

Shape Predicates

15-494 Cognitive Robotics
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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)

A functor is an object that can accept function calls via operator():

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

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

int main() {
    MyFunctor fluffy;

    cout << sizeof(fluffy) << " ";
    fluffy();
}
```

Functors Can Store Values

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

Private comparison value

Constructor initializes the private value

Function call operator compares x against the private value

Testing BiggerThan

```
int main() {  
    BiggerThan fivetest(5);  
    for (int i = 3; i < 8; i++ )  
        cout << i << (fivetest(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) const
        { 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 : public unary_function<int, bool> {  
private:  
    int value;  
public:  
    BiggerThan(int val) : value(val) {}  
    bool operator() (int x) const { 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 lines in the image against that of the third line.

```
NEW_SHAPEVEC(lines, LineData,  
             select_type<LineData>(camShS));  
  
SHAPEVEC_ITERATE(lines, LineData, someLine)  
    if ( LineData::LengthLessThan()(someLine, lines[2]) )  
        cout << "Shorter: " << someLine->getId() << endl;  
    else  
        cout << "Longer: " << someLine->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:

```
bool 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.

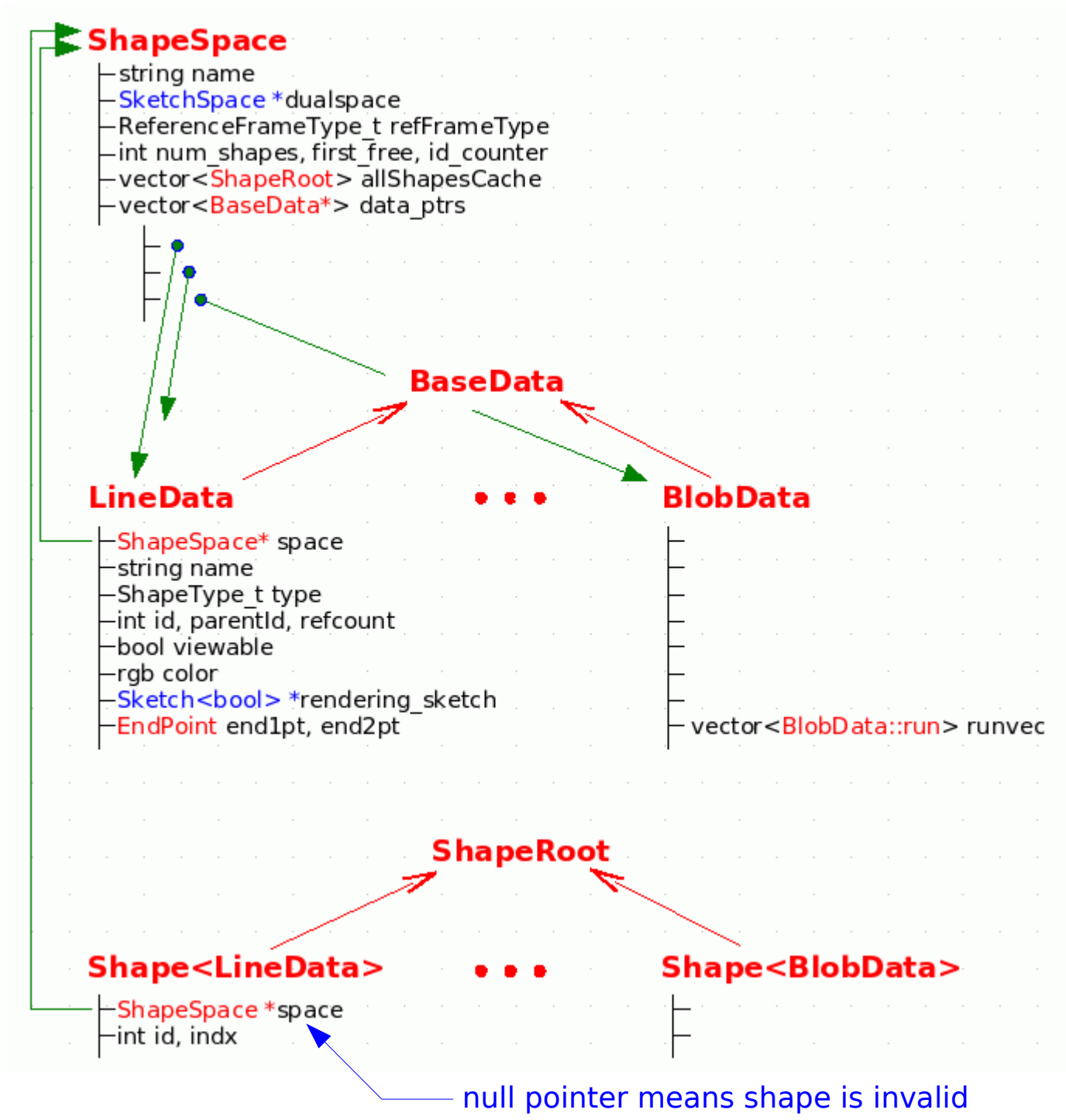
```
NEW_SHAPEVEC(blobs, BlobData,  
             select_type<BlobData>(camShS));
```

```
IsColor redtest("red");
```

```
SHAPEVEC_ITERATE(blobs, BlobData, b)  
  if ( redtest(b) )  
    cout << "Red: " << b->getId() << endl;  
  else  
    cout << "Not red: " << 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 rgb value 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

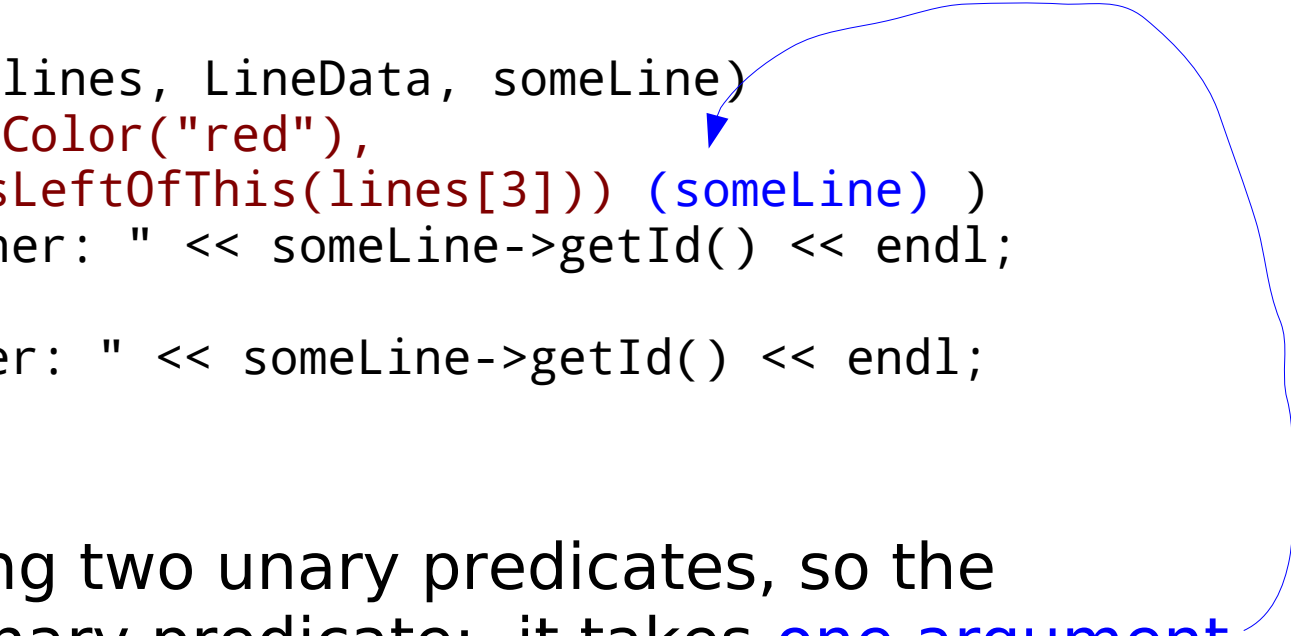
IsHorizontal
IsVertical

ParallelTest
PerpendicularTest
ColinearTest

AndPred / OrPred

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

```
SHAPEVEC_ITERATE(lines, LineData, someLine)
  if ( AndPred(IsColor("red"),
              IsLeftOfThis(lines[3])) (someLine) )
    cout << "winner: " << someLine->getId() << endl;
  else
    cout << "loser: " << someLine->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 `std::vector<ShapeRoot>`.
- `camShS` will be automatically coerced to `std::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 `DualCoding/ShapeTypes.h`

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);  
};
```

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`
- All are defined in `DualCoding/ShapeFuns.h`

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 red blobs:

```
NEW_SHAPEVEC(red_blobs, BlobData,  
             subset(all_blobs, IsColor("red")))
```

- Find the longest line:

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

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

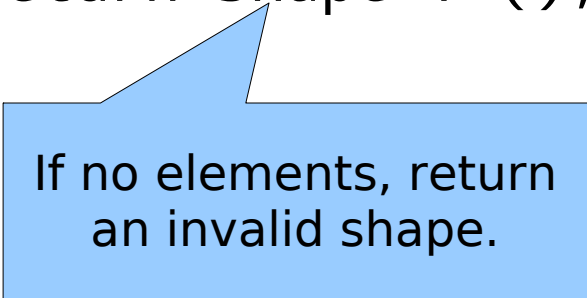
Implementing max_element

```
// 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

Functors for Negating a Predicate

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

```
NEW_SHAPEROOTVEC(non_red,  
                 subset(camShS, not1(IsColor("red"))));
```

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

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


Nested Iteration: Compare Lines, Longest First

```
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.