



**MERCUNA**

UE4 User Guide

v1.7



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## Installing

The Mercuna middleware is integrated into Unreal Engine as a standard plugin compatible with **Unreal Engine 4.19 - 4.22**.

Binary versions of Mercuna (such as the evaluation) must be installed as an Engine plugin - simply copy the Mercuna directory into the **Plugins** directory within your Unreal Engine directory.

The full source version of Mercuna can be installed as a Game plugin and then will be rebuilt as part of your game, or, if you are building the engine from source and you prefer, it can be installed as an Engine plugin.

Once installed, the Mercuna components, actors and menu will automatically be available when you next start the editor.

## Configuring the Navigation Octree

A **Mercuna Nav Octree** is used to find paths for pawns through 3D space, much like a 2D Nav Mesh is used to navigate pawns over terrain.

Nav Octree is generated in the level everywhere that is within a **Mercuna Nav Volume**. A Nav Octree can simultaneously support multiple actor sizes (within limits), so in most cases a single octree should be sufficient. However, more complex setups with multiple Nav Octrees in a single level are possible if support for very different actor sizes is required.

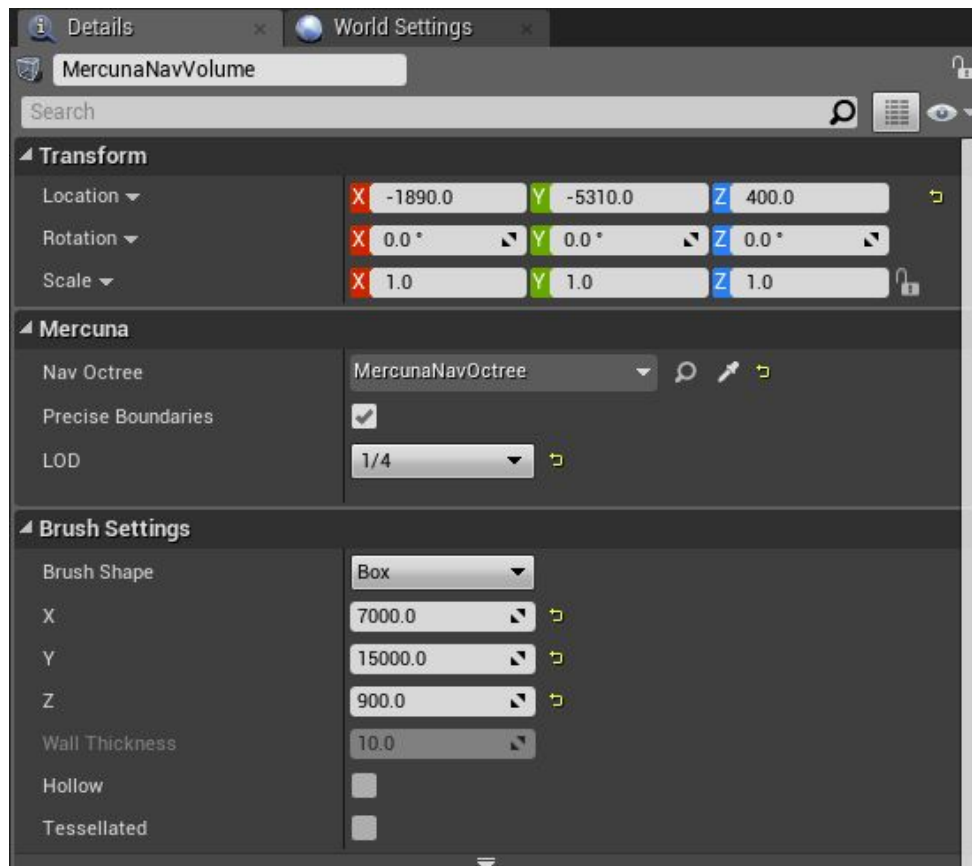


Multiple Nav Volumes can be present in one level, and overlapping Nav Volumes that are linked to the same Nav Octree allow pawns to navigate seamlessly between them. All space outside of the Nav Volumes is treated as unnavigable.

## Setting up the navigable space

To set up a nav volume, first add a Mercuna Nav Volume actor into the level, and size it using the Brush Settings. Only boxes are supported, so you must leave the brush shape set to Box. They must be resized using the brush size settings, rather than being scaled. To describe more complex boundaries to the navigable volume, multiple Nav Volumes can be configured.

If Precise Boundaries is switched on, the boundaries of the nav volume are considered hard edges, beyond which your pawns can't move. However, if the Precise Boundaries option is turned off then navigable space will extend up to a high power of 2 boundary in the octree. This allows a significant memory saving when there is open space around the navigable volume and you don't need to precisely specify the edge of the volume your agents will move within.



Example settings for Mercuna Nav Volume

The octree generation parameters to be used in this level are configured on the Mercuna Nav Octree actor. Upon creation, the parameters are set to default values. These defaults can be modified in the Mercuna project settings.



▲ Generation	
Cell Size	30.0
Min Pawn Radius	1
Max Pawn Radius	3
▲ Runtime	
Never Save	<input type="checkbox"/>
Allow Octree Merging	<input type="checkbox"/>
Geometry Collision Channel	Pawn

Example settings for Mercuna Nav Octree

The parameters determine how detailed the representation of the navigable space is in the octree, and the sizes of pawns that can accurately navigate through it.

The **cell size** determines the side length of the cubes that make up the lowest level of the octree. Cells are considered unnavigable if there is any level geometry within them, so the larger the cell size the greater the error margin in the representation of the geometry.

The **minimum** and **maximum pawn radius** determine what navigation data is stored in the octree. Paths will never go closer to geometry than the minimum pawn radius, and the octree doesn't store data to allow paths to be found with more clearance from geometry than the maximum radius.

The radius is expressed as multiples of cell size, so for a cell size of 30, a minimum radius of 2 and a maximum radius of 5, entities of radius between 60 and 150 can be accurately navigated through the level. Entities that are smaller than the minimum radius will navigate successfully, but might not take paths through small gaps they could fit through. Entities that are larger than the maximum radius aren't supported, as their paths might make them collide with geometry.

The **Never Save** property indicates whether the navigation data will be built from procedurally generated data at runtime, so any navigation data generated in the editor should not be saved (see [Runtime Octree Building](#) below).

Finally, the **Geometry Collision Channel** specifies the collision channel used to query whether geometry should be considered blocking for navigation. For a collider to be considered by navigation it must have "Can Ever Affect Navigation" set to true, and give a Block response to this collision channel.

## Level of Detail

It is possible to specify that part of the navigation octree is built at a different level of detail by setting the LOD on a nav volume. This would normally be used when you want high



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precision navigation in particular parts of the level without the expense of using a high resolution octree across the entire level.

The normal set up is to create a large nav volume with  $\frac{1}{2}$  or  $\frac{1}{4}$  level of detail, and then specify smaller overlapping nav volumes that generate particular areas at full detail. It is also possible to set the large volume to full detail and add smaller volumes at lower detail.

When generating the octree, Mercuna assumes that smaller nav volumes override the level of detail of overlapping larger volumes.

The Full Detail Build option on the nav volume specifies whether the volume is built at the reduced level of detail or at full detail. If it is built at full detail then the geometry is voxelised as normal and then the LOD is applied when the octree is stored. If full detail build is switched off then the octree is voxelized as if the voxel size in that volume has been increased, so for example a  $\frac{1}{2}$  LOD area in an octree with a voxel size of 30 will have an effective voxel size of 60 for the purposes of building the octree in this volume. Note that the settings on the octree itself are not affected, the cell size and min and max radius there are always in terms of full level of detail cells.

Full Detail Build should be switched off if you want to reduce the CPU cost of runtime octree builds for areas set to a lower LOD.

In low level of detail areas, agents won't be able to navigate as close to walls or through as small gaps as they would if full LOD was used. However, the generation time and memory usage for low LOD volumes is substantially less than for full LOD volumes.

## Multiple Octrees

Mercuna supports multiple Nav Octrees within a single level, which is normally used to allow navigation for agents of very different sizes. In this case, you must select which Nav Octree each Nav Volume is associated with - each Nav Volume can only be linked to a single Nav Octree.

By default, Mercuna is configured to automatically link Nav Volumes to Octrees, which means that no manual configuration is required when there is only a single octree in the level. If no Octree is present in a level, Mercuna will automatically create a Nav Octree actor when the first Nav Volume is added to the level, and link the Nav Volume to it.

If automatic linking is disabled (in Project Settings -> Plugins -> Mercuna) then you must manually create Mercuna Nav Octrees and link the Nav Volumes to them. This can help avoid errors when using multiple octrees, as the Octree must be set explicitly, rather than Nav Volumes potentially being automatically linked to a different Octree to the one that was intended.



## Octree Transform

The Mercuna Nav Octree is usually positioned at the world origin and aligned with the world's axis. Its transform should not be directly modified. Nav Volumes can be moved and rotated. However, the Octree and all of its other Nav Volumes must then be updated to have the same orientation.

This is enforced in the Editor. Changing the rotation of a Nav Volume in the Editor will automatically change the rotation of its linked Octree (along with all of the Octree's other associated Nav and Modifier Volumes). After any transform change the Octree will need to be rebuilt. Nav Volumes that are linked to a new or different Nav Octree will automatically adopt the orientation of that Octree .

During gameplay, levels that are streamed in containing prebuilt Octrees can be transformed (including rotated) via overall level transforms. Individual Mercuna actors, including both the Nav Volumes and Octrees should not be moved or rotated.

## Nav Seeds

In order to identify which regions should be considered navigable, Mercuna requires you to place **Mercuna Nav Seed** actors into levels. This allows uninteresting regions, such as the small isolated areas inside hollow geometry or large areas outside of the level boundaries, to be excluded and avoids pawn positions getting clamped to the wrong side of polygons.

A Mercuna Nav Seed needs to be placed in the main part of the level where pawns will move. This seed is used during construction of the octree to find all connected reachable cells, by flood filling the region starting at the nav seed. If you have multiple disconnected areas in your level where you expect pawns to move, a seed must be placed in each separate area.

## Building the Octree

Unless runtime generation is being used, the Octree must be built after it is first configured or after the level geometry has changed. This can be done by selecting Build Octree from the Mercuna menu (accessed by clicking the Mercuna button in the Toolbar). An on screen notification displays the progress of the octree construction.

When multiple Octrees are present in the level, the menu changes to show Build All Octrees and Build Selected Octree. This allows you to build all the octrees at once, or select a specific Octree and just build that one.

If full Mercuna logging is enabled (see [Logging](#) section below), then you will see the generation progress for each navigation volume in the output log, and the total memory consumption of the octree is reported.



## Memory usage and Performance

The main influences on memory usage and performance are:

- **Cell size:** Smaller cell size octrees use significantly more memory and take longer to generate.
- **Density of geometry:** Large open navigable volumes are stored efficiently, and are quick to pathfind through, volumes with dense geometry and narrow corridors use more memory and take longer to find paths through.
- **Maximum pawn radius:** Larger maximum pawn radiuses take longer to generate and slightly increase memory usage.

## Multiple levels

Mercuna supports both level streaming and world composition by saving the octree that is relevant to each streamed or composed level (sub-level) within that level.

When using level streaming or world composition, Mercuna Nav Volumes and Mercuna Nav Seeds should be placed in the sub-level so that they are loaded and unloaded at the correct times.

When editing the Persistent level you will see one Mercuna Nav Octree in each loaded sub-level, this octree is automatically associated with the Nav Volumes and Nav Seeds that are in that sub-level.

In order to allow seamless navigation between octrees loaded from different sub-levels, Mercuna merges together octrees loaded from sublevels at runtime. To enable this feature, the octrees in the sublevels must have exactly the same octree settings, have the same orientation, and have the Allow Octree Merging option set.

If Allow Octree Merging is false, or if the octree settings don't match then octrees won't be merged and multiple octrees will exist at runtime. In this case you can manually switch pawns between octrees using the Set Nav Octree function on the Mercuna Navigation Component.

## Generating Octrees in Multiple Levels

The best way to generate the sub-level octrees is from the Persistent level. Load all your sub-levels using the levels window and then select Build All Octrees from the Mercuna menu. This ensures that geometry that overlaps between levels is correctly represented in each level's octree. Once generation is complete, save all the sub-levels.

When placing nav volumes in sub-levels for octrees that will merge together on sub-level load, you should have at least one voxel size worth of overlap between the nav volumes.





If it is not possible to load all levels due to memory constraints, go through each sub-level containing a Mercuna nav octree in turn. Load a sub-level and all levels that contain geometry overlapping nav volumes within the sub-level, generate the octrees in that sub-level by selecting them and using the Build Octree option from the Mercuna menu. Then save the sub-level and go on to the next.

## Load Complete Events

When an octree is loaded and ready for use the **OnLoadComplete** event on the NavOctree triggers. In simple configurations where octrees aren't loaded from multiple sub-levels simultaneously and there is no level streaming, this event is triggered immediately after the octree is loaded. However, if the octree is merged with another octree when the level is loaded, then OnLoadComplete is not triggered until the merge is complete. Once the event fires, you know that pawns are able to navigate across the merged part of the octree.

When octrees are merged, first the octree data itself is merged and then the connectivity data used for hierarchical pathfinding is rebuilt. The second stage can take a few frames to complete, and is not required for short range pathfinding, so it can be useful to know when the first stage is complete.

Therefore, there is an **OnShortRangeLoadComplete** event that triggers once short range path finds are available on the merged octree, but before hierarchical pathfinding is available. If you don't need to pathfind long distances, then you can start navigating on the octree when this event fires. As with OnLoadComplete, if the octree is not merged with another on load, this event fires immediately after the octree is loaded.

## Runtime Octree Building

It can sometimes be desirable to build the Nav Octree at runtime, particularly for procedurally generated levels. Since these Octrees will be generated at runtime it is recommended that they should have the **Never Save** property set on them. This prevents any data that might be generated in the Editor while testing from being unnecessarily saved.

All Nav Volumes must be placed, scaled and rotated, before the Octree is generated at runtime. In order to ensure that the Nav Volumes and Nav Octree have the same orientation (see [Octree Transform](#) section) either the **SetNavigationRotation** or **SetNavigationOrientation** methods must be used to modify the rotation. These are available on both the Mercuna Nav Octree actor and the Mercuna Nav Volume actor. Either function can be used and the orientation of the Octree and all its Nav and Modifier Volumes will be updated.

The build can be triggered by making a request on the octree actor (via Blueprint or C++) using the **Build** function. The generation happens in two phases - first a low level of detail version of the octree is built. This build completes quickly and allows agents to start navigating with short range pathfinds within open spaces (but not close to geometry). The event **OnBuildLowResReady** is triggered once this low resolution octree is available to



indicate that agents can start navigating. Once octree generation has fully completed, the event **OnBuildComplete** is triggered.

## Runtime Octree Rebuild

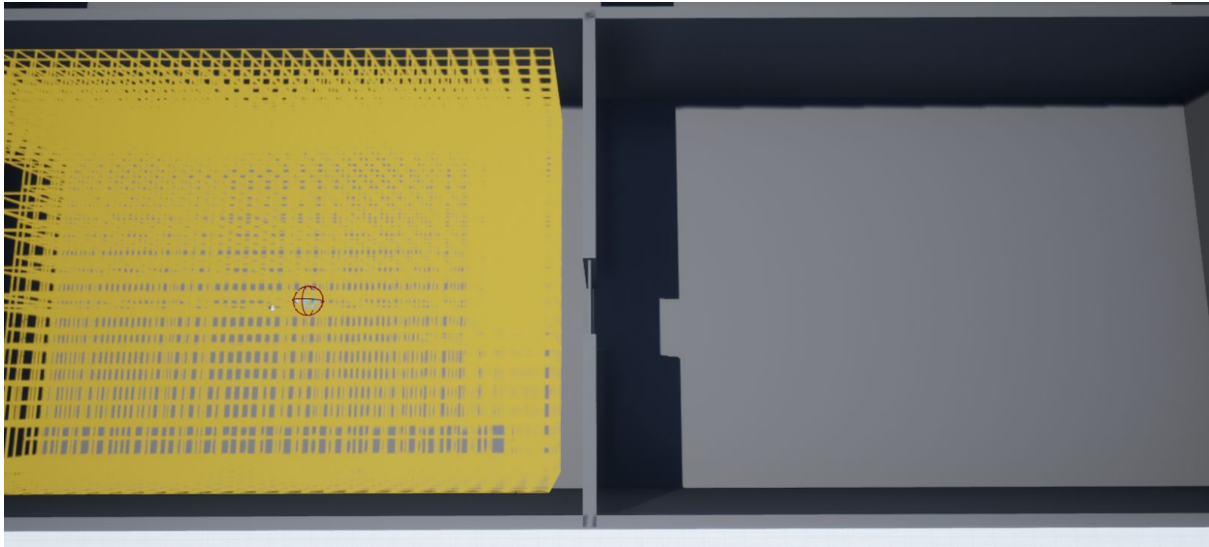
Specific volumes of the Octree can also be rebuilt while the game is running using the **Rebuild Volume** function on the Octree actor. Rebuild Volume is normally used to pick up runtime changes when just a section of the level changes, such as a door opening.

The two phase build, where a low resolution version of the octree volume is first built and then replaced by a full resolution version once it is ready, is optional when only part of the octree is rebuilt. Use the **Staged Build** flag on Rebuild Volume to specify whether or not to use it. When rebuilding only small volumes it is often more efficient to do a single phase build.

If Staged Build is used, the event **OnRebuildLowResReady** is triggered once the low resolution version of the rebuild volume is done. Either way, once the whole volume has been rebuild at full resolution, the event **OnRebuildComplete** is triggered. This event includes the volume that was regenerated, to aid with scripting.

Pathfinds and reachability tests that go through the regenerated region may fail while the regeneration is in progress. Once regeneration is complete, all active paths are recomputed if they go through or close to the regenerated region, causing actors to path around new obstacles or through newly available shortcuts. If a pathfind fails during regeneration, you may want to retry it once the OnRebuildComplete event has been triggered.

Regenerating a region will not cause newly connected areas outside the regenerated region to become seeded. If a runtime regeneration might connect a volume that is not connected to any other nav seed when the navigation octree is built in the Editor, you must place a seed within that volume.



In the screenshot above, the yellow region on the left is navigable and seeded. The wall in the centre has a door in it, and when this opens Rebuild Volume is triggered through blueprint to regenerate the navigation data around the door.

However, navigation into the region on the right will still not be possible because that region was not seeded. This can be fixed by adding a Mercuna Nav Seed into the right hand region.

## Pathfinding

Finding paths through the Nav Octree can be done implicitly by making your pawn movement controlled by Mercuna, this method allows you to take advantage of the Mercuna steering and avoidance systems. Alternatively, path finding can be requested explicitly by making a request directly to the octree (via Blueprint or C++) and receiving a MercunaPath (or MercunaSpline) object which can then be used as required.

As pathfinding is performed asynchronously, the returned MercunaPath/MercunaSpline object is not immediately valid, but can take one or two frames to complete. You must either check each frame to see if it is ready yet or subscribe to its PathUpdated/SplineUpdated delegate.

For longer paths Mercuna uses hierarchical pathfinding. An approximate path is found through a simplified representation of the level and then a detailed path find is performed guided by the approximate path. This allows much longer paths to be found than would be possible with simple A\* pathfinding alone.

Mercuna also supports partial paths (enabled by default). A partial path is returned when a complete path can't be found to the specified destination, if it is disconnected from the start point, for example. Instead Mercuna returns a path to the closest point to the destination that is reachable.



## Path Testing Actor

In order to easily debug and understand pathfinding problems a pair of **Mercuna Nav Testing Actors** can be used to generate test paths. Simply drag two testing actors into the level, and on one of the actors set the other one as the 'Other Actor' property. When you do this a test path will be drawn connecting the two actors. This path will update when either actor is moved. A red path means a complete path could be found, while an orange path means that only a partial path could be generated.

The Radius property specifies how much clearance there should be around the test path - this allows you to check what path larger and smaller actors would take.

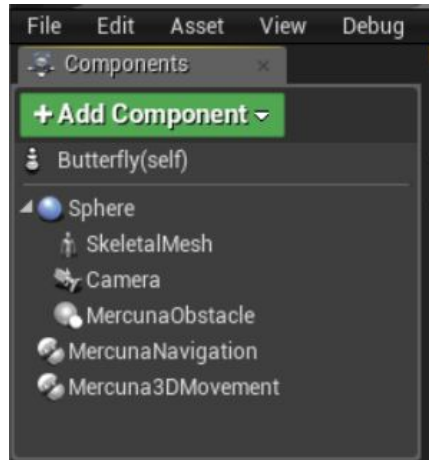


A test path between two Mercuna Nav Testing Actors

## Creating a Mercuna navigated Pawn

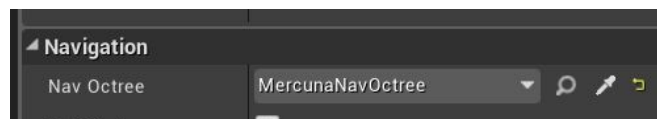
In order to allow pawns to use Mercuna to navigate they need to have the following components:

- **Mercuna Obstacle** - this marks the pawn as a dynamic obstacle for the purpose of 3D navigation. The obstacle component must be a child of the root scene component.
- **Mercuna Navigation** - this component provides the pawn with navigation capabilities, accessible through Blueprint.
- A suitable **movement component**, e.g. the **Mercuna 3D Movement** component



Pawn blueprint setup for Mercuna navigation

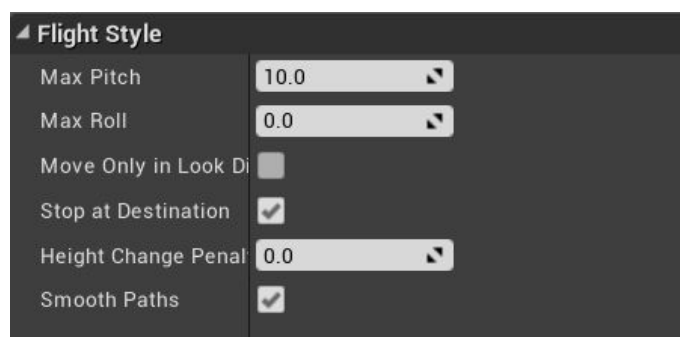
When there are multiple octrees in a level, Mercuna will automatically try and choose the best one to use based on which nav volume the pawn is currently in and which octree best fits the pawn's size. The octree that a pawn uses can be overridden by explicitly setting the Nav Octree parameter on the pawn's navigation component.



Navigation octree to use can be overridden on the navigation component

## Setting a Flight Style

How a pawn moves depends on how its flight style is configured. The flight style options are set on the **Mercuna Navigation** component:



Flight style options

The options include:

- **Max Pitch** - The default maximum angle that the pawn can pitch up or down. This is ignored if Move Only In Look Direction is set.
- **Max Roll** - The maximum roll when turning, in degrees. Causes the pawn to bank when turning.



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- **Move Only in Look Direction** - Whether to restrict movement to facing direction. This stops pawns from flying backwards or sideways when turning around.
- **Stop at Destination** - Whether the pawn should slow down in order to stop at its destination.
- **Height Change Penalty** - How much the pawn should avoid unnecessary changes in height while moving. *Note that currently this only changes the smoothed path, pathfinding itself does not yet take height change penalties into account.*
- **Smooth Paths** - Whether to use spline based paths, or simple straight line segment paths. See Steering section for more detail.

## Steering

In order to give smooth, natural looking movement Mercuna uses polynomial splines to interpolate between path points to generate smooth curves. These splines are constructed taking into account available space and define a continuous velocity curve that can be followed precisely. Mercuna navigates the pawn down the spline path taking into account the maximum speed and acceleration configured on the pawn.

Whereas the pathfind is performed when a pawn is given a destination, the spline is generated on demand. If the pawn is pushed, or has to avoid other actors causing it to move away from the spline, then the spline and the underlying path are automatically regenerated.

Spline based steering can be disabled to fall back to simple steering by turning off **Smooth Paths** in the flight style options. However, the simple steering method suffers from the problem that pawns frequently overshoot corners and fall off the path, resulting in collisions with level geometry and it is not recommended to be used unless necessary for backwards compatibility.

## Avoidance

Mercuna offers dynamic obstacle avoidance to ensure that pawns don't collide while moving. Any actor with a **Mercuna Obstacle Component** is automatically considered as an obstacle that needs to be steered around for the purpose of avoidance. The avoidance algorithm used by Mercuna is a modified version of ORCA velocity obstacle method that additionally takes into account the fixed level geometry stored in the nav octree.

It is possible to specify particular actors to be excluded from avoidance on a per pawn basis (using the `SetAvoidanceAgainst` function on Mercuna Navigation Component). A common use case is temporarily turn avoidance off against the player when executing an attack to avoid the attacking pawn veering off as it gets close to the player.

## Movement

In order for the Mercuna navigation component to drive the moment of a pawn, the pawn needs to have a suitable movement component. A simple default movement component is



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provided - the **Mercuna 3D Movement Component**. This is suitable for a variety of 3D flight styles.

Custom movement components can easily be implemented, but in order to be used by Mercuna they must provide the **IMercuna3DMovement** interface. The Mercuna Navigation component automatically detects and uses the first movement component it finds on the pawn that provides that interface.

## Mercuna 3D Movement Component

The Mercuna 3D Movement component provides a Newtonian flight model for a pawn moving freely in space. It allows you to configure:

- **Max Speed** - The maximum speed the pawn may move at
- **Max Accelerations** - The maximum accelerations of the pawn (in the pawn's local coordinates).
  - **Forward** - maximum acceleration in the forward direction
  - **Backward** - maximum acceleration in the backward direction/deceleration in the forwards direction
  - **Sideways** - maximum acceleration in the left/right and up/down directions
- **Max Pitch Rate** - The maximum angular speed the pawn may pitch at, in radians/sec
- **Max Yaw Rate** - The maximum angular speed the pawn may yaw at, in radians/sec
- **Max Roll Rate** - The maximum angular speed the pawn may roll at, in radians/sec
- **Max Ang Accel** - The maximum angular acceleration allowed on each axis, in radians/sec

## Modifier Volumes

Nav Modifier Volumes provide a mechanism for designers to influence and limit navigation within specific regions. For example, you can increase the cost of navigating through a volume, such that paths will prefer to go around it, or you can mark volumes as being restricted to particular pawn types, or pawns as restricted to staying within certain volumes.

## Usage flags

In the project settings you can define up to 32 custom global usage types. These can then be assigned to individual Modifier Volumes to mark what the volume represents. Flags corresponding to each usage type can be set on the Navigation Component of pawns to indicate which types of volumes it is allowed to enter, or that it is required to stay within.

For example, if you define a Fire usage type, you can mark Modifier Volumes as representing a region that is on Fire. Pawns can then be configured to be allowed to enter and move in Fire regions, or can be configured that they can only move inside of Fire regions. By default pawns will not be allowed to enter them.



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Alternatively, you could define a usage type such as Shallow Water and create a modifier volume, with that flag set, that covered the region just below surface of a sea. Pawns that had their Shallow Water usage flag set to Required would then be confined to pathfind and stay within that volume, and would not be able to travel down to deeper depths.

## Costs

During a path search of the Nav Octree, Modifier Volumes allow designers to increase the cost of specific volumes and therefore discourage pawns from moving through them.

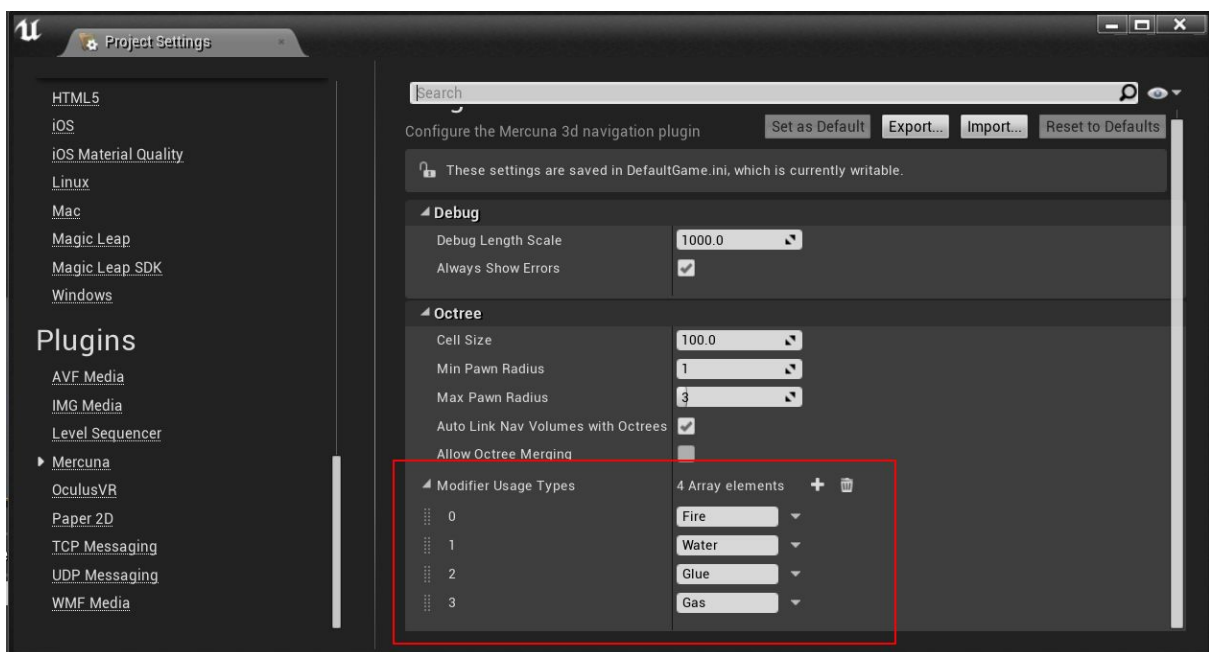
When a volume has a modified cost multiplier, the path distance is multiplied by the cost multiplier to calculate the expense of traversing a volume. The size of the additional cost of passing through a volume determines how far pathfinding will search for longer alternative routes that avoids it, before deciding to use it as part of the path.

Due to the nature of the A\* algorithm used for pathfinding, costs can only be increased and not decreased below 1.0x. Using a very high cost multiplier on a volume will mean that the pathfinder will search a long way for alternatives, and thus can considerably increase the computational cost of the path find. For this reason, the maximum cost multiplier that can be set on a volume is limited to 15.0x.

## Using Modifier Volumes

### Defining usage types

Usage types are defined in the Mercuna page of the project settings. Up to 32 usage types may be defined.







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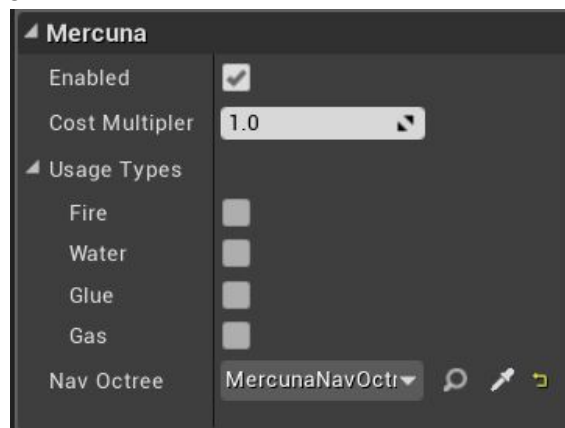
**Warning:** removing usage types, doesn't update the usage flags configured on existing modifier volumes or navigation components. Removing the Water usage type in the above example, means that all the usage flags on actors that previously corresponded to Water, will now be applied to the Glue usage type instead.

## Creating modifier volumes

To create a modifier volume, add a Mercuna Nav Modifier Volume actor into the level, and size it using the Brush Settings. Only boxes aligned to the orientation of the Nav Octree are supported, so you must not rotate or scale the volume, and you must leave the brush shape set to Box. To describe more complex boundaries, multiple Nav Modifier Volumes can be created.

## Configuring modifier volumes

In the Mercuna section of the modifier volumes property panel, the cost and usage types for this volume can be configured.



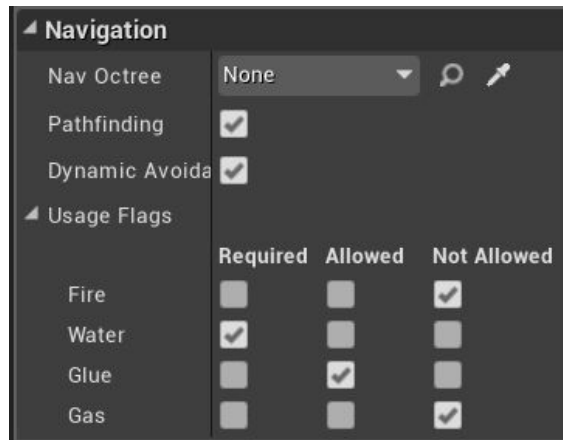
Whenever a volume is created, moved or resized in the Editor the navigation octree must be rebuilt for the change to be applied. Updating the usage types, cost multiplier or enabled setting does not require an octree rebuild.

Nav Modifier Volumes need to be associated with an octree. Similarly to Nav Volumes, if the Mercuna project setting "Auto Link Nav Volumes with Octrees" is enabled (the default) new modifier volumes will be automatically linked to the first octree they find when they are created. Otherwise you need to manually set the correct Octree in their properties.

When a Modifier Volume is associated with an Octree, the rotation of that octree will be applied to the volume.

## Configuring navigation components

Costs are automatically taken into account during pathfinding and spatial searches, but by default agents will not enter modifier volumes with usage types set. To allow or require pathfinding through volumes of particular types, the corresponding usage flags can be set on the Mercuna Navigation Component.



The default for each flag is Not Allowed. Required means the agent can only move in volumes with that usage type set, and Allowed means the agent may, but does not have to, enter volumes with that usage type.

## Runtime changes

At runtime, the settings on Modifier Volumes can be updated using the **SetEnabled**, **SetUsageFlags** and **SetCostMultiplier** functions on the Modifier Volume actor. These functions are exposed to blueprint.

Any paths through the changed modifier volume will be updated to reflect the change.

Changing these settings is relatively inexpensive, compared with the cost of a full octree rebuild for the modified volume.

Modifier volumes may be added, removed or moved at runtime, however this is nearly as computationally expensive as rebuilding the octree in the modified volume, so should not be done too frequently.

To add a modifier volume, spawn a Modifier Volume actor, set the usage types and cost multiplier, and then use the **AddToOctree** function to add the modifier volume to the octree.

To remove a modifier volume, simply destroy the actor, or alternatively call **RemoveModifierVolume** on the NavOctree.

To move and/or resize a modifier volume, use the **SetLocation**, **SetSize** or **SetLocationAndSize** functions on the Modifier Volume. Simply setting the actors location or scale directly will not update the octree, so always use these functions to move and resize the modifier volume.

## Restrictions

There is a limit to how many Modifier Volumes can be supported within each 64x64x64 voxel section of the Octree. The exact limit depends on the topology of the navigable space within



the section of the Octree, but having up to 5 overlapping modifier volumes should not cause a problem.

If you hit an “Out of regions” error while building the octree then you should reduce the number of overlapping Modifier Volumes within the volume specified in the logged error.

## Blueprint Functionality

The following functions are available on the **Mercuna Navigation Component** and can be used to direct a pawn to move between goals:

- **MoveToLocation** - move to a position, stopping within end distance of the goal.
- **MoveToActor** - move to within a given end distance of a destination actor, if the destination moves while the pawn is moving, the path will be updated to track the destination.
- **TrackActor** - get to and stay within a given distance of a target actor
- **Stop** - bring the pawn to a complete stop as quickly as possible.
- **CancelMovement** - immediately terminates the pawn's current movement action
- **OnMoveCompleted** - a delegate that is triggered whenever a movement action is complete. Returns the result of the movement action as to whether it completed successfully, failed, was cancelled or was invalid (usually due to an invalid destination).
  
- **LookAt** - specify a target actor that the pawn will try to face as it moves. If no look at target is set then by default the pawn faces in the direction of movement.
- **CancelLookAt** - clear the look at actor.
  
- **IsReachable** (Latent action) - Test whether the pawn would be able to move to a given destination position from its current position.

The MercunaNavOctree actor offers the following Blueprint functions:

- **IsNavigable** - Does a point fall within navigable space
- **ClampToNavigable** - Clamp a position to the nearest point in navigable space
- **Raycast** - Perform a raycast through the navigable octree. If it fails, return the first point it hit
- **IsReachable** - Check whether there is a path from Start to End
  
- **FindPathToLocation** - Start an asynchronous path find from Start to End positions
- **FindPathToActor** - Start an asynchronous path find from Start position to End actor. Path will update as the destination actor moves
- **FindSplineToLocation** - Start an asynchronous path find from Start to End positions, and build a spline giving a smooth curve through navigable space along the resulting path.



- **BuildAll** - Build all of a navigation octree at runtime. Normally used after procedural generation of a level is complete.
  - **OnBuildComplete** - a delegate that is triggered once a runtime Build has completed.
  - **OnBuildLowResReady** - a delegate that is triggered when a runtime Build has finished building the low resolution data, to indicate that short ranged navigation may now be possible.
- **RebuildVolume** - Rebuild the navigation octree within the bounds of the given actor.
  - **OnRebuildComplete** - a delegate that is triggered once a RebuildVolume has completed.
  - **OnRebuildLowResReady** - a delegate that is triggered when a staged RebuildVolume has finished building the low resolution data, to indicate that navigation may now be possible.

## EQS

Mercuna currently offers three simple EQS tests. These tests are simple filters returning whether a point passes or fails, and do not score the points. The available tests are:

- **Navigable** - test whether a point is within the seeded, navigable volume for a pawn of a given radius. Be aware that the points might be disconnected from the querying pawn, however this test is much cheaper than a reachability test.
- **Reachable** - test whether a point is reachable by a pawn of a given radius from its position within a specified path distance. If the path distance is set to 0.0, then a faster test is used that only filters out points with extremely long paths.
- **Raycast** - test whether there is a clear straight line path from the context to the positions.

Additionally, Mercuna offers one EQS test that modifies the positions of the test points:

- **Project** - test whether a point is in or close to navigable space. If the point is outside then clamp it to back to the closest point within navigable space that is within a given search radius. The test fails and the point is not moved if the point is further than the search radius from navigable space.

Mercuna offers two EQS generators, they simply generate points without considering whether the resulting points are in navigable space or not. Add the Mercuna Navigable or Reachable EQS tests to filter out points in navigable regions or inside objects. The two available generators are:

- **Sphere** - generates points in concentric shells either uniformly or randomly distributed.
- **3D Ring** - generates points in rings in multiple vertical layers.



## BT Nodes

Mercuna offers the following Unreal BT nodes:

- **Reachable** - Decorator - Test whether a given point is reachable by a particular actor
- **MoveTo** - Task - Move a pawn with a Mercuna navigation component to a specified location or actor read from the AI's blackboard. If the blackboard value is a location and the value changes while the node is running the path will attempt to update.

## Debugging Problems

If you find that your pawn is not moving as expected, or at all, there are several debugging mechanisms available within Mercuna to help quickly identify problems.

## Logging

Mercuna makes logs to the Unreal logging system to indicate progress and error conditions. By default, only Warning and Error logs are written, to enable progress information add the following to DefaultEngine.ini:

```
[Core.Log]
LogMercuna=Info
```

If more information is needed then Editor Preferences > Mercuna > **Enable Extra Logging**, can be enabled. This option persists between editor restarts. Extra Logging causes Mercuna to output all log messages, including additional debug messages, to a dedicated **Mercuna.log** file, located in the same directory as the standard Unreal logs.

## Profiling

Mercuna is integrated with Unreal Engine's inbuilt profiler. The current amount of time Mercuna is taking to run each frame, as well as the current memory usage, can be seen using the **stat Mercuna** console command.

Mercuna [STATGROUP_Mercuna]		CallCount	InclusiveAvg	InclusiveMax	ExclusiveAvg	ExclusiveMax
Cycle counters (flat)						
MercunaAsyncJob		3	0.15 ms	0.34 ms	0.05 ms	0.09 ms
MercunaNavigationComponent:TickComponent		2	0.05 ms	0.12 ms	0.01 ms	0.05 ms
MerAvoidanceORCA:CalculateAvoidance		2	0.02 ms	0.05 ms	0.02 ms	0.05 ms
MerOctree:FindCorridor (Job)						
FMercunaCoreModule:Tick		1	0.04 ms	0.08 ms	0.00 ms	0.02 ms
MerJobSystem:Tick		1	0.04 ms	0.07 ms	0.00 ms	0.02 ms
MerPath:Tick		2	0.02 ms	0.05 ms	0.01 ms	0.04 ms
MerSteeringSpline:CalculateSteering		2	0.02 ms	0.05 ms	0.02 ms	0.05 ms
MerSpline:Tick		2	0.01 ms	0.04 ms	0.01 ms	0.04 ms
MerPath:UpdatePath (Job)		2	0.04 ms	0.14 ms	0.01 ms	0.06 ms
MerOctree:ClampToNavigable		2	0.01 ms	0.03 ms	0.01 ms	0.03 ms
MerSpline:ComputeSpline (Job)						
MerOctreeQuery:Splincast (Job)		1	0.02 ms	0.14 ms	0.02 ms	0.14 ms
MerOctree:Query:Lock		5	0.00 ms	0.02 ms	0.00 ms	0.02 ms
MerSpline:ExtendsSpline (Job)		0	0.00 ms	0.19 ms	0.00 ms	0.06 ms
MerSpline:RecomputesplineEnd (Job)		1	0.05 ms	0.13 ms	0.04 ms	0.09 ms
MerOctree:Raycast (Job)		2	0.02 ms	0.04 ms	0.02 ms	0.04 ms
Memory Counters		UsedMax	Mem%	MemPool	Pool Capacity	
Mercuna Memory		24.75 MB		Physical		



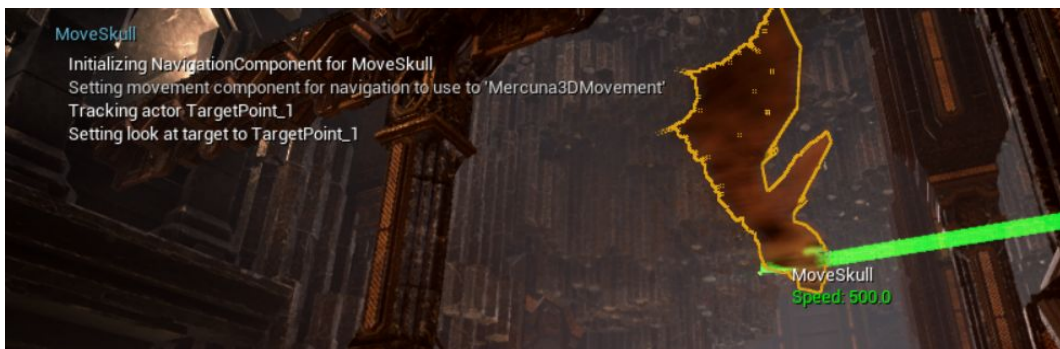
If an entry in the profiling list has *(Job)* after its name, then it is being run as an asynchronous job on a background thread and so will normally have no effect on the frame rate.

## Debug Actor

When trying to understand the actions of a particular pawn, it can be useful to set it as the Mercuna debug actor. This can be done by selecting the pawn and setting it as the Mercuna debug actor in the Mercuna toolbar menu. The same menu also allows the debug actor to be cleared.

On screen log messages will be displayed for the Mercuna debug actor and additional debug draw is available.

In Debug builds or if the define `MER_DEBUGGING` is set, then additional debug logs will also be recorded to `Mercuna.log` for the debug actor. If you report a movement problem to Mercuna support it is helpful to include these logs and a video capture of the problem.



Onscreen logging and information available about the debug actor

## Debug Draw

In order to help understand the current movement of Mercuna controlled pawns the following debug draw is available from the Mercuna editor menu:

- **General:** Shows speed and velocity vector for all Mercuna actors
- **Obstacle bounds:** Shows blue spheres representing the dynamic obstacles registered with Mercuna
- **Paths:** Shows all paths currently being followed by Mercuna actors
- **Steering:** Shows the desired velocity vector for the current debug actor
- **Avoidance:** Shows various pieces of avoidance related debug draw for the current debug actor including the velocity obstacle cones and the ORCA planes.



## Navigation Octree

### Debug Draw

In order to help understand Mercuna's representation of the geometry for navigation, you can draw the navigation octree, there are the following modes:

- **Unnavigable:** Draw the unnavigable part of the octree (in red).
- **Navigable:** Draw the navigable part of the octree (in green).
- **Navigable and unnavigable:** Draw both.

If the Mercuna debug actor is set, then the navigation radius of that actor is used to determine which cells are treated as unnavigable.

There are also options to particular cells in the octree:

- **Pathfind:** This will give a visualization of the last pathfind through the octree made by the Mercuna debug actor, or by a Mercuna Nav Testing actor. Explored cells are shown in green, cells that are on the path are shown in cyan.
- **Reachability:** This shows the cells that were included in the last reachability query. Like the pathfind, it gives a visualization of how the test flooded through the octree from the test point.

### Troubleshooting

Once the octree has built, the octree debug draw can be used to check the geometry has been built into the octree correctly. Switch on **Unnavigable** debug draw through the Mercuna menu, and you should see red boxes, representing unnavigable regions, around your geometry:





## Migration Issues

The following changes made in that may require manual action or result in changes to behavior:

### v1.7

- `UMercuna3DMovementComponent::MovementProperties::MaxAngSpeed` has been split out to allow separate max **pitch**, **yaw** and **roll** rates to be configured. The new properties will be automatically populated from the old `MaxAngSpeed` property.
- The `UMercuna3DMovementInterface` now requires the implementing component to allow a desired rotation rate to be specified and the current rotation rate to be queried. The old method of specifying desired world orientation has been removed. This makes implementation simpler, but any custom movement components will need to be updated.

### v1.5

- `UMercunaNavigationComponent::CheckReachable` and `AMercunaNavOctree::CheckReachable` have been deprecated. Use `IsReachable` instead.
- `UMercuna3DMovementComponent::MovementProperties::MaxAccel` has been changed from a vector separate accelerations in the **Forward**, **Backward**, **Sideways** directions. The new properties will be automatically populated from the old `MaxAccel` property.
- The full amount of the configured **Forward** acceleration is now used when following splines, previously it was clamped to `min(MaxAccel.X, MaxAccel.Y, MaxAccel.Z)`. This can result in pawns accelerating more aggressively. Reducing the configured **Forward** acceleration to equal the **Sideways** will give behavior similar to previous versions.

### v1.4

- The setting on the Nav Octree actor that controls whether the octree data is saved from the editor was changed from **Runtime Generation** to **Never Save**. The new **Never Save** flag should be set for octrees that are built only at runtime.
- The Nav Octree method **RebuildAll** for building a complete octree at runtime has been deprecated and replaced by **Build**.
- To aid clarity in scripting, new events **OnBuildComplete** and **OnBuildLowResReady** are triggered when the new **Build** method is used. The existing **RebuildVolume** and deprecated **RebuildAll** methods still trigger **OnRebuildComplete** and **OnRebuildLowResReady** as before.
- The existing Nav Octree **Build** method was renamed to **EditorBuild**, this method is only accessible through C++.





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## Known Issues

- Runtime octree rebuild is cancelled by a world origin shift