

Shape Predicates

15-494 Cognitive Robotics
David S. Touretzky &
Ethan Tira-Thompson

Carnegie Mellon
Spring 2008

The World is Full of Shapes

- When we extract shapes from camera images, we may get a lot of objects.
- We need ways of selecting and comparing shapes.
- “Find all the orange things.”
“Find all the lines longer than this line.”
- Tekkotsu provides *shape predicates* for testing shapes. These can be composed to form complex tests.
- To use these, you need to understand C++ functors.

Function Objects (Functors)

```
#include <iostream>
using namespace std;

class MyFunctor {
public:
    void operator() () const { cout << "Foo!" << endl; }
};

int main() {
    MyFunctor fluffy;

    fluffy();
}
```

Functors Can Store Values

```
class BiggerThan {
```

Private comparison value

```
private:  
    int value;
```

Constructor initializes the private value

```
public:  
    BiggerThan(int val) : value(val) {}
```

```
    bool operator() (int x) const { return x > value; }
```

```
};
```

Function call operator compares x against the value

Testing BiggerThan

```
int main() {  
    BiggerThan biggest(5);  
    for (int i = 3; i < 8; i++ )  
        cout << i << (biggest(i) ? " passes" : " fails" ) << endl;  
}
```

3 fails
4 fails
5 fails
6 passes
7 passes

Function Conjunction

```
class AndBigSmall {
private:
    BiggerThan biggest;
    SmallerThan smallest;

public:
    AndBigSmall(BiggerThan b, SmallerThan s) :
        biggest(b), smallest(s) {}

    bool operator() (int x) { return biggest(x) && smallest(x); }
};
```

```
int main() {
    AndBigSmall myconj(BiggerThan(0), SmallerThan(100));
    for ( int i = -10; i < 150; i+=40 )
        cout << i << " gives " << myconj(i) << endl;
}
```

```
-10 gives 0
30 gives 1
70 gives 1
110 gives 0
```

STL functional.h

- The STL (Standard Template Library) provides classes called `unary_function` and `binary_function` from which functors can be composed.

```
class BiggerThan : unary_function<int, bool> {  
private:  
    int value;  
public:  
    BiggerThan(int val) : value(val) {}  
    bool operator() (int x) { return x > value; }  
};
```

- These user-defined functor classes can then be used with STL functions for searching, etc.
- But they're kind of awkward.

Shape Predicates

- The Shape classes provide their own functor mechanism for defining shape predicates.
- Easier to use than the generic STL.
- Some predicates for common shape tests are built in, e.g.,
 - Comparing the positions of two shapes (left/right or above/below)
 - Comparing the lengths of two lines
 - Comparing line orientations
- New predicates are easy to define.

Shape<LineData> Functors

- Compare the lengths of all the pink lines in the image against that of the third line.

```
NEW_SKETCH(camFrame, uchar, sketchFromSeg());  
  
NEW_SKETCH(pink_stuff, bool,  
           visops::colormask(camFrame, "pink"));  
  
NEW_SHAPEVEC(lines, LineData,  
             LineData::extractLines(pink_stuff));  
  
SHAPEVEC_ITERATE(lines, LineData, ln)  
  if ( LineData::LengthLessThan()(ln, lines[2]) )  
    cout << "Shorter: " << ln->getId() << endl;  
  else  
    cout << "Longer: " << ln->getId() << endl;  
END_ITERATE;
```

LineData::LengthLessThan

- Class-specific shape predicates are defined with the respective shape, e.g., in LineData.h and LineData.cc.

In LineData.h:

```
class LengthLessThan : public BinaryShapePred<LineData> {  
public:  
    bool operator() (const Shape<LineData> &ln1,  
                    const Shape<LineData> &ln2) const;  
};
```

In LineData.cc:

```
void LineData::LengthLessThan::operator()  
    (const Shape<LineData> &line1,  
     const Shape<LineData> &line2) const {  
    return line1->getLength() < line2->getLength(); }  
};
```

Generic Shape Predicates

- Some predicates work for shapes of any type. They are defined on class ShapeRoot. Example: IsColor.

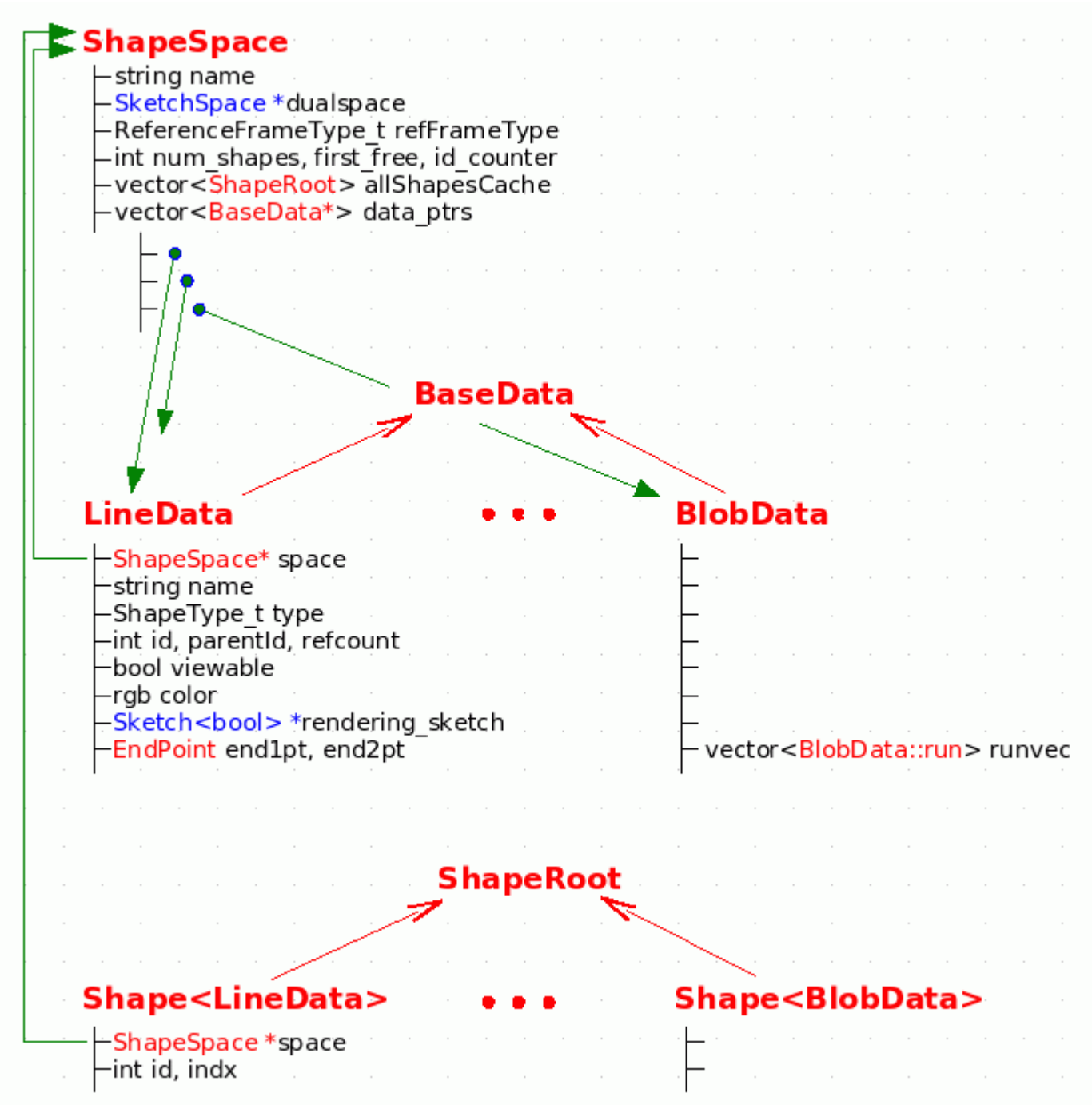
```
NEW_SHAPEVEC(blobs, BlobData,  
             BlobData::extractBlobs(camFrame,50));
```

```
IsColor orangetest("orange");
```

```
SHAPEVEC_ITERATE(blobs, BlobData, b)  
  if ( orangetest(b) )  
    cout << "Orange: " << b->getId() << endl;  
  else  
    cout << "Not orange: " << b->getId() << endl;  
END_ITERATE;
```

Subclasses of BaseData:

Subclasses of ShapeRoot:



Generic IsColor Predicate

```
class IsColor : public UnaryShapeRootPred {
private:
    rgb color;

public:
    IsColor(rgb col) : UnaryShapeRootPred(), color(col) {}

    IsColor(std::string const &colorname) :
        UnaryShapeRootPred(),
        color(ProjectInterface::getColorRGB(colorname)) {}

    bool operator() (const ShapeRoot &shape) const {
        return shape->getColor() == color; }

};
```

Note: the colorname string is looked up once, by the constructor, and the result is stored in the private variable color. When the functor is invoked on a ShapeRoot, no lookup is necessary.

IsLeftOf / IsLeftOfThis

- IsLeftOf()
 - This is a BinaryShapeRootPred that requires two arguments, and compares their centroids:

IsLeftOf() (line2, blob6)

- IsLeftOfThis(x)
 - This is a UnaryShapeRootPred that requires one argument:

IsLeftofThis(line2) (blob6)

constructor argument

Using IsLeftOfThis

- An instance of IsLeftOfThis stores a ShapeRoot inside it, and uses it for comparison tests.

```
IsLeftOfThis mytest(lines[4]);
```

```
SHAPEVEC_ITERATE(lines, LineData, ln)  
  if ( mytest(ln) )  
    cout << "This is left of me: "  
          << ln->getId() << endl;  
END_ITERATE;
```

Built-In Shape Predicates

ShapeRoot:

IsColor
IsType
IsName

IsLeftOf / IsRightOf
IsAbove / IsBelow

IsLeftOfThis ...
IsAboveThis ...

Shape<LineData>:

LengthLessThan

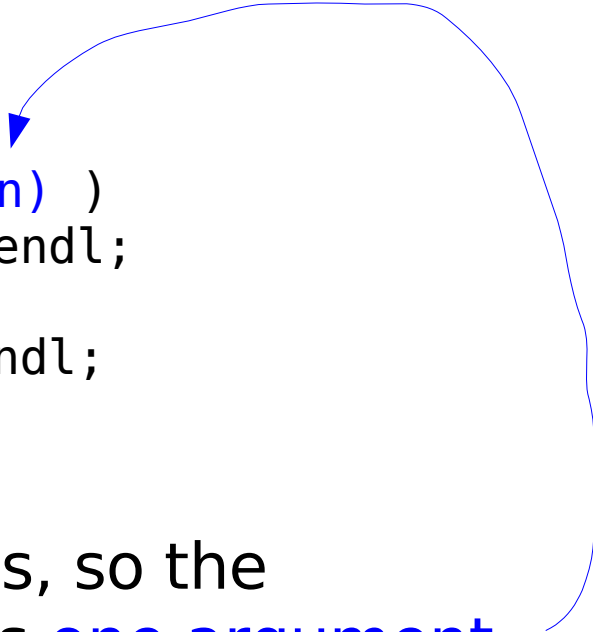
IsHorizontal
IsVertical

ParallelTest
PerpendicularTest
ColinearTest

AndPred / OrPred

- Because shape predicates are classes, we can compose them using the functors AndPred and OrPred.

```
SHAPEVEC_ITERATE(lines, LineData, ln)
  if ( AndPred(IsColor("pink"),
              IsLeftOfThis(lines[3])) (ln) )
    cout << "winner: " << ln->getId() << endl;
  else
    cout << "loser: " << ln->getId() << endl;
END_ITERATE;
```



- We are composing two unary predicates, so the result is also a unary predicate: it takes **one argument**.

Vectors of ShapeRoots

- `camShS.allShapes()` returns all the shapes in the shape space, as a `vector<ShapeRoot>`.
- `camShS` will be automatically coerced to `vector<ShapeRoot>` by an implicit call to `allShapes()`
- Use `SHAPEROOTVEC_ITERATE(vec,var)` to iterate:

```
SHAPEROOTVEC_ITERATE(camShS, s)
  if ( OrPred(IsType(blobDataType),
              IsType(lineDataType)) (s) )
    cout << "Is blob or line: " << s->getId() << endl;
END_ITERATE;
```

- Shape type constants like `blobDataType` are defined in `ShapeTypes.h`

Mirroring STL Search Functions

- The STL provides a collection of functions for searching through a vector using either a binary comparison predicate or a unary test predicate.
- Tekkotsu provides similar functions for shape predicates:
 - `find_if`, `subset`, `max_element`, `stable_sort`, `remove_copy_if`
- There are also some new functions unique to shapes:
 - `find_shape`, `select_type`

Filtering Shapes

- Find the first blob:

```
NEW_SHAPE(blob0, BlobData, find_if<BlobData>(camShS));
```

- camShS is treated as shorthand for camShS.allShapes()
- If no blobs found, an invalid Shape is returned

- Find all the blobs:

```
NEW_SHAPE_VEC(all_blobs, BlobData,  
              select_type<BlobData>(camShS));
```

More Filtering and Searching

- Find all the orange blobs:

```
NEW_SHAPEVEC(orange_blobs, BlobData,  
             subset(all_blobs, IsColor("orange")))
```

- Find the longest line:

```
NEW_SHAPE(longest, LineData,  
          max_element(lines,  
                      LineData::LengthLessThan()))
```

- Test is “less than”, but `max_element` returns *longest*.

Implementing max_element

```
// from DualCoding/ShapeFuns.h
```

```
template<class T, typename ComparisonType>  
Shape<T> max_element(const vector<Shape<T> > &vec,  
                    ComparisonType comp) {
```

```
    typename vector<Shape<T> >::const_iterator result =  
        max_element(vec.begin(), vec.end(), comp);
```

```
    if ( result != vec.end() )  
        return *result;  
    else  
        return Shape<T>();  
}
```

If no elements, return
an invalid shape.

T = LineData

ComparisonType = LengthLessThan

vec is a SHAPEVEC of LineData

comp is an instance of
LengthLessThan

Negating a Predicate

- Use `not1(p)` to negate a unary predicate:

```
NEW_SHAPEROOTVEC(non_orange,  
                 subset(camShS, not1(IsColor("orange"))));
```

- Use `not2(p)` to negate a binary (comparison) predicate:

```
NEW_SHAPEVEC(shortlines, LineData,  
              stable_sort(lines, not2(LineData::LengthLessThan())));
```

Inside SHAPEVEC_ITERATE

```
SHAPEVEC_ITERATE(lines, LineData, ln)  
    do_something_with(ln);  
END_ITERATE;
```

Expands into:

```
for ( vector<Shape<LineData> >::_iterator ln_it = lines.begin();  
      ln_it != lines.end(); ln_it++ ) {  
    Shape<LineData> &ln = *ln_it;  
    do_something_with(ln);  
};
```


Nested Iteration

```
NEW_SHAPEVEC(lines, LineData, select_type<LineData>(camShS));  
lines = stable_sort(lines, not2(LineData::LengthLessThan()));
```

```
SHAPEVEC_ITERATE(lines, LineData, ln1)  
  SHAPENEXT_ITERATE(lines, LineData, ln1, ln2)  
    if ( LineData::ParallelTest()(ln1, ln2) )  
      cout << ln1 << " parallel to " << ln2 << endl;  
    if ( LineData::PerpendicularTest()(ln1, ln2) )  
      cout << ln1 << " perpendicular to " << ln2 << endl;  
    if ( LineData::ColinearTest()(ln1, ln2) )  
      cout << ln1 << " colinear with " << ln2 << endl;  
  END_ITERATE;  
END_ITERATE;
```

```
Shape<LineData>(id=10002,indx=1) perpendicular to  
  Shape<LineData>(id=10005,indx=4)  
... etc.
```