

Moving Through Waypoints

Computer Graphics and Animation Programming Assignment 18



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# Introduction

# Basic Theory

## Speed

Just as distance and displacement have distinctly different meanings (despite their similarities), so do speed and velocity. Speed is a [scalar quantity](http://www.physicsclassroom.com/Class/1DKin/U1L1b.cfm) that refers to "how fast an object is moving." Speed can be thought of as the rate at which an object covers distance. A fast-moving object has a high speed and covers a relatively large distance in a short amount of time. Contrast this to a slow-moving object that has a low speed; it covers a relatively small amount of distance in the same amount of time. An object with no movement at all has a zero speed.

The average speed during the course of a motion is often computed using the following formula:

*Average Speed = =*

The circumference of any circle can be computed using from the radius according to the equation:

Combining these two equations above will lead to a new equation relating the speed of an object moving in uniform circular motion to the radius of the circle and the time to make one cycle around the circle (**period**).

where **r** represents the radius of the circle and **T** represents the period. This equation, like all equations, can be used as an algebraic recipe for problem solving. It also can be used to guide our thinking about the variables in the equation relate to each other. For instance, the equation suggests that for objects moving around circles of different radius in the same period, the object traversing the circle of larger radius must be traveling with the greatest speed.

# Velocity

Velocity is a [vector quantity](http://www.physicsclassroom.com/Class/1DKin/U1L1b.cfm) that refers to "the rate at which an object changes its position." Imagine a person moving rapidly - one step forward and one step back - always returning to the original starting position. While this might result in a frenzy of activity, it would result in a zero velocity. Because the person always returns to the original position, the motion would never result in a change in position. Since velocity is defined as the rate at which the position changes, this motion results in zero velocity. If a person in motion wishes to maximize their velocity, then that person must make every effort to maximize the amount that they are displaced from their original position. Every step must go into moving that person further from where he or she started. For certain, the person should never change directions and begin to return to the starting position.

Velocity is a vector quantity. As such, velocity is direction aware. When evaluating the velocity of an object, one must keep track of direction. It would not be enough to say that an object has a velocity of 55 mi/hr. One must include direction information in order to fully describe the velocity of the object. For instance, you must describe an object's velocity as being 55 mi/hr, **east**. This is one of the essential differences between speed and velocity. Speed is a scalar quantity and does not keep track of direction; velocity is a vector quantity and is direction aware.

The task of describing the direction of the velocity vector is easy. The direction of the velocity vector is simply the same as the direction that an object is moving. It would not matter whether the object is speeding up or slowing down. If an object is moving rightwards, then its velocity is described as being rightwards. If an object is moving downwards, then its velocity is described as being downwards. So an airplane moving towards the west with a speed of 300 mi/hr has a velocity of 300 mi/hr, west. Note that speed has no direction (it is a scalar) and the velocity at any instant is simply the speed value with a direction.

The average velocity during the course of a motion is often computed using the following formula:

the instantaneous velocity computed using the following formula:

# 2.3 [Acceleration](https://www.google.com/search?client=firefox-b-ab&q=acceleration&spell=1&sa=X&ved=0ahUKEwjU6eLeidXXAhWFOI8KHZuZAUsQvwUIJCgA&biw=765&bih=751)

Acceleration is a [vector quantity](http://www.physicsclassroom.com/Class/1DKin/U1L1b.cfm) that is defined as the rate at which an object changes its [velocity](http://www.physicsclassroom.com/Class/1DKin/U1L1d.cfm). An object is accelerating if it is changing its velocity. Sometimes an accelerating object will change its velocity by the same amount each second. As mentioned in the previous paragraph, the data table above show an object changing its velocity by 10 m/s in each consecutive second. This is referred to as a constant acceleration since the velocity is changing by a constant amount each second. This is referred to as a constant acceleration since the velocity is changing by a constant amount each second. An object with a constant acceleration should not be confused with an object with a constant velocity. If an object is changing its velocity -whether by a constant amount or a varying amount - then it is an accelerating object. And an object with a constant velocity is not accelerating. The data tables below depict motions of objects with a constant acceleration and a changing acceleration. Note that each object has a changing velocity.

The average acceleration (a) of any object over a given interval of time (t) can be calculated using the equation:

Since acceleration is a [vector quantity](http://www.physicsclassroom.com/Class/1DKin/U1L1b.cfm), it has a direction associated with it. The direction of the acceleration vector depends on two things:

* whether the object is speeding up or slowing down
* whether the object is moving in the *+* or- direction

The general principle for determining the acceleration is, if an object is slowing down, then its acceleration is in the opposite direction of its motion. This general principle can be applied to determine whether the sign of the acceleration of an object is positive or negative, right or left, up or down, etc.

# 2.4 Projectile Motion

Projectile motion is a form of motion where an object moves in a bilaterally symmetrical, parabolic path. The path that the object follows is called its trajectory. Projectile motion only occurs when there is one force applied at the beginning on the trajectory, after which the only interference is from gravity. In a previous atom we discussed what the various components of an object in projectile motion are. In this atom we will discuss the basic equations that go along with them in the special case in which the projectile initial positions are null

The initial velocity can be expressed as x components and y components:

In this equation, stands for initial velocity magnitude and θ refers to projectile angle. In projectile motion, there is no acceleration in the horizontal direction. The acceleration, a, in the vertical direction is just due to gravity, also known as free fall:

The horizontal velocity remains constant, but the vertical velocity varies linearly, because the acceleration is constant. At any time, t, the velocity is:

Pythagorean Theorem to find velocity:

At time, t, the displacement components are:

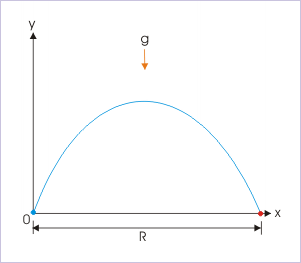
The equation for the magnitude of the displacement is

Use the displacement equations in the x and y direction to obtain an equation for the parabolic form of a projectile motion:

The maximum height is reached when . Using this can rearrange the velocity equation to find the time it will take for the object to reach maximum height

Where stands for the time it takes to reach maximum height. From the displacement equation we can find the maximum height

The range of the motion is fixed by the condition . Using this can rearrange the parabolic motion equation to find the range of the motion:

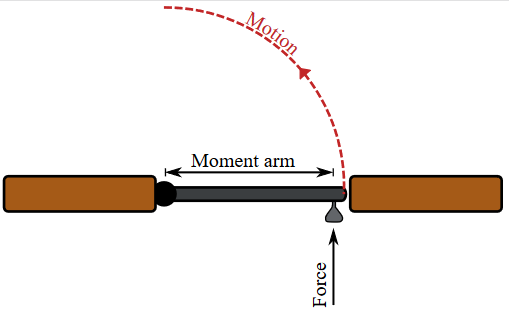


*The range of a trajectory is shown in this figure.*

# 2.5 Torque

Torque is a measure of the force that can cause an object to rotate about an axis. Just as force is what causes an object to accelerate in linear kinematics, torque is what causes an object to acquire angular acceleration. Torque is a vector quantity. The direction of the torque vector depends on the direction of the force on the axis.

Anyone who has ever opened a door has an intuitive understanding of torque. When a person opens a door, they push on the side of the door **farthest** from the hinges. Pushing on the side **closest** to the hinges requires considerably more force. Although the [work done](https://www.khanacademy.org/science/physics/torque-angular-momentum/torque-tutorial/a/science/physics/work-and-energy/work-and-energy-tutorial/a/what-is-work) is the same in both cases (the larger force would be applied over a smaller distance) people generally prefer to apply less force, hence the usual location of the door handle.



*Opening a door with maximum torque*

Torque can be either *static* or *dynamic*. A *static torque* is one which does not produce an angular acceleration. Someone pushing on a closed door is applying a static torque to the door because the door is not rotating about its hinges, despite the force applied. Someone pedaling a bicycle at constant speed is also applying a static torque because they are not accelerating. The drive shaft in a racing car accelerating from the start line is carrying a *dynamic torque* because it must be producing an angular acceleration of the wheels given that the car is accelerating along the track. The terminology used when describing torque can be confusing. Engineers sometimes use the term *moment*, or *moment of force* interchangeably with torque. The radius at which the force acts is sometimes called the *moment arm*.

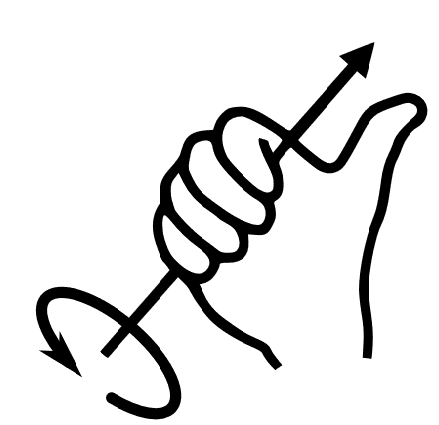
The magnitude of the torque vector τ for a torque produced by a given force F is

τ=F⋅rsin(θ)

where *r* is the length of the moment arm and θ is the angle between the force vector and the moment arm. In the case of the door shown in above, the force is at right angles (90∘) to the moment arm, so the sine term becomes 1 and

τ=F⋅r

The direction of the torque vector is found by convention using the right hand grip rule. If a hand is curled around the axis of rotation with the fingers pointing in the direction of the force, then the torque vector points in the direction of the thumb.



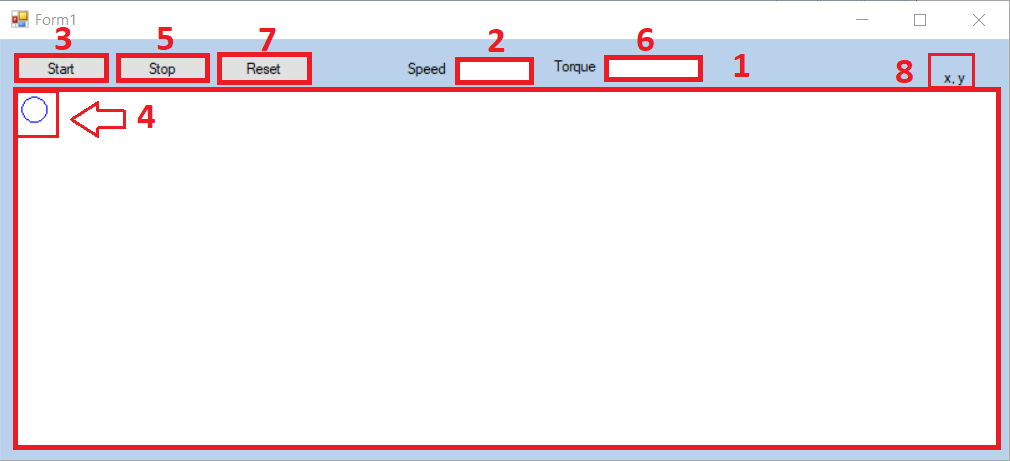
The [SI unit](https://en.wikipedia.org/wiki/International_System_of_Units) for torque is the Newton-meter. In imperial units, the Foot-pound is often used. This is confusing because colloquially the pound is sometimes used as a unit of mass and sometimes force. What is meant here is *pound-force*, the force due to earth gravity on a one-pound object. The magnitude of these units is often similar as 1 Nm≃1.74 ft⋅lbs.

Measuring a static torque in a non-rotating system is usually quite easy, and done by measuring a force. Given the length of the moment arm, the torque can be found directly. Measuring torque in a rotating system is considerably more difficult. One method works by measuring strain within the metal of a drive shaft which is transmitting torque and sending this information wirelessly.

# Implementation

## Main Interface of the Application

This application has one interface, which it uses as its main interface. The interface is pictured below:



The interface consists of the following components:

1. Canvas Picture Box

The canvas is used to display every object generated by the user using the application.

1. Speed Text Box

This Speed textbox is used to enter Speed values of the waypoint.

1. Start Button

This button is used to move the car towards the waypoint.

1. Car

This is the representation of a car in the application.

1. Stop Button

This Button is used to stop while moving.

1. Torque textbox

This Torque textbox is used to enter Torque values of the waypoint.

1. Reset Button

This button is used to reset the application back to the original state.

1. Coordinate label

This Coordinate label is used to show the current x and y coordinate of the mouse.

## Features of the Applicaton

The application has several features, namely:

1. Initializing the position of the car.

The application is able to initialize the position of the car on load.

1. Set waypoints.

the application is able to set the waypoints of the car to go through.

1. Set the speed and torque of the car.

The application is able to input the values of speed and torque for the car to move.

1. Make the car move.

The application is able to make the car move using start button.

1. Stop the car.

The application is able to make the car stop while moving using stop button.

1. Make the car accelerate when it starts to move until it reaches maximum speed.

The car is able to accelerate from the moment it moves until it reaches maximum speed.

1. Make the car decelerate when it stops.

The car is able to decelerate when it decides to stop or when the user demands it to stop

# Design

## Representation of the Car in the Application

## Representation of the Waypoints in the Application

## Next Waypoint Direction Algorithm

## Waypoint Collision Detection Algorithm

## Car Acceleration and Deceleration Algorithm

# Evaluation

## Adding Waypoints

## Moving the Car to Waypoints and Stopping After It Has Reached the Final Waypoint

## Stopping the Car Abruptly and Making It Move Again

## Setting a Low Torque Value for the Car and Making It Move

## Setting a High Torque Value for the Car and Making It Move

## Increasing the Car’s Acceleration

# Work Log

The work log is extracted directly from Visual Studio’s Git Log History, which is also available publicly at <https://github.com/bakanui/MovingThroughWaypoints/commits/master>.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| No | Author | Date | Time | Commit Message |
| 1 | Bhaskara Ida Bagus | 11/21/2017 | 7:09:33 PM | Initialized project |
| 2 | Bhaskara Ida Bagus | 11/21/2017 | 7:16:34 PM | Added blank report document |
| 3 | Bhaskara Ida Bagus | 11/21/2017 | 9:24:34 PM | Update report with blank chapters |
|  |  |  |  |  |
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# Conclusion and Remarks