Shape Representations

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

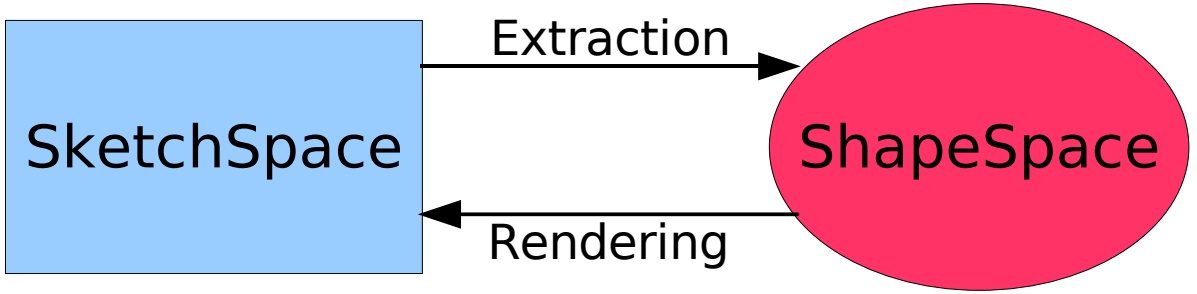
Carnegie Mellon
Spring 2011

Types of Shapes

- Basic:
  - PointData, LineData, EllipseData
- Complex:
  - PolygonData, BlobData, MarkerData
- 3-D:
  - SphereData, BrickData
- Robot shape:
  - AgentData

Shapes Live in a ShapeSpace

- SketchSpace and ShapeSpace are duals:



- We'll be using camSkS and camShS: the camera spaces.

SHAPEVEC and SHAPEROOTVEC

- Often we want to work with collections of shapes.

- A “SHAPEVEC” is a vector of shapes of a specific type:

```
std::vector<Shape<BlobData> >
```

This space is required

- A “SHAPEROOTVEC” is a vector of generic shapes, useful when we mix shapes of different types:

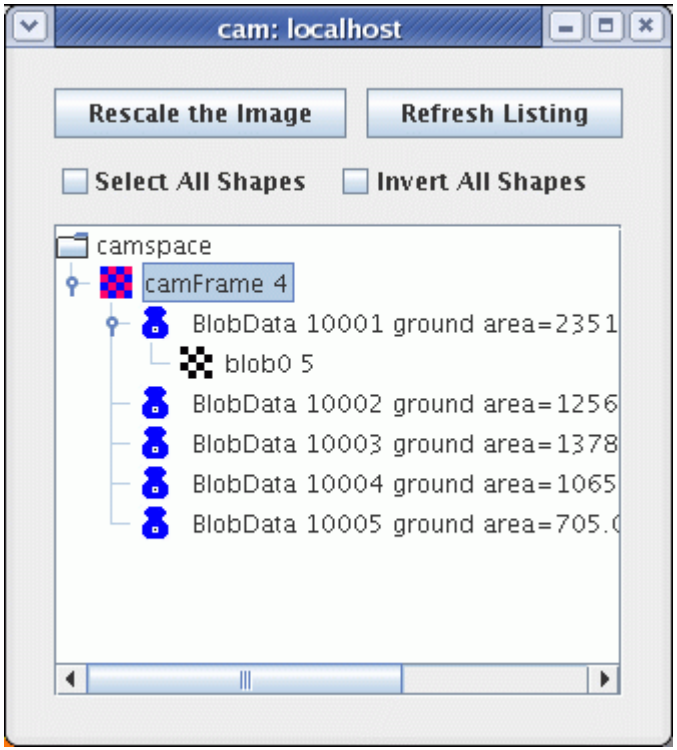
```
std::vector<ShapeRoot>
```

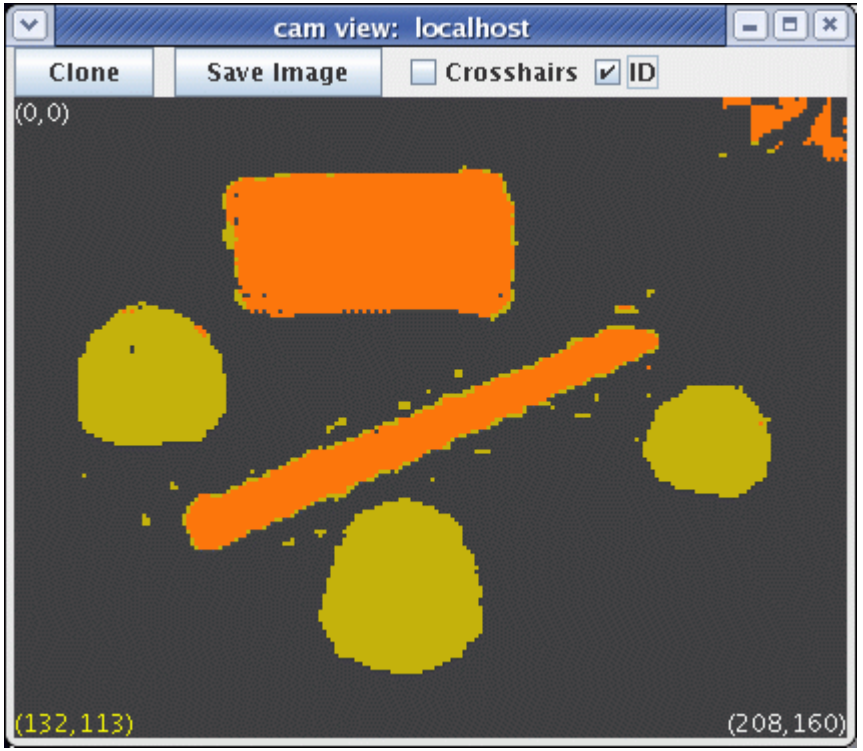
- There are macros for creating and iterating over these vectors:
  - NEW_SHAPEVEC, NEW_SHAPEROOTVEC
  - SHAPEVEC_ITERATE, SHAPEROOTVEC_ITERATE

Vectors of Shapes

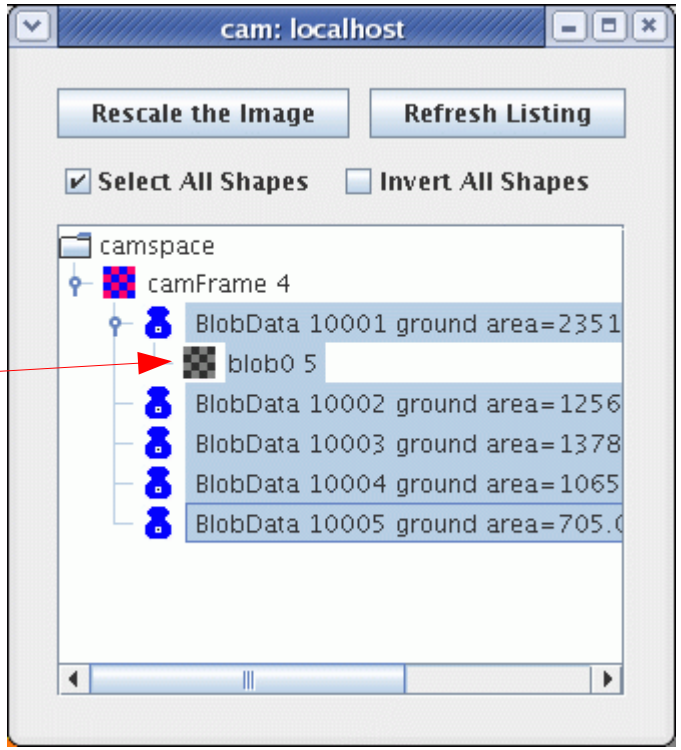
```
$nodeclass ShapeExample : VisualRoutinesStateNode : doStart {
  NEW_SKETCH(camFrame, uchar, sketchFromSeg());

  NEW_SHAPEVEC(blob_shapes, BlobData,
               BlobData::extractBlobs(camFrame,100));

  if ( blob_shapes.size() > 0 ) {
    NEW_SKETCH(blob0, bool, blob_shapes[0]->getRendering());
  }

  SHAPEVEC_ITERATE(blob_shapes, BlobData, myblob)
    cout << "Id: " << myblob->getId()
         << "  Color: " << myblob->getColor()
         << "  Area: " << myblob->getArea()
         << endl;
  END_ITERATE;

}
```

Some Orange and Yellow Blobs

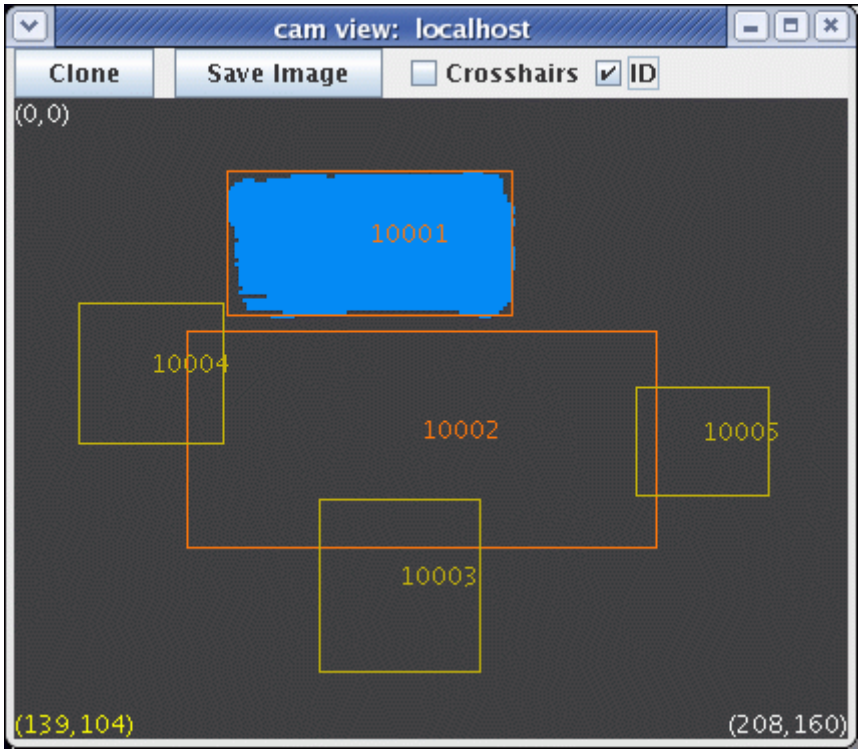




Extracted Blob Shapes



Inverted:
right click



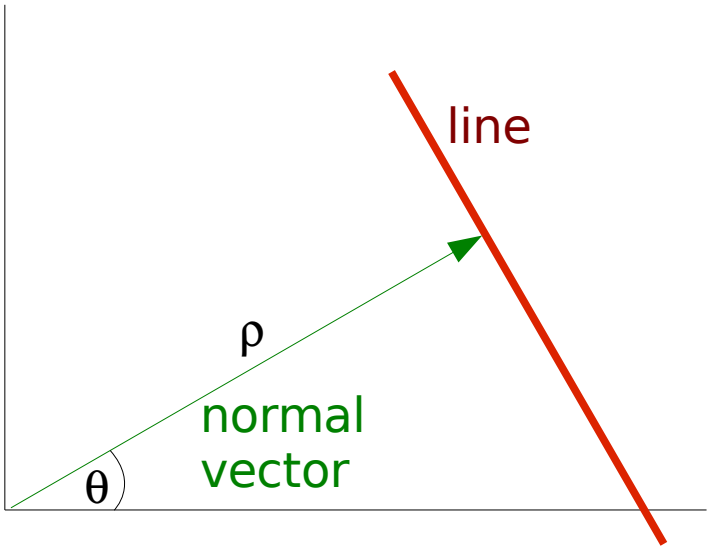
Id: 10001 Color: [253,119,15] Area: 2351
Id: 10002 Color: [253,119,15] Area: 1256
Id: 10003 Color: [193,177,9] Area: 1378
Id: 10004 Color: [193,177,9] Area: 1065
Id: 10005 Color: [193,177,9] Area: 705

Line Shapes

- A line has two endpoints, which can be
  - Valid or invalid (e.g., line runs out of the camera frame)
  - Active or inactive

  If both endpoints are inactive, line extends to infinity.

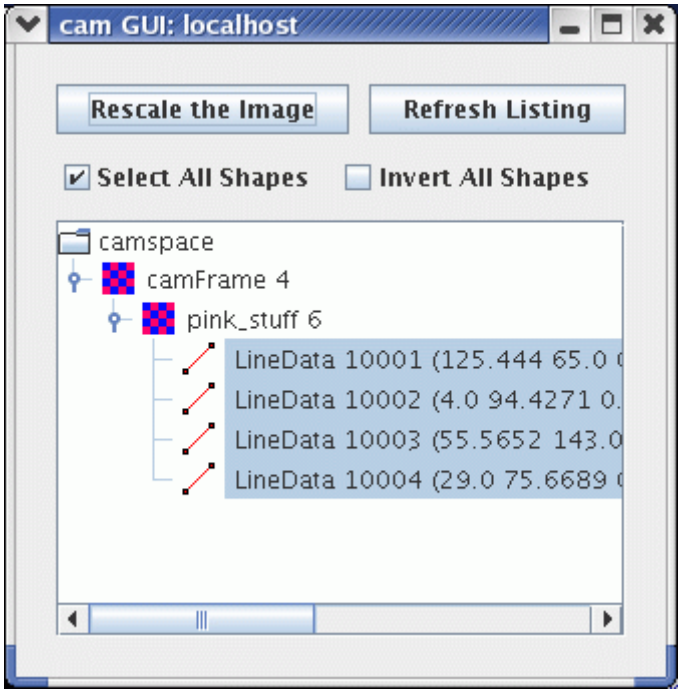
- Lines have several derived properties that are maintained automatically:
  - Length
  - Orientation (0 to π)
  - Normal vector (ρ, θ)

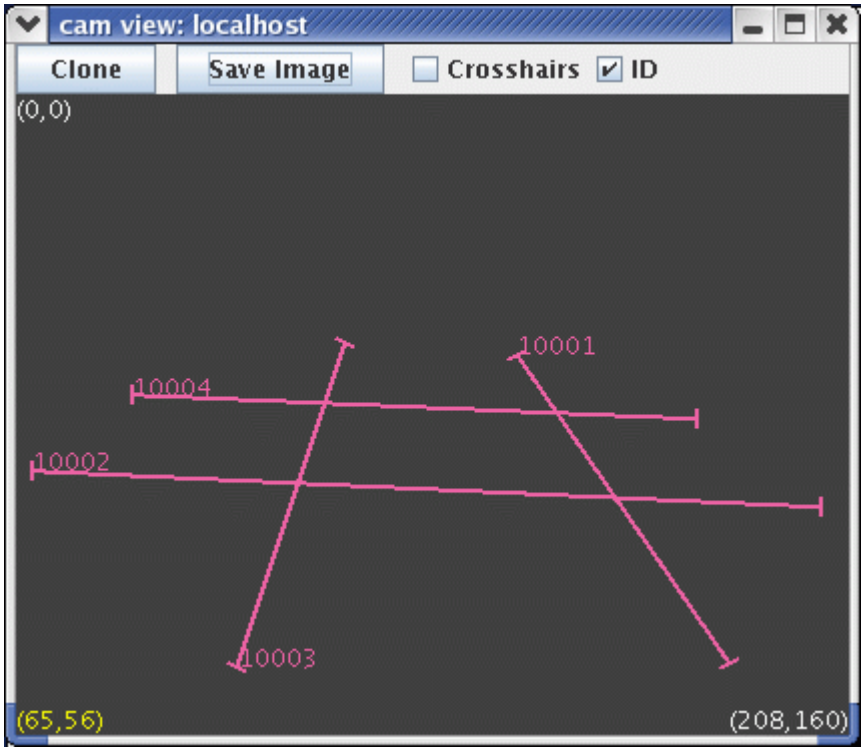


Extracting the Lines

```
$nodeclass LineExample : VisualRoutinesStateNode : doStart {
  NEW_SKETCH(camFrame, uchar, sketchFromSeg());

  NEW_SKETCH(pink_stuff, bool,
             visops::colormask(camFrame,"pink"));

  NEW_SHAPEVEC(lines, LineData,
               LineData::extractLines(pink_stuff));

}
```

Extracted Line Shapes





- "Select All Shapes" displays everything.
- "ID" checkbox displays shape IDs.

Line EndPoints

- Lines have two endpoints: end1Pt and end2Pt
- Order is arbitrary

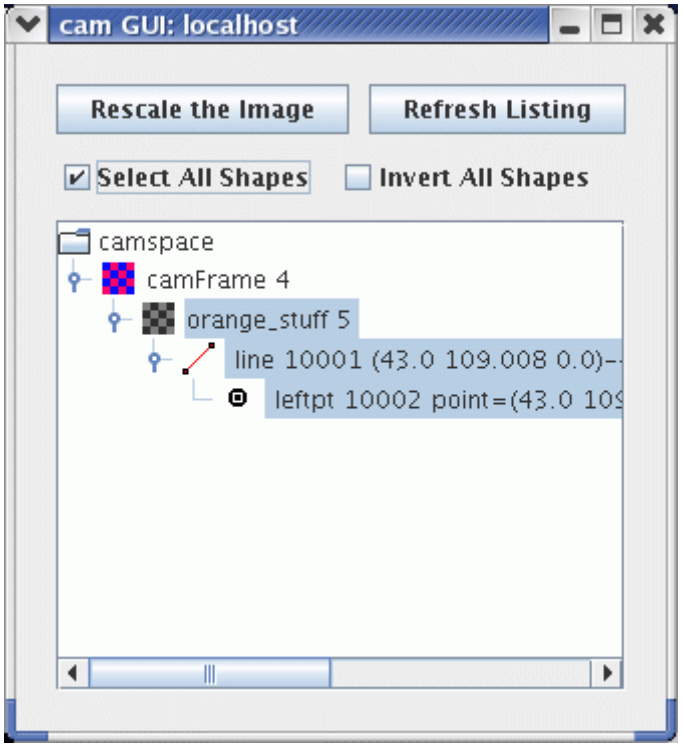
- Extracting endpoints:
  - end1Pt(), end2Pt() -- simple accessor functions
  - leftPt(), rightPt() –- compare X coords.
  - topPt(), bottomPt() –- compare Y coords.

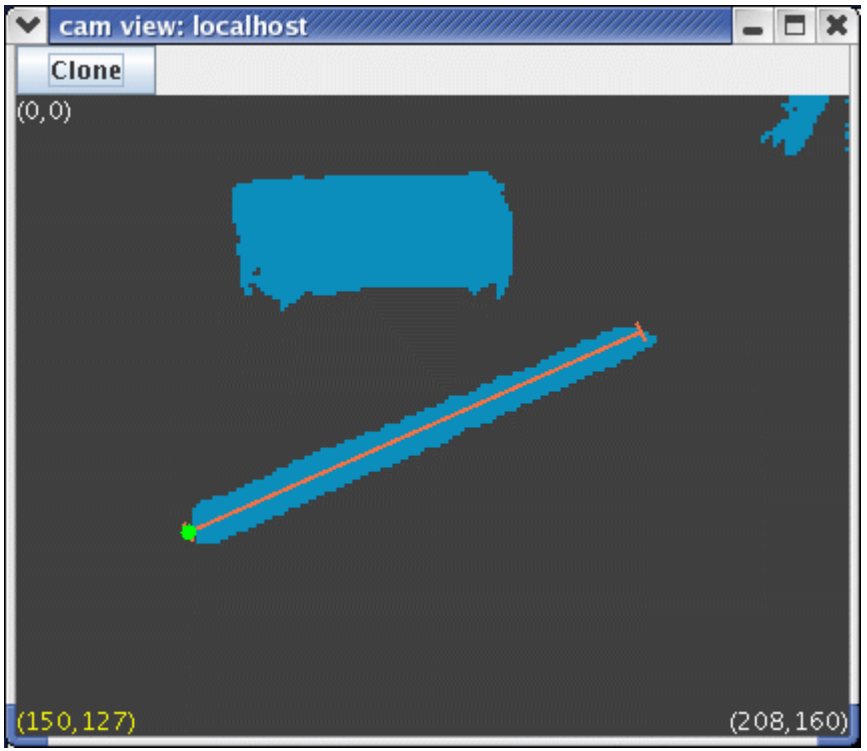
- Orientation predicates:
  - IsHorizontal –- true if slope is < 60 degrees
  - IsVertical –- true if slope is > 30 degrees
  - These thresholds are user-adjustable

Extracting the Leftmost Point

```
$nodeclass LineExample : VisualRoutinesStateNode : doStart {
  NEW_SKETCH(camFrame, uchar, sketchFromSeg());

  NEW_SKETCH(orange_stuff, bool,
             visops::colormask(camFrame,"orange"));

  NEW_SHAPE(line, LineData,
            LineData::extractLine(orange_stuff));

  NEW_SHAPE(leftpt, PointData, line->leftPtShape());

  leftpt->setColor(rgb(0,255,0));

}
```

Extracted Point Shape

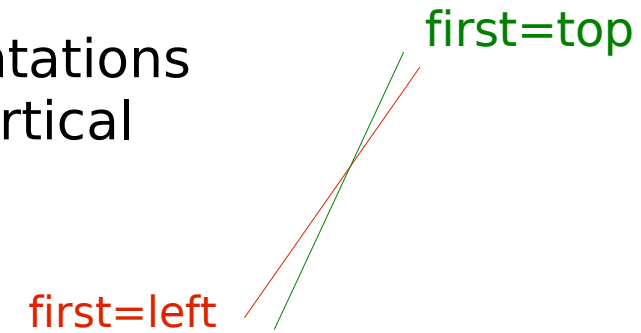




- leftpt's parent is line
- line's parent is orange_stuff: a shape whose parent is a sketch

Logical EndPoint Descriptions

- firstPt() –- if line is horizontal, returns leftPt(), else returns topPt()
- secondPt() –- similar: returns rightPt() or bottomPt()
- How do we compare two lines? Example:
  - Two lines are “close” if their first endpoints are close, and their second endpoints are also close.
  - But what about lines whose orientations straddle the critical horizontal/vertical threshold of 60 degrees?



- line1->firstPt(line2) –- returns first point of line2 based on line1's decision about horizontal/vertical

Constructing New Lines

- Use a LineData(camShS, ...) constructor to make new lines in camera space.

- Since we want to use smart pointers for shapes, the result should be fed to a Shape<LineData> constructor.
  - The NEW_SHAPE macro does this for us:

    NEW_SHAPE(myline, LineData, new LineData(camShS, ...));

- Can define a new line by specifying:
  - two points
  - a point plus an orientation (0 to π)

NEW_SHAPE

- NEW_SHAPE is a bit of syntactic sugar:

```
NEW_SHAPE(myline, LineData,
          new LineData(camShS,pt1,pt2))
```

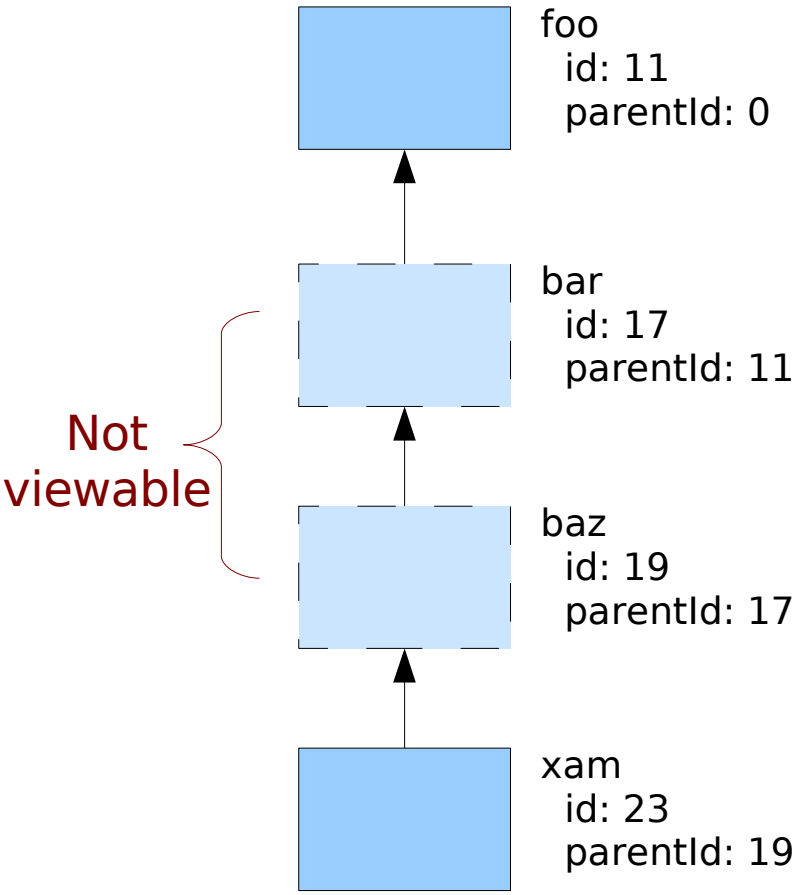
- Expands into:

```
Shape<LineData> myline(new LineData(camShS,pt1,pt2));
if ( myline.isValid() )
  myline->V("myline");      // make viewable
```

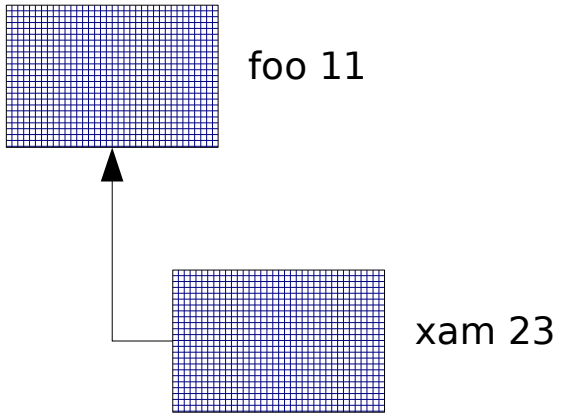
- Use NEW_SHAPE_N for shapes not to be viewable.

Parents and Viewable IDs

On the Robot



SketchGUI Display



Mixing Sketches and Shapes

- Problem: which side of an orange line has more yellow blobs?

- If all we have is a line segment, people can still interpret it as a “barrier”.
- How do we make the robot do this?

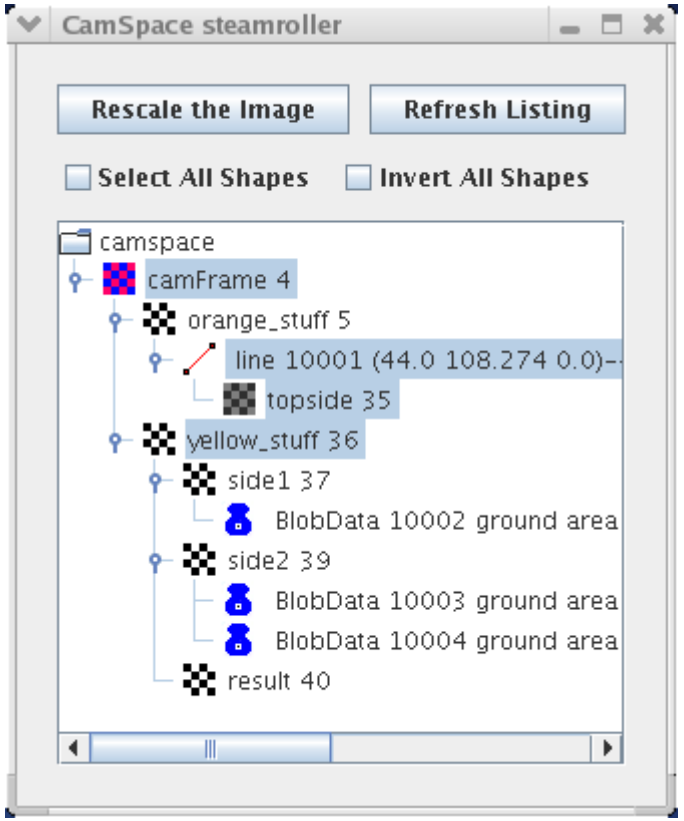
Lines as Barriers

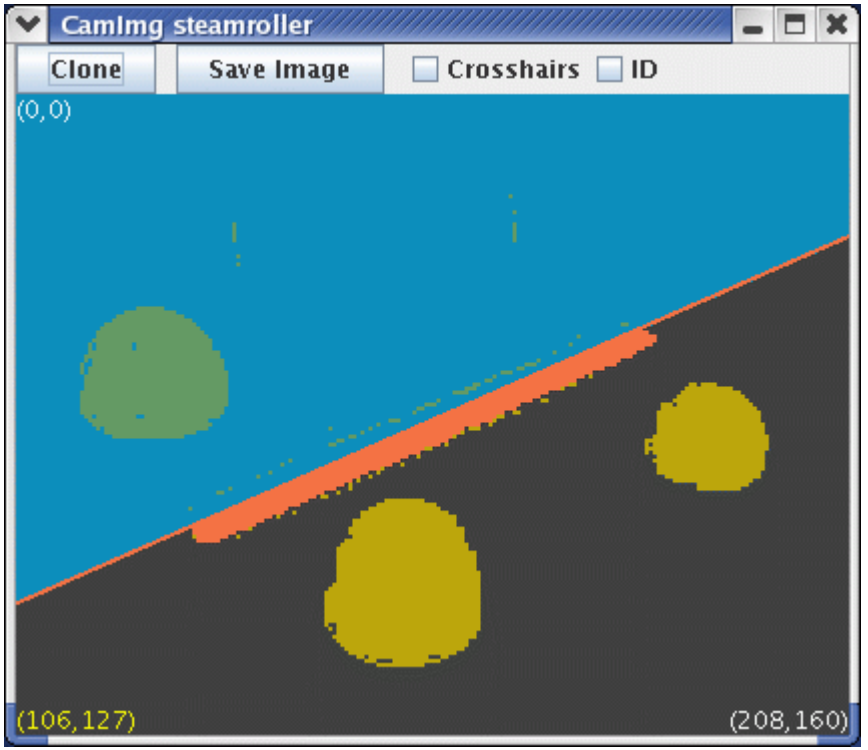
```
$nodeclass LineExample : VisualRoutinesStateNode : doStart {
  NEW_SKETCH(camFrame, uchar, sketchFromSeg());
  NEW_SKETCH(orange_stuff, bool,
             visops::colormask(camFrame,"orange"));
  NEW_SKETCH(yellow_stuff, bool,
             visops::colormask(camFrame,"yellow"));

  NEW_SHAPE(boundary_line, LineData,
            LineData::extractLine(orange_stuff));

  NEW_SKETCH(topside, bool,
             visops::topHalfPlane(boundary_line));

  NEW_SKETCH(side1, bool, yellow_stuff & topside);
  NEW_SKETCH(side2, bool, yellow_stuff & ! topside);
```

Lines as Barriers (cont.)

```
  NEW_SHAPEVEC(side1blobs, BlobData,
               BlobData::extractBlobs(side1,50));
  NEW_SHAPEVEC(side2blobs, BlobData,
               BlobData::extractBlobs(side2,50));

  vector<Shape<BlobData> > &winners =
    side1blobs.size() > side2blobs.size() ?
      side1blobs : side2blobs;

  NEW_SKETCH(result, bool, visops::zeros(yellow_stuff));

  SHAPEVEC_ITERATE(winners, BlobData, b)
    result |= b->getRendering();
  END_ITERATE;

  boundary_line->setInfinite();   // for display purposes

}
```

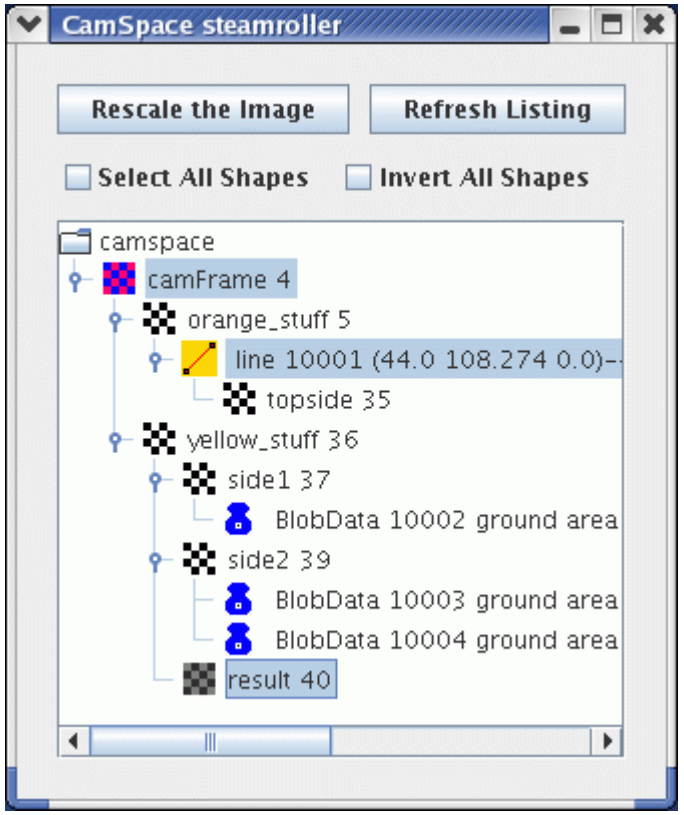
Lines As Barriers

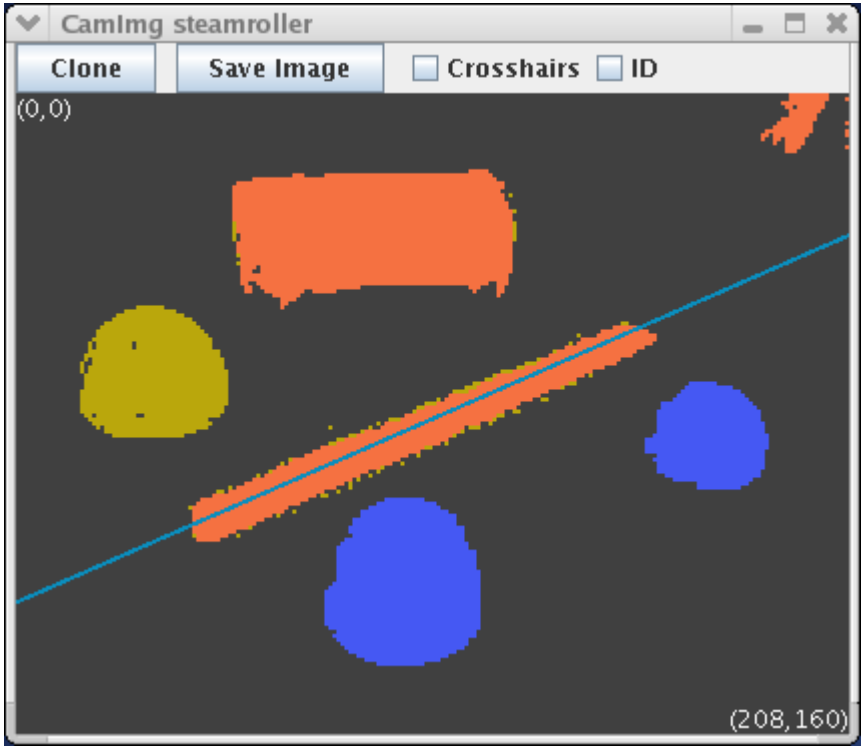




Subtle point: bool overrides uchar in the SketchGUI, so selecting yellow_stuff allows the top yellow blob to display even though the inverted (orange) *topside* is covering its appearance in *camFrame*. (Competing bools are averaged.)

Lines As Barriers

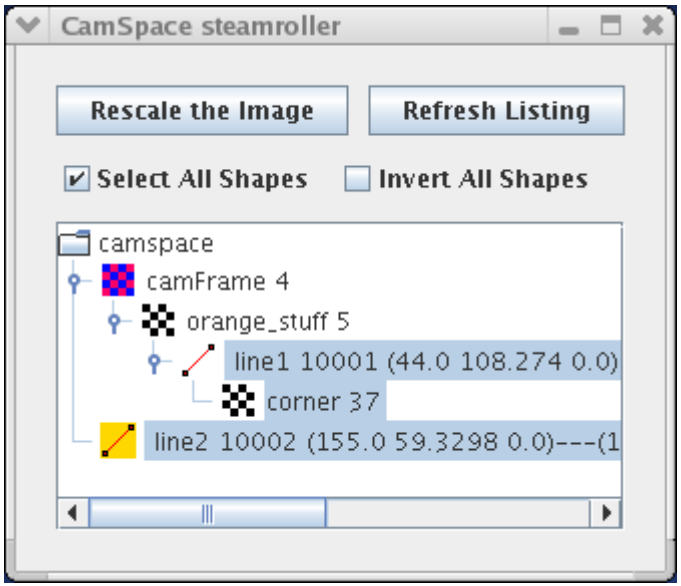


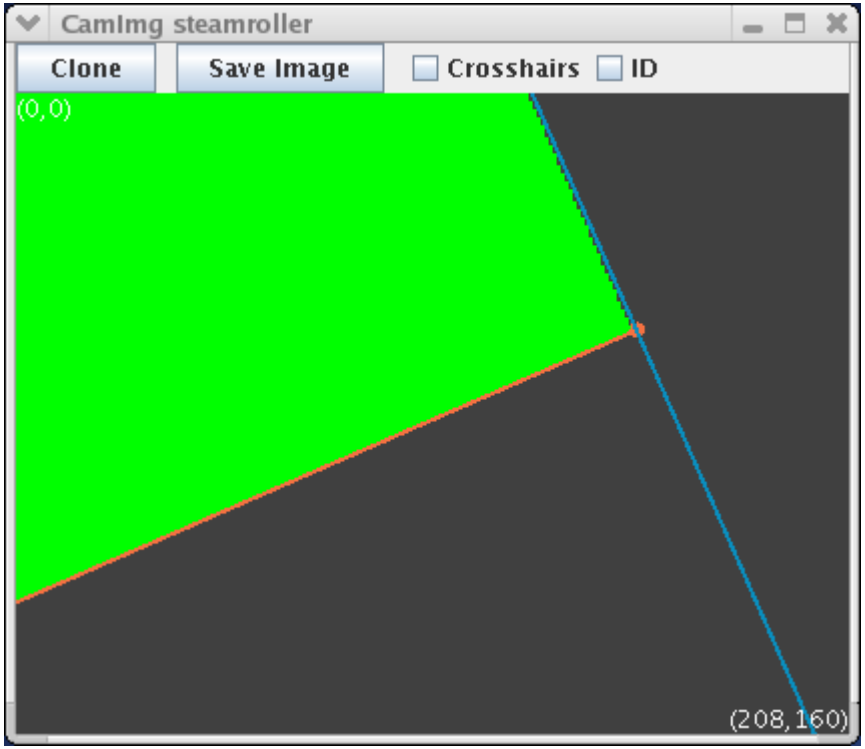


Constructing a Perpendicular

```
$nodeclass LineExample : VisualRoutinesStateNode: doStart {
  NEW_SKETCH(camFrame, uchar, sketchFromSeg());
  NEW_SKETCH(orange_stuff, bool,
             visops::colormask(camFrame,"orange"));

  NEW_SHAPE(line1, LineData,
            LineData::extractLine(orange_stuff));

  line1->leftPt().setActive(false);

  NEW_SHAPE(line2, LineData,
            new LineData(camShS,line1->rightPt(),
                         line1->getThetaNorm()));

  NEW_SKETCH(corner, bool,
             visops::seedfill(line1->getRendering() |
                              line2->getRendering(), 0));

  corner->setColor(rgb(0,255,0));
}
```

Constructing a Perpendicular





- Why isn't line2 shown as a child of line1?

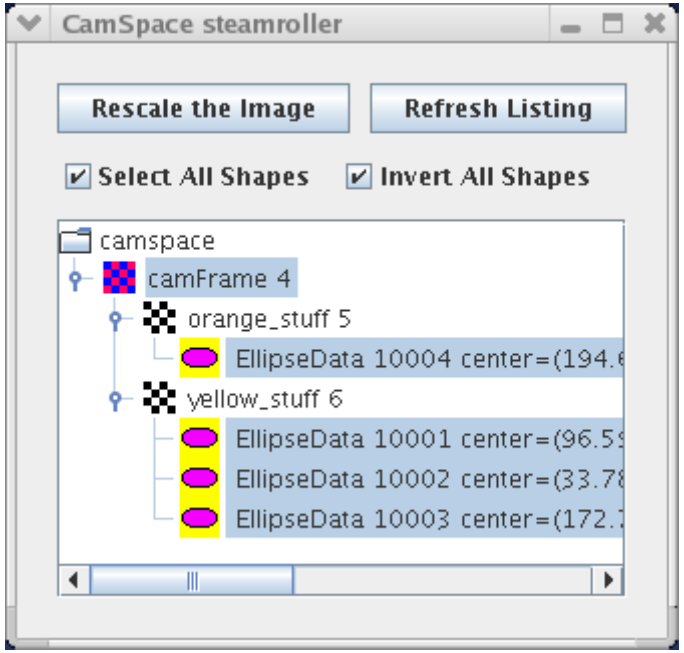
Ellipses

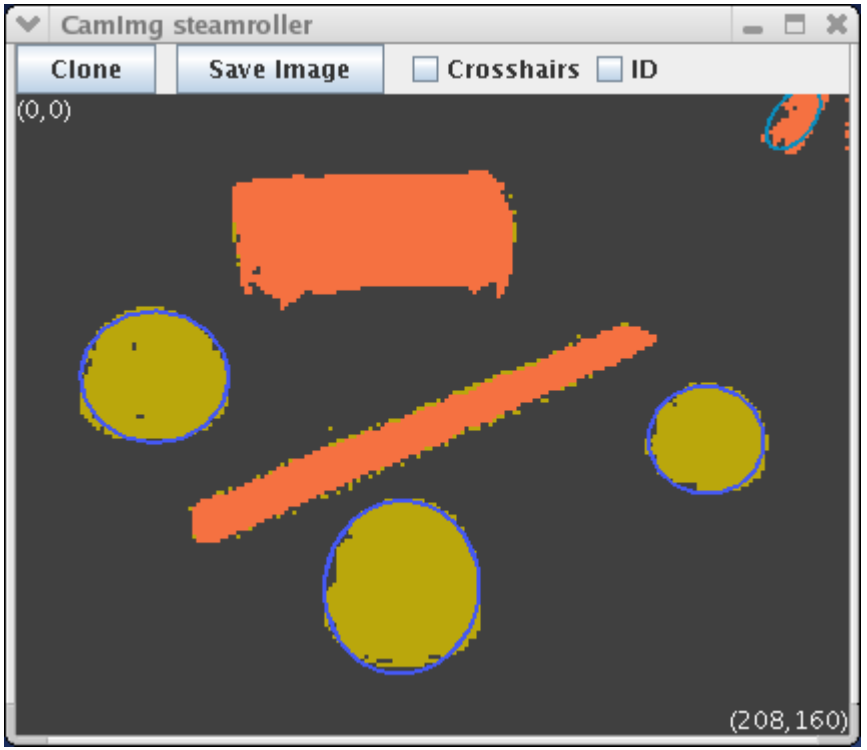
- Used to describe circular or elliptical shapes.
- Different from blobs. Ellipse properties:
  - semi-major, semi-minor axis lengths
  - major axis orientation
- Ellipse extraction routine will ignore regions that aren't roughly elliptical in shape.

Extracting Ellipses

```
$nodeclass EllipseExample : VisualRoutinesStateNode : doStart {

  NEW_SKETCH(camFrame, uchar, sketchFromSeg());
  NEW_SKETCH(orange_stuff, bool,
             visops::colormask(camFrame,"orange"));
  NEW_SKETCH(yellow_stuff, bool,
             visops::colormask(camFrame,"yellow"));

  NEW_SHAPEVEC(ellipses, EllipseData,
               EllipseData::extractEllipses(yellow_stuff));

  NEW_SHAPEVEC(ellipses2, EllipseData,
               EllipseData::extractEllipses(orange_stuff));

}
```

Extracting Ellipses





Assignment and Copying

- Sketches: assignment is deep; copying is shallow.

  “A = 1” only makes sense for deep assignment.

  “A += B” only makes sense for deep assignment.

  So “A = B” should be deep as well.

  NEW_SKETCH(A, bool, B) does shallow copy. For deep copy, do:
  NEW_SKETCH(A, bool, visops::copy(B))

  For shallow assignment, do: A.bind(B)

- Shapes: assignment and copying are *both* shallow.

  Mostly we want to just pass shapes around, so shallow copy is all that's necessary.

  For deep copy, do: NEW_SHAPE(A, LineData, B->copy())

  Deep assignment is not supported.

Point vs. PointData

- Point(x,y,z) uses fmat::Column<4>.
- Operators +-*/ == are defined on Point objects.
- EndPoint is a subclass of Point with a few extra properties: valid, active.
- LineData contains two EndPoints.
  EllipseData contains one Point defining its center.

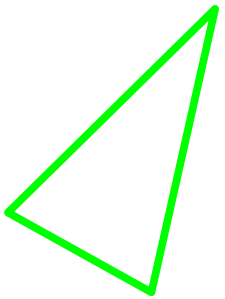
- PointData is a *shape* representation with a Point inside.

- Why have both Point and PointData?
  - Shapes aren't allowed to nest, so you can't put a PointData inside a LineData or EllipseData.

Other Shape Types

- PolygonData can represent boundaries (like the edge of the robot's playpen) or containers.
- SphereData can be used to represent a ball in 3-D.
- BrickData will be used for blocks world tasks.

- AgentData represents the robot's position (as a Point) and orientation (as an AngTwoPi).



ShapeSpace:

A Look Under the Hood