3< T > &rayDir, const typename CGAL::Point_3< T > &point)

  Compute the closest point on a ray to the specified point.
- template<class T >
  std::pair< bool, typename T::Point_3 > SPL::findRaySphereIntersection (const typename CGAL::Point_3< T > &sphereCenter, typename T::FT sphereRadius, const typename CGAL::Point_3< T > &rayOrigin, const typename CGAL::Vector_3< T > &rayDir)

  Compute the intersection of a ray and a sphere.
- template<class T >
  std::pair< bool, typename T::Point_3 > SPL::findRayPlaneIntersection (const typename CGAL::Point_3< T > &planePoint, const typename CGAL::Vector_3< T > &planeNormal, const typename CGAL::Point_3< T > &rayOrigin, const typename CGAL::Vector_3< T > &rayDir)

  Compute the intersection of a ray and a plane.

11.1.1 Detailed Description

This file contains the Arcball class and related code.

11.2 Array1.hpp File Reference

This file contains the Array1 template class and supporting code.

```
#include <SPL/config.hpp>
#include <iostream>
#include <fstream>
#include <sstream>
#include <iomanip>
#include <vector>
#include <cassert>
#include <algorithm>
#include <functional>
#include <iterator>
#include <numeric>
#include <SPL/misc.hpp>
```

Classes

- class SPL::Array1< T >

  A one-dimensional array class with lazy copying and reference counting.
- class SPL::Array1< T >

  A one-dimensional array class with lazy copying and reference counting.

Macros

- #define SPL_ARRAY1_INLINE inline

  Defining this symbol will enable extra code for debugging.

Typedefs

- typedef Array1< double > SPL::RealArray1

  A one-dimensional array with real elements.
- typedef Array1< int > SPL::IntArray1

  A one-dimensional array with integer elements.

Functions

- template<class T >
  std::ostream & SPL::operator<< (std::ostream &out, const Array1< T > &a)
  Output an array to the specified stream.
- template<class T >
  std::istream & SPL::operator>> (std::istream &in, Array1< T > &a)
  Input an array from the specified stream.
- template<class T >
  bool SPL::operator== (const Array1< T > &a, const Array1< T > &b)
  Test two arrays for equality.
- template<class T >
  SPL_ARRAY1_INLINE bool SPL::operator!= (const Array1< T > &a, const Array1< T > &b)
  Test two arrays for inequality.

11.2.1 Detailed Description

This file contains the Array1 template class and supporting code.

11.2.2 Macro Definition Documentation

11.2.2.1 SPL_ARRAY1_INLINE

```
#define SPL_ARRAY1_INLINE inline
```

Defining this symbol will enable extra code for debugging.

Allow the inlining of functions.

11.3 Array2.hpp File Reference

This file contains the Array2 template class and its supporting code.

```
#include <SPL/config.hpp>
#include <iostream>
#include <iomanip>
#include <fstream>
#include <vector>
#include <cassert>
#include <iterator>
#include <algorithm>
#include <numeric>
#include <boost/iterator/iterator_facade.hpp>
#include <SPL/pnmCodec.hpp>
#include <SPL/misc.hpp>
```

Classes

- class SPL::Array2< T >

  A two-dimensional array class with lazy copying and reference counting.
- class SPL::Array2< T >

  A two-dimensional array class with lazy copying and reference counting.

Macros

- #define SPL_ARRAY2_INLINE inline

  Defining this symbol will enable extra code for debugging.

Typedefs

- typedef Array2< double > SPL::RealArray2

  A two-dimensional array with real elements.
- typedef Array2< int > SPL::IntArray2

  A two-dimensional array with integer elements.

Functions

- template<class T >
  std::ostream & SPL::operator<< (std::ostream &out, const Array2< T > &a)

  Output an array to the specified stream.
- template<class T >
  std::istream & SPL::operator>> (std::istream &in, Array2< T > &a)

  Input an array from the specified stream.
- template<class T >
  Array2< T > SPL::transpose (const Array2< T > &a)

  Get the transpose of the array.
- template<class T >
  bool SPL::operator== (const Array2< T > &a, const Array2< T > &b)

  Test two arrays for equality.
- template<class T >
  bool SPL::operator!= (const Array2< T > &a, const Array2< T > &b)

  Test two arrays for inequality.
- template<class T >
  int SPL::encodePnm (std::ostream &outStream, const std::vector< Array2< T > > &comps, int maxVal, bool sgnd, bool binaryFormat=true)

  Output the array as an image in the PNM format.
- template<class T >
  int SPL::encodePbm (std::ostream &outStream, const Array2< T > &bits, bool binaryFormat=true)

  Output the array as an image in the PNM format (PBM type).
- template<class T >
  int SPL::encodePgm (std::ostream &outStream, const Array2< T > &gray, int maxVal, bool sgnd, bool binary↩ Format=true)

Output the array as an image in the PNM format (PGM type).

- template<class T >
  int SPL::encodePpm (std::ostream &outStream, const Array2< T > &red, const Array2< T > &green, const Array2< T > &blue, int maxVal, bool sgnd, bool binaryFormat=true)

  Output the array as an image in the PNM format (PPM type).
- template<class T >
  int SPL::decodePnm (std::istream &inStream, std::vector< Array2< T > > &comps, int &maxVal, bool &sgnd)

  Input an array as an image in the PNM format.
- template<class T >
  int SPL::decodePbm (std::istream &inStream, Array2< T > &bits)

  Input an array as an image in the PNM format.
- template<class T >
  int SPL::decodePgm (std::istream &inStream, Array2< T > &gray, int &maxVal, bool &sgnd)

  Input an array as an image in the PNM format.
- template<class T >
  int SPL::decodePpm (std::istream &inStream, Array2< T > &red, Array2< T > &green, Array2< T > &blue, int &maxVal, bool &sgnd)

  Input an array as an image in the PNM format.

11.3.1 Detailed Description

This file contains the Array2 template class and its supporting code.

11.3.2 Macro Definition Documentation

11.3.2.1 SPL_ARRAY2_INLINE

```
#define SPL_ARRAY2_INLINE inline
```

Defining this symbol will enable extra code for debugging.

Allow the inlining of functions.

11.4 audioFile.hpp File Reference

This file contains code for performing reading and writing of audio files in WAV format.

```
#include <SPL/config.hpp>
#include <iostream>
#include <string>
#include <algorithm>
#include <SPL/Array1.hpp>
```

Functions

- int SPL::loadAudioFile (const std::string &fileName, int &samplingRate, RealArray1 &samples)

  Read audio data from a file in WAV format.
- int SPL::saveAudioFile (const std::string &fileName, int samplingRate, const RealArray1 &samples)

  Write a sequence to a file in WAV format.

11.4.1 Detailed Description

This file contains code for performing reading and writing of audio files in WAV format.

11.5 bitStream.hpp File Reference

Bit Stream Classes.

```
#include <SPL/config.hpp>
#include <cassert>
#include <iostream>
```

Classes

- class SPL::BitStream

  A common base class for the input and output bit stream classes.
- class SPL::InputBitStream

  Input bit stream class.
- class SPL::OutputBitStream

  Output bit stream class.

11.5.1 Detailed Description

Bit Stream Classes.

11.6 cgalUtil.hpp File Reference

This file contains various CGAL utility code.

```
#include <SPL/config.hpp>
#include <SPL/math.hpp>
#include <cmath>
#include <CGAL/Cartesian.h>
#include <CGAL/Vector_3.h>
#include <CGAL/Point_3.h>
```

Classes

- struct SPL::Rotation_3< T >

  A 3-D rotation.
- struct SPL::Quaternion< T >

  A quaternion represented in terms of its scalar and vector parts.

Functions

- template<class T >
  T::FT SPL::norm (const typename CGAL::Vector_3< T > &v)

  Compute the norm of a vector.
- template<class T >
  T::Vector_3 SPL::normalize (const typename CGAL::Vector_3< T > &v)

  Compute a unit vector.
- template<class T >
  T::FT SPL::angleBetweenVectors (const typename CGAL::Vector_3< T > &u, const CGAL::Vector_3< T > &v)

  Compute the angle between two vectors.
- template<class T >
  Quaternion< T > SPL::operator* (const Quaternion< T > &q, const Quaternion< T > &r)

  Compute the product of two quaternions.
- template<class T >
  Quaternion< T > SPL::operator/ (const Quaternion< T > &q, const Quaternion< T > &r)

  Compute the quotient of two quaternions.
- template<class T >
  Quaternion< T > SPL::rotationToQuaternion (const Rotation_3< T > &rot)

  Convert a rotation into its corresponding quaternion.
- template<class T >
  Rotation_3< T > SPL::quaternionToRotation (const Quaternion< T > &q)

  Convert a unit-norm quaternion into its corresponding rotation.

11.6.1 Detailed Description

This file contains various CGAL utility code.

11.7 filterDesign.hpp File Reference

This file contains code for performing filter design.

```
#include <SPL/config.hpp>
#include <SPL/Sequence1.hpp>
```

Functions

- RealSequence1 SPL::lowpassFilter (double cutoffFreq, double transWidth, double maxPassbandRipple=0.1, double minStopbandAtten=20.0)

  Design a zero-phase FIR lowpass filter.
- RealSequence1 SPL::highpassFilter (double cutoffFreq, double transWidth, double maxPassbandRipple=0.1, double minStopbandAtten=20.0)

  Design a zero-phase FIR highpass filter.
- RealSequence1 SPL::bandpassFilter (double cutoffFreq0, double cutoffFreq1, double transWidth0, double transWidth1, double maxPassbandRipple=0.1, double minStopbandAtten=20.0)

  Design a zero-phase FIR bandpass filter.

11.7.1 Detailed Description

This file contains code for performing filter design.

11.8 math.hpp File Reference

This file contains various mathematical functions/code.

```
#include <SPL/config.hpp>
#include <iostream>
#include <cmath>
#include <cassert>
#include <boost/tr1/cmath.hpp>
```

Functions

- template<class T >
  T SPL::absVal (T x)

  The absolute value function.
- template<class T >
  T SPL::signum (T x)

  The signum function.
- template<class T >
  T SPL::sqr (const T &x)

  The square function.
- template<class T >
  T SPL::clip (T x, T min, T max)

  The clip function.
- double SPL::sinc (double x)

  The cardinal sine function.
- long SPL::roundTowardZeroDiv (long x, long y)

  Compute a quotient with the result rounded towards zero.
- long SPL::floorDiv (long x, long y)

Compute the floor of a quotient.

- template<class T >
  T SPL::mod (T x, T y)

  Compute the remainder after division.
- long SPL::ceilDiv (long x, long y)

  Compute the ceiling of a quotient.
- double SPL::radToDeg (double x)

  Convert from radians to degrees.
- double SPL::degToRad (double x)

  Convert from degrees to radians.

11.8.1 Detailed Description

This file contains various mathematical functions/code.

11.9 mCoder.hpp File Reference

This file contains interface information for an implementation of the M-Coder arithmetic coder from: ISO/IEC 14496-10:2008 (a.k.a. H.264)

```
#include <SPL/config.hpp>
#include <vector>
#include <iostream>
#include <SPL/bitStream.hpp>
```

Classes

- class SPL::MEncoder

  The M-Coder (binary) arithmetic encoder class.
- class SPL::MDecoder

  The M-Coder (binary) arithmetic decoder class.

11.9.1 Detailed Description

This file contains interface information for an implementation of the M-Coder arithmetic coder from: ISO/IEC 14496-10:2008 (a.k.a. H.264)

11.10 misc.hpp File Reference

This file contains miscellaneous code.

```
#include <SPL/config.hpp>
```

Functions

- template<class InputIterator , class Size , class OutputIterator >
  OutputIterator SPL::copy_n (InputIterator first, Size count, OutputIterator result)

  This template function is equivalent to std::copy_n in the new C++ 0x standard.

11.10.1 Detailed Description

This file contains miscellaneous code.

11.10.2 Function Documentation

11.10.2.1 copy_n()

```
template<class InputIterator , class Size , class OutputIterator >
OutputIterator SPL::copy_n (
            InputIterator first,
            Size count,
            OutputIterator result )
```

This template function is equivalent to std::copy_n in the new C++ 0x standard.

11.11 pnmCodec.cpp File Reference

This file contains a PNM codec.

```
#include <SPL/config.hpp>
#include <iostream>
#include <sstream>
#include <cassert>
#include <cstdlib>
#include <SPL/pnmCodec.hpp>
```

Functions

- int SPL::pnmPutHeader (std::ostream &out, PnmHeader &header)

  Write a PNM header to the specified stream.
- int SPL::pnmPutBinInt (std::ostream &out, int wordSize, bool sgnd, long val)

  Write an integer from the specified stream.
- int SPL::pnmGetHeader (std::istream &in, PnmHeader &header)

  Read a PNM header from the specified stream.
- int SPL::pnmGetTxtBit (std::istream &in)

  Read a bit from the specified stream.
- long SPL::pnmGetTxtInt (std::istream &in, bool sgnd, int &status)

  Read an integer from the specified stream.
- int SPL::pnmGetChar (std::istream &in)

  Read a character from the specified stream.
- long SPL::pnmGetBinInt (std::istream &in, int wordSize, bool sgnd, int &status)

  Read an integer from the specified stream.
- PnmType SPL::pnmGetType (PnmMagic magic)

  Determine the type (i.e., PGM or PPM) from the magic number.
- PnmFmt SPL::pnmGetFmt (PnmMagic magic)

  Determine the format (i.e., text or binary) from magic number.
- int SPL::pnmGetNumComps (PnmType type)

  Get the number of components from the PNM type.
- int SPL::pnmMaxValToPrec (int maxVal)

  Determine the precision from the maximum value.

11.11.1 Detailed Description

This file contains a PNM codec.

11.11.2 Function Documentation

11.11.2.1 pnmGetBinInt()

```
long SPL::pnmGetBinInt (
            std::istream & in,
            int wordSize,
            bool sgnd,
            int & status )
```

Read an integer from the specified stream.

11.11.2.2 pnmGetChar()

```
int SPL::pnmGetChar (
            std::istream & in )
```

Read a character from the specified stream.

11.11.2.3 pnmGetFmt()

```
PnmFmt SPL::pnmGetFmt (
            PnmMagic magic )
```

Determine the format (i.e., text or binary) from magic number.

11.11.2.4 pnmGetHeader()

```
int SPL::pnmGetHeader (
            std::istream & in,
            PnmHeader & header )
```

Read a PNM header from the specified stream.

11.11.2.5 pnmGetNumComps()

```
int SPL::pnmGetNumComps (
            PnmType type )
```

Get the number of components from the PNM type.

11.11.2.6 pnmGetTxtBit()

```
int SPL::pnmGetTxtBit (
            std::istream & in )
```

Read a bit from the specified stream.

11.11.2.7 pnmGetTxtInt()

```
long SPL::pnmGetTxtInt (
            std::istream & in,
            bool sgnd,
            int & status )
```

Read an integer from the specified stream.

11.11.2.8 pnmGetType()

```
PnmType SPL::pnmGetType (
            PnmMagic magic )
```

Determine the type (i.e., PGM or PPM) from the magic number.

11.11.2.9 pnmMaxValToPrec()

```
int SPL::pnmMaxValToPrec (
            int maxVal )
```

Determine the precision from the maximum value.

11.11.2.10 pnmPutBinInt()

```
int SPL::pnmPutBinInt (
            std::ostream & out,
            int wordSize,
            bool sgnd,
            long val )
```

Write an integer from the specified stream.

11.11.2.11 pnmPutHeader()

```
int SPL::pnmPutHeader (
            std::ostream & out,
            PnmHeader & header )
```

Write a PNM header to the specified stream.

11.12 pnmCodec.hpp File Reference

This file contains a PNM codec.

```
#include <SPL/config.hpp>
#include <iostream>
#include <sstream>
#include <cassert>
#include <cstdlib>
```

Classes

- struct SPL::PnmHeader

  The header information for PNM data.

Enumerations

- enum SPL::PnmMagic

  The signature values that can appear at the start of the header.
- enum SPL::PnmType

  The type of the PNM data.
- enum SPL::PnmFmt

  The format of the PNM data (i.e., binary or text).

Functions

- PnmType SPL::pnmGetType (PnmMagic magic)

  Determine the type (i.e., PGM or PPM) from the magic number.
- PnmFmt SPL::pnmGetFmt (PnmMagic magic)

  Determine the format (i.e., text or binary) from magic number.
- int SPL::pnmMaxValToPrec (int maxVal)

  Determine the precision from the maximum value.
- int SPL::pnmGetNumComps (PnmType type)

  Get the number of components from the PNM type.
- long SPL::pnmOnes (int n)

  Get an integer whose representation in binary consists of the specified number of ones.
- int SPL::pnmGetHeader (std::istream &in, PnmHeader &header)

  Read a PNM header from the specified stream.
- int SPL::pnmPutHeader (std::ostream &out, PnmHeader &header)

  Write a PNM header to the specified stream.
- int SPL::pnmGetChar (std::istream &in)

  Read a character from the specified stream.
- int SPL::pnmGetTxtBit (std::istream &in)

  Read a bit from the specified stream.

- long SPL::pnmGetTxtInt (std::istream &in, bool sgnd, int &status)

  Read an integer from the specified stream.
- long SPL::pnmGetBinInt (std::istream &in, int wordSize, bool sgnd, int &status)

  Read an integer from the specified stream.
- int SPL::pnmPutBinInt (std::ostream &out, int wordSize, bool sgnd, long val)

  Write an integer from the specified stream.
- template<class GetData >
  int SPL::pnmEncode (std::ostream &outStream, int width, int height, int numComps, int maxVal, bool sgnd, GetData &getData, bool binaryFormat)

  Write data encoded in the PNM format to the specified stream.
- template<class GetData >
  int SPL::putData (std::ostream &out, PnmHeader &header, GetData &getData)

  Write the actual image data to a stream.
- template<class Initialize >
  int SPL::pnmDecode (std::istream &inStream, Initialize &initialize)

  Read data encoded in the PNM format from the specified stream.
- template<class PutData >
  int SPL::getData (std::istream &in, PnmHeader &header, PutData &putData)

  Read the actual image data from the specified stream.

Variables

- const int SPL::pnmMaxLineLen = 80

  The maximum line length to be produced when encoding in text format.

11.12.1 Detailed Description

This file contains a PNM codec.

11.12.2 Enumeration Type Documentation

11.12.2.1 PnmFmt

`enum SPL::PnmFmt`

The format of the PNM data (i.e., binary or text).

11.12.2.2 PnmMagic

```
enum SPL::PnmMagic
```

The signature values that can appear at the start of the header.

11.12.2.3 PnmType

```
enum SPL::PnmType
```

The type of the PNM data.

11.12.3 Function Documentation

11.12.3.1 getData()

```
template<class PutData >
int SPL::getData (
            std::istream & in,
            PnmHeader & header,
            PutData & putData )
```

Read the actual image data from the specified stream.

11.12.3.2 pnmDecode()

```
template<class Initialize >
int SPL::pnmDecode (
            std::istream & inStream,
            Initialize & initialize )
```

Read data encoded in the PNM format from the specified stream.

11.12.3.3 pnmEncode()

```
template<class GetData >
int SPL::pnmEncode (
             std::ostream & outStream,
             int width,
             int height,
             int numComps,
             int maxVal,
             bool sgnd,
             GetData & getData,
             bool binaryFormat )
```

Write data encoded in the PNM format to the specified stream.

11.12.3.4 pnmGetBinInt()

```
long SPL::pnmGetBinInt (
             std::istream & in,
             int wordSize,
             bool sgnd,
             int & status )
```

Read an integer from the specified stream.

11.12.3.5 pnmGetChar()

```
int SPL::pnmGetChar (
             std::istream & in )
```

Read a character from the specified stream.

11.12.3.6 pnmGetFmt()

```
PnmFmt SPL::pnmGetFmt (
             PnmMagic magic )
```

Determine the format (i.e., text or binary) from magic number.

11.12.3.7 pnmGetHeader()

```
int SPL::pnmGetHeader (
            std::istream & in,
            PnmHeader & header )
```

Read a PNM header from the specified stream.

11.12.3.8 pnmGetNumComps()

```
int SPL::pnmGetNumComps (
            PnmType type )
```

Get the number of components from the PNM type.

11.12.3.9 pnmGetTxtBit()

```
int SPL::pnmGetTxtBit (
            std::istream & in )
```

Read a bit from the specified stream.

11.12.3.10 pnmGetTxtInt()

```
long SPL::pnmGetTxtInt (
            std::istream & in,
            bool sgnd,
            int & status )
```

Read an integer from the specified stream.

11.12.3.11 pnmGetType()

```
PnmType SPL::pnmGetType (
            PnmMagic magic )
```

Determine the type (i.e., PGM or PPM) from the magic number.

11.12.3.12 pnmMaxValToPrec()

```
int SPL::pnmMaxValToPrec (
            int maxVal )
```

Determine the precision from the maximum value.

11.12.3.13 pnmOnes()

```
long SPL::pnmOnes (
            int n )  [inline]
```

Get an integer whose representation in binary consists of the specified number of ones.

11.12.3.14 pnmPutBinInt()

```
int SPL::pnmPutBinInt (
            std::ostream & out,
            int wordSize,
            bool sgnd,
            long val )
```

Write an integer from the specified stream.

11.12.3.15 pnmPutHeader()

```
int SPL::pnmPutHeader (
            std::ostream & out,
            PnmHeader & header )
```

Write a PNM header to the specified stream.

11.12.3.16 putData()

```
template<class GetData >
int SPL::putData (
            std::ostream & out,
            PnmHeader & header,
            GetData & getData )
```

Write the actual image data to a stream.

11.12.4 Variable Documentation

11.12.4.1 pnmMaxLineLen

```
const int SPL::pnmMaxLineLen = 80
```

The maximum line length to be produced when encoding in text format.

11.13 Sequence.hpp File Reference

Common header for sequence classes.

```
#include <SPL/config.hpp>
```

Classes

- struct SPL::ConvolveMode

  Constants identifying various convolution modes.

11.13.1 Detailed Description

Common header for sequence classes.

11.14 Sequence1.hpp File Reference

This file contains code for the Sequence1 template class.

```
#include <SPL/config.hpp>
#include <iostream>
#include <vector>
#include <SPL/Array1.hpp>
#include <SPL/math.hpp>
#include <SPL/Sequence.hpp>
```

Classes

- class SPL::Sequence1< T >

  A one-dimensional sequence class with lazy copying and reference counting.

Macros

- #define SPL_SEQUENCE1_DEBUG

  Defining this symbol will enable extra code for debugging.
- #define SPL_SEQUENCE1_USE_NEW_CONV

  Defining this symbol will enable the use of new convolution code.
- #define SPL_SEQUENCE1_INLINE

  Prevent the inlining of functions.

Typedefs

- typedef Sequence1< double > SPL::RealSequence1

  Real sequence.
- typedef Sequence1< int > SPL::IntSequence1

  Integer sequence.

Functions

- template<class T >
  std::ostream & SPL::operator<< (std::ostream &out, const Sequence1< T > &f)

  Output a sequence to a stream.
- template<class T >
  std::istream & SPL::operator>> (std::istream &in, Sequence1< T > &f)

  Input a sequence from a stream.
- template<class T >
  SPL_SEQUENCE1_INLINE Sequence1< T > SPL::operator+ (const Sequence1< T > &f, const Sequence1< T > &g)

  Compute the sum of two sequences.
- template<class T >
  SPL_SEQUENCE1_INLINE Sequence1< T > SPL::operator- (const Sequence1< T > &f, const Sequence1< T > &g)

  Compute the difference of two sequences.
- template<class T >
  SPL_SEQUENCE1_INLINE Sequence1< T > SPL::operator* (const Sequence1< T > &f, const Sequence1< T > &g)

  Compute the (element-wise) product of two sequences.
- template<class T >
  SPL_SEQUENCE1_INLINE Sequence1< T > SPL::operator/ (const Sequence1< T > &f, const Sequence1< T > &g)

  Compute the (element-wise) quotient of two sequences.
- template<class T >
  Sequence1< T > SPL::add (const Sequence1< T > &f, const Sequence1< T > &g)

  Compute the sum of two sequences with potentially differing domains.
- template<class T >
  SPL_SEQUENCE1_INLINE Sequence1< T > SPL::operator+ (const T &a, const Sequence1< T > &f)

  Add a value to a sequence.
- template<class T >
  SPL_SEQUENCE1_INLINE Sequence1< T > SPL::operator+ (const Sequence1< T > &f, const T &a)

Add a value to a sequence.

- template<class T >
  SPL_SEQUENCE1_INLINE Sequence1< T > SPL::operator- (const Sequence1< T > &f, const T &a)

  Subtract a value from a sequence.
- template<class T >
  SPL_SEQUENCE1_INLINE Sequence1< T > SPL::operator* (const T &a, const Sequence1< T > &f)

  Compute a scalar multiple of a sequence.
- template<class T >
  SPL_SEQUENCE1_INLINE Sequence1< T > SPL::operator* (const Sequence1< T > &f, const T &a)

  Compute a scalar multiple of a sequence.
- template<class T >
  SPL_SEQUENCE1_INLINE Sequence1< T > SPL::operator/ (const Sequence1< T > &f, const T &a)

  Divide a sequence by a scalar.
- template<class T >
  SPL_SEQUENCE1_INLINE bool SPL::operator== (const Sequence1< T > &f, const Sequence1< T > &g)

  Test two sequences for equality.
- template<class T >
  SPL_SEQUENCE1_INLINE bool SPL::operator!= (const Sequence1< T > &f, const Sequence1< T > &g)

  Test two sequences for inequality.
- template<class T >
  SPL_SEQUENCE1_INLINE bool SPL::approxEqual (const Sequence1< T > &f, const Sequence1< T > &g, T threshold=1e-9)

  Test two sequences for approximate equality.
- template<class T >
  Sequence1< T > SPL::subsequence (const Sequence1< T > &f, int startInd, int size)

  Extract a subsequence from a sequence.
- template<class T >
  SPL_SEQUENCE1_INLINE Sequence1< T > SPL::translate (const Sequence1< T > &f, int delta)

  Translate a sequence by the specified amount.
- template<class T >
  Sequence1< T > SPL::convolve (const Sequence1< T > &f, const Sequence1< T > &g, int mode=ConvolveMode::full)

  Compute the convolution of two sequences.
- template<class T >
  Sequence1< T > SPL::downsample (const Sequence1< T > &f, int factor)

  Downsample a sequence by the specified factor.
- template<class T >
  Sequence1< T > SPL::upsample (const Sequence1< T > &f, int factor, int pad=0)

  Upsample a sequence by the specified factor.
- template<class T >
  Array1< Sequence1< T > > SPL::polyphaseSplit (const Sequence1< T > &seq, int type, int numPhases)

  Split a sequence into its polyphase components.
- template<class T >
  Sequence1< T > SPL::polyphaseJoin (const Array1< Sequence1< T > > &comps, int type)

  Reassemble a sequence from its polyphase components.

11.14.1 Detailed Description

This file contains code for the Sequence1 template class.

11.14.2 Macro Definition Documentation

11.14.2.1 SPL_SEQUENCE1_DEBUG

```
#define SPL_SEQUENCE1_DEBUG
```

Defining this symbol will enable extra code for debugging.

11.14.2.2 SPL_SEQUENCE1_INLINE

```
#define SPL_SEQUENCE1_INLINE
```

Prevent the inlining of functions.

11.14.2.3 SPL_SEQUENCE1_USE_NEW_CONV

```
#define SPL_SEQUENCE1_USE_NEW_CONV
```

Defining this symbol will enable the use of new convolution code.

11.15 Sequence2.cpp File Reference

This file contains code for the Sequence2 template class.

```
#include <SPL/config.hpp>
#include <iostream>
#include <cassert>
#include <cstdlib>
#include <SPL/Sequence2.hpp>
```

Functions

- void SPL::combineDomains (int firstStartX, int firstStartY, int firstEndX, int firstEndY, int secondStartX, int secondStartY, int secondEndX, int secondEndY, int &startX, int &startY, int &endX, int &endY)

  Find the bounding box of the union of the domains of two sequences.

11.15.1 Detailed Description

This file contains code for the Sequence2 template class.

11.15.2 Function Documentation

11.15.2.1 combineDomains()

```
void SPL::combineDomains (
            int firstStartX,
            int firstStartY,
            int firstEndX,
            int firstEndY,
            int secondStartX,
            int secondStartY,
            int secondEndX,
            int secondEndY,
            int & startX,
            int & startY,
            int & endX,
            int & endY )
```

Find the bounding box of the union of the domains of two sequences.

11.16 Sequence2.hpp File Reference

This file contains code for the Sequence2 template class.

```
#include <SPL/config.hpp>
#include <iostream>
#include <vector>
#include <SPL/Array2.hpp>
#include <SPL/Sequence.hpp>
#include <SPL/Sequence1.hpp>
#include <SPL/math.hpp>
```

Classes

- class SPL::Sequence2< T >

  A two-dimensional sequence class with lazy copying and reference counting.

Macros

- #define SPL_SEQUENCE2_USE_NEW_CONV

  Defining this symbol will enable extra code for debugging.
- #define SPL_SEQUENCE2_INLINE inline

  Allow the inlining of functions.

Typedefs

- typedef Sequence2< double > SPL::RealSequence2

  Real sequence.
- typedef Sequence2< int > SPL::IntSequence2

  Integer sequence.

Functions

- template<class T >
  std::ostream & SPL::operator<< (std::ostream &out, const Sequence2< T > &f)

  Output a sequence to a stream.
- template<class T >
  std::istream & SPL::operator>> (std::istream &in, Sequence2< T > &f)

  Input a sequence from a stream.
- template<class T >
  SPL_SEQUENCE2_INLINE Sequence2< T > SPL::operator+ (const Sequence2< T > &f, const Sequence2< T > &g)

  Compute the sum of two sequences.
- template<class T >
  SPL_SEQUENCE2_INLINE Sequence2< T > SPL::operator- (const Sequence2< T > &f, const Sequence2< T > &g)

  Compute the difference of two sequences.
- template<class T >
  SPL_SEQUENCE2_INLINE Sequence2< T > SPL::operator* (const Sequence2< T > &f, const Sequence2< T > &g)

  Compute the (element-wise) product of two sequences.
- template<class T >
  SPL_SEQUENCE2_INLINE Sequence2< T > SPL::operator/ (const Sequence2< T > &f, const Sequence2< T > &g)

  Compute the (element-wise) quotient of two sequences.
- template<class T >
  Sequence2< T > SPL::add (const Sequence2< T > &f, const Sequence2< T > &g)

  Compute the sum of two sequences with potentially differing domains.
- template<class T >
  SPL_SEQUENCE2_INLINE Sequence2< T > SPL::operator+ (const T &value, const Sequence2< T > &f)

  Add a value to a sequence.
- template<class T >
  SPL_SEQUENCE2_INLINE Sequence2< T > SPL::operator+ (const Sequence2< T > &f, const T &value)

  Add a value to a sequence.

- template<class T >
  SPL_SEQUENCE2_INLINE Sequence2< T > SPL::operator- (const Sequence2< T > &f, const T &value)

  Subtract a value from a sequence.
- template<class T >
  SPL_SEQUENCE2_INLINE Sequence2< T > SPL::operator* (const T &value, const Sequence2< T > &f)

  Compute a scalar multiple of a sequence.
- template<class T >
  SPL_SEQUENCE2_INLINE Sequence2< T > SPL::operator* (const Sequence2< T > &f, const T &value)

  Compute a scalar multiple of a sequence.
- template<class T >
  SPL_SEQUENCE2_INLINE Sequence2< T > SPL::operator/ (const Sequence2< T > &f, const T &value)

  Divide a sequence by a scalar.
- template<class T >
  bool SPL::operator== (const Sequence2< T > &f, const Sequence2< T > &g)

  Test two sequences for equality.
- template<class T >
  SPL_SEQUENCE2_INLINE bool SPL::operator!= (const Sequence2< T > &f, const Sequence2< T > &g)

  Test two sequences for inequality.
- template<class T >
  SPL_SEQUENCE2_INLINE bool SPL::approxEqual (const Sequence2< T > &f, const Sequence2< T > &g, T threshold=1e-9)

  Test two sequences for approximate equality.
- template<class T >
  Sequence2< T > SPL::subsequence (const Sequence2< T > &f, int startX, int startY, int width, int height)

  Extract a subsequence from a sequence.
- template<class T >
  SPL_SEQUENCE2_INLINE Sequence2< T > SPL::translate (const Sequence2< T > &f, int deltaX, int deltaY)

  Translate a sequence by the specified amount.
- template<class T >
  Sequence2< T > SPL::convolve (const Sequence2< T > &f, const Sequence2< T > &g, int mode)

  Compute the convolution of two sequences.
- template<class T >
  Sequence2< T > SPL::convolveSeparable (const Sequence2< T > &f, const Sequence1< T > &horzFilt, const Sequence1< T > &vertFilt, int mode=ConvolveMode::full)

  Compute the convolution of a sequence with two 1-D filters (i.e., convolution with a separable filter).
- template<class T >
  Sequence2< T > SPL::downsample (const Sequence2< T > &f, int factorX, int factorY)

  Downsample a sequence in each of the horizontal and vertical directions by the specified factors.
- template<class T >
  Sequence2< T > SPL::upsample (const Sequence2< T > &f, int factorX, int factorY)

  Upsample a sequence in each of the horizontal and vertical directions by the specified factors.
- template<class T >
  Sequence2< T > SPL::upsample (const Sequence2< T > &f, int factorX, int factorY, int padX, int padY)

  Upsample a sequence in each of the horizontal and vertical directions by the specified factors.
- template<class T >
  Array2< Sequence2< T > > SPL::polyphaseSplit (const Sequence2< T > &seq, int typeX, int numPhasesX, int typeY, int numPhasesY)

  Split a sequence into its polyphase components.
- template<class T >
  Sequence2< T > SPL::polyphaseJoin (const Array2< Sequence2< T > > &comps, int typeX, int typeY)

  Reassemble a sequence from its polyphase components.

11.16.1 Detailed Description

This file contains code for the Sequence2 template class.

11.16.2 Macro Definition Documentation

11.16.2.1 SPL_SEQUENCE2_INLINE

```
#define SPL_SEQUENCE2_INLINE inline
```

Allow the inlining of functions.

11.16.2.2 SPL_SEQUENCE2_USE_NEW_CONV

```
#define SPL_SEQUENCE2_USE_NEW_CONV
```

Defining this symbol will enable extra code for debugging.

Defining this symbol will enable some new code for convolution.

11.17 Timer.cpp File Reference

The file contains code for obtaining timing/memory usage information.

```
#include <SPL/config.hpp>
#include <SPL/Timer.hpp>
#include <iostream>
#include <fstream>
#include <cassert>
#include <iterator>
#include <vector>
#include <string>
#include <unistd.h>
#include <boost/lexical_cast.hpp>
#include <boost/tokenizer.hpp>
```

Functions

- double SPL::getPeakMemUsage ()

  Get the peak memory usage for the process.
- double SPL::getCurrentMemUsage ()

  Get the amount of memory currently being used by the process.

11.17.1 Detailed Description

The file contains code for obtaining timing/memory usage information.

11.18 Timer.hpp File Reference

This file contains code for the Timer class.

```
#include <SPL/config.hpp>
#include <iostream>
#include <cstdlib>
```

Classes

- class SPL::Timer

  A class for making timing measurements.

Functions

- double SPL::getCurrentMemUsage ()

  Get the amount of memory currently being used by the process.
- double SPL::getPeakMemUsage ()

  Get the peak memory usage for the process.

11.18.1 Detailed Description

This file contains code for the Timer class.