Msc project proposal

Project:   
Creating a physics engine for use in mobile app development.

Aim:   
Purpose of this project is to create a Physics engine for mobile game development to be built through the use of with The use of open source graphics and rendering libraries.

# The physics engine should be able to do:

* Simulate the linear and Rotational Motion of an Object
* Simulate Collisions between objects and accurately simulate the result of collision
* Simulate physical properties of both Soft and rigid body objects
* Be able to incorporate different shapes for different objects with different properties.

# Objects In Motion:

As mentioned above, Two types of motion will be examined, linear and rotational motion. By understanding linear motion, the ability to grasp circular motion will be much easier.

## Linear motion

In the most basic sense, an object in motion could be derived from a graph charting uniform velocity against time as demonstrated below:

### Uniform displacement, velocity and acceleration

(draw constant velocity/time diagram here)

with a constant velocity, the total distance travelled can easily be determined by calculating the area of the rectangle below the velocity line as shown below:

.1

Where:

* s = displacement
* v = velocity
* t = time elapsed

However, when velocity has a constant acceleration as shown below:

(draw constant accelerating velocity/ time here)

The total displacement(distance in this case) can still be determined by calculating the area of a triangle as shown below

.2

However, if the object is already in motion i.e. v < 0 when t = 0.

(draw constant acceleration velocity/time diagram where v < 0)

Then by finding the change in velocity during the total time elapsed **t**; we can determine the distance travelled during time elapsed **t** again through the equation below

.3

Where:

* v0 = the initial velocity of the object
* v1 = the final velocity of the object

Also through the use of the graph above, we can determine the rate of change of velocity as the gradient of the line. This is known as the acceleration of an object and can be calculated as shown bellow:

.4

Where:

* a = acceleration of the object

Further equations of motions can also be derived from an acceleration vs time graph as shown below

(draw constant acceleration/time graph here)

As demonstrated earlier with the constant velocity against time diagram, we can calculate the velocity at the total time elapsed by calculating the area of the rectangle under the line as demonstrated below

.5

And the same approach can be used when calculating the current velocity with a constantly increasing acceleration by calculating the area of the triangle instead of a rectangle as shown below

(draw constantly increasing acceleration/time graph here)

If v > 0 when t = 0

By substituting the equation for velocity as shown in eq.1 we get the following

And re-arrange to get an equation for the displacement s

.7

Non uniform displacement, velocity and acceleration  
  
So far, all equations where derived from uniform displacement, velocity and acceleration. However, in realistic scenarios, the plotting of velocity against time would look something like this.

(insert non-uniform velocity / time)

Therefore, more approaches are required to determine the displacement or acceleration. One method would be to divide the graph up into segments

#### Segmentation and the trapezium rule

One method of determining values for either displacement, velocity or acceleration would be to segment the graph into multiple segments and then calculate the average values from those segments as demonstrated below.

(demonstrate using the trapezium rule on the non-uniform velocity time graph)

In order to determine the acceleration at a given segment, we simply apply the same calculation used with the uniform velocity/time graph as shown in eq. 4 shown below

Therefore, if we want to assess the average acceleration across the velocity/time graph, we could get the mean value of all acceleration segments as shown below

where:

n = number of segments

Also using this method of segmentation would also allow us to more accurately determine the area under the velocity curve to get a more accurate value of displacement through the use of the trapezium rule as demonstrated below.

And with a variable acceleration/time graph

(insert variable acceleration/time here)

As demonstrated with determining the displacement using the trapezium rule, we can also determine the velocity using the trapezium rule as shown below

However, the values obtained through segmentation will never be 100% accurate. However, by introducing more segments to the graph, the accuracy of the value obtained will get much closer to the actual value.

#### Using differential and integral equations for non-uniform motion

As demonstrated with segmentation, the more segments in the graph, the more accurate the final result. Therefore, through observing each segments. It could be determined that velocity is a measure of the rate of change of displacement against the change in time as shown below

And that acceleration is a measure of the rate of change of velocity against the change in time as demonstrated below aswel

Therefore, we can determine that this will remain the case with an infinitely small value for t as shown bellow

Therefore allowing for the use of differential equations as shown from the graphs above, velocity is the differential of displacement as acceleration is the differential of velocity

where:

* v = the velocity(speed with a vector)of the object in motion
* S0 = the initial displacement (position) of the object
* S1 = the final displacement of the object (think of s0 – s1 as the distance travelled)
* t0 = the initial time of motion
* t1­ = the final time of motion (think of t1 – t0 as the total time elapsed

Therefore, from the equation above, It can be said that velocity is a measure of the change in displacement (distance travelled) against the change in time. Therefore to calculate the velocity at a given instance; we can take (s0 - s1) to be Δs and and (t0 – t1) to be Δt and can be written as followed:

**v = Δs/Δt**

where:

* Δ = the change in (so Δs is the change in displacement or distance travelled)

Now velocity has been expressed with the change of displacement against the change in time, the equation above can be written as a differential equation for the changing **Δ** for **d** where we take the time elapsed as a value infinitely small as shown below:

The equation above does not account for the acceleration of the object. However, acceleration is simply the change of velocity over a given period of time. Therefore, the equation for acceleration can be written as the following:

**a = v1/t1 – v0/t0**

where:

* v1 = the final value for velocity
* v0 = the initial value for velocity
* a = rate of change of velocity over time period (t0 – t1)

Therefore, Like the equation for velocity, the equation for acceleration over a change in velocity and time can be denoted as the following:

**a = Δv/Δt**

and for a given instance where **t** is infinitely small of acceleration:

**a = dv/dt**

Therefore, it can be said that velocity is a differential equation of displacement and acceleration is a differential equation of velocity. Therefore, acceleration can be viewed as the second differential of displacement as demonstrated below:

**A = d2s/dt2**

As we have derived equations from displacement to velocity to acceleration. The same can be done in reverse through integrating acceleration to get the value for velocity and integrating velocity to get the value for displacement as shown below:

And

This can be applied whether the acceleration of an object is constant or is constantly varying with respect to time for example:  
if an acceleration profile takes the value; a = vt2 + 2t, then the velocity would be calculated as

Which would give us



## References:

1. [Physics for Game Developers, 2nd Edition](https://learning.oreilly.com/library/view/physics-for-game/9781449361037/) by Bryan Bywalec; David M Bourg  
   Chapter 2: Kinematics; velocity and acceleration   
   (viewed from https://learning.oreilly.com/library/view/physics-for-game/9781449361037/ch02.html**)**