Programming in C++ using RAVL

Bill Christmas

This presentation:

- includes a bit of the background to Ravl
- gives you an idea of some of the functionality available in RAVL;
- provides some examples of programming using RAVL;

..... *not* a comprehensive tour of RAVL

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RAVL features

- C++ class library:
  - Basic containers
  - System interface
  - Maths, geometry inc. projective geometry - 2D & 3D
  - Image, video, 2D & 3D, audio and supporting tools
  - Pattern recognition
  - GUIs (GTK-based)
  - Applications (a few)
- Motivation:
  - lack of existing s/w (c. 1995)
  - C++ "difficult"
  - explicit memory management tedious
- Consistent programming interface
- Not much C++ knowledge required to use it
- RAVL and STL
- RAVL and OpenCV

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- Multi-platform: Linux, MS, ...
- Used for real products (Omniperception Ltd.)
- Source code available from SourceForge, under LGPL
- Simplified compilation system
- Recompiled and tested nightly
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- RAVL namespaces — easily overlooked
- RAVL primitive typedefs — for more consistent word lengths
- RAVL constants — under `RavlConstN` namespace:

```
RealT x = RavlConstN::pi;
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using namespace RavlConstN;
RealT x = pi;
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- `IndexC` - replacement for `int` that provides more consistent rounding behaviour
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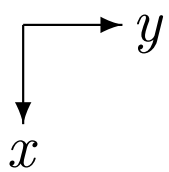

Member function syntax

In general, C++ classes have 2 ways of accessing member functions:

- "struct" syntax:

```
a.b();
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- "pointer" syntax:

```
a->b();
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Reference counting: big / small objects

All "big" objects:

- are generally objects of indeterminate size (e.g. containers)
- have a *handle* (a reference-counted pointer)
- identified by
  inheritance of `RCHandleC` or `BufferAccessC`
  (+ StringC)

"Small" objects behave like built-ins (int, double etc.)

$\longrightarrow$ "JAVA-like" class interfaces
$\longrightarrow$ (almost) no pointers
$\longrightarrow$ automatic destruction
$\longrightarrow$ no memory leaks (I believe)
$\longrightarrow$ thread-safe for SMP

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Example: big object

Only the handle is copied in this example, *not* the contents (like a "C" array):

```
Array1dC<IntT>a(6);
a.Fill(27);
Array1dC<IntT>b = a;
b[4] = 55;
cout << a[4] << endl;
```

```
> myprog
55
```

Thus the value of a[4] is also changed.

Copying big objects


```
Array1dC<DListC<IntT> > a(6);
// then initialise object 'a' somehow

// just copies array handle:
Array1dC<DListC<IntT> > b = a;
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```
// copies array of list handles:
Array1dC<DListC<IntT> > b = a.Copy();
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// copies everything (maybe - best avoided 'til ready):
Array1dC<DListC<IntT> > b = a.DeepCopy()
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Text and files

- `StringC` - for basic text processing. E.g.:

```
StringC a("Hello");  StringC b("World");
StringC c = a + ' ' + b;
cout << c.from('o') << endl;
```

generates "o World".

- `FilenameC`, `DirectoryC` — derived from `StringC` to provide information on and manipulate file properties and directories:

```
FilenameC f("myfile.txt");
if (f.Exists()) {
  f.SetPermissions(0444);
  f.Rename("yourfile.txt");
}
```

- Using "-" as a file name denotes stdin or stdout as appropriate.

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Command-line options

`OptionC` handles processing of command-line options and parameters. This code fragment:

```
OptionC opt(argc, argv);
bool select     (opt.Boolean("bw",       "b&w (default: colour)"));
RealT gamma     (opt.Real   ("gamma", 1.0,       "display gamma"));
Index2dC size   (opt.Index2d("size",  576, 720,  "image size"));
StringC logFile (opt.String ("log",   "-",       "log file"));
StringC opName  (opt.String ("",      "out.ppm", "o/p image"));
opt.Compulsory("size");
opt.Check();
```

might handle this command line:

```
myprog file.pgm -bw -size 768 1024
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- The default value of a boolean option is always `false`.
- Options without tags ("opName") *must* be handled last.
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Command-line options (cont.)

The command:

```
myprog -help
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generates this o/p:

```
Usage: myprog [options]
   -bw (false) [false] b&w (default: colour)
   -gamma (1) [1] display gamma
   -size (576 720) [576 720] image size
   -log (-) [-] log file
   arg (out.ppm) [out.ppm] o/p image name
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Dependencies:
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Command-line errors produce a similar output.

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- `IStreamC / OStreamC`: provide the usual text stream I/O.
- `BinIStreamC / BinOStreamC`: corresponding binary I/O - reads back in exactly what is written out (c.f. `fread / fwrite`).
- `StrIStreamC / StrOStreamC`: like `IStreamC / OStreamC`, but reads from / writes to a string (like `sscanf / sprintf`). Can also be used (with care) to initialise small arrays:

```
SArray1dC<RealT> coeffs(5);
StrIStreamC ("5 0.363 0.291 0.135 0.012 -0.030") >> coeffs;
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- `XMLIStreamC / XMLOStreamC`: additional XML support for linear XML file handling.

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Series of template classes that generate complex objects:

- arrays: `Array1dC`, `Array2dC`, `Array3dC`
- "simple" versions: `SArray1dC`, `SArray2dC`, `SArray3dC`
- dynamic 1D arrays: `DArray1dC`
- doubly linked lists: `DListC`
- hash tables: `HashC`, `RCHashC`
- trees
- queues
- .....

Iterators for containers

"Intelligent pointers": Each container class has one or more associated iterators to provide efficient indexing through the container object. So, to take square root of array values:

```
#include "Ravl/Array1d.hh"
#include "Ravl/Array1dIter.hh"

using namespace RavlN;

int main() {
  Array1dC<RealT>a(1,4);
  for (Array1dIterC<RealT> i(a); i; ++i) {
    *i = Sqrt(i.Index());
  }
  cout << a << endl;
}
```

Compiler options for array bound checking.

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```

☹ Compiler options for array bound checking.

Compound iterators

- You can iterate over more than one object using a single compound iterator.
  - E.g. to copy one array to another that is offset from the first:

```
#include "Ravl/Array1d.hh"
#include "Ravl/Array1dIter2.hh"
#include "Ravl/Index.hh"

using namespace RavlN;

int main() {
  Array1dC<RealT>a(4);
  Array1dC<IndexC>b(3,6);
  a.Fill(8.6);
  for (Array1dIter2C<RealT,IndexC> i(a,b); i; ++i) {
    i.Data2() = i.Data1();
  }
}
```

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int main() {
  Array1dC<RealT>a(4);
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  a.Fill(8.6);
  for (Array1dIter2C<RealT,IndexC> i(a,b); i; ++i) {
    i.Data2() = i.Data1();
  }
}
```

`ImageC`: 2-D array with extensions

- Can have any pixel type - byte, integer, real, boolean ....
- Variety of pre-defined pixel types
- Image border is object of class `ImageRectangleC`
- Comprehensive file and device I/O for images and video
- Image processing / computer vision algorithms

Filtering images

Example using user-specified mask:

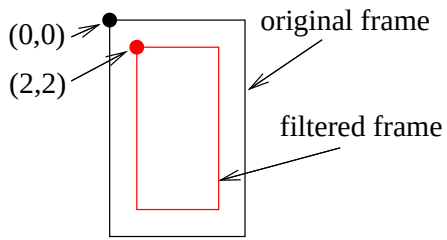
```
#include "Ravl/Image/ConvolveSeparable2d.hh"
#include "Ravl/IO.hh"
#include "Ravl/StrStream.hh"
using namespace RavlN;
using namespace RavlImageN;

int main (int argc, char* argv[]) {
  ImageC<RealT> im;  Load ("image.pgm", im);
  Array1dC<RealT> coeffs;
  StrIStreamC ("-2 2 1 3 5 3 1") >> coeffs;
  ConvolveSeparable2dC<RealT> filter(coeffs);
  im = filter.Apply(im);
  cout << im.Frame() << endl;
}
```

Note symmetric image shrinkage:

> myprog

2 297 2 197



Indexing images

Really bad:

```
for (IntT x(0); x<576; ++x)  for (IntT y(0); y<720; ++y)
  im[x][y] += 3;
```

Slightly better:

```
for (IntT x(0); x<im.Rows(); ++x)  for (IntT y(0); y<im.Cols(); ++y)
  im[x][y] += 3;
```

Better:

```
for (IndexC x(im.TRow()); x<=im.BRow(); ++x)
  for (IndexC y(im.LCol()); y<=im.RCol(); ++y)
    im[x][y] += 3;
```

Best (and fastest):

```
for (Array2dIterC<IntT>i(im); i; ++i)
  *i += 3;
```

Indexing images

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Best (and fastest):

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for (Array2dIterC<IntT>i(im); i; ++i)
  *i += 3;
```
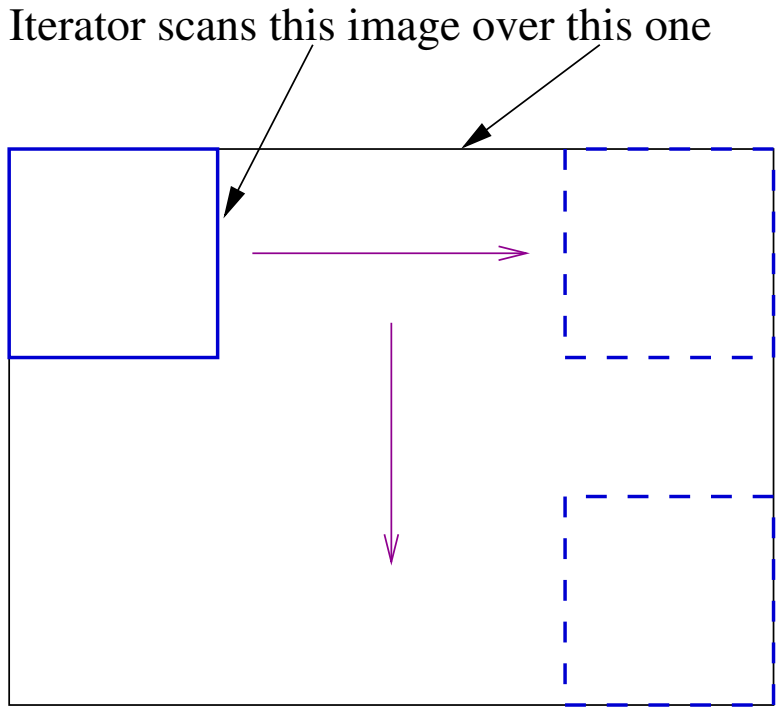

Sliding one image around another

The `Rectangle2dIterC` iterator allows one image to scan over another larger one:



— e.g. for image convolution

Subimages

Construct new image from old:

```
ImageC<ByteT> a(576,720);
a.Fill(12);
ImageC<ByteT> b(a, IndexRange2dC(100,400,200,700));
b.Fill(135);
```

Data is *not* copied when constructing `b`. So `a` finally is:

Image I/O using `Load()` / `Save()`

- can be files or devices ("virtual files")
- conversion between pixel types is automatic
  E.g. conversion of RGB 8-bit file to grey-scale float object:

```
#include "Ravl/IO.hh"
#include "Ravl/Image/Image.hh"

using namespace RavlN;
using namespace RavlImageN;

int main (int argc, char* argv[]) {
  ImageC<RealT> im;
  if (! Load ("image.png", im))    cerr << "panic!!" << endl;
  Save ("image.pgm", im);
  Save ("@X:image", im); // write to screen with title "image"
}
```

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  Save ( "@X:image" , im); // write to screen with title "image"
}
```

Image I/O (cont.)

Corresponding `defs.mk` file:

```
MAINS= myprog.cc

PROGLIBS = RavlImageIO RavlExtImgIO RavlDPDisplay
```

Image sequence I/O — to read and write a sequence:

```
#include "Ravl/DP/SequenceIO.hh"
#include "Ravl/Image/Image.hh"
#include "Ravl/Image/ByteRGBValue.hh"
using namespace RavlN;
using namespace RavlImageN;

int main (int argc, char* argv[]) {
  if (argc < 3)  exit(-1);
  DPIPortC<ImageC<ByteRGBValueC> > in;
  if(!OpenISequence(in, argv[1]))  exit(-2);
  DPOPortC<ImageC<ByteRGBValueC> > out;
  if(!OpenOSequence(out, argv[2])) exit (-3);
  ImageC<ByteRGBValueC> im;
  while(in.Get(im))
    out.Put(im);
}
```

Video I/O (cont.)

Corresponding `defs.mk` file:

```
MAINS= seqio.cc

PROGLIBS = RavlVideoIO RavlLibFFmpeg RavlDPDisplay
```

Run it like this to convert to sequence of 'ppm's:

```
seqio movie.mpeg tmp.ppm
```

Run it like this to display the file:

```
seqio movie.mpeg @X
```

[1]

Run it like this to display a camera o/p (include RavlImgIOV4L library):

```
seqio @V4L @X
```

[1] To run this example, you need to (a) be using xpdf to run the presentation, (b) have compiled up the "seqio" example, and (c) have "movie.mpeg" in your current directory.

Video I/O (cont.)

Corresponding `defs.mk` file:

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More general I/O

Automatic numbering of file sequences:

- `OpenOSequence(out,"a.ppm")` creates a0.ppm, a1.ppm, ..., a10.ppm, ...
- `OpenOSequence(out,"a%4d.ppm")` creates a0000.ppm, a0001.ppm, ..., a0010.ppm, ...
- `OpenISequence(in,"a.ppm")` will read either style.
- `Load()`, `Save()`, `OpenISequence`, `OpenOSequence` can also be used for reading writing arbitrary objects (including images) as text files:

```
ImageC<IntT>
0 1 0 2
32 35 45
33 39 42
```

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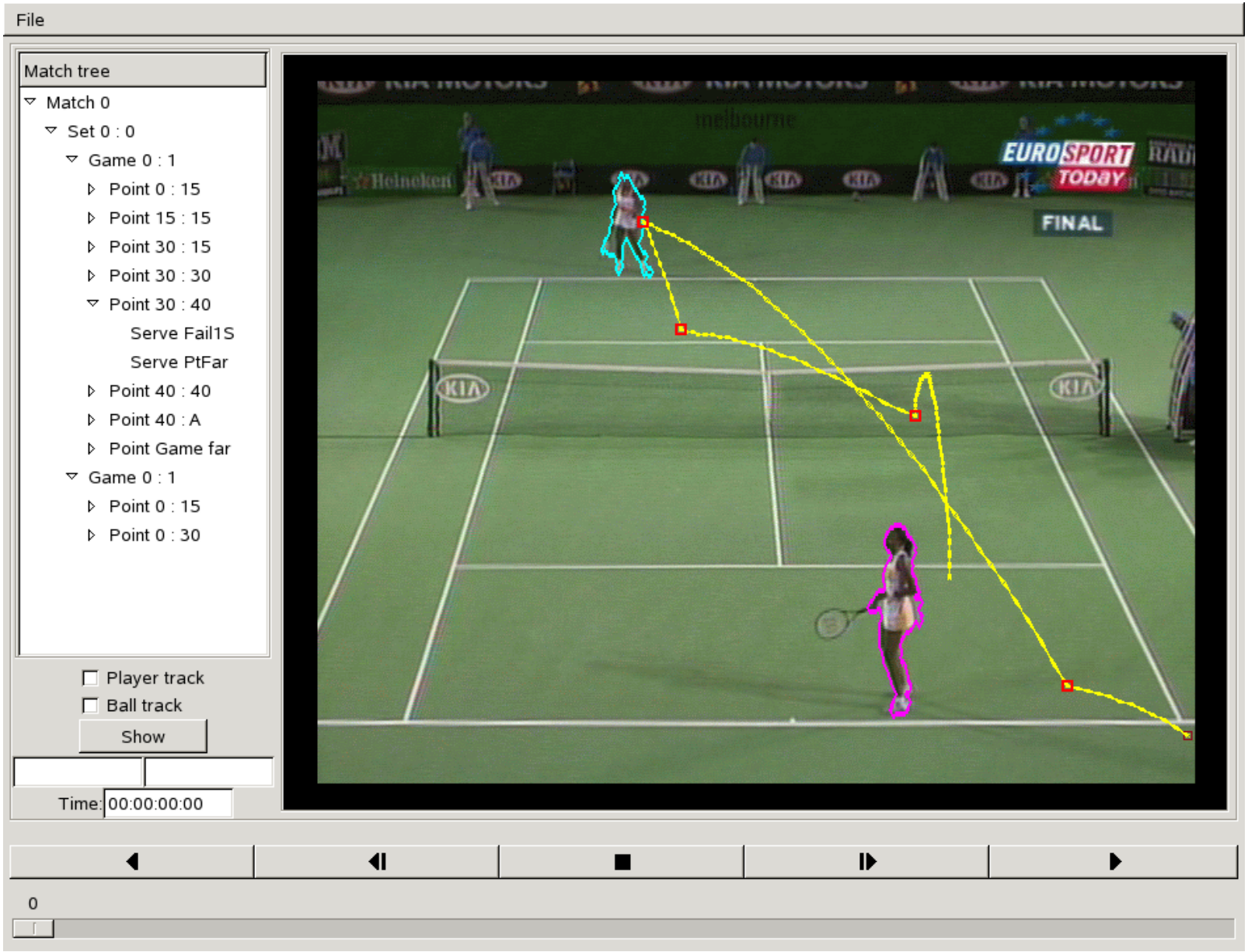

Maths

- linear algebra
- Euclidean geometry
- projective geometry
  - mosaicking:

- .....

Pattern recognition

Some standard classifiers:

- SVM
- GMM
- ANN
- KNN
- .....

Optimisers:

- conjugate gradient
- .....

O/S interfaces: threads

1. Define the function to be launched as a thread, e.g.:

```
bool PrintNumber(int &i) {
  cout << "PrintNumber called with value " << i << endl;
  return true;
}
```

2. Create a "trigger":

```
TriggerC myTrigger = Trigger(&PrintNumber, 53);
```

3. Then launch it as a separate thread:

```
LaunchThreadC thread = LaunchThread (myTrigger) ;
```

4. and wait for it to finish:

```
thread.Wait()
```

QMake: a compilation tool

Compiling main programs

To compile (1 or more) main program(s) in a directory:

- Create a file called `defs.mk` in that directory, consisting of one line to tell QMake what the files are called:

```
MAINS = main1.cc main2.cc main3.cc
```

- Execute the command `qm`

If your program(s) need RAVL libraries that QMake cannot find automatically at link time (mainly I/O libs), you will need to add them to the `defs.mk` file. E.g.:

```
MAINS = main1.cc main2.cc main3.cc
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Adding extra libraries

You can including your own class and header files:

```
MAINS = main1.cc main2.cc main3.cc
HEADERS = header1.hh header2.hh
SOURCES = class1.cc class2.cc
```

And much more...

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And much more...

Compiling with QMake

- `qm` is just an alias for `make`:

```
> alias qm
gmake -f /vol/vssp/localsoft/Auto/linux/Ravl/share/RAVL/QMake/QMake.mk USERBUILD=1 !* && rehash
```

- For faster linking:

  `qm shared`

- For faster runtime:

  `qm optshared`

- Debugging using ddd / gdb:

  `qm debugshared`

  - a bit of help in debugging RAVL
  - `qm shared`, `qm debugshared` → run-time array bound checking

- `$PROJECT_OUT`, `/tmp/<user>/qm` can always be deleted:

  `qm distclean`

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Compiling with QMake (cont.)

Static or shared (dynamic) libraries?

- static libs (use `qm`, `qm debug`, `qm opt`)
  – good for long-running jobs (libs can't change)
- shared libs (use `qm shared`, `qm debugshared`, `qm optshared`)
  – good for development (fast linking)

"Complete" list of `qm` commands:

```
qm help
```

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"Complete" list of `qm` commands:

```
qm help
```

Documentation

- Class documentation automatically generated from header files
- Background documentation in branches, not in class leaves
- – while examples *are* usually in class leaves
- Search engine
- 2 lots of documentation: internal, public
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- Contributions always welcome (including C):
  - for RAVL itself
  - for use within CVSSP
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We are here to help