Farseer Physics Engine 2.0 Manual

## Introduction

The Farseer Physics Engine is an easy to use 2D physics engine designed specifically for Microsoft's XNA platform. The Farseer Physics Engine focuses on simplicity, useful features, and enabling the creation of fun, dynamic games.

## Overview

Getting right to the nut, the Farseer Physics Engine is designed to control the position and rotation of game entities over time.

In the real world, things move and spin due to applied forces and torques. In Farseer, the same is true. Objects called "Bodies" represent the real world things.  As forces and torques are applied, the bodies react according to the laws of 2D physics. The position and rotation of these bodies are then used to update game entities.

In the very simplest outline it works like this:

1. Create "Body" object
2. Add Body object to simulator.
3. Begin Game Loop
   1. Apply forces and torques to Body.
   2. Update the simulator
   3. Set game entity(sprite or whatever) position and rotation equal to Body position and rotation.
   4. Draw game entity
4. End Game Loop

Bodies, by design, have no geometry in the 2D world and therefore have no concept of collisions.

For collision, Farseer has the "Geometry" object. Geometry objects are represented as 2D polygons and can be either concave or convex. They are defined by a set of vertices.  One or more Geometries are attached to a Body in order to give the Body geometrical awareness. This allows the Body to participate in collisions with other Bodies(actually other Geometries attached to other Bodies, but you get the picture.)

## Body

Body is the core physics object in Farseer. Forces, torques, and impulses are applied to bodies and the bodies react by moving realistically. Bodies do not contain any form of collision geometry by themselves. You will need to create a Geom for collision detection. To create a body you usually use BodyFactory.

You create a body like this:

int mass = 1;

float width = 128;

float height = 128;

Body rectBody = new Body();

rectBody.Mass = mass;

rectBody.MomentOfInertia = mass \* (width \* width + height \* height) / 12;

As you can see, calculating MOI (Moment Of Inertia) for a rectangle is done like this:

D:\Projects\TFS\FarseerPhysics\Documentation\ManualImages\MOIRectangle.png  
Instead of remembering MOI for each shapes, Farseer can calculate the MOI for you. All you have to do is use the BodyFactory class as described below.

### Body Factory

You create a body with the factory like this:  
Body rectBody = BodyFactory.Instance.CreateRectangleBody(PhysicsSimulator, 128, 128, 1);  
  
This body has a size of 128 width, 128 height and a mass of 1. The MOI (Moment Of Inertia) is calculated for you. Note that the body is added right away by adding the PhysicsSimulator as a parameter.

You can create each of these type of bodies with the factory:

* Rectangle
* Circle
* Polygon
* Body

The last item (body) is for when you want to create a body, without Farseer calculating the MOI for you. You can also use it to create clones of bodies.

There is some overloads for each BodyFactory method. One that takes a PhysicsSimulator object and another one that don't. If you provide a PhysicsSimulator object, the body you create will be added directly to the simulator.

## Geometry

The geometry (Called Geom in Farseer code) is the heart of collision detection. A geometry need a body and a set of vertices that define the edge of your shape.

While the body is in control of forces, torques, and impulses, the geometry is in control of collision detection and calculating the impulses associated with colliding with other geometries.

To create a geometry, do the following:

Body rectBody = BodyFactory.Instance.CreateRectangleBody(128, 128, 1);

Vertices vertices = new Vertices();

vertices.Add(new Vector2(-64, -64));

vertices.Add(new Vector2(64, -64));

vertices.Add(new Vector2(64, 64));

vertices.Add(new Vector2(-64, 64));

Geom rectGeom = new Geom(rect,vertices,11);

This will create a rectangle body (by using the BodyFactory) a set of vertices that represent the outline of a rectangle (relative to 0, 0) and create a new geometry with the defined vertices and a grid cell size of 11.

We will have a deeper look into grid cell size in the **Grid** chapter.

### GeomFactory

Another and much easier way to create a geometry is by using the GeomFactory. The GeomFactory can create a vertices collection for simple shapes such as rectangle and circle. All you need is the width, height or radius.

Here is an example of creating a Geom using the GeomFactory:

Body rectBody = BodyFactory.Instance.CreateRectangleBody(128, 128, 1);

Geom rectGeom = GeomFactory.Instance.CreateRectangleGeom(PhysicsSimulator, rectBody, 128, 128);

Notice that you don't have to supply any vertices or grid cell size. The GeomFactory creates the vertices for you and calculates the grid cell size for you.

There are situations where you would want to control the grid cell size. This is also very easy with the GeomFactory, just use the overloaded methods that takes a grid cell size:

Geom rectGeom = GeomFactory.Instance.CreateRectangleGeom(PhysicsSimulator, rectBody, 128, 128, 12.8f);

Now we have a grid cell size of 12.8.

If you pass 0 into the grid cell size, it will get calculated for you. They way it's calculated is by finding the shortest side of the geometry (128 in this instance) and multiply it by the default grid cell size factor of 0.1. This would yeld 12.8.

You can adjust the default grid cell size by setting the **GridCellSizeAABBFactor** on the GeomFactory object.

## Joints

Farseer Physics Engine provide you with some of the basic joints. You can create almost any dynamic behavior by combining these joints:

* Revolute joint\*
* Angle joint\*
* Angle limit joint\*
* Pin joint
* Slider joint

\* Has a "fixed" version. The fixed versions mean that the joint is anchored to the world, and not to another body as their non-fixed versions.

### Revolute Joint

### Angle Joint

### Pin Joint

### Slider Joint

### Joint Factory

## Springs

### Linear Spring

### Angle Spring

## Collision detection

Farseer Physics Engine provides you with an easy to use collisions system containing 4 different parts:

1. Broad phase collision detection
2. Narrow phase collision detection
3. AABB (Axis Aligned Bounding Box)
4. Grid collision detection

Each system is described below:

### Broad phase

The broad phase collision detection relies on advanced algorithms to speed up the collision detection, by reducing the work the engine has to do.

We currently have 3 kinds of broad phase collision detection algorithms:

1. Sweep And Prune (called SAP)  
2. Selective Sweep  
3. Brute Force

The **Sweep And Prune** algorithm is frame coherent, this means that if objects more a lot around the screen, this might be a bad choice. This also means that if your objects are near the position they were the last frame, this algorithm is good.

Also note that the SAP algorithm does not like teleporting objects or very high speed objects such as moving from one end of the world to the other or bullets. It may break down from it.

More information on SAP can be found [here](http://en.wikipedia.org/wiki/Sweep_and_prune) and [here](http://www.ziggyware.com/readarticle.php?article_id=128) (called sort and sweep).

The **Selective Sweep** algorithm is developed by BioSlayer. The SS algorithm is the default one in Farseer Physics Engine. SS was originally build on Sweep And Prune, but had some changes that made it perform better than SAP.

More information on SS can be found [here](http://www.codeplex.com/FarseerPhysics/Thread/View.aspx?ThreadId=17811).

The **Brute Force** algorithm is the most simple of them all, but also the least performing of the 3. It iterates all the geometries in the world and compare their AABB's. The Brute Force algorithm is O(n^2) complexity, but is still very fast for low geometry count.

### Narrow phase

The narrow phase is where we take all the collision pairs generated by the broad phase, and do further calculation on them. All the narrow phase code lives inside the **Arbiter** class.

Here is a short overview of what happens in the narrow phase:  
We assume that the broad phase provided us with a pair of colliding geometries contained in an Arbiter object.

1. Iterate all the world vertices on the first geometry
2. If the current vector intersects with the second geometry
   1. If false: Continue to next vector in vertice list
   2. If true: Create a contact and insert it in a contact list
3. Do 1. and 2. on the second geometry
4. If there are any contacts in the contact list, fire the OnCollision event providing the 2 geometries and the contact list.

The Arbiter class is also used to calculate the impulse, that should be applied to the geometries, when they collide.

### AABB

AABB stands for Axis Aligned Bounding Box and as the names says, it's a bounding box that aligns itself to an axis. All geometries have an AABB that is recalculated on each update, AABB are relative inexpensive and used to quickly test if 2 geometries are close to each other (or even touching).

You can test if 2 geometries are close to each other by doing this:

if (AABB.Intersect(\_circleGeom.AABB,\_rectangleGeom.AABB))  
{  
 //The 2 AABB's intersect  
}

Remember that because the AABB's are not rotated and they outline the geometry with a rectangle, when you test for intersection between 2 AABB's, the geometries might actually not touch. Have a look at these pictures.

|  |  |
| --- | --- |
| Intersection  C:\Users\Genbox\Desktop\Intersection.png | Intersection and collision (touching)  C:\Users\Genbox\Desktop\IntersectionTouching.png |

The AABB is the black outline of the geometries. As you see, they are not rotated, but are axis aligned. If you look real close, you can see that the contact created when colliding is red.

### Grid

All geometries contains a Grid object. It's used by the narrow phase collision detection and uses a pre-computed "distance grid". A distance grid is a pre-computed grid where each grid point contains the distance to the closest point on the geometry and the normal at that point.

The grid is calculated from the provided grid cell size in the Geom constructor or when using the GeomFactory

Calculation of the grid can be quite time consuming. TODO: Write more

### Collision group and categories

Farseer provides you with a way of creating different collision groups and the more advanced collision categories.

By default all geometries are in **collision group** 0, this means that it collides with all other geometries. If two geometries are in the same collision group, they will not collide with each other, the 0 collision group is an exception.

Here is how to set the collision group on a geometry:

Body rectBody = BodyFactory.Instance.CreateRectangleBody(PhysicsSimulator, 128, 128, 1);

rectBody.Position = new Vector2(250, 400);

Geom rectGeom = GeomFactory.Instance.CreateRectangleGeom(PhysicsSimulator, rectBody, 128, 128);

rectGeom.CollisionGroup = 10;

Body circleBody = BodyFactory.Instance.CreateCircleBody(PhysicsSimulator, 64, 1);

circleBody.Position = new Vector2(300, 400);

Geom circleGeom = GeomFactory.Instance.CreateCircleGeom(PhysicsSimulator, circleBody, 64, 20);

circleGeom.CollisionGroup = 10;

Even if rectGeom and circleGeom are overlapping each other, they will not collide with each other.

While collision groups are easy to use, they can be very limited, so **collision categories** also exist.

There are two properties of interest when using collision categories:

1. CollisionCategories
   1. Defaults to CollisionCategory.All
   2. Used to define witch categories the geometry a member of.
2. CollidesWith
   1. Defaults to CollisionCategory.All
   2. Used to define witch categories the geometry collides with.

Collision categories uses an enum called CollisionCategory that has a special flag enabled on it, so it's able to do bitwise operations. (more info [here](http://msdn.microsoft.com/en-us/library/system.flagsattribute.aspx))  
  
Example:

Body rectBody = BodyFactory.Instance.CreateRectangleBody(PhysicsSimulator, 128, 128, 1);  
rectBody.Position = new Vector2(250, 400);  
Geom rectGeom = GeomFactory.Instance.CreateRectangleGeom(PhysicsSimulator, rectBody, 128, 128);  
rectGeom.CollisionCategory = CollisionCategories.Cat5;

rectGeom.CollidesWith = CollisionCategories.All & ~CollisionCategories.Cat4;

Body circleBody = BodyFactory.Instance.CreateCircleBody(PhysicsSimulator, 64, 1);

circleBody.Position = new Vector2(300, 400);

Geom circleGeom = GeomFactory.Instance.CreateCircleGeom(PhysicsSimulator, circleBody, 64, 20);

circleGeom.CollisionCategory = CollisionCategories.Cat4;

circleGeom.CollidesWith = CollisionCategories.All & ~CollisionCategories.Cat5;

This time, the rectGeom is a member of Cat5 (Category 5) and collides with All **but** Cat4

The circleGeom is a member of Cat4 and collides with All **but** Cat5.

This means that the two geometries will not collide with each other.

### Collision Events

There are 3 different collision events:

* OnCollision (in Geom class)
* OnSeparation (in Geom class)
* OnBroadPhaseCollision (in IBroadPhaseCollider interface)

The **OnCollision** event is fired when the geometry hits another geometry. You will need to return a boolean inside the event method to indicate if you want the collision to happen or not.

The **OnSeparation** event is fired when the geometry is separated after a collision with another geometry.

The **OnBroadPhaseCollision** event is just like the OnCollision event, but is fired already in the broad phase. Canceling this event prevents an arbiter from being constructed, this means that no impulses are applied and no narrow phase collision is done, to the geometries involved in the collision.

To register the events, do the following:

Body circleBody = BodyFactory.Instance.CreateCircleBody(PhysicsSimulator, 64, 1);

Geom circleGeom = GeomFactory.Instance.CreateCircleGeom(PhysicsSimulator, circleBody, 64, 20);

circleGeom.OnSeparation += OnSeperation;

circleGeom.OnCollision += OnCollision;

PhysicsSimulator.BroadPhaseCollider.OnBroadPhaseCollision += OnBroadPhaseCollision;

Note that the OnBroadPhaseCollision event is registered inside the BroadPhaseCollider of the PhysicsSimulator.

And the methods that is run when the events are fired:

private bool OnCollision(Geom geom1, Geom geom2, ContactList contactList)

{

return true;

}

private void OnSeperation(Geom geom1, Geom geom2)

{

}

private bool OnBroadPhaseCollision(Geom geom1, Geom geom2)

{

return true;  
}

## Impulses

There are 2 systems for impulses:

* Collision response
* Manual impulses

The **collision response** is what happens when 2 geometries collide with each other. The Arbiter class that was described in the "Narrow phase" chapter is responsible for the calculations of impulses when a collision happens.

If we get a little more technical, what actually happens, is that the contacts calculated in the narrow phase collision detection gets applied an impulse so that the geometries behave like real physics.

The collision response can be deactivated by setting the geometries **CollisionResponseEnabled** to false, like this:

Geom circleGeom = GeomFactory.Instance.CreateCircleGeom(PhysicsSimulator, circleBody, 64, 20);

circleGeom.CollisionResponseEnabled = false;

Disabling the collision response means that it will pass through all other geoms. It will still fire the collision events described in the "Collision Events" Chapter.

You can also apply **manual impulses** to a body. (remember that it's the body that controls dynamics and the geometry that controls collision, but arbiter controls geometry impulses that are related to collisions.) You can apply 3 kinds of forces/impulses to a body. The forces and their methods are listed below:

1. Force
   1. ApplyForce
   2. ApplyForceAtLocalPoint
   3. ApplyForceAtWorldPoint
   4. ClearForce
2. Impulse
   1. ApplyImpulse
   2. ClearImpulse
   3. ApplyAngularImpulse
3. Torque
   1. ApplyTorque
   2. ClearTorque

TODO: Describe force, impulse and torque.

## Performance

Performance is really important in many application types, but you should never optimize before the end of you development. If you as an example introduce multithreading into your application in the beginning of your development, you will have a lot of headache from synchronization, locking and race conditions.

Writing clean code and relying on the compiler to do its job is the most important factor. A clean design is so much more important than a thousand micro optimizations.

Here is some tips and tricks to improve your application performance:

* **TODO: Write about "Chunk up the landscape"**
* **TODO: Write about "Simplify the sides of the geometry that will never come into contact with world objects"**
* **TODO: Write about "Keeping grid cell size small"**
* **Minimal number of bodies/geometries**

The easiest and most logical way of gaining more performance is to minimize the number of bodies and geometries active at one time. If you have a large level and it takes the player a long time to get to another section of the level, you could keep that part of the level deactivated until the player arrives.

This is really easy in some games. You could for example place a sensor (note: setting IsSensor to true on geometry) at certain places on the level, and when the player reaches that sensor, the next part of the level will be activated.

There is a lot of ways of doing this, it all depend on the type of game you are developing.

* **Caching**

Another very easy implementation is caching rapid-spawning objects. If you are spawning a lot of enemies or bullets, you can pre-create the bodies and geometries that makes up the enemies/bullets.

Farseer Physics uses a pool (cache) for Arbiters, it speeds up the creation a lot. This pool is actually public, so you can use the generic Pool class from Farseer to cache your objects.

To create a pool of 10 soldiers, you could do something like this:

Pool<Enemy> pool = new Pool<Enemy>();

for (int i = 0; i < 100; i++)

{

Enemy enemy = new Enemy(EnemyType.Soldier, Health.100);

pool.Insert(enemy);

}

And when you need the soldier in your game:

Enemy enemy = pool.Fetch();

enemy.Shoot();

There are 2 reasons why you would want a pool like this, one of them is the garbage collector, and the other is pre-instanciation.

The **garbage collector** cleans up after you, but this also means that if you create an enemy and run Dispose() on him when he dies, the garbage collector will remove him from your system memory.

But if you have the enemy inside the Pool, you don't need to call Dispose() on him, you just have to deactivate him (and not draw him). This results in fewer garbage collections.

The **pre-instanciation** is also a very good thing since Farser Physics uses what's called a distance grid. This grid is calculated when you create a new geometry and it can be quite time consuming.

So creating the pool of enemies when the game starts (or a new level loads) speeds up the creation of enemies a lot.

* **Remember to use release compilation.**

Whenever you release your application to the public, be sure to compile your application with release settings. The .net platform works by first compiling your C#/Vb.net code into IL (Intermediate Code) code and then the JIT (Just-In-Time compiler) compiles your code into native machine code, when you execute your application.

When you turn on release configuration and compile your application, the IL code generated states that when the JIT runs the IL, it should perform optimizations.

This can speed up your application a lot and might reduce the overall size of your application.

* **Pass vectors and matrix by reference**

Vectors (Vector2, Vector3) and Matrix in XNA is what's called structs or value types. Whenever you put a value type into a method as a parameter, it gets copied. If you have a large matrix or a lot of vectors, this can slow down your code.

So by passing the vectors or matrix by reference instead of value, might speed up your application a little. Farseer supports passing of value types in certain places, here is an example:

Body body = BodyFactory.Instance.CreateCircleBody(PhysicsSimulator, 64, 1);

Vector2 force = new Vector2(10,10);

for (int i = 0; i < 100; i++)

{

body.ApplyForce(ref force);

}

In this code example, using the ref keyword, we save 100 copies of the "force" vector. Some places in your code might benefit a lot from this.

* **Multithreading**

Multithreading can be quite a tricky thing and can be hard to accomplish correctly. Using multithreading might increase your game performance, and more often increase the number of concurrent elements on screen. The implementation details about this is out of scope for this manual, but Farseer Physics Engine 2.0 does include an example on multithreading. Have a look at the **Getting Started** sample (demo 4) for more details.

* **Inactivity controller**

Farseer Physics Engine 2.0 includes a new thing called an inactivity controller. This controller enables what's called "resting bodies". This means that if your game contains a lot of elements that does not move around a lot, you can get some performance by deactivating them for the time being.

Inactivity controller does this for you. You only have to enable it in the physics simulator and set some basic settings. See the "Inactivity controller" chapter for more information.

* **Scaling**

Scaling is yet another new feature of Farseer Physics Engine 2.0. TODO: Write about it. but wait for dp2208 to answer email :)

* **Circle-Circle optimization**

This is one of the more rare occasions, but might be useful for someone.

More info here: [Circle - Circle optimization](http://www.codeplex.com/FarseerPhysics/Thread/View.aspx?ThreadId=19861)

There are also many other ways of optimizing your code. We are not going into details about them, as they are not Farseer Physics specific, but here is a short list:

**Note:** Items in this list is classified as micro-optimization and should not be used, unless you have some really performance critical code. Have a look at [Understanding XNA Framework Performance](http://www.microsoft.com/downloads/details.aspx?FamilyId=B11AD912-4158-44CC-A771-A5E044F7E3BB&displaylang=en) for more information. Farseer Physics Engine 2.0 is already optimized this way.

* Inline performance critical methods

Before:

if (IsColorBlack(new Color(10, 4, 1)))

{

}

private bool IsColorBlack(Color color)

{

return color == Color.Black;

}

After:

if (new Color(10, 4, 1) == Color.Black)

{

}

* Inline vectors instead of referencing

Before:

Vector2 distance = Vector2.Zero;

Vector2.Subtract(ref GeometryB.Body.Position, ref GeometryA.Body.position, out distance);

After:

Vector2 distance = Vector2.Zero;

distance.X = GeometryB.Body.Position.X - GeometryA.Body.position.X;

distance.Y = GeometryB.Body.Position.Y - GeometryA.Body.position.Y;

* Inline constructors

Before:

Vector2 distance = new Vector2(10,10);

After:

Vector2 distance = new Vector2();

distance.X = 10;

distance.Y = 10;

## Known issues

There are some known issue that is related to Farseer Physics. Some of these issues are not only found in Farseer Physics, but also in many other physics engines. They are not easy to fix without sacrificing performance or usability.

* **Tunneling**

This phenomenon occurs when you have a fast moving object that hits a wall and gets stuck inside it or even pass through the wall without even colliding.

Farseer Physics 2.0 does not currently have any good solution to this, but we have plans of implementing CCD (Continues Collision Detection) that would prevent this from happening. Until then, these are your options:

1. Make your objects move slower
2. Make your objects larger
3. Decrease your time step
4. Use ray casting
5. Swept collision detection ([info here](http://www.gamasutra.com/features/19991018/Gomez_1.htm))
6. Multisampling

* **Geometries going into each other**

This can be caused by 2 things: Your geometries has sharp points or too few points, even on straight edges.

If you have **sharp points**, you may need to use smaller grid cell size values, than the default.

By default, if you pass 0 for the collisionGridCellSize to the CreatePolygonBody method, the method will calculate a collisionGridCellsize for you based on the size of the AABB.

If you have a geom with sharp points you will probably want a smaller value than the default. You can either pass in your own non-zero value or you can adjust the default calculation by setting the GeomFactory.GridCellSizeAABBFactor property.

This property is used to calculate the default collisionGridCellSize. Currently it is set to .1 which means the collisionGridCellSize will be 1/10th the smallest dimension of you geoms AABB.

The other thing you could try is inserting **more points** into the geometry. Farseer Physics has a methods to help you do this. It's called SubDivideEdges() and lives inside the Vertices class. TODO: Example

* **Drawing is off center**

Since Farseer Physics Engine 1.0.0.4, the vertices supplied to the GeomFactory's CreatePolygonGeom method gets centered around the centroid of the vertices.

You can work around it by following the steps described in [this thread](http://www.codeplex.com/FarseerPhysics/Thread/View.aspx?ThreadId=28747)

or use the Vector2 offset parameter in the CreatePolygonGeom method.