

# John Romero Programming Proverbs



- John Romero, “The Early Days of Id Software - John Romero @ WeAreDevelopers Conference 2017”

## Collision prediction between circles

- de-tour
  - recall we can predict the time a point travels a distance by:

- $$s = ut + \frac{1}{2} at^2$$

- s = distance  
u = initial velocity  
a = acceleration  
t = time

## De-tour

- if we were to drop a small ball bearing from 1 metre, how long would it take to hit the ground?
- initial velocity ( $u = 0$ )
- acceleration approx ( $a = 10$ )  $ms^2$

## De-tour

■ thus

■  $1 = \frac{1}{2} at^2$

■  $1 = \frac{1}{2} 10t^2$

■  $1 = 5t^2$

■  $\frac{1}{5} = t^2$

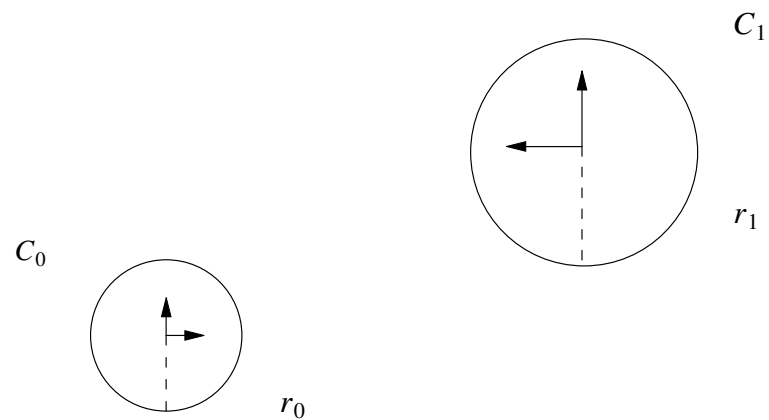
■  $t = \pm \sqrt{\frac{1}{5}}$



## De-tour

- $t = 0.45$
- $t = -0.45$
- we also note that for more complicated quadratic equations we can use the formula:
- $$t = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$
- for any equation matching:  $at^2 + bt + c = 0$

## Collision prediction between circles



- each circle has a radius, position, velocity and acceleration
  - radius is a scalar, all others are vectors

## Collision prediction between circles

- remember that when these circles collide the distance between the two circle mid points will be  $r_0 + r_1$
- we know generally that the distance between the circles can be calculated as:  $\sqrt{(c_{0x} - c_{1x})^2 + (c_{0y} - c_{1y})^2}$
- so we need to find the time when:  $r_0 + r_1 = \sqrt{(c_{0x} - c_{1x})^2 + (c_{0y} - c_{1y})^2}$



## Collision prediction between circles

- using the formula for initial position, velocity and acceleration:

$s = s_0 + ut + \frac{at^2}{2}$  it is also known that the position circle  $c_0$  at time,  $t$ , is:

$$\left[ c_{0x} + v_{0x}t + \frac{a_{0x}t^2}{2}, c_{0y} + v_{0y}t + \frac{a_{0y}t^2}{2} \right]$$

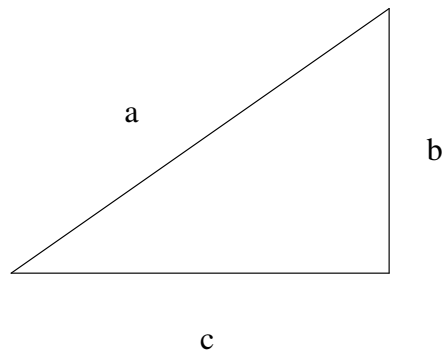
- correspondingly the position circle  $c_1$  at time,  $t$ , is:

$$\left[ c_{1x} + v_{1x}t + \frac{a_{1x}t^2}{2}, c_{1y} + v_{1y}t + \frac{a_{1y}t^2}{2} \right]$$

## Collision prediction between circles

- recall Pythagorean theorem can be used to find the length of the hypotenuse from the length of the base and height of a right angled triangle

## Collision prediction between circles



$$a^2 = b^2 + c^2$$



$$a = \sqrt{b^2 + c^2}$$

## Collision prediction between circles

- $a$  is the radius of circle 0 and circle 1
  - $a = r_0 + r_1$
- $b$  is the difference of the y-axis position of the circles
- $c$  is the difference of the x-axis position of the circles

## Collision prediction between circles

- therefore we need to find the time at which the distance between both circles is  $r_0 + r_1$  which is:

- $$r_0 + r_1 = \sqrt{\left[\left(c_{0x} + v_{0x}t + \frac{a_{0x}t^2}{2}\right) - \left(c_{1x} + v_{1x}t + \frac{a_{1x}t^2}{2}\right)\right]^2 + \left[\left(c_{0y} + v_{0y}t + \frac{a_{0y}t^2}{2}\right) - \left(c_{1y} + v_{1y}t + \frac{a_{1y}t^2}{2}\right)\right]^2}$$

- which can be easily rearranged as:

- $$0 = \left[\left(c_{0x} + v_{0x}t + \frac{a_{0x}t^2}{2}\right) - \left(c_{1x} + v_{1x}t + \frac{a_{1x}t^2}{2}\right)\right]^2 + \left[\left(c_{0y} + v_{0y}t + \frac{a_{0y}t^2}{2}\right) - \left(c_{1y} + v_{1y}t + \frac{a_{1y}t^2}{2}\right)\right]^2 - (r_0 + r_1)^2$$

## Collision prediction between circles

- we need to multiply the equation and separate out the values: A, B, C, D, E where:
- $At^4 + Bt^3 + Ct^2 + Dt + E = 0$
- then we solve for,  $t$  and the smallest value of  $t$  which is greater than zero is the next collision time
- see `pge/twoDsim.mod` in the function `findCollisionCircles`

## wxmaxima

- fortunately, we have a tool called `wxmaxima` (similar to Mathematica) which will manipulate the algebra without mistake :-)

## wxmaxima

```
ri + rj == sqrt(abs(xin-xjn)^2 + abs(yin-yjn)^2)      for values of t

ri + rj == sqrt(((xi + vxi * t + aix * t^2 / 2.0) - (xj + vxj * t + ajx * t^2 / 2.0))^2 +
                ((yi + vyi * t + aiy * t^2 / 2.0) - (yj + vyj * t + ajy * t^2 / 2.0))^2)

let:

a = xi
b = xj
c = vxi
d = vxj
e = aix
f = ajx
g = yi
h = yj
k = vyi
l = vyj
m = aiy
n = ajy
o = ri
p = rj
t = t
```



# wxmaxima

```
o + p == sqrt(((a + c * t + e * t^2 / 2.0) - (b + d * t + f * t^2 / 2.0))^2 +
              ((g + k * t + m * t^2 / 2.0) - (h + l * t + n * t^2 / 2.0))^2)

o + p == sqrt(((a + c * t + e * t^2 / 2.0) - (b + d * t + f * t^2 / 2.0))^2 +
              ((g + k * t + m * t^2 / 2.0) - (h + l * t + n * t^2 / 2.0))^2)

0      == ((a + c * t + e * t^2 / 2.0) - (b + d * t + f * t^2 / 2.0))^2 +
          ((g + k * t + m * t^2 / 2.0) - (h + l * t + n * t^2 / 2.0))^2 -
          (o + p)^2

now using wxmaxima
expand ; factor ; ratsimp
```

# wxmaxima

```
p+o == (sqrt((n^2-2*m*n+m^2+f^2-2*e*f+e^2)*t^4+
((4*l-4*k)*n+(4*k-4*l)*m+(4*d-4*c)*f+(4*c-4*d)*e)*t^3+
((4*h-4*g)*n+(4*g-4*h)*m+4*l^2-8*k*l+4*k^2+(4*b-4*a)*f+
(4*a-4*b)*e+4*d^2-8*c*d+4*c^2)*t^2+
((8*h-8*g)*l+(8*g-8*h)*k+(8*b-8*a)*d+(8*a-8*b)*c)*t+
4*h^2-8*g*h+4*g^2+4*b^2-8*a*b+4*a^2))/2

2*(p+o) == (sqrt((n^2-2*m*n+m^2+f^2-2*e*f+e^2)*t^4+
((4*l-4*k)*n+(4*k-4*l)*m+(4*d-4*c)*f+(4*c-4*d)*e)*t^3+
((4*h-4*g)*n+(4*g-4*h)*m+4*l^2-8*k*l+4*k^2+(4*b-4*a)*f+
(4*a-4*b)*e+4*d^2-8*c*d+4*c^2)*t^2+
((8*h-8*g)*l+(8*g-8*h)*k+(8*b-8*a)*d+(8*a-8*b)*c)*t+
4*h^2-8*g*h+4*g^2+4*b^2-8*a*b+4*a^2))
```

# wxmaxima

```
(2*(p+o))^2 == ( (n^2-2*m*n+m^2+f^2-2*e*f+e^2)*t^4+
  ( (4*l-4*k)*n+(4*k-4*l)*m+(4*d-4*c)*f+(4*c-4*d)*e)*t^3+
  ( (4*h-4*g)*n+(4*g-4*h)*m+4*l^2-8*k*l+4*k^2+(4*b-4*a)*f+
    (4*a-4*b)*e+4*d^2-8*c*d+4*c^2)*t^2+
  ( (8*h-8*g)*l+(8*g-8*h)*k+(8*b-8*a)*d+(8*a-8*b)*c)*t+
  4*h^2-8*g*h+4*g^2+4*b^2-8*a*b+4*a^2) )

0 == (n^2-2*m*n+m^2+f^2-2*e*f+e^2)*t^4+
  ( (4*l-4*k)*n+(4*k-4*l)*m+(4*d-4*c)*f+(4*c-4*d)*e)*t^3+
  ( (4*h-4*g)*n+(4*g-4*h)*m+4*l^2-8*k*l+4*k^2+(4*b-4*a)*f+
    (4*a-4*b)*e+4*d^2-8*c*d+4*c^2)*t^2+
  ( (8*h-8*g)*l+(8*g-8*h)*k+(8*b-8*a)*d+(8*a-8*b)*c)*t+
  4*h^2-8*g*h+4*g^2+4*b^2-8*a*b+4*a^2) -
  ( (2*(p+o))^2)
```

## wxmaxima

■ solve polynomial:

```
A := sqrt(n)-2.0*m*n+sqrt(m)+sqrt(f)-2.0*e*f+sqrt(e) ;  
B := (4.0*l-4.0*k)*n+(4.0*k-4.0*l)*m+(4.0*d-4.0*c)*f+(4.0*c-4.0*d)*e ;  
C := (4.0*h-4.0*g)*n+(4.0*g-4.0*h)*m+4.0*sqrt(l)-8.0*k*l+4.0*sqrt(k)+  
      (4.0*b-4.0*a)*f+(4.0*a-4.0*b)*e+4.0*sqrt(d)-8.0*c*d+4.0*sqrt(c) ;  
D := (8.0*h-8.0*g)*l+(8.0*g-8.0*h)*k+(8.0*b-8.0*a)*d+(8.0*a-8.0*b)*c ;  
E := 4.0*sqrt(h)-8.0*g*h+4.0*sqrt(g)+4.0*sqrt(b)-8.0*a*b+4.0*sqrt(a)-sqrt(2.0*(p+o)) ;
```

■ fortunately, we can cut and paste the output from wxmaxima into our code and carefully convert it into program code and it works!

## Conclusion

- we have seen that we can predict when two circles will collide in the future
  - using  $x$  and  $y$  components based on  $s = ut + a \frac{t^2}{2}$
- in the next lecture we will extend this to look at calculating the time a circle hits a polygon