Next Steps: Procedural Animation

M03 - Introduction to Dynamics

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NERD ALERT

This is not a fun class today. No fun examples to play with.
Instead it is a lot of theory

If you endure the theory the following weeks when we do fun examples will make much more sense

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Agenda

Review from First Steps - Creating the Simplest Dynamics Test Bed

Understanding that DOP Networks is a Data Framework - Very Different then a SOPNetwork

We are going to examine:

- Details View
- Look at Relationships
- Look at Affector Matrix
- Look at MultiSolver
- Look at SOP Solver

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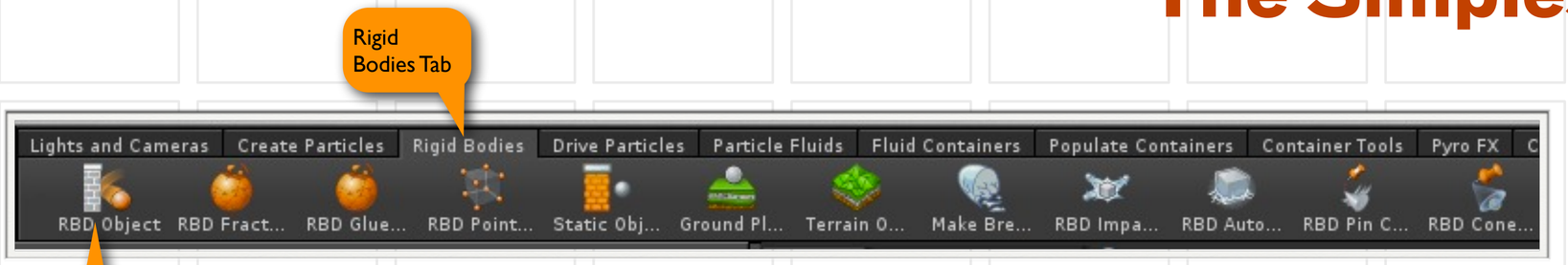
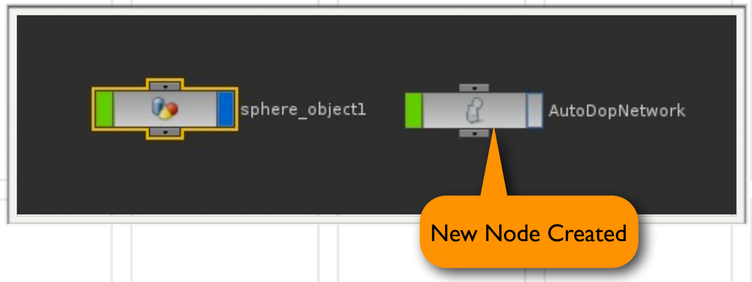
The Simplest Dynamics Testbed

A review from Houdini:First Steps





At the Object Level drop down a sphere (You can use the shelf tool)

Move the sphere up a few units in the +y direction

In the Rigid Bodies Tab of the Shelf Tools select RBD Object and then select the sphere and hit Return/Enter

Notice in the Network View a new node has been created - AutoDopNetwork

Play the animation and see the ball fall

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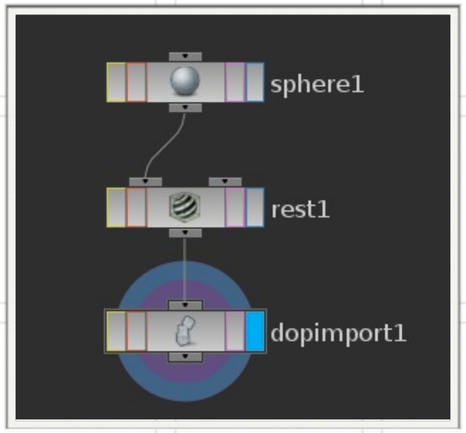
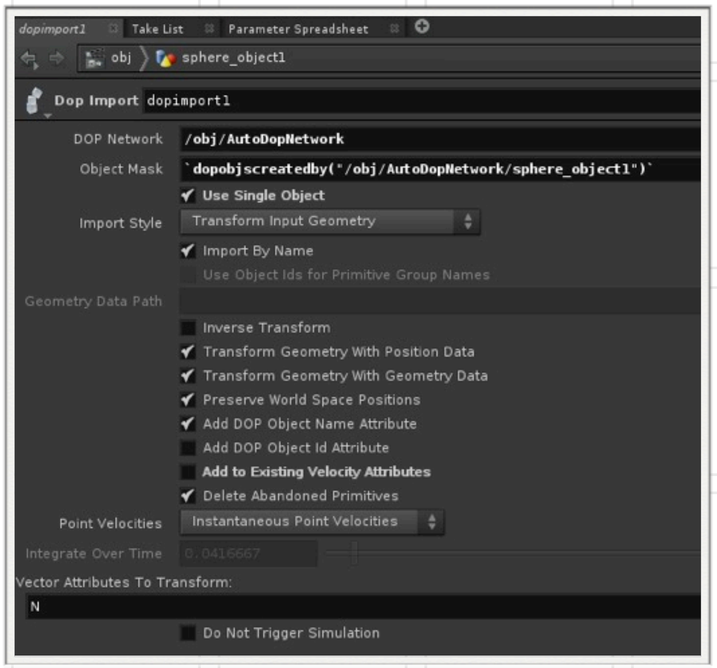
The Simplest Dynamics Testbed (cont.)





Let us dive inside the Sphere Object

When using the shelf too - RBD Object, the shelf tool added two nodes to geometry network of the sphere

- rest - this is to make sure when dynamics deforms geometry the materials will stick
- dopimport -Imports and transforms geometry based on information extracted from a DOP simulation.
- **This node is very important - It allows us to light and render the results of the simulation**

Looking at the parameters for dopimport we can see it imports the transforms from /obj/AutoDopNetwork

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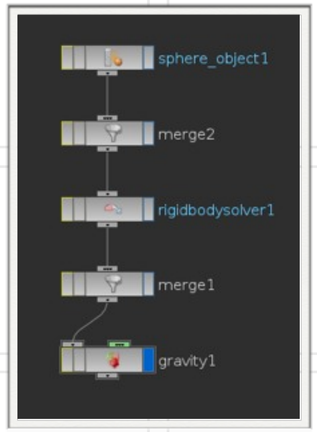
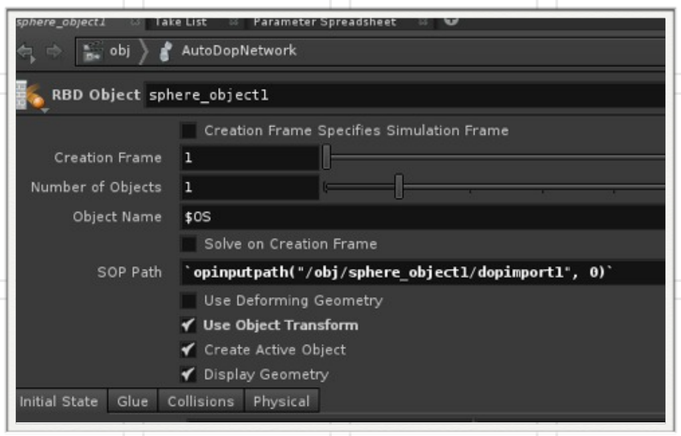
The Simplest Dynamics Testbed (cont.)





Let us now dive into the AutoDOPNetwork

The first node is sphere_object1

- It is a RBD Object Node and its main function is to pull the data from our SOP Node - /obj/sphere_object1/dopimport1

The next main node is the RBDSOLVER and finally we apply a gravity node to add a force to the sphere

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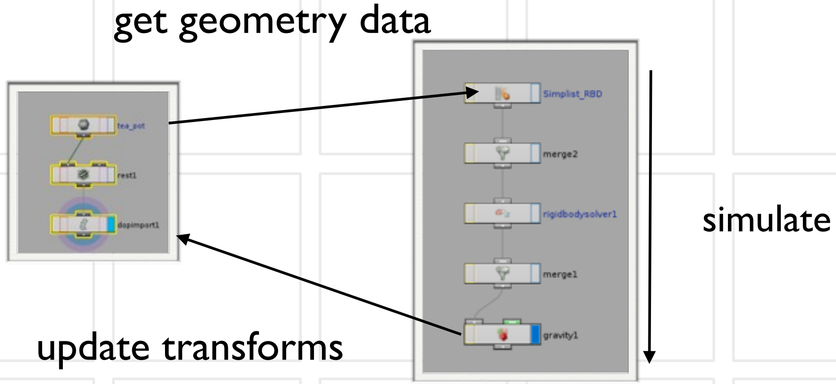
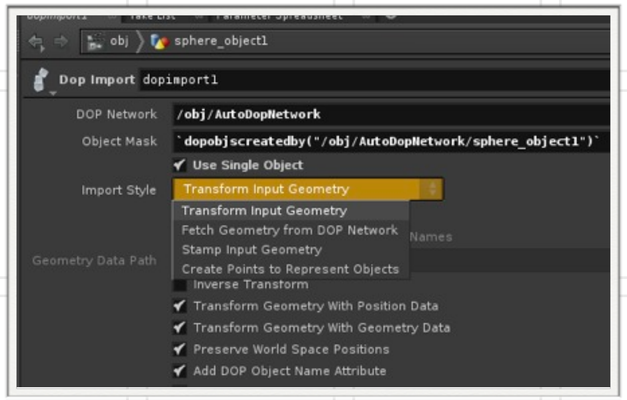
Simulation Cycle



Why am I saying update Transforms and not update geometry in the diagram to the left?

- I we look at the dopimport1 node we see there is a parameter named “Import Style” by default it is set to “Transform Import Geometry”
- This just fetches the transforms and not the geometry from the simulation. This is much more memory and CPU efficient since we do not have to transfer all the geometry from the simulation
- If we wanted to, there is a menu option to Fetch Geometry from the DOP Network.



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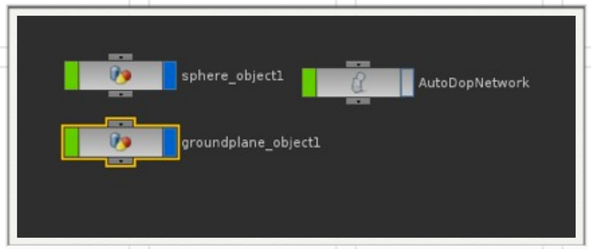
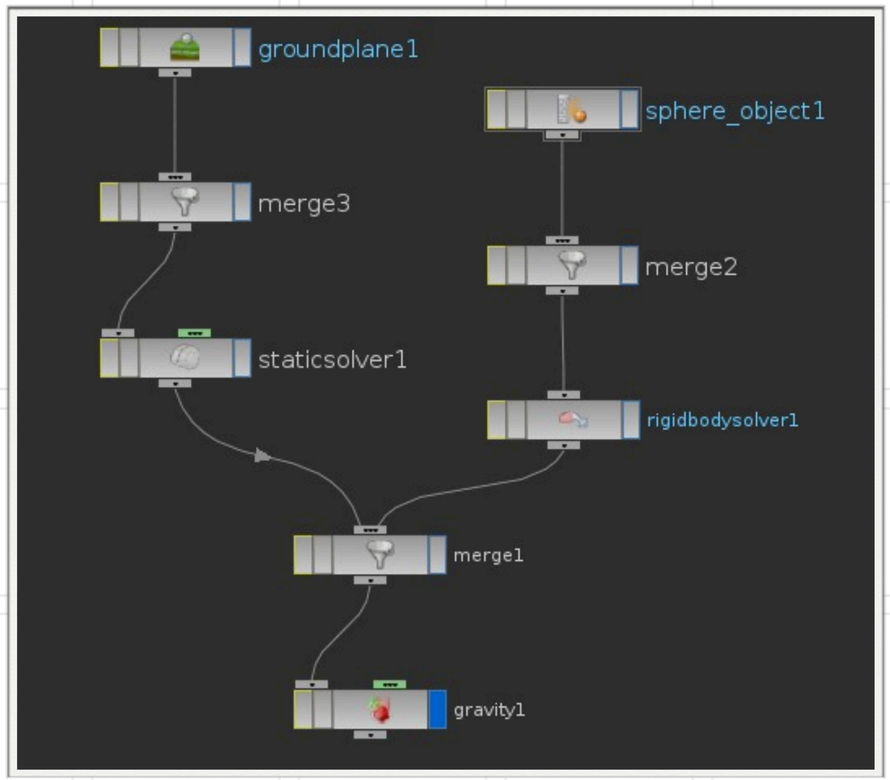
Finishing Up the Testbed





Click on Ground Plane in the RBD Tab of the Shelf Tools

Run the Animation and see the ball stop falling once it hits the Ground Plane

Notice the AutoDOPNetwork Now has a static solver chain

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End of Review - On to New Stuff

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AutoDOPNetworks

AutoDOP Networks are completely different then the rest of Houdini

- You might even think of them as a plug-in
- They might reside in Obj or a SOP network but they work differently
- To render a DOP network you have to extract the data (transforms) and apply it to your geometry to get results

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Major Solvers

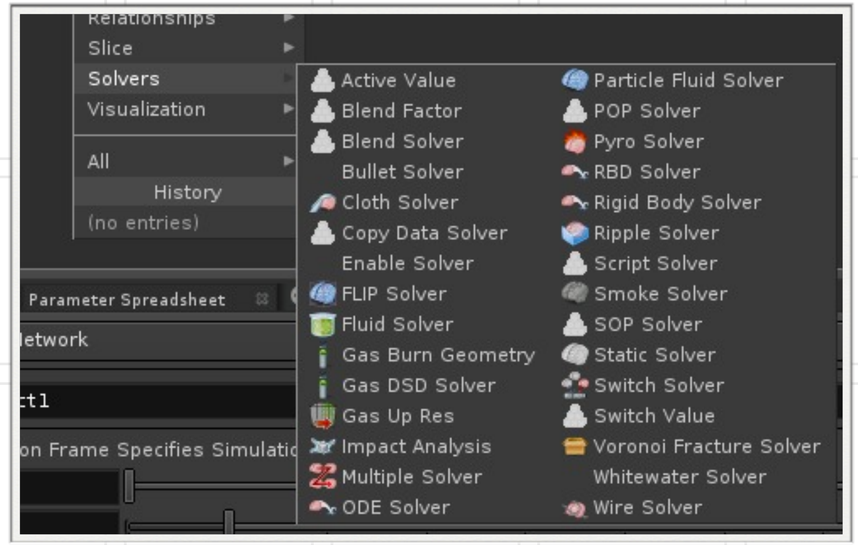
The network currently has two solvers.

- RBD Solver - Rigid Body Dynamics
- Static Solver

There are many Solvers (see image on the right)

The Main ones include:

- Bullet, Cloth, FLIP, Fluid, POP, Pyro, RBD, Ripple, Smoke, Wire



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DOP Simulation Runs in Two Passes

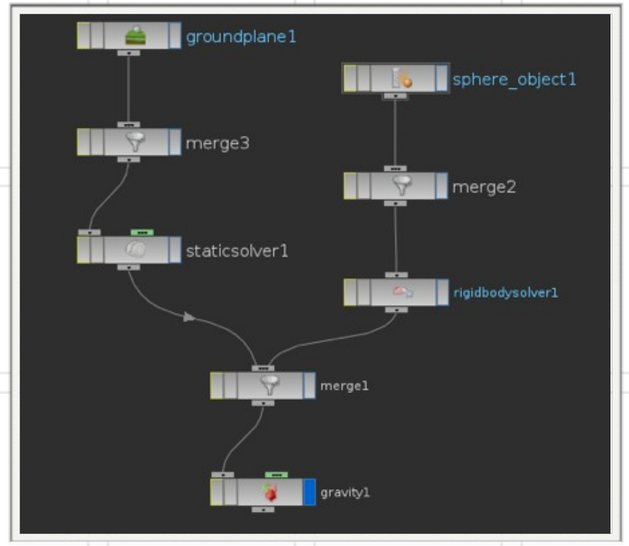
The First Pass creates all the data needed for the simulation

The Second Pass passes the data to the DOP parser which then has the various solvers perform the simulation

The two passes are run for each time step

The First Pass always starts at the node where the display flag is active

- It then goes up each node and determines all the dependencies between different object and solvers
- It then goes back down the network and fills in all the data for the simulation



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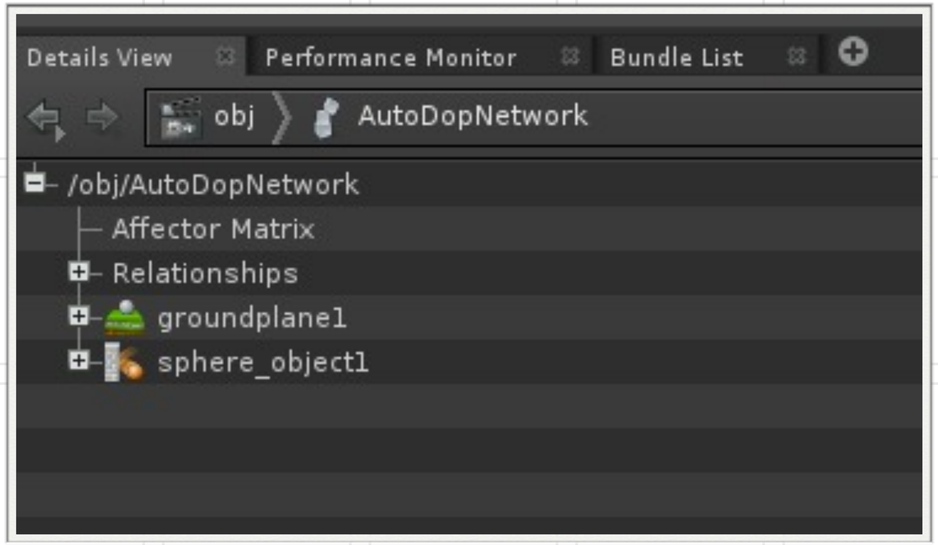
DOP Simulation Runs in Two Passes (cont.)

To understand the data we must be in the Technical Desktop and/or have a Details View open

No matter what node has the visibility flag set the Details View will show the first three lines

- /obj/AutoDOPNetwork
- Affector Matrix
- Relationships



The Details View will show a snapshot of the AutoDOPNetwork just prior to the simulation being run for the specific time step

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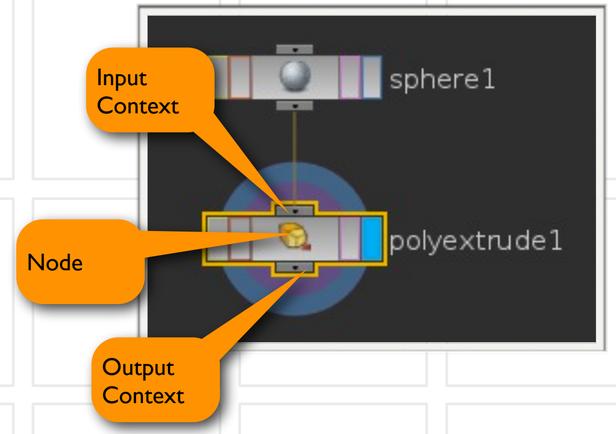
DOPs is a Data Framework

What is the difference between and SOP Network and a DOP Network?

Imagine the SOP network you see on the right



- If you are programmer/scripter you can think of the polyextrude node as containing three parts
  - the input context
  - the node
  - the output context
- The node can be thought of as a function/method written in a programming language
- The input context contains the arguments that are passed to the function - in our case the primitive and point data of the sphere
- The function (node) does the action, in this case the polyextrude and then returns the results in the output context

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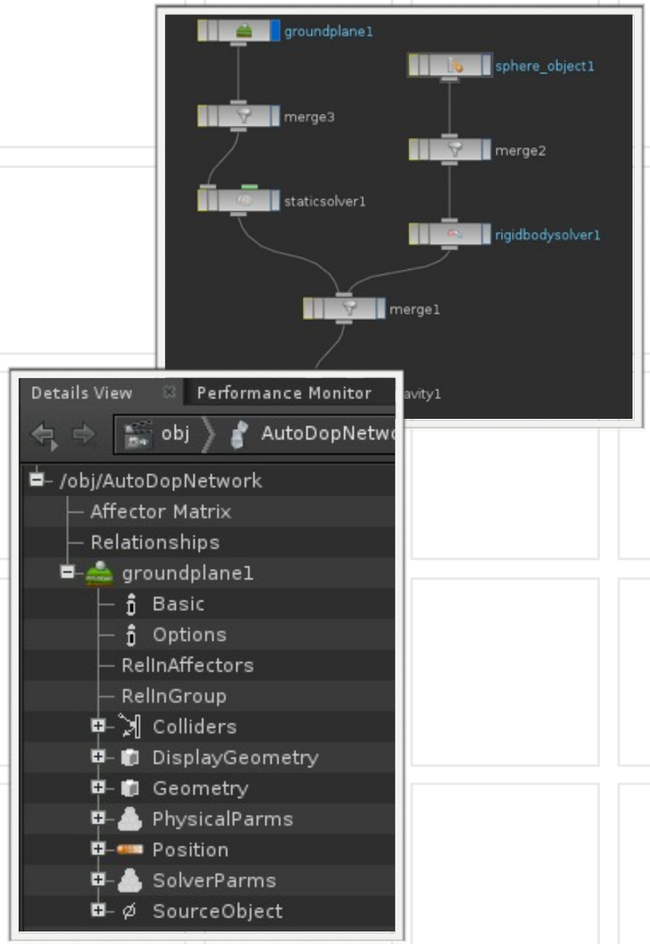
DOPs is a Data Framework (cont.)

The AutoDopNetwork runs completely differently

- As we stated before it is a data framework. Therefore there is no concept of a function doing work
- All each node does is fill out a table with the appropriate data to be parsed and sent to the simulation engine

Set the Visibility Flag to the groundplane

- Let us look at the details view
- continued on next slide....



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DOPs is a Data Framework (cont.)

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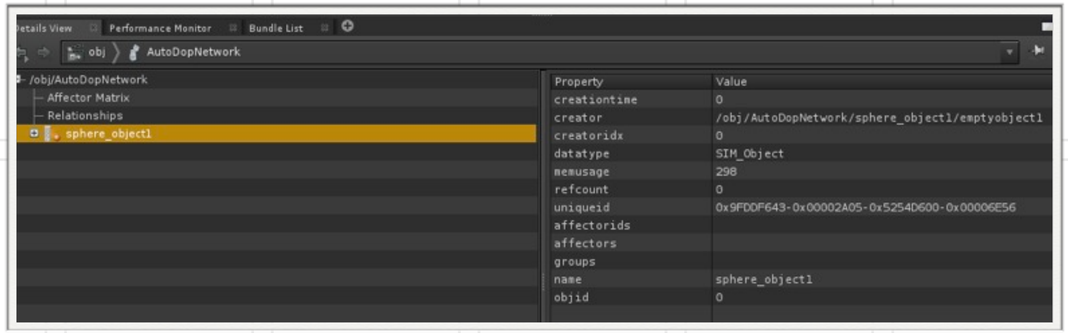
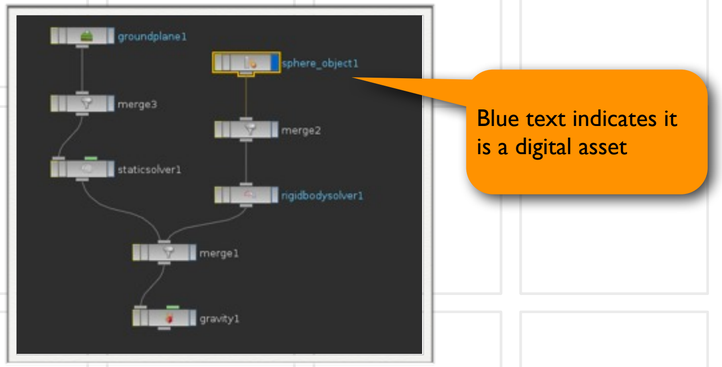


Set the Visibility Flag to the SphereObject

- Let us look at the details view
- All the data associated with the sphere object can be seen
- **Notice the sphere object is a digital asset!**



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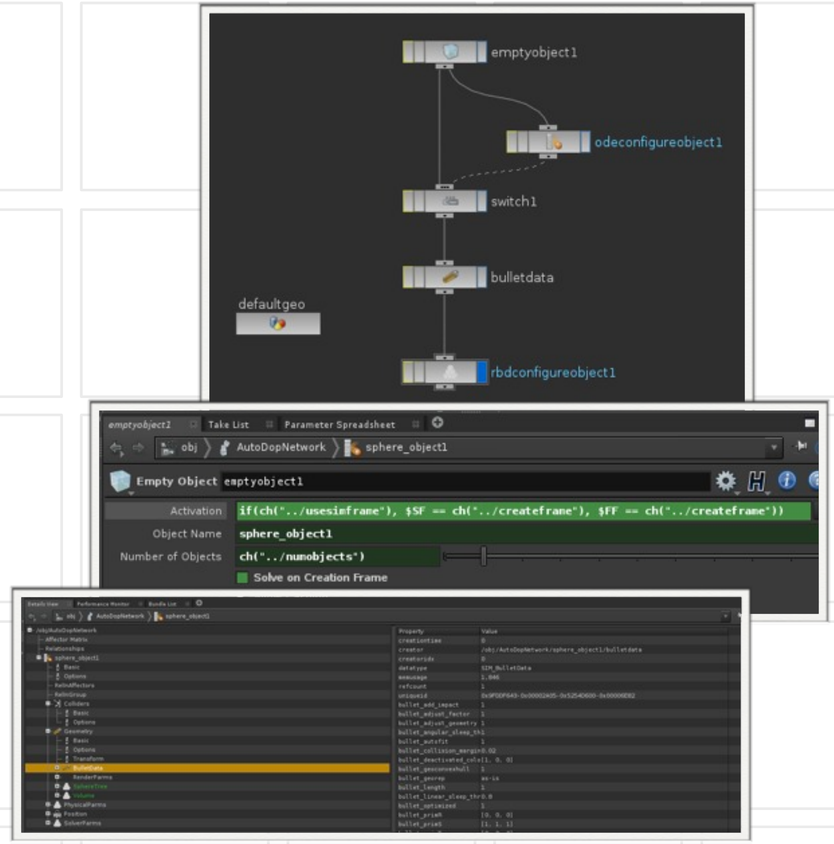
Looking at the Sphere Object in the DOP Netwok

Sphere Object - Allow Editing of Contents

- Dive Inside
- Every Object starts with a “Empty Object” node
  - This node creates the name for the network chain and node
- You can see that this network gives us the data to work with both the Bullet, ODE, and RBD Data
- Each Node unlike a SOP Network is just building up a table of data to be passed on to the Simulation Engine in pass 2



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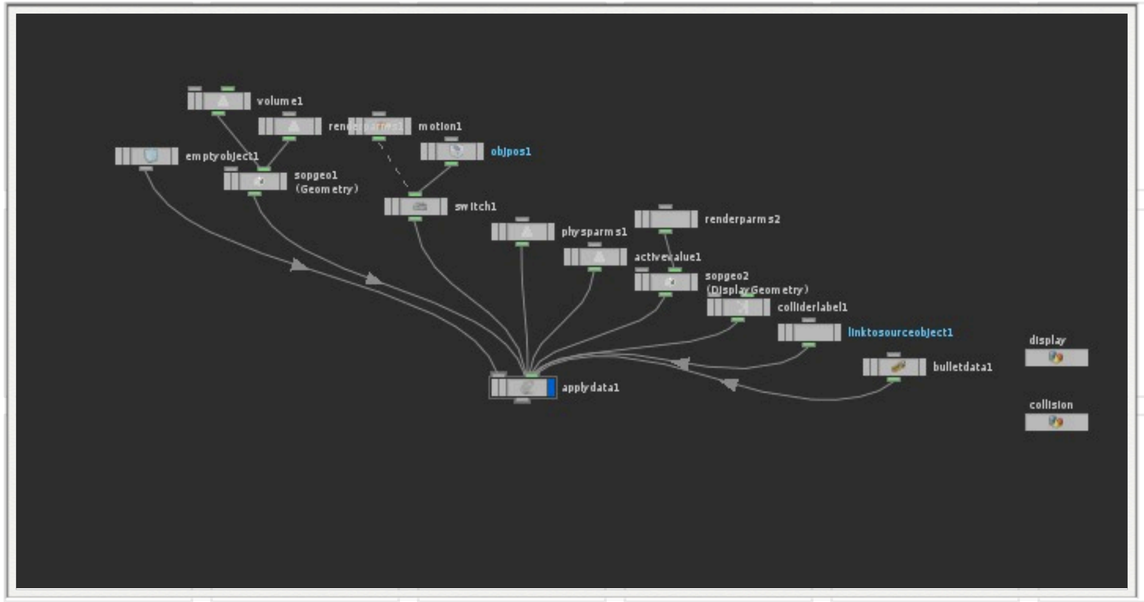
Look at the Ground Plane Object

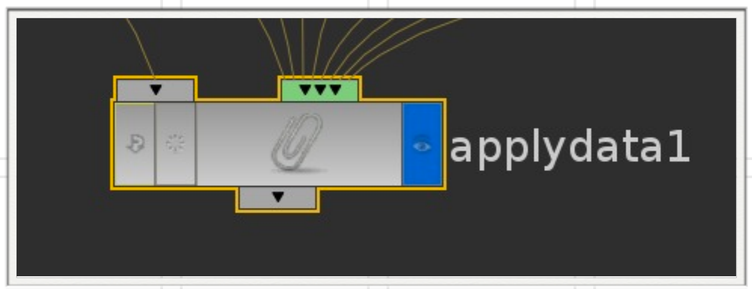
Dive inside - Many DOP Nodes look like this

All nodes are wired into a Apply Data Node

Attaches data to simulation objects or other data.

- Left Context is the Object you want to attach the data to
- Right Context is the data you want to attach





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Apply Data

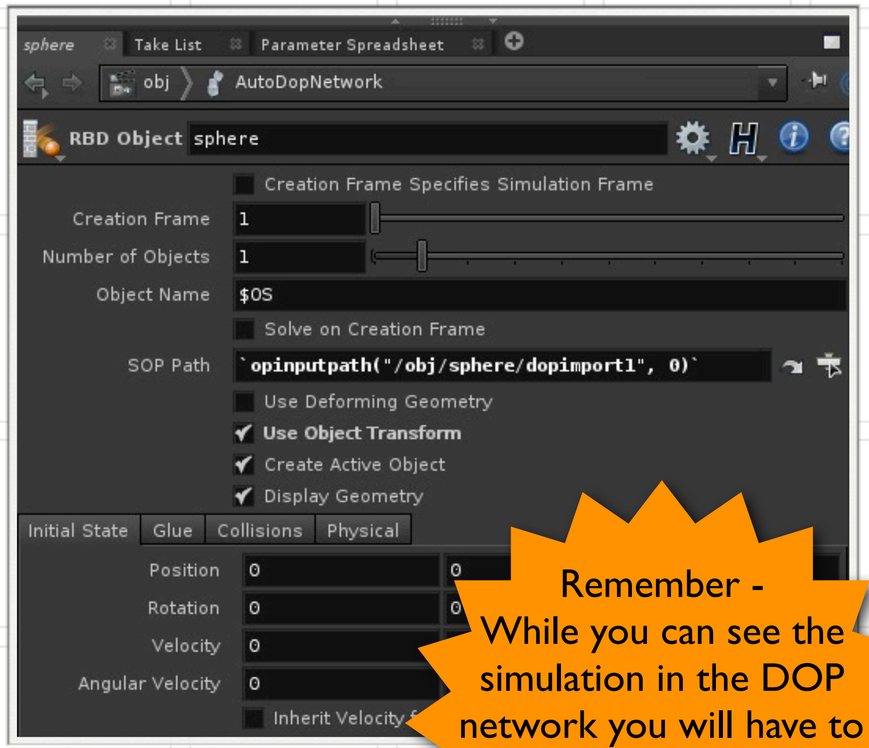
The Apply Data DOP attaches one or more pieces of data to a set of simulation objects, or to another piece of data.

The effect of attaching data to an object varies depending on the way in which the data is attached, and the solver attached to the object. For example, force data (Fan Force, Gravity Force) can be attached to an object to influence the motion of the object.

Geometry data may be attached to give a form to the object so it can be used in collision detection with other objects. Position or Motion data can be attached to directly control the way an object moves through space.

Although data is primarily attached to an object for use by the object's solver, there are no limitations on what kind of data can be attached to an object. Any data that a solver doesn't have a specific use for is simply ignored.

Looking at the RBD Object



Remember -
While you can see the simulation in the DOP network you will have to export the transforms to light and render the objects

Creation Frame Specifies Simulation Frame - Do you want to use Time ($T) or Simulation Time ($ST)

Creation Frame - What Frame does the Simulation Object get created

Number of Objects - While the AutoDOP Network fetches the Object it does not use the geometry data. Therefore you can use it as a template and make many simulation objects

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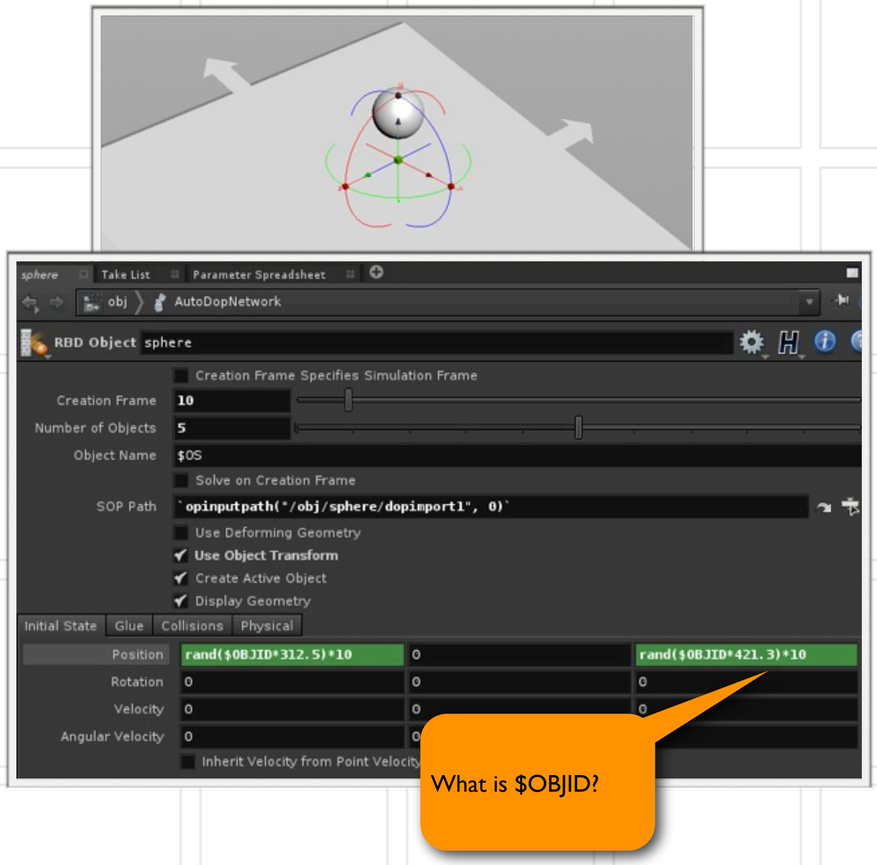
A Small Example of the RBD Object



Set Creation Frame to 10 - run the simulation

- Notice the Simulation Object is not created until frame 10

Set the Number of Objects to 5

- Run the simulation again. It does not look different because the 5 spheres are on top of each other

In the Initial State Tab set Position x & z

- rand($OBJID*312.5), rand($OBJID*412.3)
- Run the simulation again. See the 5 balls created

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Local Variables for the RBD Object

ST - This value is the simulation time for which the node is being evaluated.

This value may not be equal to the current Houdini time represented by the variable T, depending on the settings of the DOP Network Offset Time and Time Scale parameters.

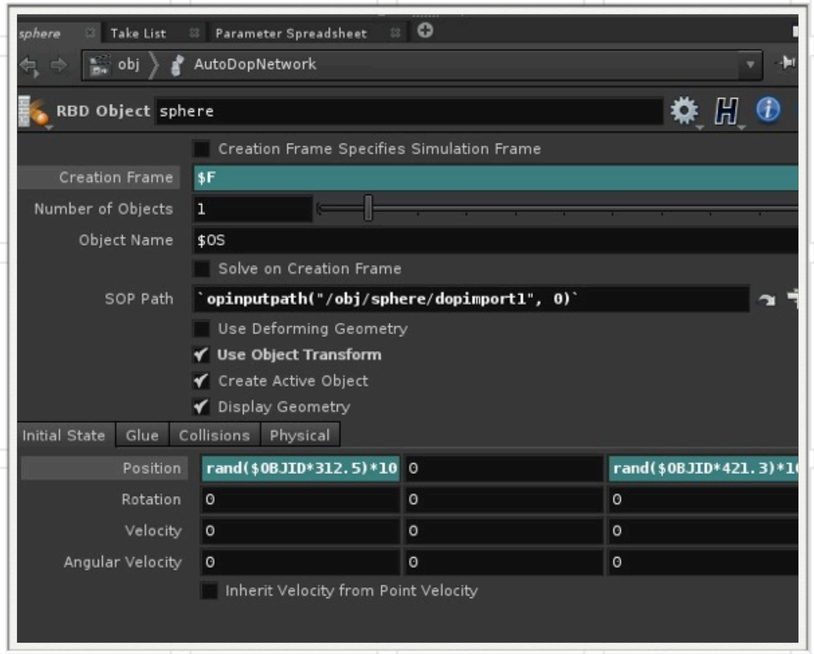
This value is guaranteed to have a value of zero at the start of a simulation, so when testing for the first timestep of a simulation, it is best to use a test like $ST == 0 rather than $T == 0 or $FF == 1.

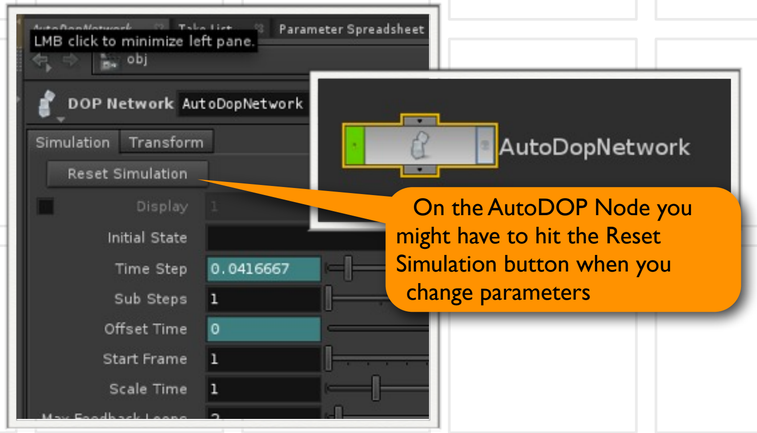
SF - This value is the simulation frame (or more accurately, the simulation time step number) for which the node is being evaluated.

OBJ -This value is the index of the specific object being processed by the node. This value will always run from zero to NOBJ-1 in a given timestep. This value does not identify the current object within the simulation like OBJID or OBJNAME, just the object's position in the current order of processing.

OBJID - This is the unique object identifier for the object being processed. Every object is assigned an integer value that is unique among all objects in the simulation for all time. Even if an object is deleted, its identifier is never reused.

A Couple More Variations





Try Changing Creation frame to $F and Number of Objects to 1

- Run Simulation

Try another variation - Set Creation Frame to:

- $F>10 and $F<30

Try adding an initial velocity and angular velocity

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Where Should I Set Initial Position?

Three Possibilities

- At the Object Level
- At the Geometry Level
- At the DOPs level

If you are setting your scene it makes sense to set the position at the object level

Initial velocities make sense to set at the DOP level

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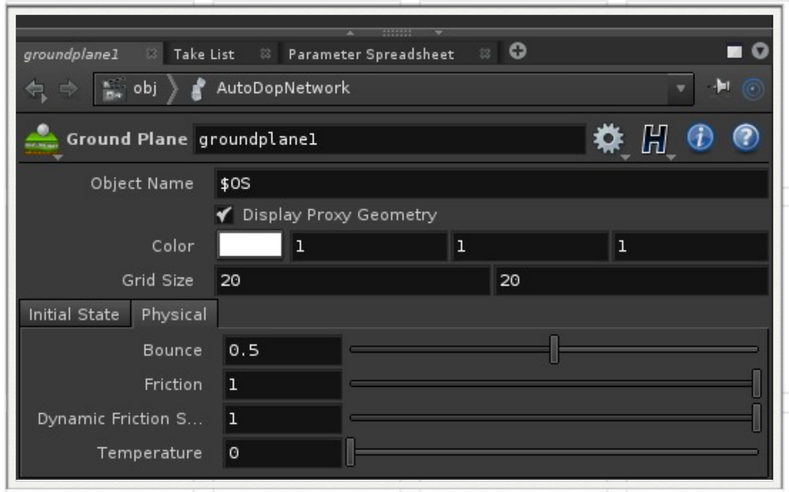
Looking at the Ground Plane Object

Go to the Physical Tab and Play with Bounce

What are the differences between

- Friction
- Dynamic Friction



Bounce	The elasticity of the object. If two objects of bounce 1.0 collide, they will rebound without losing energy. If two objects of bounce 0.0 collide, they will come to a standstill.
Friction	The coefficient of friction of the object. A value of 0 means the object is frictionless. This governs how much the tangential velocity is affected by collisions and resting contacts.
Dynamic Friction Scale	An object sliding may have a lower friction coefficient than an object at rest. This is the scale factor that relates the two. It is not a friction coefficient, but a scale between zero and one. A value of one means that dynamic friction is equal to static friction. A scale of zero means that as soon as static friction is overcome the object acts without friction.
Temperature	Temperature marks how warm or cool an object is. This is used in gas simulations for ignition points of fuel or for buoyancy computations. Since this does not relate directly to any real world temperature scale, ambient temperature is usually considered 0.

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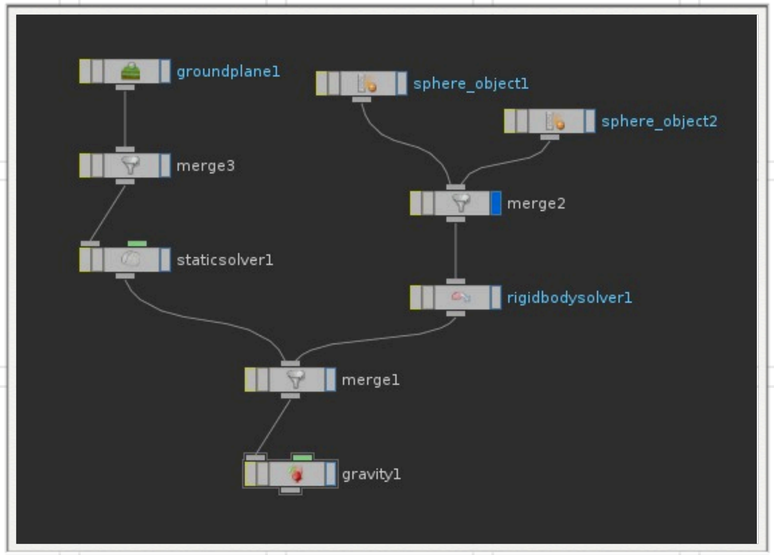
Creating a Second RBD Object



Make sure the visibility flag is set on the gravity node

Go back up to the object level and add a second sphere

- Move it up on the +y direction and offset it in the xz plane

Make it an RBD Object like you did on the first sphere

- Dive inside AutoDOPNetwork and see how it is attached to the merge node

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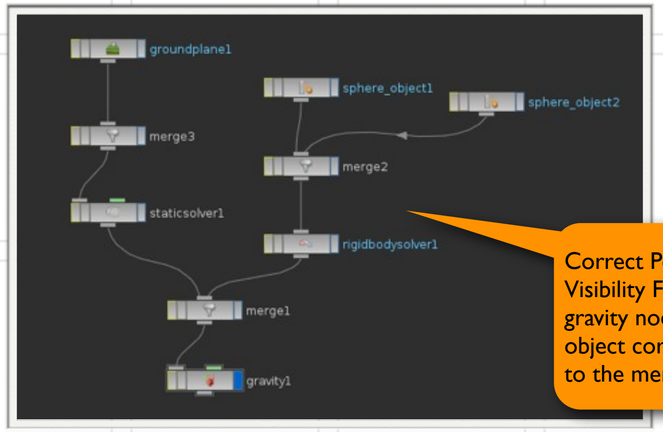
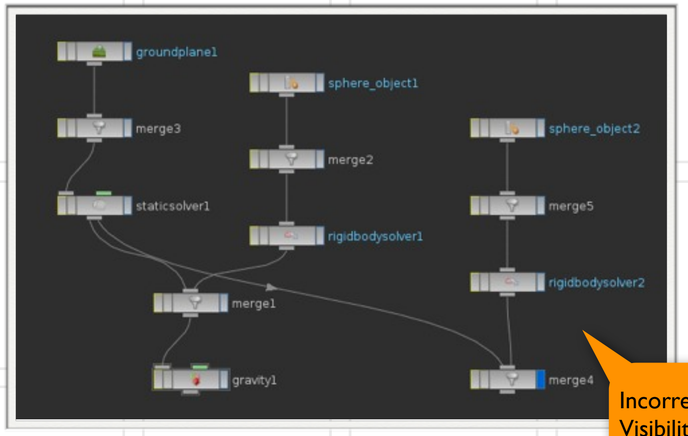
A Couple of Mistakes You Can Make



Correct Positioning - The Visibility Flag was set to the gravity node and the sphere object correctly was attached to the merge

If you create the second RBD at anything other then frame 1 your sphere might disappear from the scene view

- Remember simulations start at frame 1 and when you create additions to the simulation the simulation must recook



Incorrect Positioning - The Visibility Flag was set to the the merge 3 node and the sphere object incorrectly was given its own chain

If You forget to have your visibility flag at the bottom of the AutoDOPNetwork the new nodes will be placed in the wrong position in the AutoDOP Network

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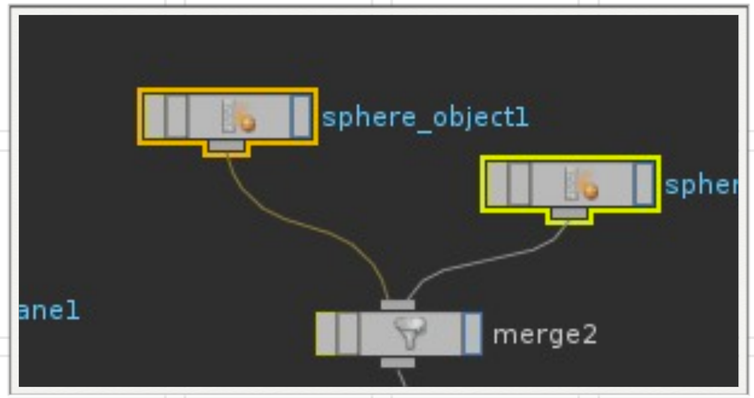
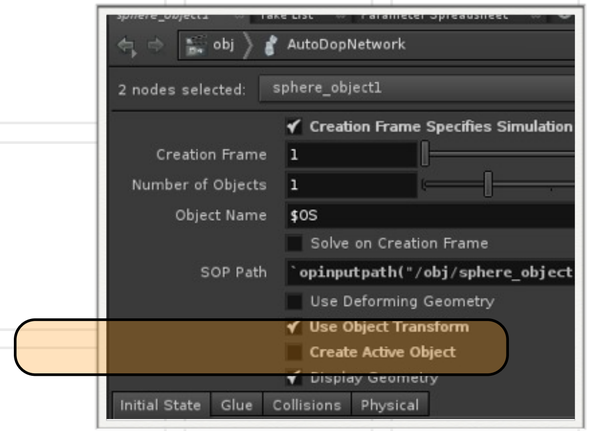
Making a Simulation Object Passive

Select the two Sphere Objects and deselect in the parameters “Create Active Object”

Create Active Object - Sets the initial active state of the object. An inactive object does not react to other objects in the simulation.

- Therefore by turning it off it will not react with the gravity object and not move





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ActiveValue DOP

Marks a simulation object as active or passive.

An active object is one which is controlled by a solver and can be affected by other objects. A passive object, even if it has a solver attached to it, is never modified by the solver. It may still affect other objects, but is not affected by those objects. This value can also be animated to make an object switch between these two states.

- We can turn off and on simulations by using ActiveValue with an Apply Data

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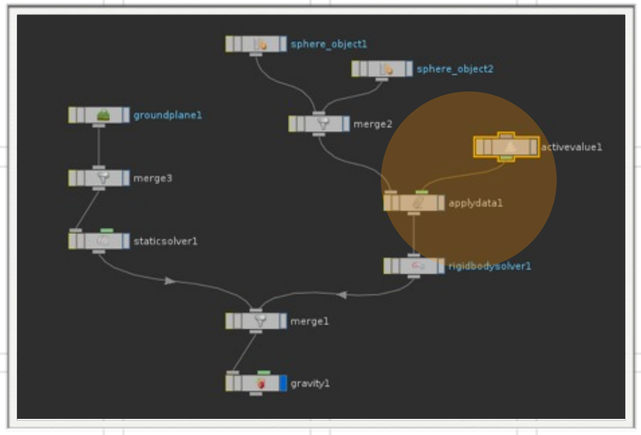
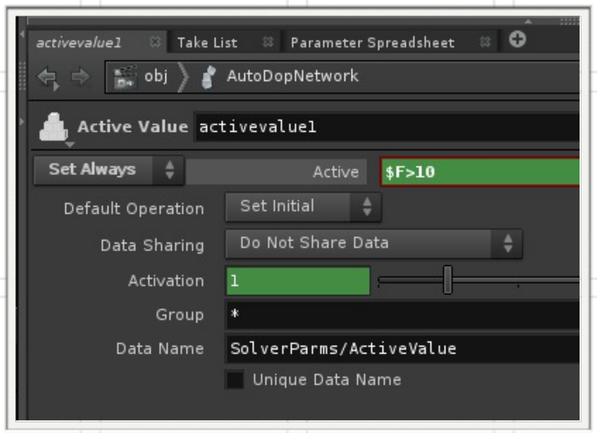
ActiveValue DOP (cont.)





In this example I dropped down an active data with an apply data. I wanted the spheres to only start falling after frame 10

- In the Parameters
  - Active - Set Always
  - Active - $F>10

If I wanted the balls to start falling after frame 10 and then stop before frame 30

- $F>10&&$F<30

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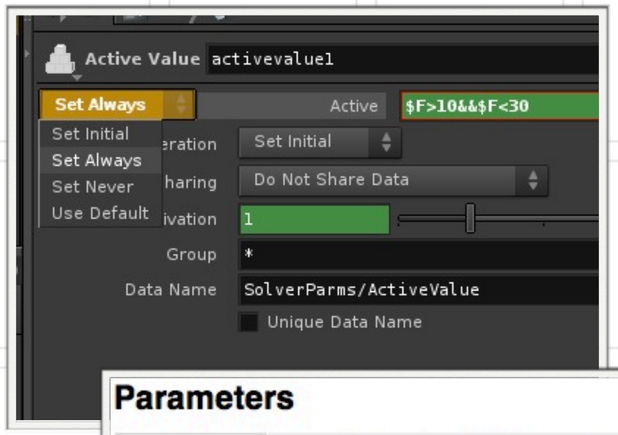
What is Set Always?



Four Options in DOPs - Use Default, Set Initial, Set Always, Set Never

Parameters

Active	Controls whether the object is active or passive. A value greater than or equal to one indicates an active object. A value less then one indicates a passive object.
Parameter Operations	Each data option parameter has an associated menu which specifies how that parameter operates.
Use Default	Use the value from the Default Operation menu.
Set Initial	Set the value of this parameter only when this data is created. On all subsequent timesteps, the value of this parameter is not altered. This is useful for setting up initial conditions like position and velocity.
Set Always	Always set the value of this parameter. This is useful when specific keyframed values are required over time. This could be used to keyframe the position of an object over time, or to cause the geometry from a SOP to be refetched at each timestep if the geometry is deforming. You can also use this setting in conjunction with the local variables for a parameter value to modify a value over time. For example, in the X Position, an expression like `$tx + 0.1` would cause the object to move 0.1 units to the right on each timestep.
Set Never	Do not ever set the value of this parameter. This option is most useful when using this node to modify an existing piece of data connected through the first input. For example, an RBD State DOP may want to animate just the mass of an object, and nothing else. The **Set Never** option could be used on all parameters except for **Mass**, which would use **Set Always**.

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Geometry Type

DOPS converts Geometry internally to Polygons

At the Geometry level for each sphere switch the geometry type to polygons

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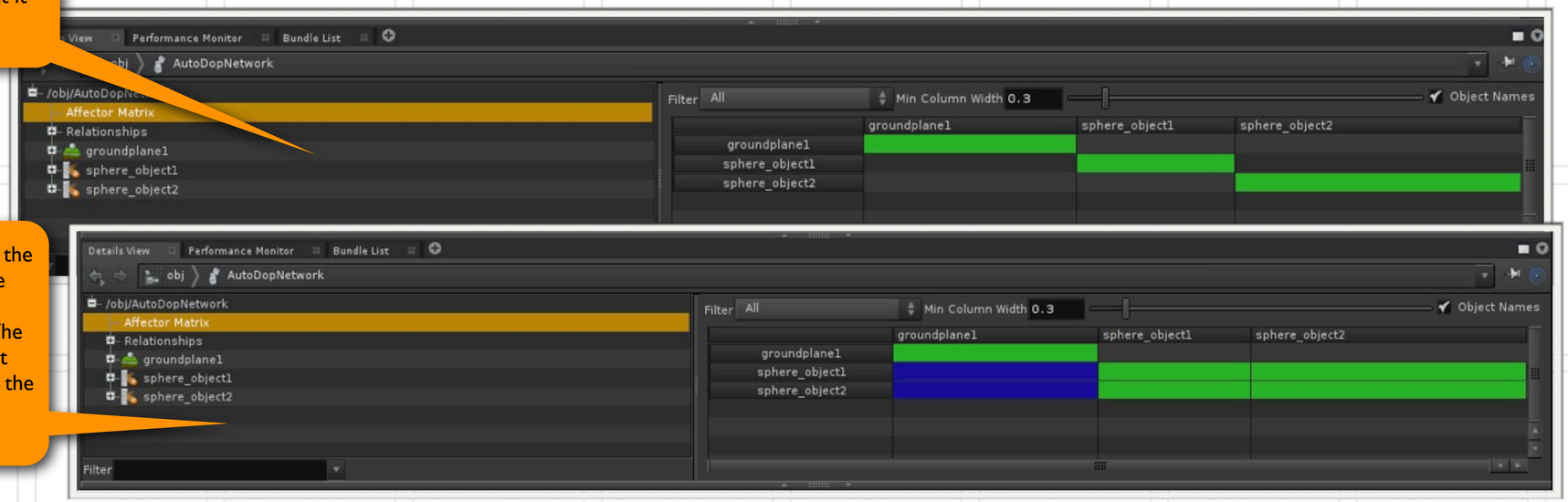
Framework of the Details View

At Frame 5 - Activate for the Sphere Objects is turned off. Therefore the only object it interacts with is itself

At frame 11 - Activate for the Sphere is turned on so the Sphere objects mutually interact with each other. The blue indicates they interact with the ground plane but the ground plane does not interact with the spheres



The Affector Matrix is just under the /obj/AutoDOPNetwork

It displays the relationship each object has with each other

- Green - The Object Interacts mutually
- Blue - One way interaction

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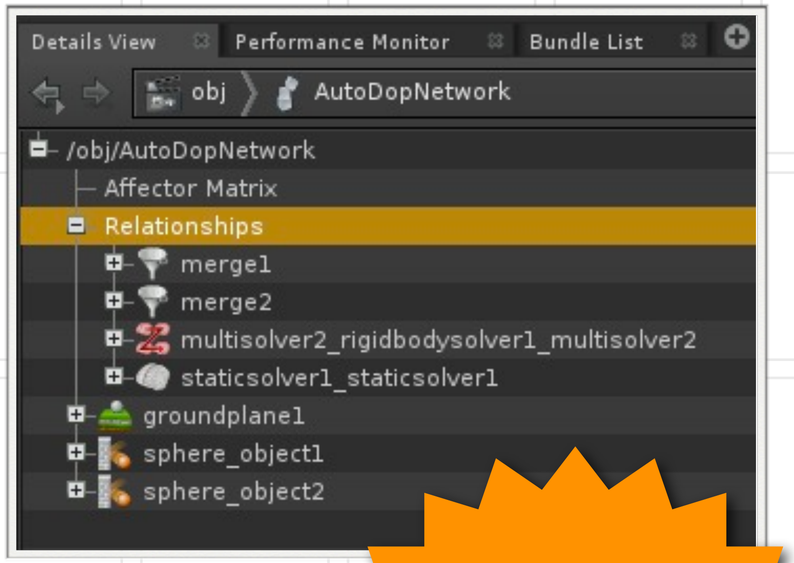
Relationships



Why do I bring this up? - See on next slide...

The color coding we just saw is the result of the next item in the Details View - Relationships

If you open up Relationships you can seethe nodes that affect the relationships

- merge1, merge2, rigid body solver, and the static solver

The nodes in the list are the nodes that create relationships or have relationships

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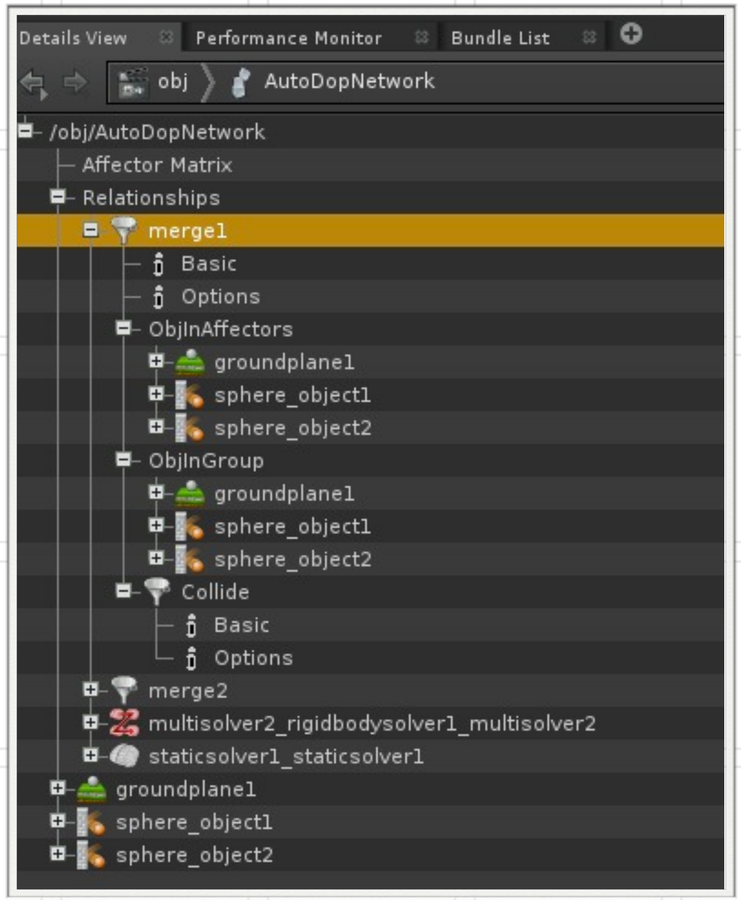
The Merge DOP is NOT the Merge SOP



The Merge SOP combine different pieces of geometry and makes them into one pie

The Merge DOP defines the **relationship** between various DOP Objects

The Merge DOP is quite sophisticated

Remember - The Merge DOP is doing nothing in the simulation. It just creates data to pass to the simulation

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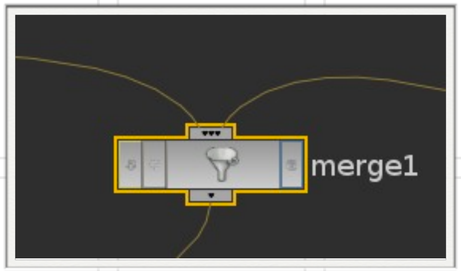
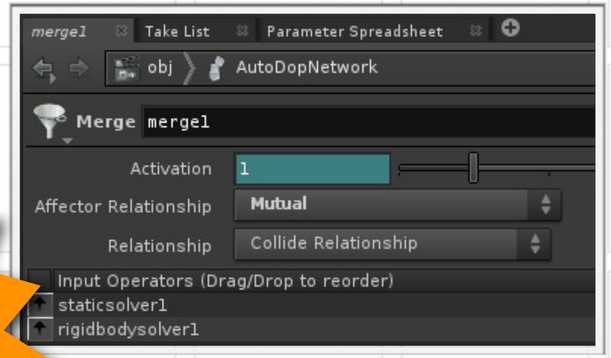
Merge DOP (Cont...)

If we look at the parameters of the Merge DOP we see we have options for how the relations effect each other and what action occurs in that relationship

Affector Relationship	If this node is merging streams of simulation objects, this parameter sets up affector relationships between the objects.	
	No Change	No new affector relationships are created between the input objects.
	Left Inputs Affect Right Inputs	Given a series of inputs 1, 2, 3, and so on, the objects connected to input 1 become affectors for the objects on inputs 2, 3, and so on. The objects at input 2 become affectors of the objects at input 3 and beyond. Using this option will cause the input objects to be solved in the order in which they are connected to this node.
	Mutual	All objects on all input streams become mutual affectors.
Relationship	When merging streams of objects, this determines what sort of relationship should be created between the streams. Useful choices are:	
	None	No affector relationship is created - the same as setting No Change in the Affector Relationship field.
	Constraint	Used internally to define two objects that have a constraint between them.
	Pump	Affected objects will set their local velocities to match the velocity of the source object. Applies to fluid objects.
	Sink	Affected objects will delete their volume where it contacts the affectors. Applies to fluid objects.
	Group	Used internally to make objects part of the same group.
	Collide	Affected objects will respond to collisions from affector objects.
	Target	A place holder affector for user defined effects. Used by the Gas Target Forces.
	Source	Affected objects will use the affector objects as sources for operations such as creating liquid or smoke density.
	Empty	Enforces a particular solve order - affected objects will be solved after affector objects - but no other intrinsic meaning. This is useful when SOP Solvers refer to other objects creating a dependency that isn't visible to the DOP Engine.





Notice some of the options are for fluids, others for smoke,others for geometry

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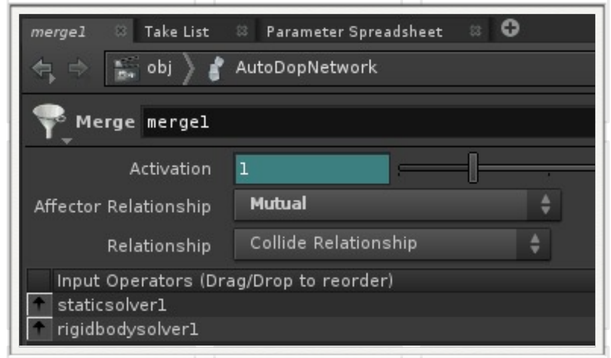
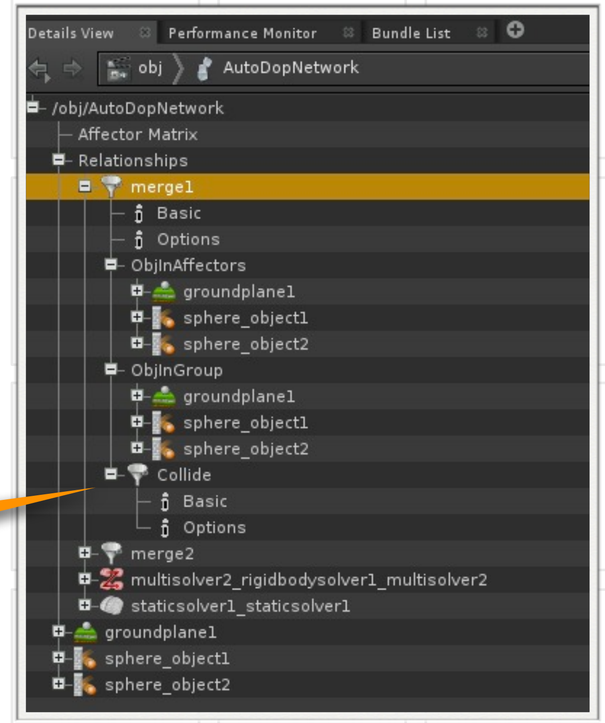
Merge DOP (Cont…)





Collide Relationship

The Collide relationship can be seen in the Relationship Tree

- Try changing the Relationship in the Merge parameters to something else and se how it effects the tree

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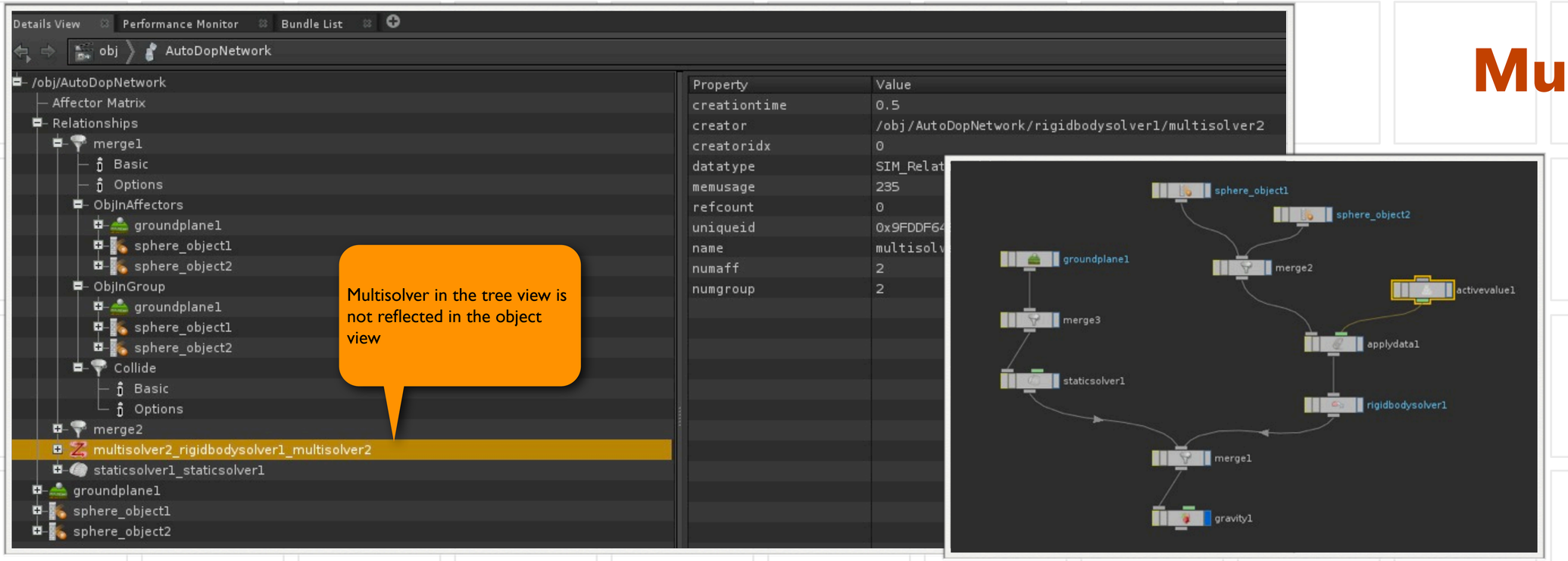
Multi-Solver



If you look at the tree view there is a multisolver but if you look at the network view there is no multisolver. What is going on?

In the tree view if you select the multisolver you will see there is a parameter called “creator”

- Creator defines where the solver is: It is inside the rigidbody solver

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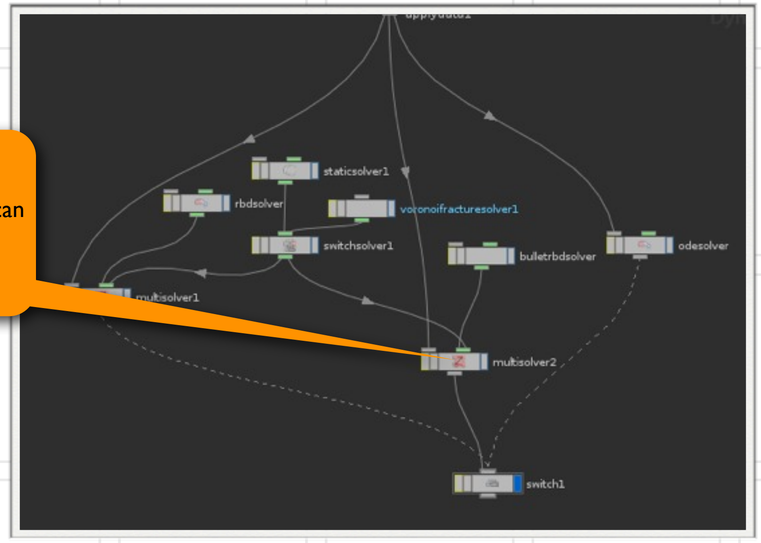
Multi-Solver (cont.)

Inside the RBD Solver you can see there is a multisolver.



The Rigidbody Solver is a Digital Asset

- If you dive inside you will find a multisolver
- The multisolver is how you bind solver to a simulation object

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Multiple Solver dynamics node

The Multiple Solver DOP causes a simulation object to be solved by more than one Solver at each timestep. Each solver attached to this node is applied in order to the object.

Many solver combinations will produce strange or unexpected results. For example, applying two RBD Solvers will simply make objects move twice as fast.

The most useful solver combinations are ones where each solver acts on a different piece of data on the object. For example, the RBD Solver alters the Position data of an object. This may be followed by a SOP Solver that modifies the geometry of the object based on the position, velocity, or impact information generated by the RBD Solver.

It is important that you make sure the attached solvers have different names. Solvers by default all have the name “Solver” and will thus overwrite each other. The **Unique Data Name** toggle on the incoming solvers can be used to ensure that the names are different.

Deforming Geometry

Remember the Solvers do not own the Data

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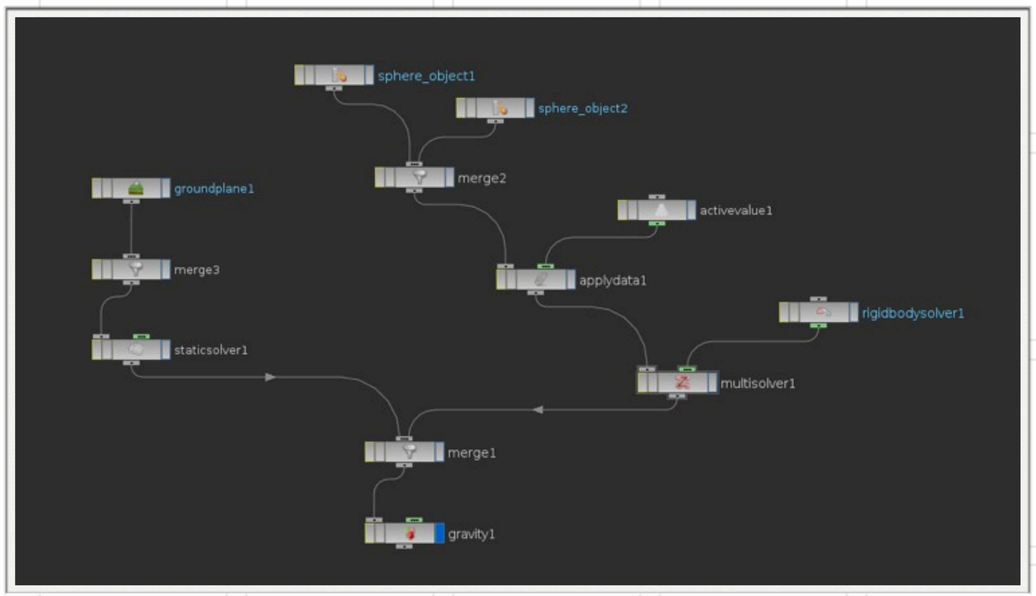
Adding a Multisolver to the Network



Drop down a multisolver dop just above the rigidbodysolver in the network

Shake off the rigidbody solver and put it to the side

- Do not delete it

Rewire the rigidbody solver to the second context of the multisolver (see image on right)

The simulation works just like before

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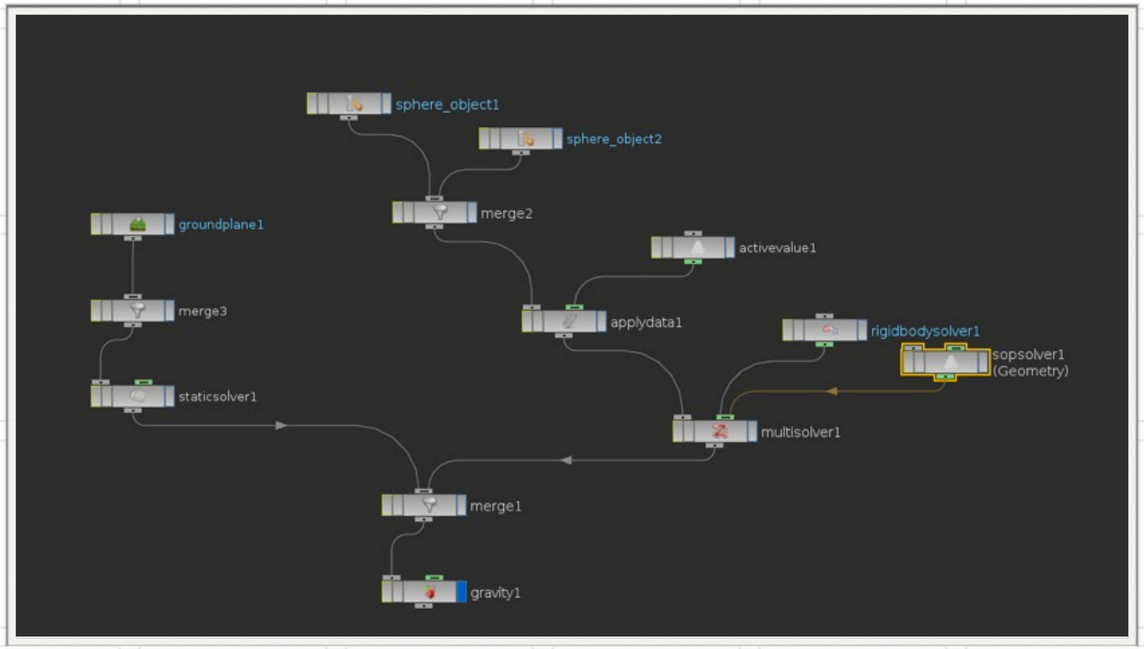
Let's Add a SOP Solver



The SOP Solver DOP lets the DOP simulation use a SOP Network or chain of SOPs to evolve an object's geometry over time. At each timestep, the SOP specified in the SOP Path parameter is set up with a number of global parameters accessible with the stamp or stamps expression function. Since these global parameters are modified at each timestep, any SOPs that feed into the output SOP are forced to recook.

Drop down a SOPSolver and Attach it to the second context of the MultiSolver

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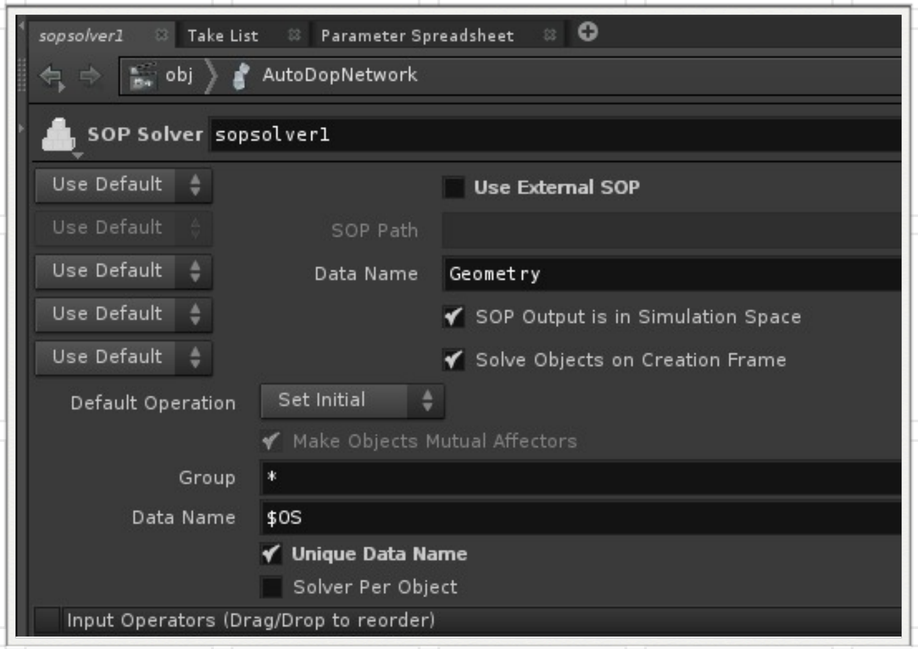
SOP Solver Parameters



By default the SOP Solver uses a Data name of Geometry

- This means that if any data entering the SOP Solver is of type Geometry the SOP Solver will work on it

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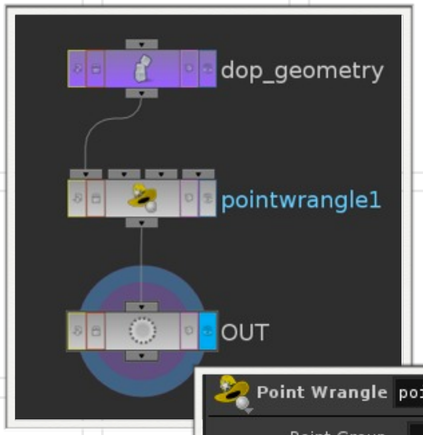
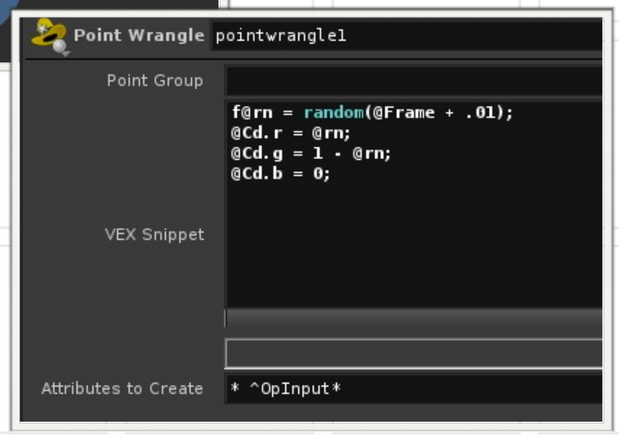
Dive Into the SOP Solver



SOP Solvers work on only one object at a time



Append a Null to the dop_geometry

- Name it OUT
- Set the Visibility flag

We just want to do a quick test to see if the SOP Solver will work

- Append a Point Wrangle to the dop_geometry and reate random colors

Test it

Open the help card for Multisolvers and look at the Local Variables - OBJ, OBJID

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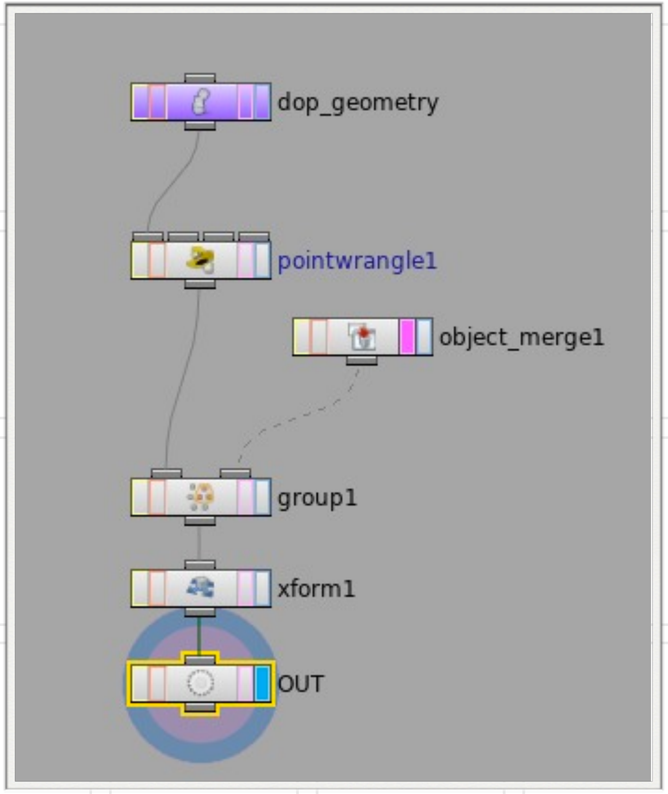
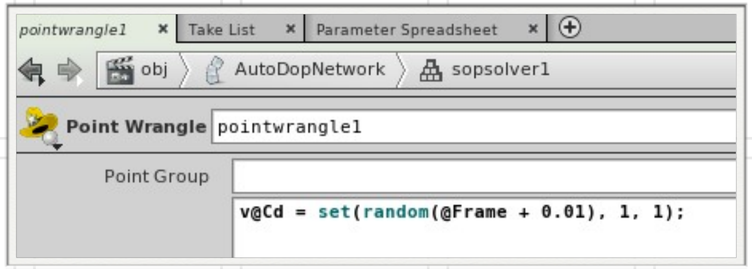
Look at Exhelp for DOP

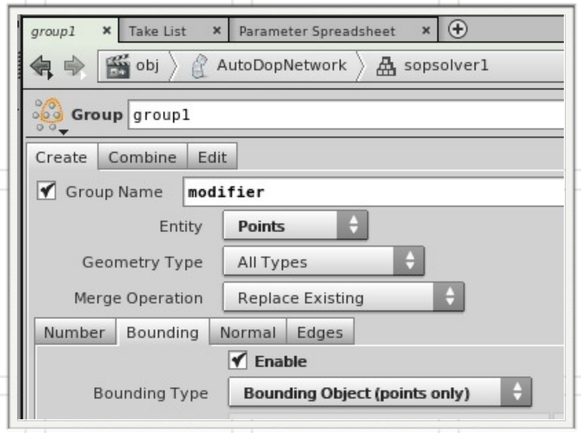
```
/ -> exhelp -k dop
dopallfields                dopnumfields                dopsolvenumnewobjects
dopcontextgeo               dopnumobjects               dopsolvenumobjects
dopcountslices              dopnumrecords               dopsolveobject
dopfield                    dopnumrecordtypes           dopsolvetimestep
dopfieldname                dopnumsubdata               dopsttoframe
dopfields                   dopobjectlist               dopsttot
dopfieldtype                dopobjectsareaffectors      dopsubdataname
dopframe                    dopobjscreatedby            doptime
dopframetost                dopoption                   doptransform
dopgrouphasobject           dopoptions                  dopttost
dopgrouplist                doprecordtypename           dopvelatpos
dophasfield                 dopsolvedopnet              opflag
dophassubdata               dopsolvenewobject           stamps
dopnodeobjs
/ ->
```

Lots of functions to work with

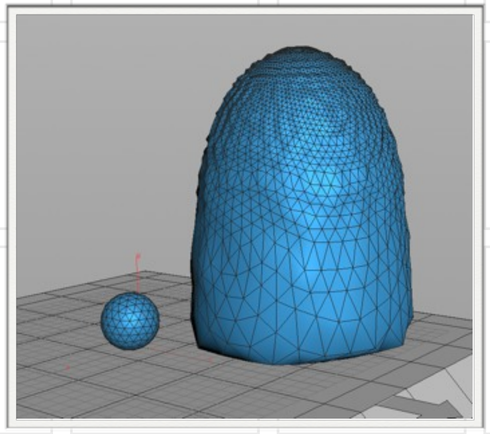
A Little Project

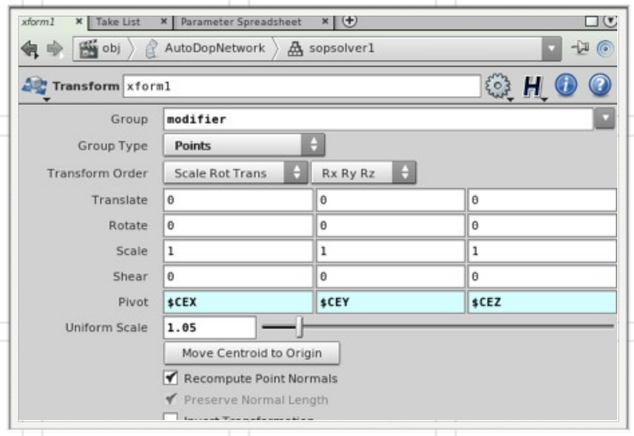






Dissect BallScale.hip





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End of Module 03

Procedural Animation

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