7 Programming with Animations

7.1 Animated Graphics: Principles and History

7.2 Types of Animation

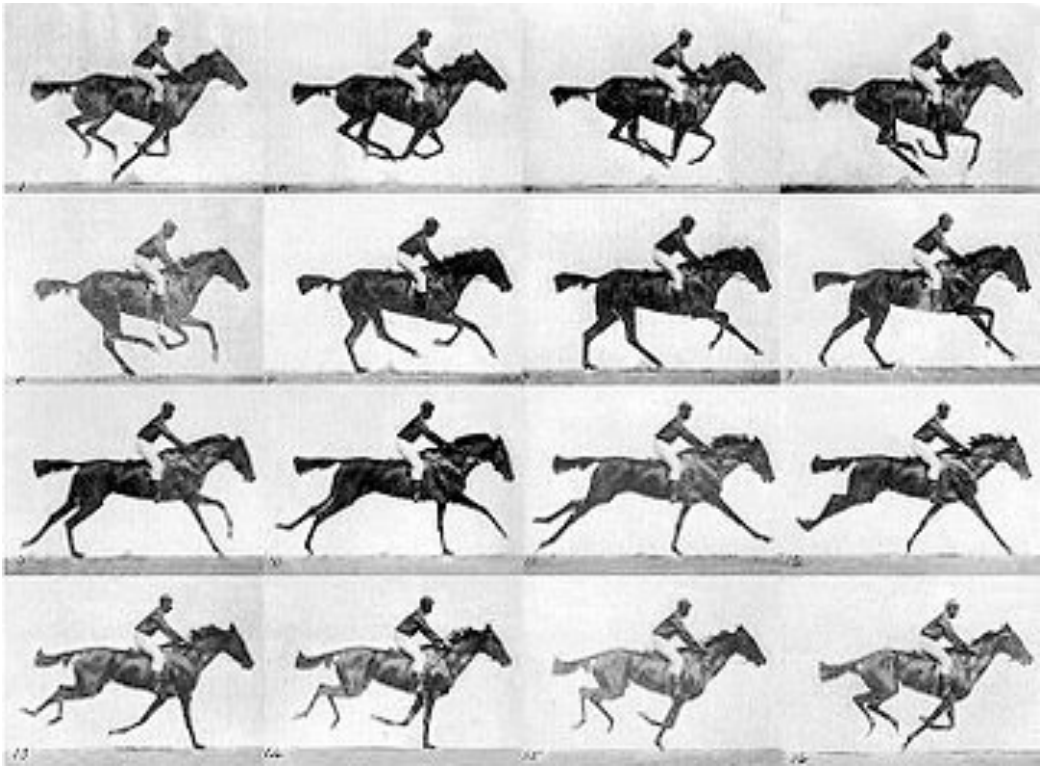
7.3 Programming Animations: Interpolation

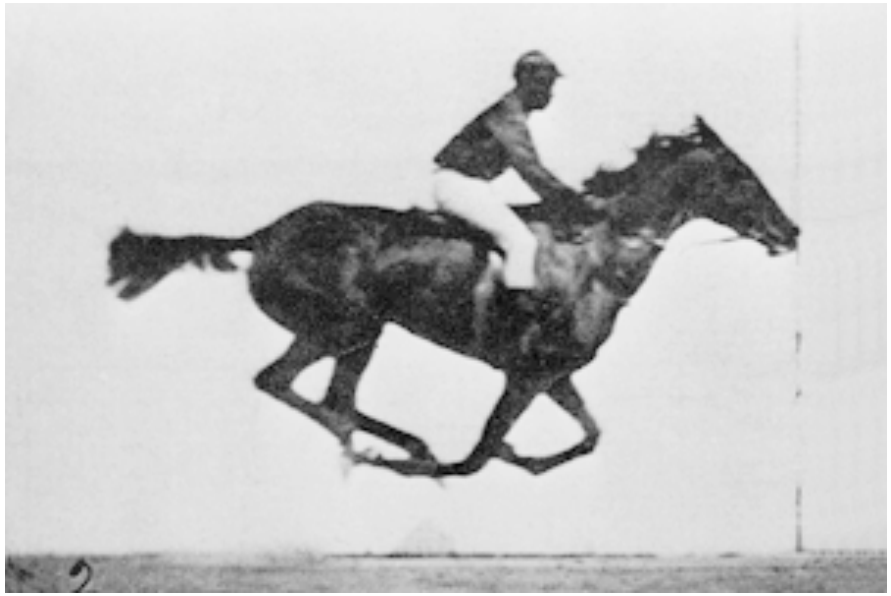
7.4 Design of Animations

7.5 Game Physics

Eadweard Muybridge: Chronofotografie

- 1830 – 1904

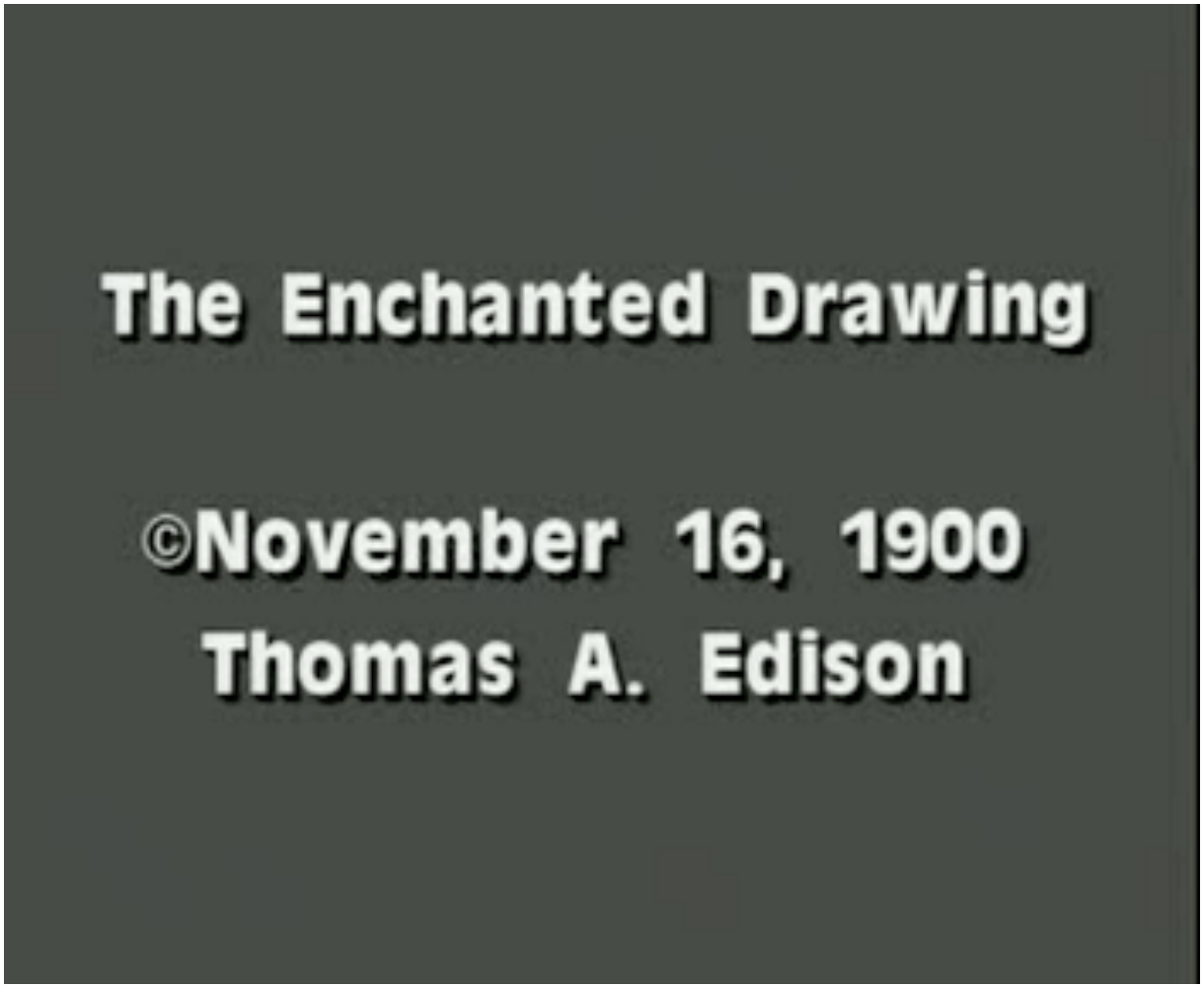




Quelle: Wikipedia

J. Stuart Blackton: The Father of Animation

- 1875 – 1941
- Became “rapid drawing cartoonist” for Thomas A. Edison



The Enchanted Drawing
1900

Problem: How to Create SO Many Pictures?

Drawing work for “Gertie the Dinosaur”

Winsor McKay: Character Animation

Winsor McKay:
1867 – 1934

Gertie the Dinosaur
1914

First character animation
First keyframe animation

“He devised what he called the "McCay Split System", ...
Rather than draw each frame in sequence, he would start by drawing Gertie's key poses, and then go back and fill in the frames between.” (Wikipedia)

Walt Disney: Animation Industry

1901 – 1966

Pencil

Pen

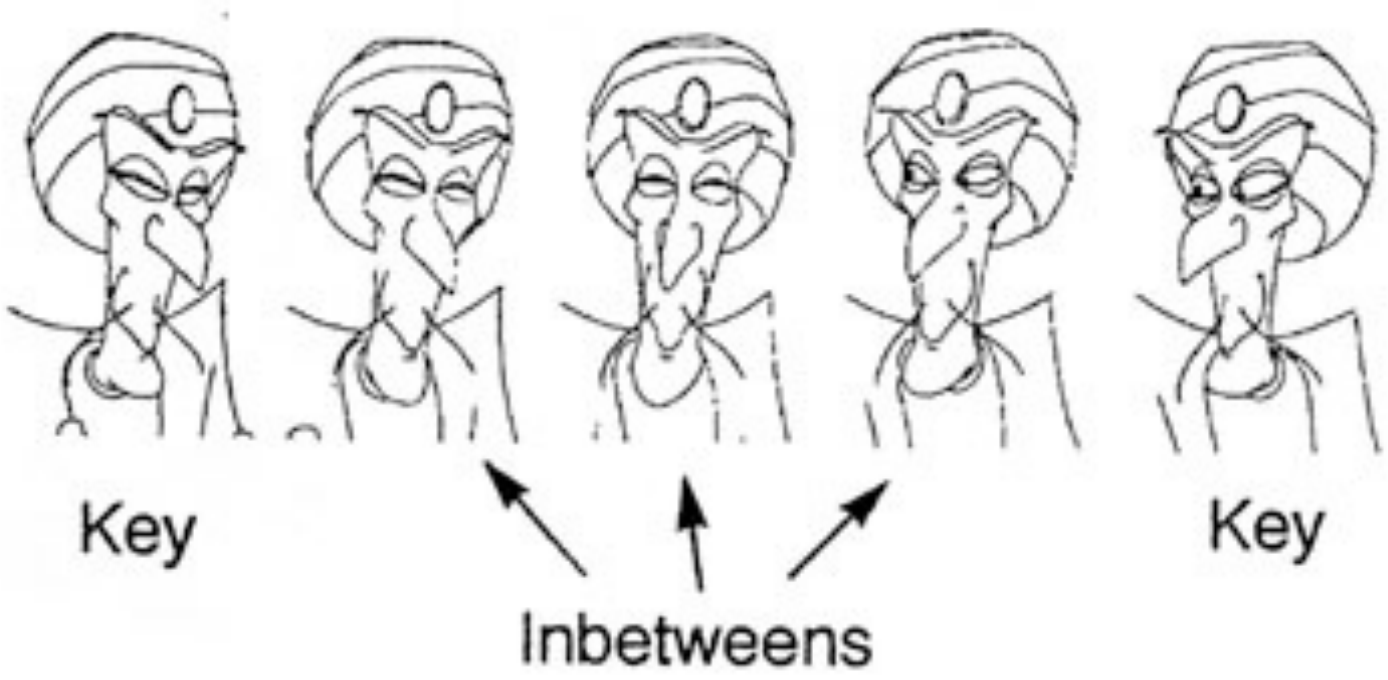
Ink

Source: Midori Kitagawa, http://atec.utdallas.edu/midori

In-Between Drawing

- *Key frames:* Define the start and end points of a smooth transition
- *In-between frames:* Filled in to create the transition

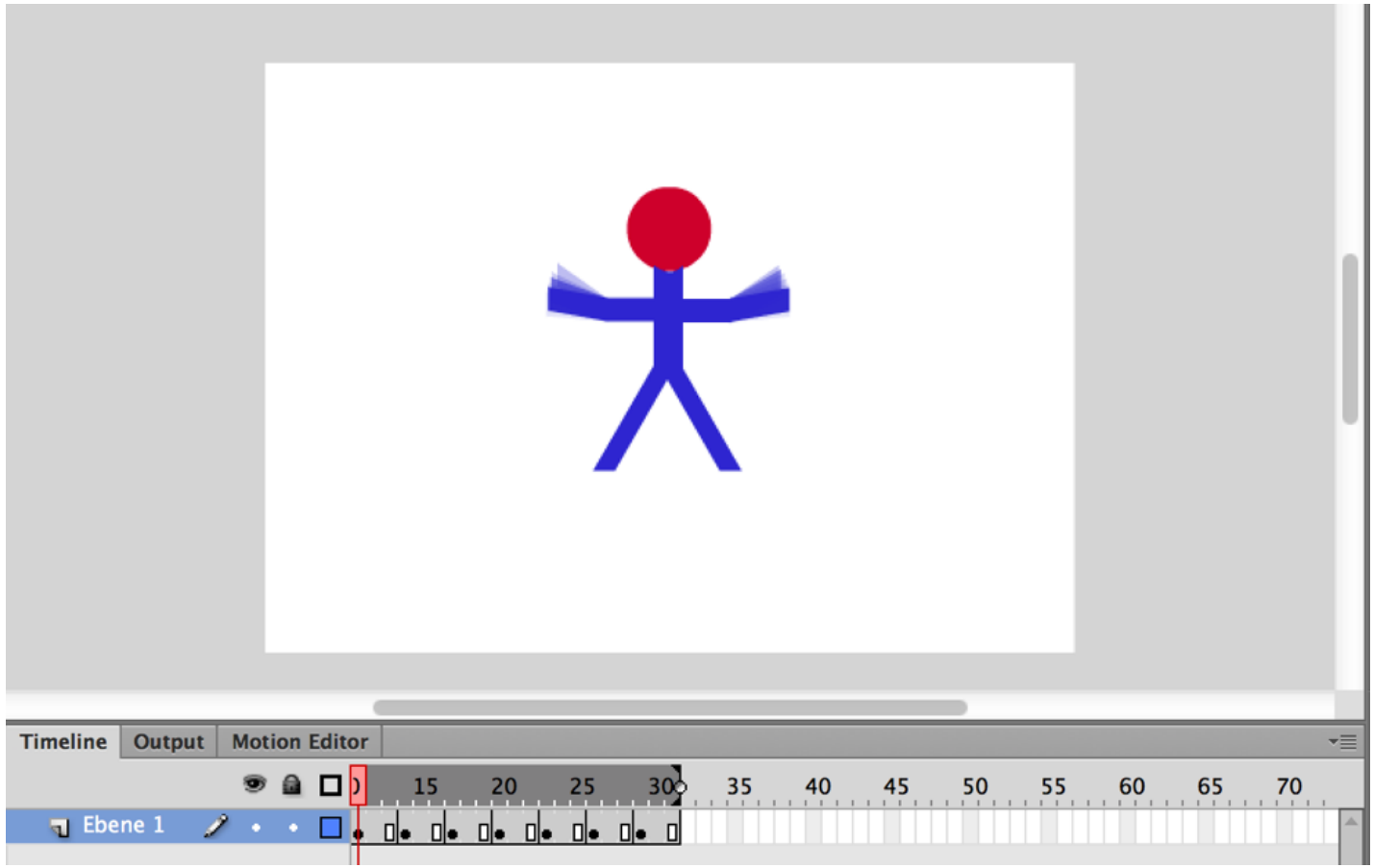
Traditional hand-drawn animation:
Work split between senior artist and assistant



Source: Midori Kitagawa, http://atec.utdallas.edu/midori

4 Programming with Animations

Frame-By-Frame Animation



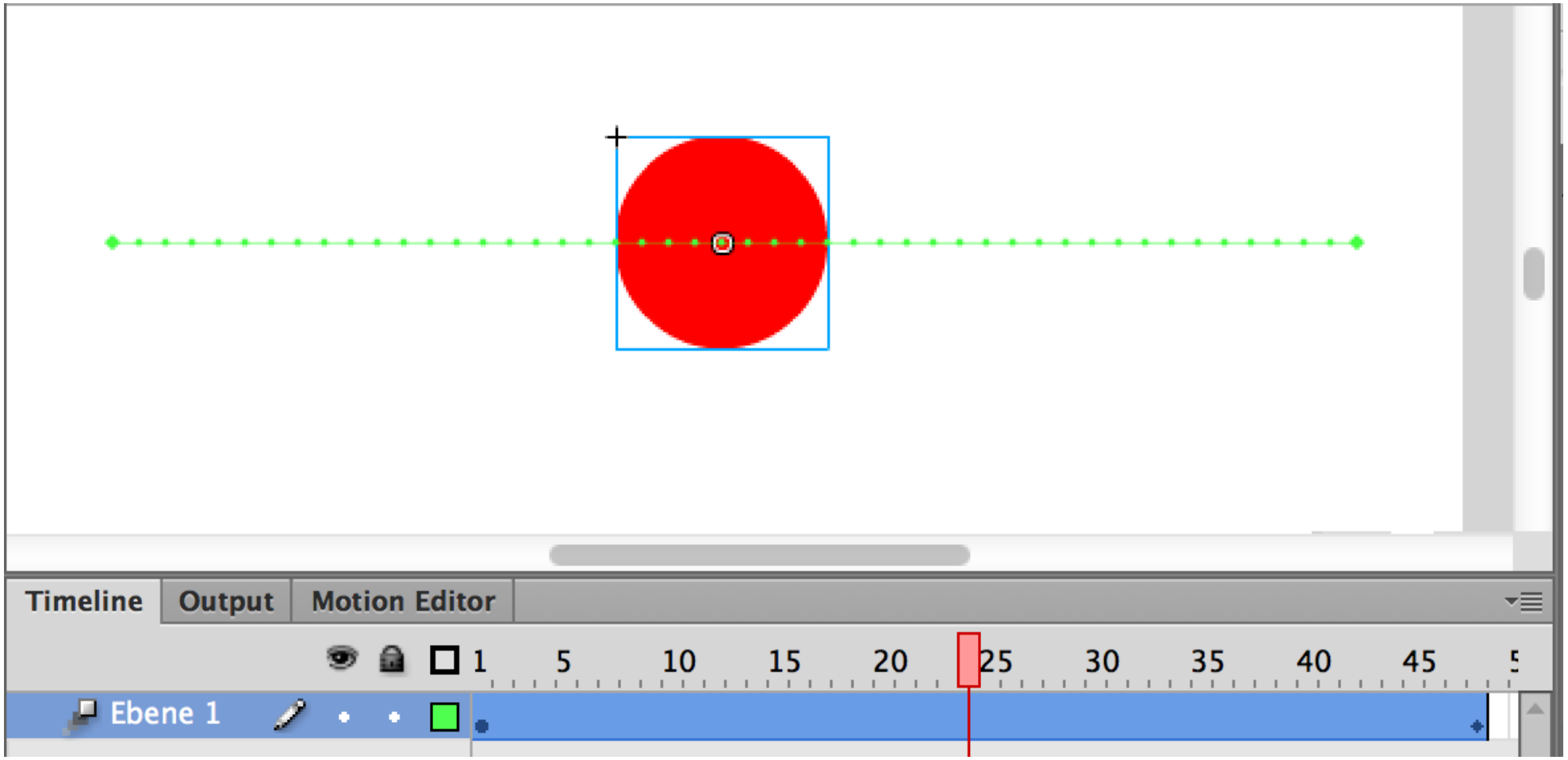
Each image is drawn manually

Special tools may be used for previewing the effect
(onion skinning)

Keyframe Animation: Motion Tween (Flash)

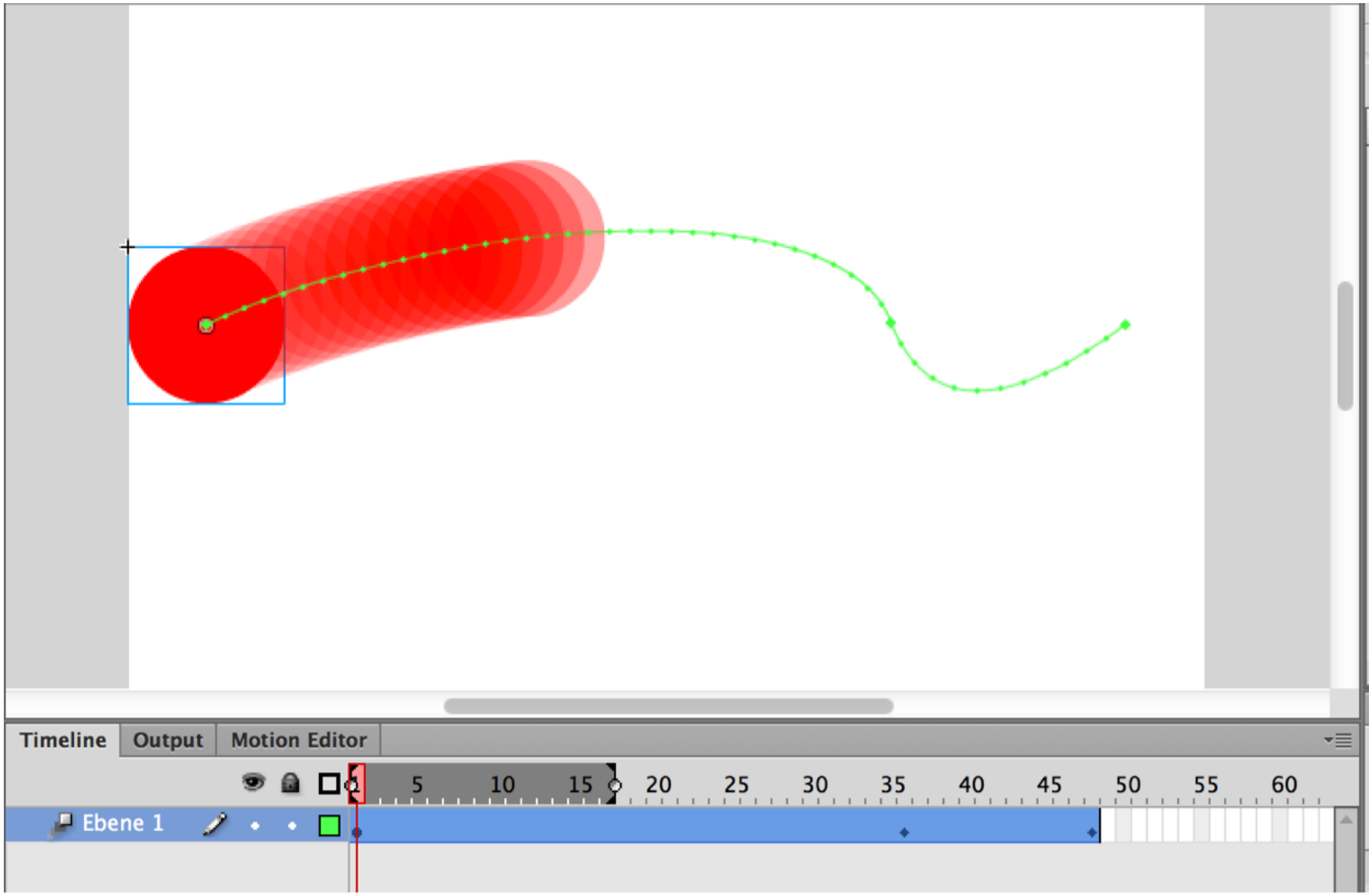
- Properties of a (2D) object manipulated by motion tween:
  - Position (x and y)
  - Rotation (z)
  - Skew/Shear *(Neigung)*
  - Size
  - Color effects
- Basic idea of graphically creating a motion tween:
  - Place an object (instance!) on a separate layer
  - Invoke “Create Motion Tween” (context menu)
  - Re-adjust property values graphically or by inspector dialogue for end frame
- Property key frames:
  - Intermediate frames with individually defined object properties
- Motion path:
  - Bezier curve, can be adjusted graphically

Example: Motion Tween in Flash (1)



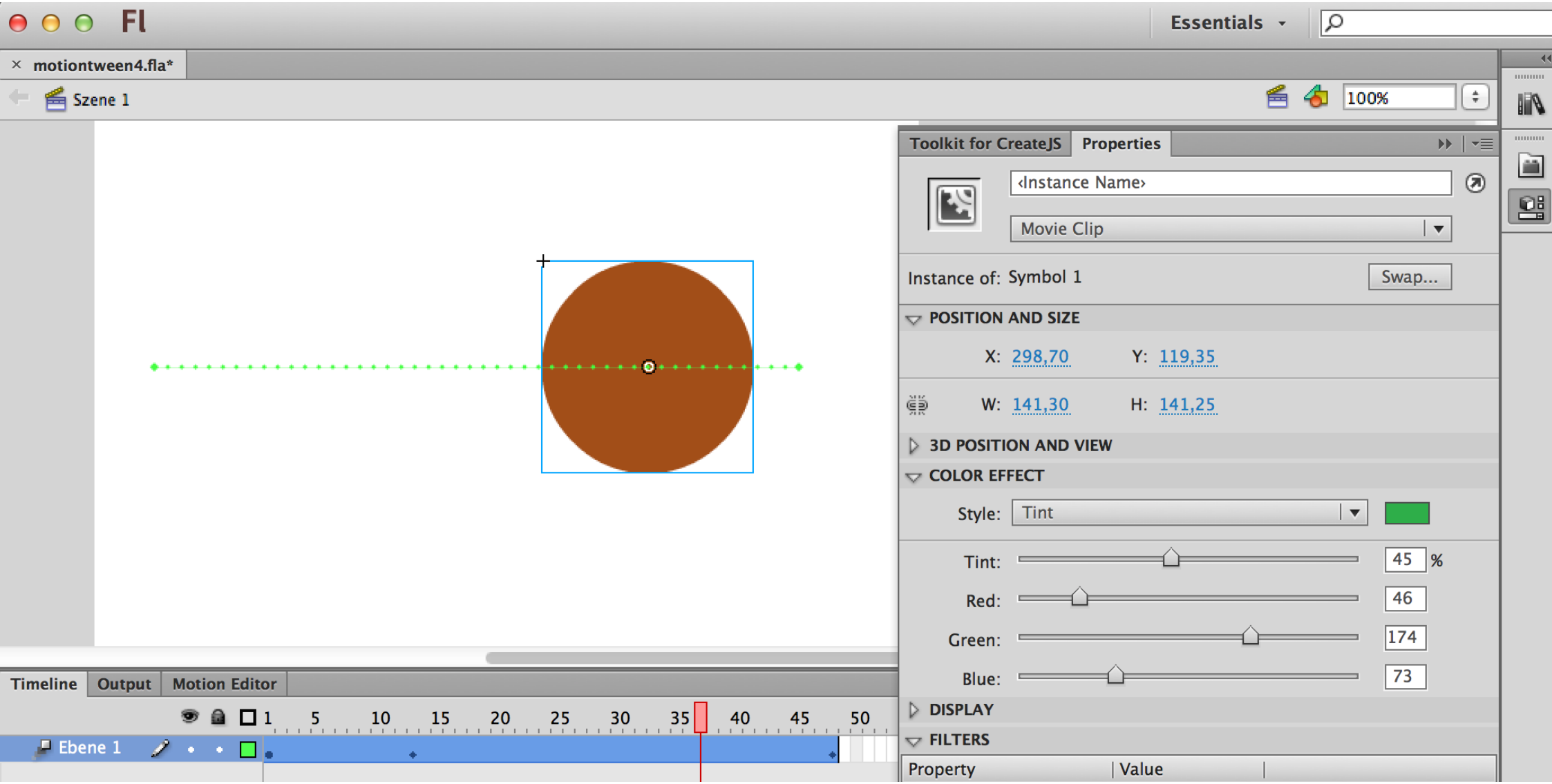
motiontween0.fla

Example: Motion Tween in Flash (2)

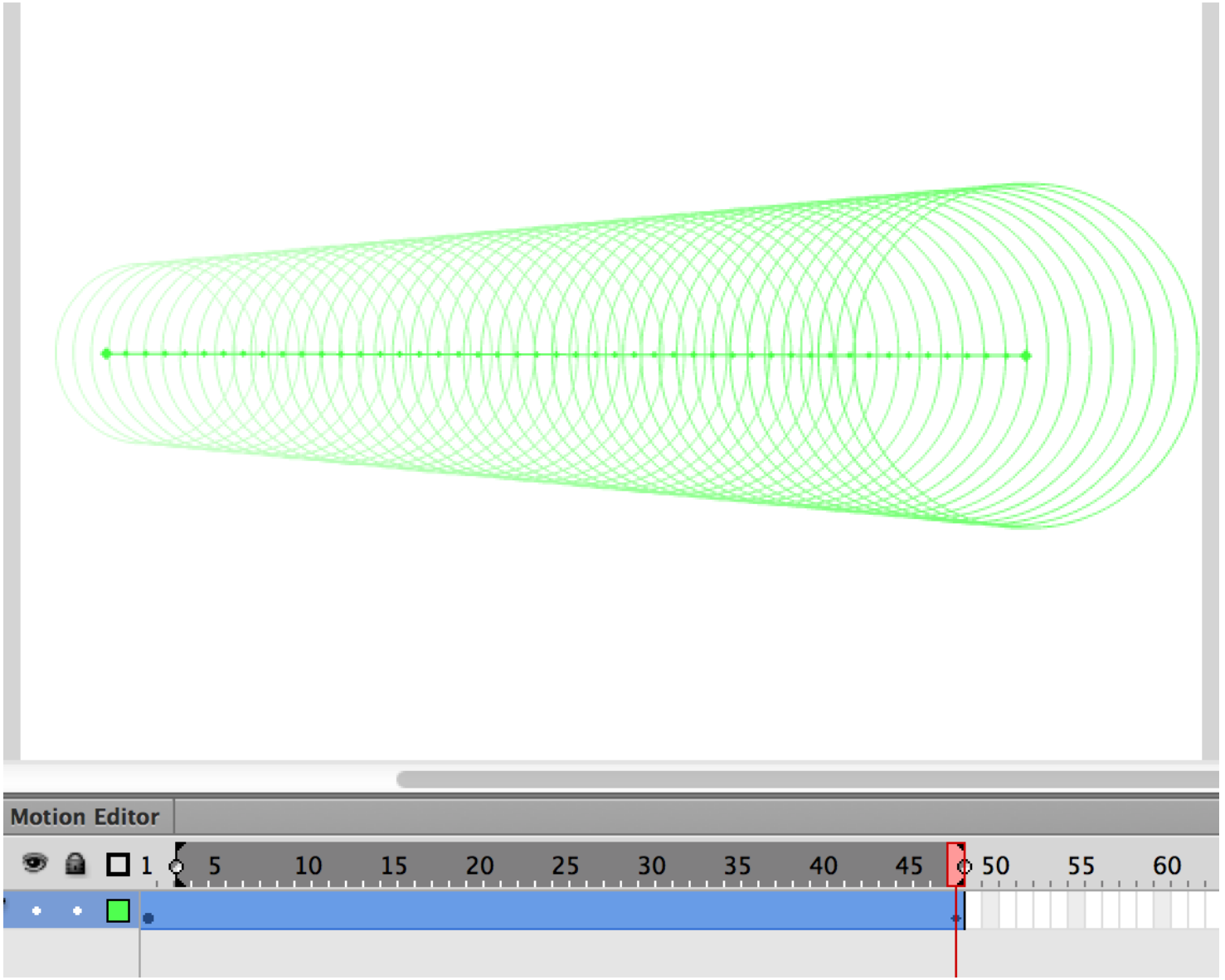


motiontween1.fla

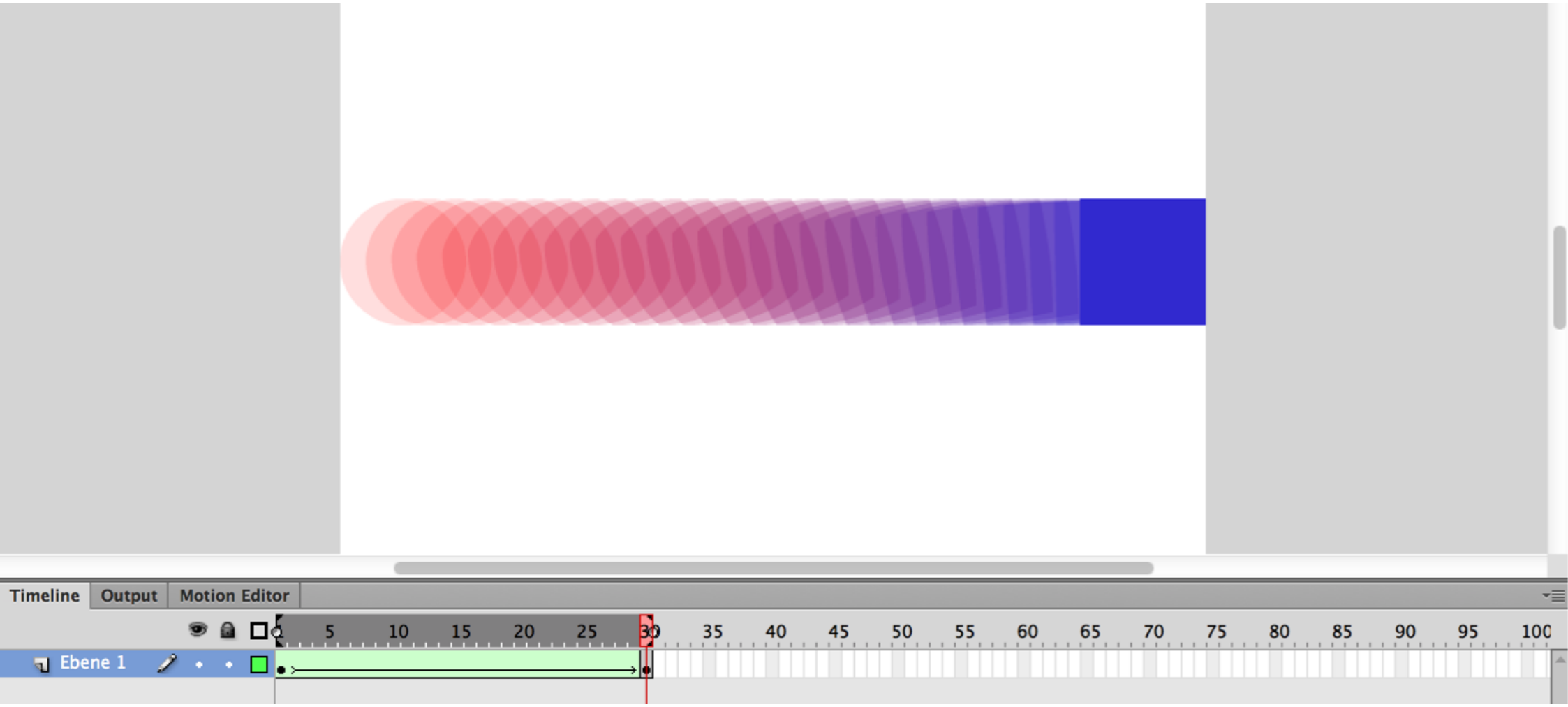
Example: Tweening Colours in Flash



Example: Tweening Object Size in Flash



Example: Shape Tweening in Flash

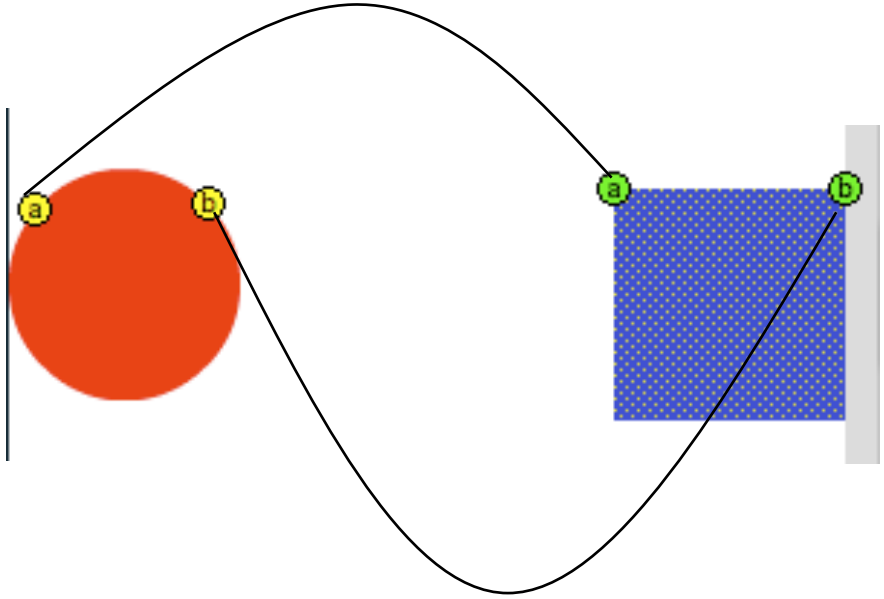


Shape tweening interpolates between geometric shapes

Example: Shape Hints (Flash)

Shape hints (Formmarker) enable fine control of shape tweening

- Pair of (start/end) points to be mapped on each other in transformation



4 Programming with Animations

4.1 Animated Graphics: Principles and History

4.2 Types of Animation

4.3 Programming Animations: Interpolation 

4.4 Design of Animations

4.5 Game Physics

Literature:

W. McGugan 2007 (see above)

K. Peters: ActionScript 3.0 Animation - Making Things Move!
Friends of ED/Apress 2007

Interpolation (General)

- Given: (Finite) set of data points
- Computed: New data points such that a function exists which
  - has the given data points in its graph
  - is defined on a given input range
  - fulfills certain constraints
- Most simple case: Linear interpolation
  - Two data points given
  - Computes a linear function
- Multimedia interpolation:
  - Discrete inputs and values for all functions
  - Example: Interpolating horizontal position along x-axis

Discrete Linear Interpolation

- Given:
  - Number *n* of steps (e.g. animation frames)
  - Value in step 0: v_{start}
  - Value in step n: v_{end}
- Compute:
  - Value *v* for all intermediate steps *i* between 0 and *n*
- Traditional (Newton) interpolation formula:

$$v_i = v_{start} + \frac{v_{end} - v_{start}}{n} \cdot i$$

- Using a constant:

$$dv = \frac{v_{end} - v_{start}}{n}$$

$$v_i = v_{start} + dv \cdot i$$

```
i = 0
while True:
    if i <= n:
        print 'Step no', i, ': v=', v
        i += 1
        v = vstart + dv*i
    else:
        break
```

Linear Interpolation of Position

```
vstart = 40
xstart = 40
xend = 600
n = 80 #Number of steps
dx = (xend - xstart)/n

i = 0
x = xstart
y = 240

while True:
    for event in pygame.event.get():
        if event.type == QUIT:
            exit()
    if i <= n:
        pygame.draw.rect(scr, white, Rect((0, 0),(scr_w, scr_h)))
        pygame.draw.circle(scr, red, (x, y), 40)
        i += 1
        x = xstart + dx*i

    pygame.display.update()
```

But:

Interpolated variable (x) can be computed differentially

Speed of animation depends on computing speed

Beware of Rounding Problems!

```
vstart = 40
vend = 500
vdiff = vend - vstart
dv = vdiff/n # // in Python 3!
v = vstart
i = 0

while True:
    if i <= n:
        print 'Step no', i, ': v=', v
        i += 1
        v = vstart + dv*i
    else:
        break
```

```
Step no 80 : v= 440
```

```
vstart = 40
vend = 500
vdiff = float(vend - vstart)
dv = vdiff/n   # easier in Python 3!
v = vstart
i = 0

while True:
    if i <= n:
        print 'Step no', i, ': v=', v
        i += 1
        v = vstart + dv*i
    else:
        break
```

```
Step no 80 : v= 500.0
```

QUIZ: Why are the results different?

Interpolation using Fixed Frame Rate

```
xstart = 40
xend = 600
framerate = 30 #frames per second
n = 80 #Number of steps
dx = (xend - xstart)/n

clock = pygame.time.Clock()
x = xstart
y = 240

while True:
    for event in pygame.event.get():
        if event.type == QUIT:
            exit()

    if x+40 <= scr_w:
        pygame.draw.rect(scr, white, Rect((0, 0), (scr_w, scr_h)))
        pygame.draw.circle(scr, red, (x, y), 40)
        x += dx

    timepassed = clock.tick(framerate)
    pygame.display.update()
```

Clock.tick() documentation

If you pass the optional framerate argument the function will delay to keep the game running slower than the given ticks per second. This can be used to help limit the runtime speed of a game. By calling Clock.tick(40) once per frame, the program will never run at more than 40 frames per second.

Differential positioning simplifies code

Termination test now based on scene!

Speed of animation relative to frame rate

Computation of Speed

- Assume a given frame rate *fr*
- Specifying speed of an object in absolute terms
  - [pixel/second]
- How is the relationship between:?
  - the relative delta per frame *delta* [px]
  - the absolute speed of the object *speed* [px/s]
  - the frame rate *fr* [1/s]

$$delta \cdot fr = speed$$

- Consequence:

$$delta = \frac{speed}{fr}$$

```
speed = 210 #pixels per second
dx = speed/framerate
```

Alternative: Compute *dx* within loop from *timepassed* * *speed*

QUIZ

- Look at the source code of the preceding example (AnimationBasics2)
- Do we actually need the variable *xend*? What is its purpose?

Interpolating Colors

```
red = (255, 0, 0)
blue = (0, 0, 255)
white = (255, 255, 255)

def blend_color (color1, color2, blend_factor):
    red1, green1, blue1 = color1
    red2, green2, blue2 = color2
    red0 = red1+(red2-red1)*blend_factor
    green0 = green1+(green2-green1)*blend_factor
    blue0 = blue1+(blue2-blue1)*blend_factor
    return int(red0), int(green0), int(blue0)


blend_color(red, blue, colorfactor)
```

Interpolating Colors and Size

```
…
steps = (xend - xstart)/dx
dsize = 1.0/steps
dcolor = 1.0/steps
clock = pygame.time.Clock()
x = xstart
y = 240
r = 40
sizefactor = 1
colorfactor = 0

while True:
    for event in pygame.event.get():…
    xr = r*sizefactor
    if x+xr <= scr_w:
        pygame.draw.rect(scr, white, Rect((0, 0), (scr_w, scr_h)))
        pygame.draw.circle
         (scr, blend_color(red, blue, colorfactor), (x, y), int(xr))
        x += dx
        sizefactor += dsize
        colorfactor += dcolor
    timepassed_secs = clock.tick(framerate) / 1000.0
    pygame.display.update()
```

Animation Using Transitions in JavaFX

- *Transitions*:
  - Simple built-in animation framework in JavaFX, using implicit time container
  - Various types of transitions: Fade, Fill, Path, Rotate, Scale, Stroke, Translate
  - Parallel and sequential composition of transitions

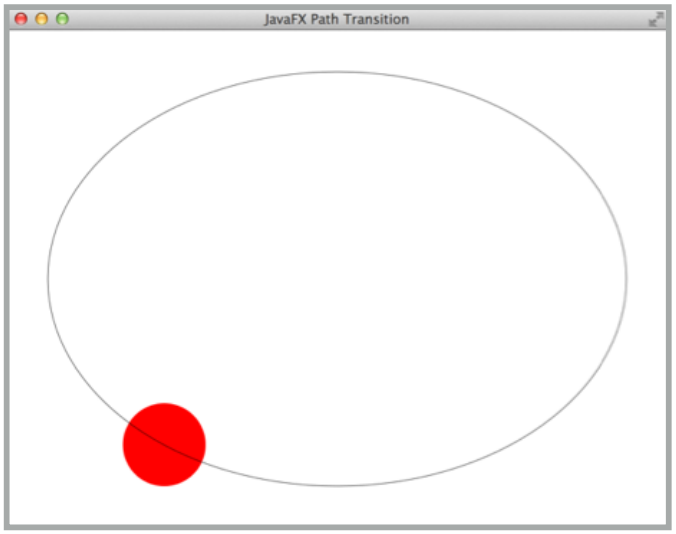
```
Circle c = new Circle(40, 240, 40);
c.setFill(Color.RED);
root.getChildren().add(c);

TranslateTransition tt = new TranslateTransition
                                (Duration.millis(3000), c);
tt.setToX(520);
…
primaryStage.show();
tt.play();
```

Parallel Transitions in JavaFX

```
Circle c = new Circle(40, 240, 40);…
root.getChildren().add(c);

TranslateTransition tt = new TranslateTransition
                                    (Duration.millis(3000), c);
tt.setToX(520);

ScaleTransition st = new ScaleTransition
                                    (Duration.millis(3000), c);
st.setToX(2.0f);
st.setToY(2.0f);

FillTransition ft = new FillTransition
                                    (Duration.millis(3000), c);
ft.setToValue(Color.BLUE);

ParallelTransition trans = new ParallelTransition();
trans.getChildren().addAll(tt, st, ft);
…
primaryStage.show();
trans.play();
```

Path Transitions in JavaFX

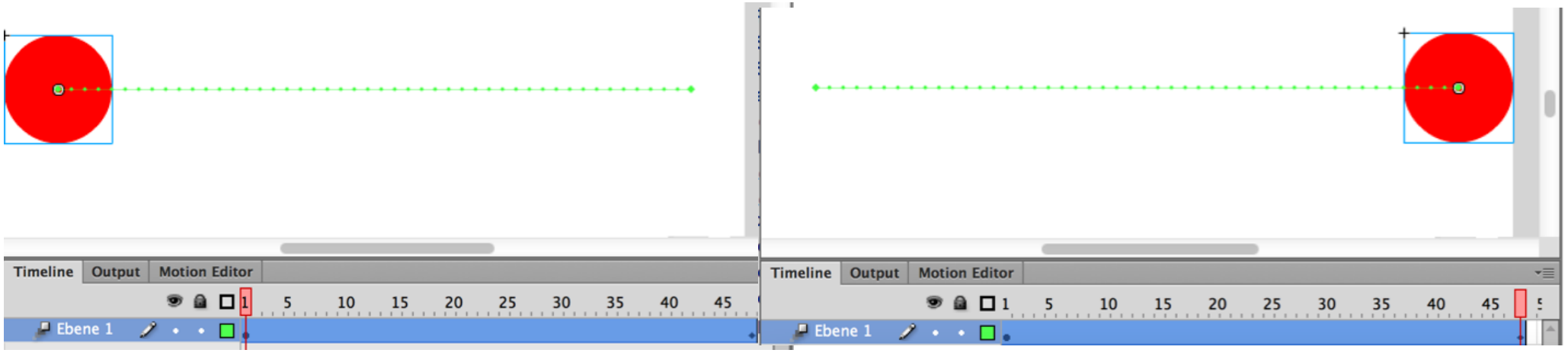
```
Path path = new Path();
path.getElements().add(new MoveTo(40, 240));
path.getElements().add(
     new ArcTo(280, 200, 0, 320, 440, false, false));
path.getElements().add(
     new ArcTo(280, 200, 0, 600, 240, false, false));
path.getElements().add(
     new ArcTo(280, 200, 0, 320, 40, false, false));
path.getElements().add(
     new ArcTo(280, 200, 0, 40, 240, false, false));
path.setStroke(Color.BLACK);
path.setStrokeWidth(0.5);
root.getChildren().add(path);

PathTransition pt = new PathTransition();
pt.setDuration(Duration.millis(4000));
pt.setPath(path);
pt.setNode(c);
pt.setInterpolator(Interpolator.LINEAR);
pt.setCycleCount(Timeline.INDEFINITE);
```



Non-Linear Interpolation, Easing

- Plain linear interpolation does not match physical reality
  - Inertia, acceleration, deceleration, overshooting
- Custom interpolators
  - Use different computation of intermediate values
  - In Java FX: Create subclass of **`Interpolator`** and implement the **`curve()`** function (mapping [0.0 … 1.0] to itself)
- Frequently used non-linear interpolators:
  - ***EaseIn***, ***EaseOut***, ***EaseBoth***
  - Smooth acceleration and deceleration of movement
  - In some frameworks, acceleration factors are adjustable
  - JavaFX: *EaseBoth* is default for Transitions, acceleration factor is 0.2
  - CreateJS: Ease in and easy out plus additional effects (bounce)

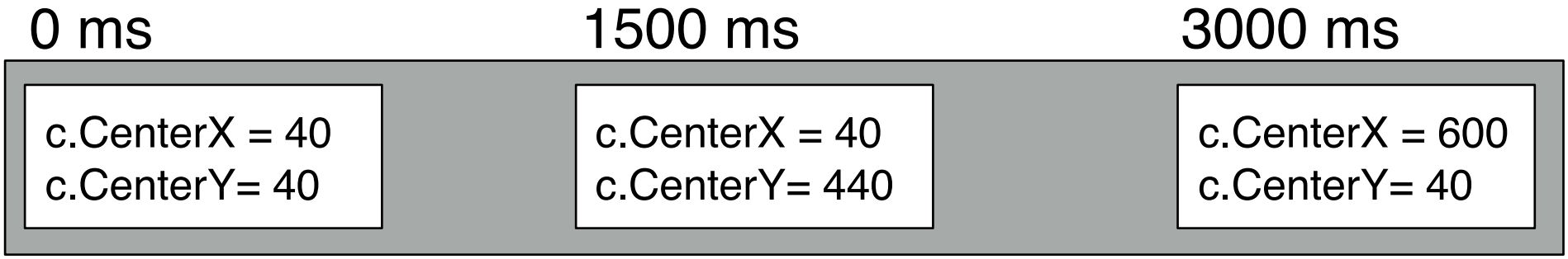
Timelines and Keyframes



- *Timeline:*
  - Playable time container containing *key frames*
- *Key frame:*
  - Carries time stamp relative to time line
  - Container for *key values*
- *Key value:*
  - Pair of (property of a stage object, value for the property)
- Interpolation between key frames is automatically inferred

Timeline Animation in JavaFX

```
Circle c = new Circle(40, 40, 40);
…
Timeline timeline = new Timeline();
timeline.setCycleCount(Timeline.INDEFINITE);
timeline.setAutoReverse(true);
KeyFrame endFrame = new KeyFrame(Duration.millis(3000),
    new KeyValue(c.centerXProperty(), 600),
    new KeyValue(c.centerYProperty(), 40));
timeline.getKeyFrames().add(endFrame);
KeyFrame middleFrame = new KeyFrame(Duration.millis(1500),
     new KeyValue(c.centerYProperty(), 440));
timeline.getKeyFrames().add(middleFrame);
…
timeline.play();
```



QUIZ

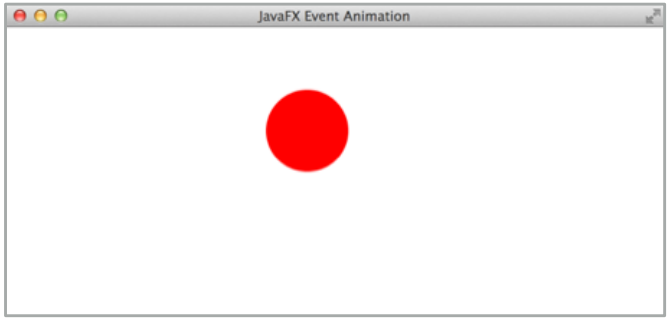
- What do we see if we run the preceding program?

Regularly Timed Update Events

- Many programs update the stage at regular positions in time
  - Framerate dependent clock in Pygame programs
  - EnterFrame event in Adobe Flash
  - KeyFrame events in JavaFX
- Typical realisation:
  - Event handler, being called at regular intervals
  - Timeline concept can be used
  - JavaFX: Event at certain (timed) key frames
  - Flash: Event when entering a frame

Time Event Animation in JavaFX

```
Timeline timeline = new Timeline();
timeline.setCycleCount(Timeline.INDEFINITE);
KeyFrame moveCircle = new KeyFrame(Duration.millis(20),
      new EventHandler<ActionEvent>() {
          public void handle(ActionEvent event) {
              if (c.getTranslateX()+2*r > sc_w ||
                  c.getTranslateX() < 0) {
                  dx = -dx;
              }
              if (c.getTranslateY()+2*r > sc_h ||
                  c.getTranslateY() < 0) {
                  dy = -dy;
              }
              c.setTranslateX(c.getTranslateX()+dx);
              c.setTranslateY(c.getTranslateY()+dy);
          }
      });
timeline.getKeyFrames().add(moveCircle);
…
timeline.play();
```



Interpolation (Tweening) in CreateJS

```
var circle = new createjs.Shape();
circle.graphics
       .beginFill("red")
       .drawCircle(0, 0, r);
circle.x = 40;
circle.y = 240;
stage.addChild(circle);

createjs.Tween.get(circle,{loop:true})
       .to({x:st_w-2*r, scaleX:2.0, scaleY:2.0}, 4000,
              createjs.Ease.bounceOut);

createjs.Ticker.setFPS(30);
createjs.Ticker.addEventListener("tick", stage);
```