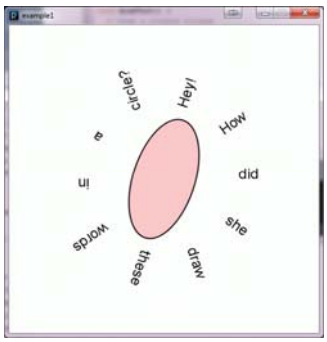
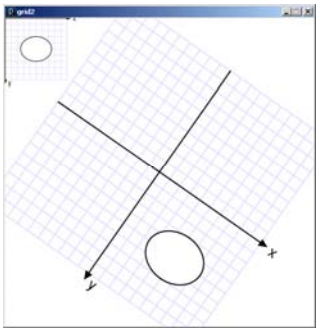
Review
- Inheritance
- Overloading and overriding

example1.pde



Up until now …
- *All movement and sizing of graphical objects have been accomplished by **modifying object coordinate values.***

Going forward, we have a new option…
- *We can leave coordinate values unchanged, and **modify the coordinate system** in which we draw.*



The commands that draw these two ellipses are identical.

What has changed is the coordinate system in which they are drawn.

Three ways to transform the coordinate system:

1. **Scale**
   - Magnify, zoom in, zoom out …
2. **Translate**
   - Move axes left, right, up, down …
3. **Rotate**
   - Tilt clockwise, tilt counter-clockwise …

Scale
- All coordinates are multiplied by an x-scale-factor and a y-scale-factor.
- Stroke thickness is also scaled.

```
scale( factor );
scale( x-factor, y-factor );
```

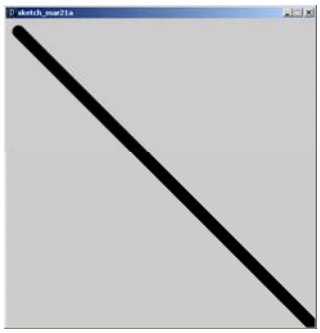
```
void setup() {
  size(500, 500);
  smooth();
  noLoop();

  line(1, 1, 25, 25);
}
```

example2.pde

```
void setup() {
  size(500, 500);
  smooth();
  noLoop();

  scale(2,2);
  line(1, 1, 25, 25);
}
```

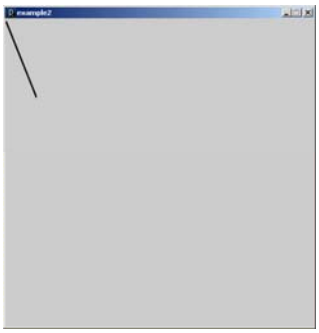
example2.pde

```
void setup() {
  size(500, 500);
  smooth();
  noLoop();

  scale(20,20);
  line(1, 1, 25, 25);
}
```



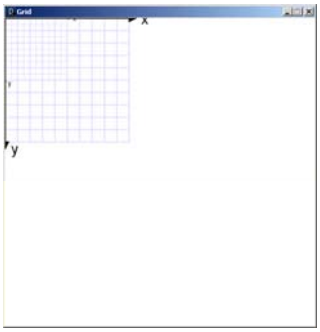
example2.pde

```
void setup() {
  size(500, 500);
  smooth();
  noLoop();

  scale(2,5);
  line(1, 1, 25, 25);
}
```



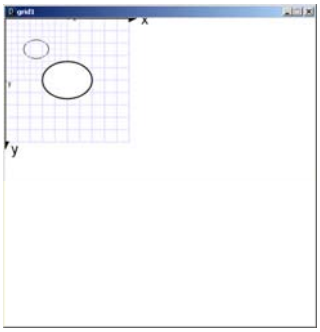
example2.pde

```
void setup() {
  size(500, 500);
  background(255);
  smooth();
  noLoop();
}

void draw() {
  grid();
  scale(2,2);
  grid();
}
```



grid1.pde

```
void draw() {
  grid();
  fill(255);
  ellipse(50,50,40,30);

  scale(2,2);
  grid();
  fill(255);
  ellipse(50,50,40,30);
}
```



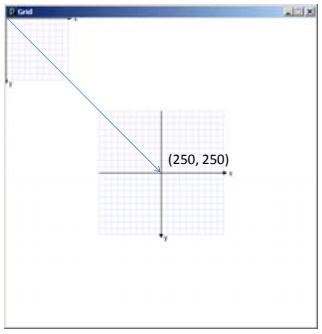
grid1.pde

Translate

– The coordinate system is shifted by the given amount in the x and y directions.

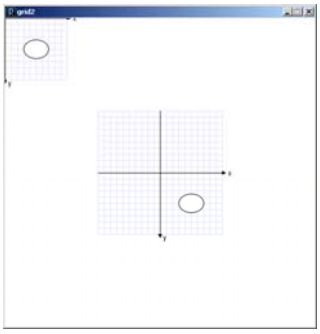
```
translate( x-shift, y-shift);
```

```
void draw() {
  grid();
  translate(250,250);
  grid();
}
```



grid2.pde

```
void draw() {
  grid();
  fill(255);
  ellipse(50, 50, 40, 30);

  translate(250, 250);
  grid();
  fill(255);
  ellipse(50, 50, 40, 30);
}
```

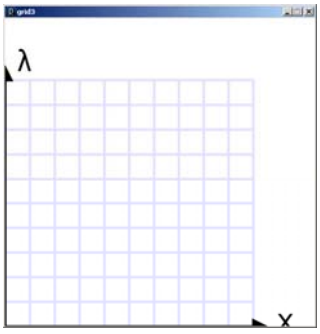


Transformations can be combined

– Combine Scale and Translate to create a coordinate system with the y-axis that increases in the upward direction

– Axes can be flipped using negative scale factors

```
void draw() {
  translate(0,height);
  scale(4,-4);
  grid();
}
```



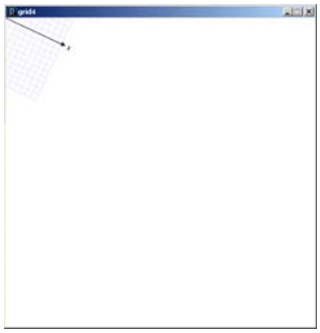
grid3.pde

Rotate

– The coordinate system is rotated around the origin by the given angle (in radians).

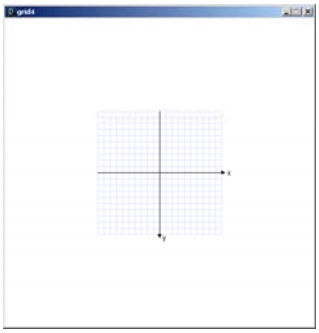
```
rotate( radians );
```

```
void draw() {
  rotate( 25.0 * (PI/180.0) );
  grid();
}
```



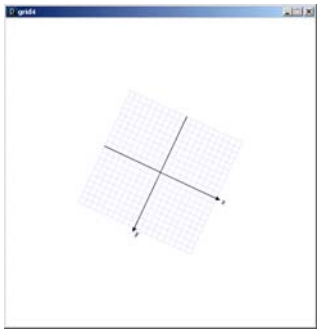
grid4.pde

```
void draw() {
  translate(250.0, 250.0);
  //rotate( 25.0 * (PI/180.0) );
  //scale( 2 );
  grid();
}
```



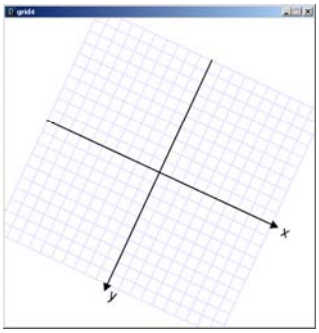
grid4.pde

```
void draw() {
  translate(250.0, 250.0);
  rotate( 25.0 * (PI/180.0) );
  //scale( 2 );
  grid();
}
```



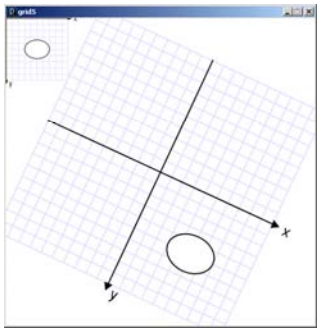
grid4.pde

```
void draw() {
  translate(250.0, 250.0);
  rotate( 25.0 * (PI/180.0) );
  scale( 2 );
  grid();
}
```



grid4.pde

```
void draw() {
  grid();
  fill(255);
  ellipse(50, 50, 40, 30);

  translate(250.0, 250.0);
  rotate( 25.0 * (PI/180.0) );
  scale(2);
  grid();
  fill(255);
  ellipse(50, 50, 40, 30);
}
```

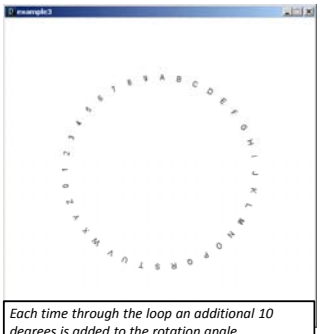


grid5.pde

Some things to note:

- Transformations do NOT work within beginShape()/endShape();
- Transformations are cumulative.
- All transformations are cancelled prior to calling draw().
- You can save and restore the current state of the coordinate system by calling
  - pushMatrix();
  - popMatrix();

```
String[] word = new String[]
{"A","B","C","D","E","F","G","H","I","J","K","L","M","N","O","P","Q","R","S
","T","U","V","W","X","Y","Z","0","1","2","3","4","5","6","7","8","9"};

void setup() {
  size(500, 500);
  smooth();
  noLoop();
}

void draw() {
  background(255);
  translate(250,250);

  fill(0);
  for (int i=0; i<word.length; i++) {
    text( word[i], 0.0, -150.0 );
    rotate(radians(10));
  }
}
```

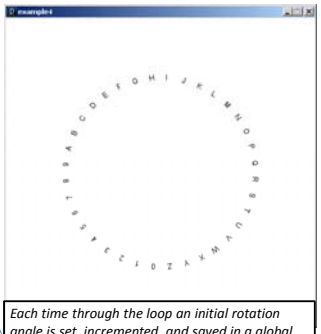


Each time through the loop an additional 10 degrees is added to the rotation angle.

Total rotation accumulates.

example3.pde

```
String[] word = new String[]
{"A","B","C","D","E","F","G","H","I","J","K","L","M","N","O","P","Q","R","S","T",
"U","V","W","X","Y","Z","0","1","2","3","4","5","6","7","8","9"};

float start = 0.0;

void setup() {
  size(500, 500);
  smooth();
}

void draw() {
  background(255);
  translate(250,250);

  fill(0);
  rotate(start);

  for (int i=0; i<word.length; i++) {
    text( word[i], 0.0, -150.0 );
    rotate(radians(10));
  }

  start += radians(1);
}
```

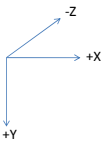


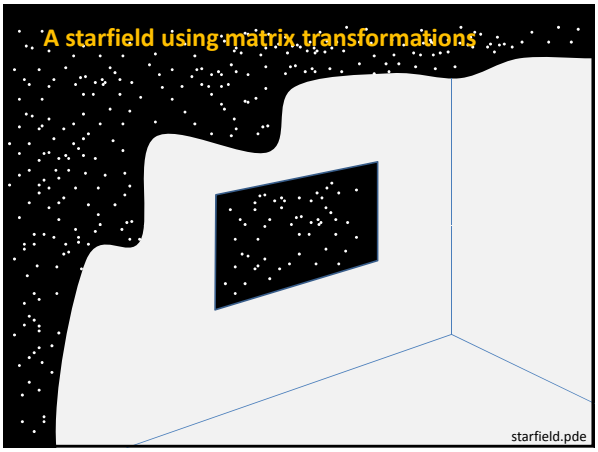
Each time through the loop an initial rotation angle is set, incremented, and saved in a global.

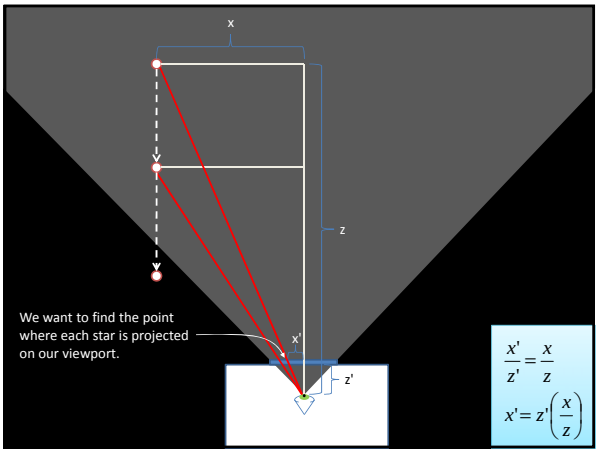
Transformations reset each time draw() is called.

example4.pde

- Transformations work in 3D
  - Z is depth (into or out of the screen)
  - Negative z goes into the screen
  - translate(0, 0, -100);
  - Translate(0, 0, 100);
- If using 3D transformations
  - Change to 3D coordinates
  - Add a third argument to size to change the default renderer to P3D or OPENGL
  - import processing.opengl.*







$$\frac{x'}{z'} = \frac{x}{z}$$

$$x' = z'\left(\frac{x}{z}\right)$$