

ePMV Advanced Molecular Techniques: Rigging a motor protein *kinesin* to walk on a microtubule

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Goal: To animate a simplistic model of a walking motor protein using C4D's built-in character animation tools.

Tutorial Step-by-step

Section 1: Rigging a protein to walk a straight line

I. Prepare protein surface models

To keep things simple for today, we will import only a tubulin dimer (the functional subunit that makes up a microtubule). We will animate an empty skeleton and then attach a tubulin to it to show how vibrations can be applied to generate brownian motion.

A. Build a Character Rig and experiment with walking

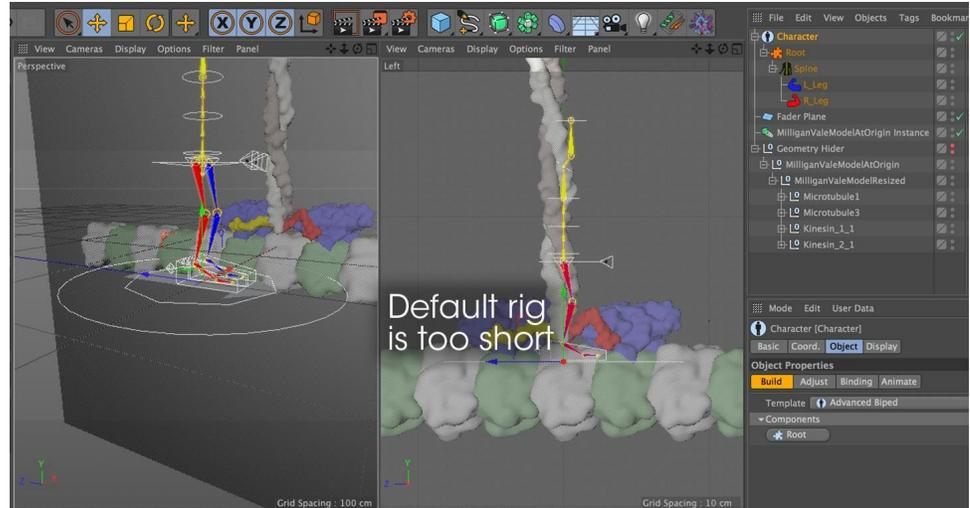
1. Restart C4D
2. Build a Character object with the Character tool
 - a) C4D main menu: Character>Character. This will add a new Character object
 - b) in the Character Build tab, click [Root], then [Spine], then [Leg].
 - c) In the object manager, select Spine, then click [Leg] again to make the other leg
 - d) Zoom in to see your armless/headless character rig
3. Add a default walk cycle
 - a) In the object manager select Character
 - (1) Jump to the Animate tab and click [Add Walk]
 - (2) Push Play and notice there is now a CMotion object in the hierarchy below the Character object.
4. Experiment with walking
 - a) In the object manager, select CMotion
 - (1) Change Object Tab > Walk = {Line}
 - (2) Draw a path and then change Walk = {Path} and drag your spline into that path
 - (3) Lengthen your animation to 300, then experiment with the CMotion Object Tab > Stride and Time values
 - b) When you are satisfied, uncheck CMotion to return to the default pose.

B. Import PDB of kinesin bound to a microtubule to use as a reference

1. Download the file <KinesinModels_NovaMilligan_Resize_3.c4d> and open it
2. Build a character rig into this scene
 - a) C4D main menu: Character>Character. This will add a new Character object
 - b) in the Character Build tab, click [Root], then [Spine], then [Leg].
 - c) In the object manager, select Spine, then click [Leg] again to make the second leg

C. Modify the character to fit kinesin

1. Ideally, we would build a rig from scratch that has a proper neck linker and that fits the atomic coordinates, however, for a quick and dirty walk that gets the job done for many audiences, we will just modify an existing rig with the powerful (but overwhelming) character tools in C4D since R13.... this will save on about 100 hours of tutorials and reading that it would take to understand and construct a custom character rig.

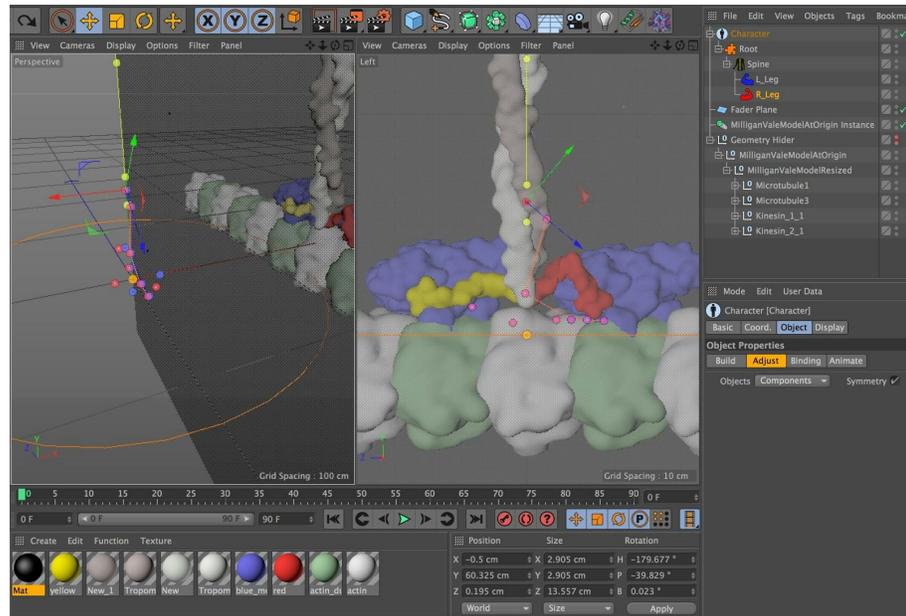


- 2.
3. In the Object Manager, select the Character object
 - a) In the Coords Tab, set S.X, S.Y, and S.Z = 1.5, 1.5, 1.5 to better fit the kinesin
4. Go to the Object Tab and the Adjust tab, then split your screen to have both a Perspective view and a Left view and zoom in on both. (The file KinesinModels_NovaMilligan_Resize_2.c4d is already setup like this.)
 - a) Viewport menu: Panel>Arrangement>2 views side-by-side
 - b) [You can download and open Graham_KinesinWalking_Workshop_1.c4d to start from this point if you get behind](#)
5. Adjust the height of the knees, the spine and the hips as follows:
 - a) In the Coordinates Manager, change {Object} to {World} so we can see absolute coordinates as we adjust in real-time in the viewport

	Position	Size	Rotation
X	-11.358 cm	X 10.671 cm	H 0.216 °
Y	62.195 cm	Y 10.671 cm	P -77.198 °
Z	-9.1 cm	Z 49.8 cm	B 179.904 °
	World	Size	Apply

- b) In the 3D viewport, select a knee (hover to read Right/Left Leg R NB Knee)
- c) In the LEFT view, hold the number 7 on your keypad, and move straight downward until Y is goes from 62.195 cm to somewhere near 52 cm (7 moves the parent while leaving the children (ankles and feet) in place.
- d) In the Object manager, select the Spine and move it straight down holding 7 in the LEFT Viewport until Y = ~ 67
- e) In the Perspective Viewport select one of the hips and in the Left Viewport holding 7, drag it down to Y= ~ 60
- f) Also set the hip's x value to -0.5 (if the red Left hip, or +0.5 if the blue right hip) , i.e. Select each hip and reduce the X coordinate to +/- 0.5 respectively with the Coordinate Manager to put the hips roughly on top of each other sagittally. This should put the hips nearly atop one another in 3D.

- Your file should look about like this, note the short “femur” compared to the default

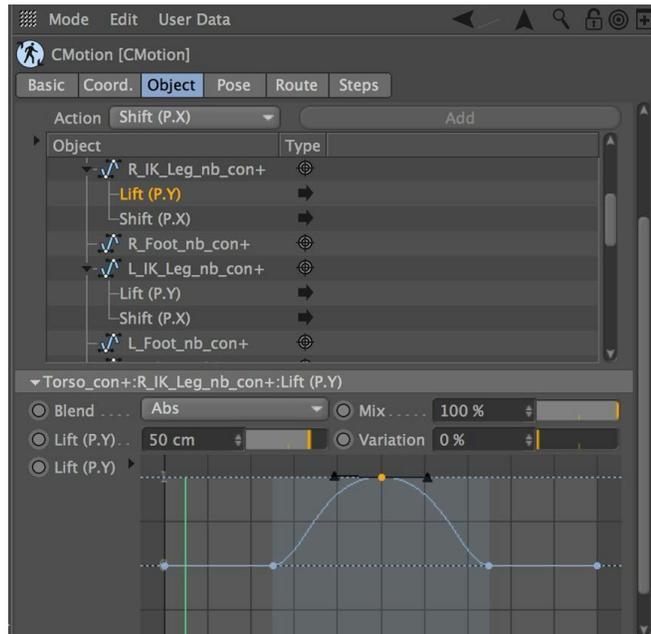


- In the Object Manager, select the Character Object and in the Animate tab, [Add Walk]
- Push Play
- You can download and open [Graham_KinesinWalking_Workshop_2.c4d](#) to start from this point if you get behind

D. Modify the cMotion parameters to walk less like a troll and more like kinesin:

- In the Object Manager, select the CMotion object and open its Object Tab
- Push Play and set time = 100 to slow down the walk
- With Play on, note that our gate is too short... the monomers of the microtubule are about 80 Å long, so we need to increase the stride to 160
 - Looking better! However, this causes a new problem. Notice how the ankles now flex and strain to reach this wide gate (they lift out of or sink into the foot box controller outlines). Compare that to Graham’s kinesin movie from 1999- ([narrated](#)) ([“high” resolution](#)) we need to fix that
 - Lower the hips
 - Under the spline Torso_con+, select Lift(P.Y)
 - Explain how the Character tools turn complex parameters into editable graphs- the length of the graph = one cycle of the walk... the middle of the graph is the middle of the walk cycle.
 - Set Lift(P.Y) = 34 cm and lower the top nodes in the graph to zero...
 - Getting close now! That fixes the ankles
 - Raise the feet during steps.
 - Similarly, under R_IK_Leg_nb_con+, select Lift(P.Y)
 - Set Lift(P.Y)=50
 - Set Lift(P.Y)=60 for the other leg L_IK_Leg_nb_con+

- (c) Adjust the bezier handles at the top of the curve to give a more circular arc



- d) Swing the legs outward

- (1) Add new Shift(P.X) objects under each leg

- (a) Select R_IK_Leg_nb_con+
 (b) In the Action menu above, select {Shift(P.X)}, click [Add]

- (2) Set the values to about 40 for the Left and -40 for the Right

- (a) Note that they swing well past the center line even when landing- this is because the default graphs don't match the foot swing

- (b) Fix the graphs:

- (i) Select Lift(P.Y) for that foot
 (ii) Right click on the word Lift(P.Y) next to the graph below to copy the graph
 (iii) Select Shift(P.X)
 (iv) Right click on the word Shift(P.X) next to the graph below to paste the correct graph
 (v) They should now swing nicely outward

4. You can download and open [Graham_KinesinWalking_Workshop_3.c4d](#) to start from this point if you get behind

E. Walk the line

- In the CMotion attributes manager Object Tab change (at the top) change Walk {Static} to {Line} and watch your guy walk the MT
- If you're bored, make a spline, Fit the MT to the spline with SplineWarp and make your guy walk on the curve (turn on banking under the CMotion Route Tab).

F. Add geometry to the walking joint skeleton and make it vibrate to simulate Brownian motion with dampening when it approaches the binding site.

- Under GeometryHider, a few Nulls deep, find and select Kinesin_2_1 and make an instance of it. If you see the long white coiled coil also appear, open the actual

Kinesin_2_1 and move Tropomyosin out of it to sit between Kinesin_1_1 and Kinesin_2_1 in the Geometry hider.

2. Add a Null object, put it under Kinesin_2_1 Instance and zero it out with the Coordinate manager set to Object (Rel)
3. Pull the Null back out and put Kinesin_2_1 under it. Rename the Null KinesinMotor2Pivot
4. Expose the magic of the blackbox Character
 - a) Select Character and select the Display Tab
 - b) Unfold Managers and set Object Managers to Full Hierarchy
 - c) Drag KinesinMotor2Pivot to become a child of the spline (about halfway through the nasty hierarchy) called L_IK_Leg_nb_con+
 - (1) Select L_NB_Leg_nulls and drag it back into to sit just above L_IK_Leg_nb_con+KinesinMotor2Pivot, because it much immediately follow L_IK_Leg_nb_con+ in the hierarchy to maintain the blackbox magic.
5. Push Play
 - a) Siiiiick! OK, you have a walking motor, but its not very natural looking, lets enhance the biophysics with some simulated Brownian motion.
6. Add a vibration to simulate dynamics
 - a) Group KinesinMotor2Pivot into itself (Select it and hit alt-G)
 - b) Rename the new Null to be KinesinMotor2Home
 - c) Right click on KinesinMotor2Pivot and add a vibrate tag (Right click C4D Tag, Vibrate)
 - d) Check Enable Rotation and set the parameters for rotation to 90, 90, 90
 - e) Push Play
 - (1) Too crazy right ? ! ? It keeps wiggling when it should be docked to the MT and it has a very limited range at other times
 - (2) Lets control it with Xpresso
 - (3) Right click, Add and Xpresso tag-
 - (a) Control the amount of vibration (Xpresso Vibration Node input>TagProperties>Rotation Amplitude) with some clever math to make the rotation increase with a dependency on height and be zero when docked.
7. [You can download and open Graham_KinesinWalking_Workshop_4.c4d to explore the final setup.](#)
8. **Its Alive!**