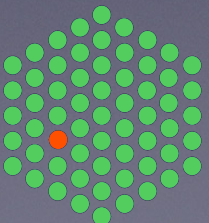


Simulating the cytoskeleton using Cytosim

Help sheet

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The Cytosim help sheet

Executables

Compilation

On the terminal, navigate to the Cytosim directory:

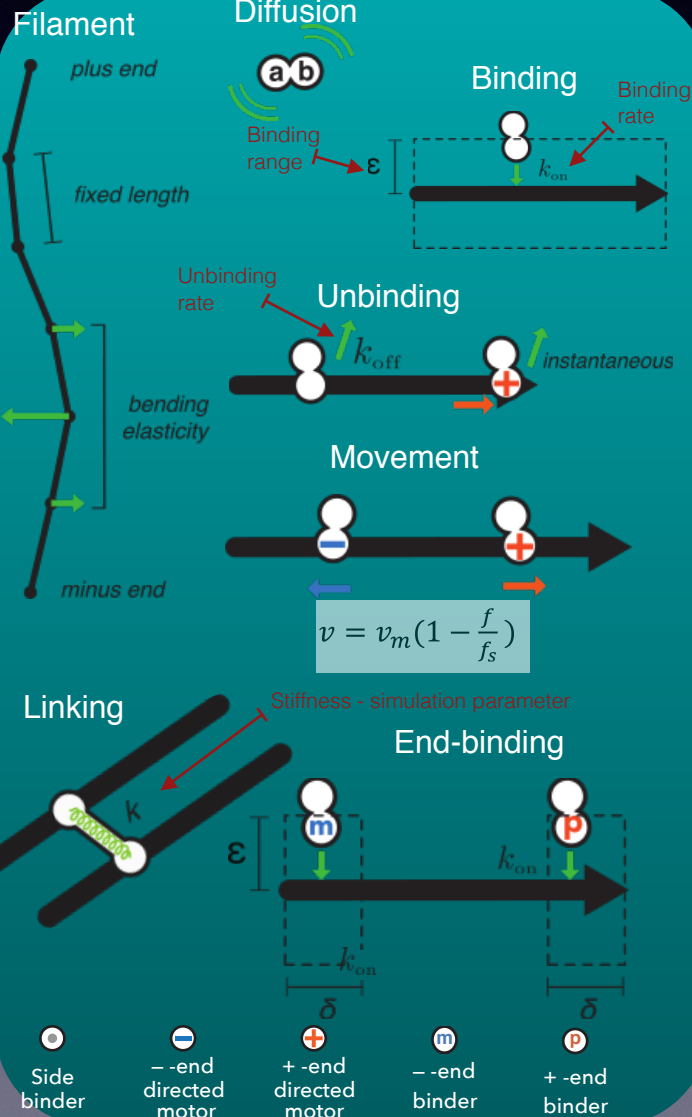
Compile sim and play

make

Compile report

make report

Filament-related activities



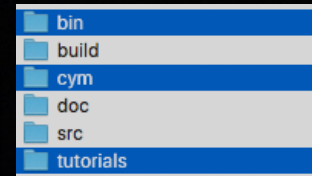
Running simulations

Navigate to a directory where you want to save the results of the simulation.

cd cytosim/tutorials

Specify the path of the executable and the path of the config file, in that order

../bin/executable config.cym or
../bin/executable ../cym/config.cym



Live Run

Opens a graphical window and displays the results of the simulation at the same time as making the calculations. Does not save any data.

../bin/play live
config.cym
or
../bin/play live ../
cym/config.cym

Simulation

Simulate the system and get readout output properties.cmo, objects.cmo, messages.cmo. Then display the results of the simulation.

../bin/sim config.cym
play
or
../bin/sim ../cym/
config.cym
play

Reporting

Generate quantitative data from simulation of config file.

../bin/report what >
filename.txt

organizer	sphere	fiber:speckles	bead:all
bead	time	fiber:segments	bead:singles
couple	parameters	fiber:ends	single:all
fiber	fiber:lengths	fiber:forces	single:NAME
single	fiber:dynamics	fiber:tensions	couple:all
solid	fiber:points	fiber:clusters	couple:NAME

Display parameters

Display parameters can be embedded in the config file. Each class of object has its own display parameters, which should be specified within the set command.

hand display = (size=3; color=green;)
fiber display = (line_width=3; color=blue;)

Commands

Syntax

Define a new object

```
set CLASS NAME  
{  
    PARAMETER = VALUE  
}
```

Create a new object

```
new [No. OBJs] CLASS NAME  
{  
    position = (x,y,z)  
    orientation = ROTATION  
    VEC  
}
```

Perform simulation steps and write frames to files

```
run CLASS NAME  
{  
    PARAMETERS  
}
```

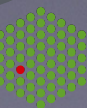
Standard Physical Units

Quantity	Unit
Distance	micro-meter
Force	pico-Newton
Time	second

Parameter	Default value
viscosity	1 pN.s/um^2
kT	0.0042 pN.um

Keyboard display controls

h	show/hide help	arrow-keys	move around
p, s	play, stop	R	write display
< >	previous, next	CTRL-Q	quit
+ =	zoom in, out		



The Cytosim help sheet - Most commonly used objects

Singles with hands that binds



Set simulation

Define the global parameters

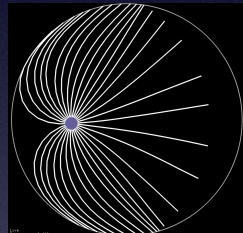
```
set simul aster
{
  time_step = 0.001
  viscosity = 0.01
  diffusion =
}
```

Define space

Define a confined region:

```
set space cell
{
  geometry = ( sphere 10 )
}
```

new space cell



Aster

Define asters

Built from solid and filament objects.
Filaments are attached at two points.

```
set solid core
{
  display = ( style=3 )
}
```

```
set aster centrosome
{
  solid = core
  fibers = microtubule
  stiffness = 1000, 500
}
```

```
new 1 aster centrosome
{
  radius = 0.5
  nb_fibers = 32
  length = 12
}
```

Define filaments

Possible nature of filaments:

- classic: two-state model of dynamic instability at plus end
- tubule: Adds dynamic instability of ends
- treadmill: Filament with assembly at both ends
- dynamic: filament with discrete growth and dynamic instability at plus end

Microtubule

```
set fiber microtubule
{
  rigidity = 20
  segmentation = 0.5
  confine = inside, 100

  activity = dynamic
  unit_length = 0.008
  growing_speed = 0.06
  shrinking_speed = -0.15
  hydrolysis_rate = 0.06
  growing_force = 1.7
  display = { line_width=4;
plus_end=16, 2; }
}
```

```
new 1 fiber microtubule
{
  position = 0 0 0
  orientation = horizontal
  length = 10
}
```

Actin

```
set fiber actin
{
  rigidity = 0.05
  segmentation = 0.05
  binding_key = 2
  confine = inside, 100
  display = ( line_width=5;
plus_end=5,5; minus_end=5,5; )
}
```

```
new 3 fiber actin
{
  length = 1
}
```

Define hands

Bind and act on filaments. Components necessary to create singles and solids.

Possible activities on a filament:

```
- bind
- move
- nucleate
- slide
- track
- rescue
- cut

set hand dynein
{
  binding_rate = 5
  binding_range = 0.01
  unbinding_rate = 0.2
  unbinding_force = 3

  activity = move
  max_speed = -1
  stall_force = 5
}
```

```
set hand kinesin
{
  binding_rate = 10
  binding_range = 0.01
  unbinding_rate = 0.2
  unbinding_force = 3

  activity = move
  max_speed = 0.8
  stall_force = 6
  display = { size=8;
color=0x00FF00FF; }
}
```

```
set hand myosin
{
  binding_key = 2
  binding_rate = 10
  binding_range = 0.01
  unbinding_rate = 0.1
  unbinding_force = 4

  activity = move
  max_speed = -0.8
  stall_force = 5
  display = ( size=10;
color=sky_blue )
}
```

Define singles

Contains one hand.

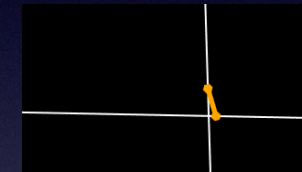
Possible activities:

- diffuse
- fixed: anchored to a fixed position

```
set single grafted
{
  hand = dynein
  stiffness = 100
  activity = fixed
}
```

new 2000 single grafted

Couple with activity fork



Define couples

Contain two hands.

Possible activities:

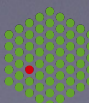
- Diffuse
- Crosslink
- Bridge
- Slide
- Fork

```
set couple motor
{
  hand1 = end_binder
  hand2 = dynein
  stiffness = 100
  diffusion = 20
  fast_diffusion = 1
}
```

Run a simulation

Perform simulation steps and write frame to files.

```
run simul *
{
  nb_steps = 20000
  nb_frames = 100
}
```



The Cytosim help sheet

Keyboard display controls

Parameters of Biological Systems

Medium viscosity	Water	0.001 pN s/ μm^2	
	D. melanogaster	~ 0.3 pN s/ μm^2	(Polyakov, 2013)
	C. elegans cytosol	~ 1 pN s/ μm^2	
	Cleared cytoplasm	0.02 pN s/ μm^2	
F-Actin	Length in vitro	0–10 μm	(Burlacu et al., 1992)
	Rigidity	0.075 pN μm^2	(Gittes et al., 1993)
Microtubules	Rigidity	22 pN μm^2	(Gittes et al., 1993)
Crosslinkers	α -actinin unbinding rate	0.37-3.2 s ⁻¹	(Wachsstock et al., 1993)
		0.4 s ⁻¹	(Goldmann and Isenberg, 1993)
		5-15 s ⁻¹	(Miller et al., 2003)
		0.3-0.4 s ⁻¹	(Fritzsche et al., 2013)
	Filamin unbinding rate	0.6 s ⁻¹	(Goldmann and Isenberg, 1993)
Myosin	Fascin unbinding rate	0.12 s ⁻¹	(Aratyn et al., 2007)
	Binding rate	0.5-1 s ⁻¹	(Rovner et al., 2006)
		6 s ⁻¹	(Guo and Guilford, 2006)
	Unbinding rate	0.18 s ⁻¹	(Mehta et al., 1999)
		13-15 s ⁻¹	(Guo and Guilford, 2006)
	Speed	0.04–1.7 $\mu\text{m/s}$	(Finer et al., 1994)
		0.3 $\mu\text{m/s}$	(Mehta et al., 1999)
		0.01–5 $\mu\text{m/s}$	(Barua et al., 2014)
Kinesin	Stall force	2.2 pN	(Norstrom et al., 2010)
		4-12 pN	(Walcott et al., 2012)
	Speed	0.6-0.7 $\mu\text{m/s}$	(Svoboda and Block, 1994)
Kinesin	Unbinding rate	0.314 s ⁻¹	(Bhat and Gopalakrishnan, 2012; Soppina et al., 2009)
	Stall force	5-6 pN	(Svoboda and Block, 1994)
Dynein	Speed	0.8 $\mu\text{m/s}$	(Toba et al., 2006)
	Stall force	7-8 pN	(Toba et al., 2006)
	Unbinding rate	0.667 s ⁻¹	(Bhat and Gopalakrishnan, 2012; Soppina et al., 2009)

```

-----Keyboard Commands-----
Fibers:
^      Select another type of fibers for modifications
1      Change display: line / color-coded forces / hide
3 4    Decrease; increase line width (ALT; point size)
!      Change tip display: none / plus / both / minus
# #    Decrease; increase fiber tip display size
2      Change speckle display: random / regular / off)
c d w  Coloring, Right/left-pointing, Fractional masking
t T    Auto-tracking nematic, Auto-tracking polar

Beads / Solids / Spheres:
5      Switch between different bead/sphere display style
%      Change first bead/solid display style
* (    Decrease; increase point size

Singles / Couples:
8 *    Change Couple; Single selection mode
9 0    Decrease; Increase point size
( )    Decrease; Increase line width

-----Animation-----
< >   Show previous / next frame ( , . also works)
u i o p Play reverse; stop; slower; play/faster
z Z    Reset simulation; Rewind movie to first frame
space F Reset view; adjust window to screen width
escape Quit

-----Simulation-----
a A    Start live mode; double nb-steps/display
s S    Step simulation engine; set nb-steps/display = 1
z Z    Reset simulation; create new initial state
g G    Delete mouse-hands; Create new Hand for mouse

-----Input/Output-----
r      Read parameter file and update simulation
R      Write display parameters to terminal
y Y    Save displayed image; Play and save all images

```

```

-----Mouse Controls-----
press TAB to toggle between different modes:
Rotate      (3D only)
Translate in XY
Active
Translate in XZ (3D only)
Spin
Zoom
Select ROI

hold SHIFT for live action!
Right click to access the menu
Mouse wheel to zoom in/out (this may not work)

-----Keyboard Controls-----
+ -      Zoom in and out (+SHIFT; small increments)
arrow keys Translate in XY, hold SHIFT for fine motion
space    Reset view and refresh display
h        Hide/show help
b        Show/hide a 10  $\mu\text{m}$  scale bar
f        toggle fullscreen mode

```

