FormationControl

August 1, 2020

[1]:
```
using DifferentialEquations, Plots; pyplot();
using LinearAlgebra
theme(:ggplot2)
```

[2]:
```
n = 6;
kv = 0.05;

Adj = [0 1 0 0 0 1;
       1 0 1 0 0 1;
       0 1 0 1 0 1;
       0 0 1 0 1 1;
       0 0 0 1 0 1;
       1 1 1 1 1 0];

d = zeros(n,n);
c1 = cos(2*pi/5);
c2 = cos(pi/5);
s1 = sin(2*pi/5);
s2 = sin(4*pi/5);
x_coor = [0; -s1; -s2; s2; s1; 0];
y_coor = [1; c1; -c2; -c2; c1; 0];
z_coor = [0.0; 0.0; 0.0; 0.0; 0.0; 0.0];
```

[3]:
```
for ii = 1:n
    for jj = 1:n
        d[ii,jj] =␣
↪sqrt((x_coor[ii]-x_coor[jj])^2+(y_coor[ii]-y_coor[jj])^2+(z_coor[ii]-z_coor[jj])^2)
    end
end
```

[4]:
```
ub = 0.5;                          # Upper bound for random ini. condition
lb = -0.5;                         # Lower bound for random ini. condition
tfinal = 10;                       # Simulation ending time assume always
                                   # starts at 0
h = 1e-2;                          # ODE step
```

[5]:
```
mutable struct para
n
kv
Adj
d
end
```

[ ]:
```
```

[6]:
```
p=para(n,kv,Adj,d)
```

[6]:
```
para(6, 0.05, [0 1 … 0 1; 1 0 … 0 1; … ; 0 0 … 0 1; 1 1 … 1 0], [0.0
1.1755705045849463 … 1.1755705045849463 1.0; 1.1755705045849463 0.0 …
1.902113032590307 0.9999999999999999; … ; 1.1755705045849463 1.902113032590307 …
0.0 0.9999999999999999; 1.0 0.9999999999999999 … 0.9999999999999999 0.0])
```

[7]:
```
q_0 = [0.3147   -0.5377   -0.8093    1.0527    1.4082   -0.3581;
       1.4058    0.4414   -0.7621   -1.1514    0.2944   -0.0782;
            0         0         0         0         0         0];
```

[8]:
```
q_0_vec = reshape(q_0,(1,:));
```

[9]:
```
time_span = (0.0,10.0);
```

[10]:
```
function f(du,u,p,t)
    n = p.n
    kv = p.kv
    Adj = p.Adj
    d = p.d
    u = reshape(u,(3,:))

    z = zeros(2*n-3,1)
    R = zeros(2*n-3,3*n)
    e = zeros(n,n)

    ord = 1
    for i=1:n-1
        for j=i+1:n
            e[i,j] = sqrt((u[:,i]-u[:,j])'*(u[:,i]-u[:,j]))-d[i,j]
            # print("i =",i,"j=",j,"\n")
            if Adj[i,j] == 1
                z[ord] = e[i,j]*(e[i,j]+2*d[i,j]);
                R[ord,3*i-2:3*i] = (u[:,i]-u[:,j])';
                R[ord,3*j-2:3*j] = (u[:,j]-u[:,i])';
                ord = ord+1;
            end
        end
```

```
    end
    control =  -kv * R' * z
    control = reshape(control,(1,:))
    du .= control;
end
```

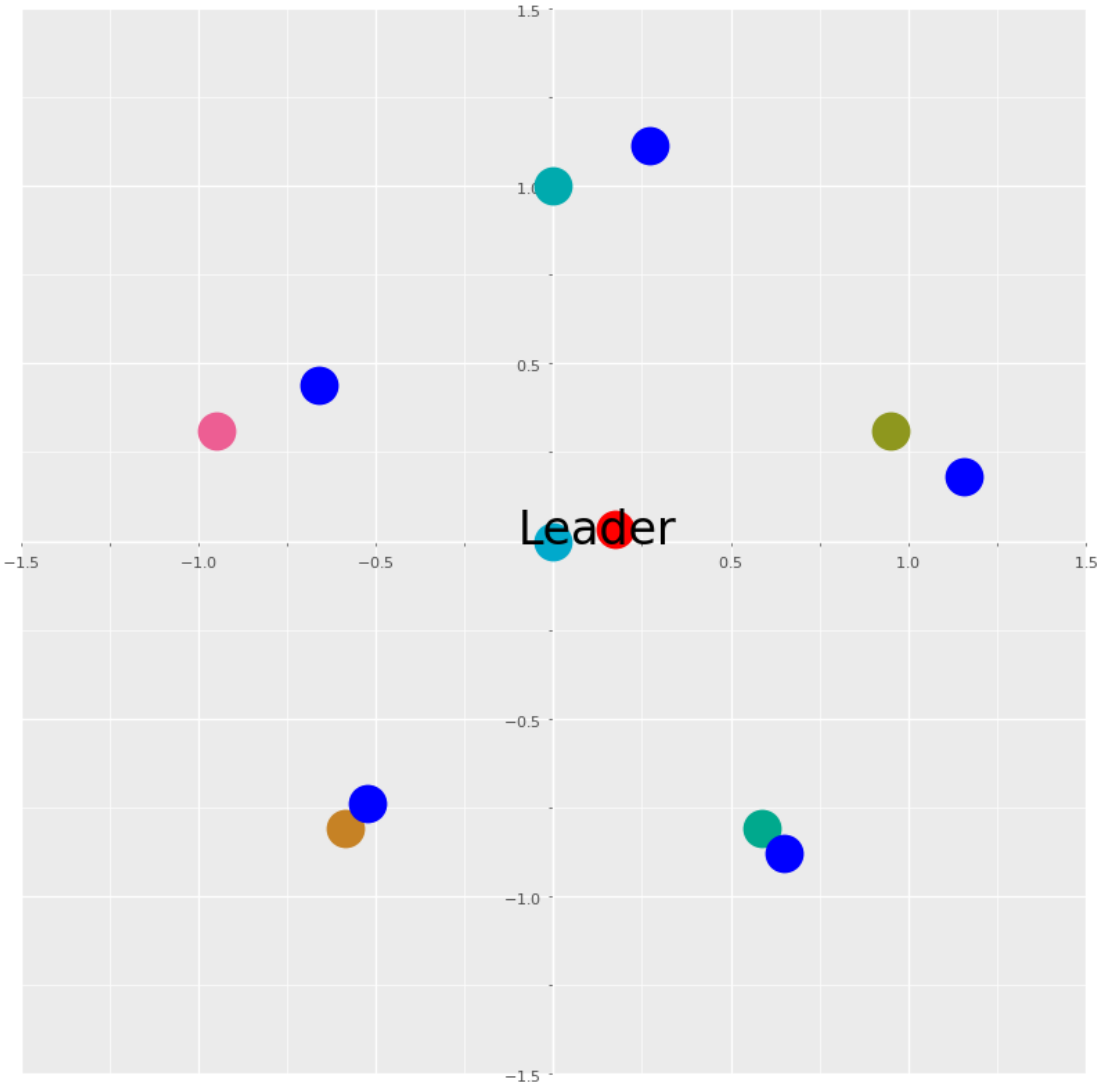
[10]:
```
f (generic function with 1 method)
```

[11]:
```
prob = ODEProblem(f,q_0_vec,time_span,p)

sol = solve(prob,saveat=0.1)

pos = sol.u
```

[11]:
```
101-element Array{Array{Float64,2},1}:
 [0.3147 1.4058 … -0.0782 0.0]
 [0.30842678862813994 1.3927913813211976 … -0.07396898554134113 0.0]
 [0.3029691184556908 1.3808556808014574 … -0.06989686960240833 0.0]
 [0.298187972192451 1.3698443227076347 … -0.06599350183135236 0.0]
 [0.29397463968446186 1.3596368709775513 … -0.0622610071964926 0.0]
 [0.2902439278499775 1.3501354194689228 … -0.058696483611583486 0.0]
 [0.2869278996711181 1.3412592031974386 … -0.05529427568477855 0.0]
 [0.2839704352583543 1.3329397160479293 … -0.05204755913995581 0.0]
 [0.28132519709257536 1.3251188697478264 … -0.04894887653593608 0.0]
 [0.27895416438603665 1.3177475523368491 … -0.0459903776506315 0.0]
 [0.2768254345385491 1.310783526502298 … -0.043164323069599 0.0]
 [0.2749117208779738 1.304189886489155 … -0.04046323671931769 0.0]
 [0.27318923570603754 1.297933919486112 … -0.03788001424643709 0.0]

 [0.2690329264362398 1.1251755227342017 … 0.029343561065221856 0.0]
 [0.2692192825138863 1.1242442992409636 … 0.02957257443909716 0.0]
 [0.26940375270888706 1.1233253217608257 … 0.029795273053418003 0.0]
 [0.26958632038981695 1.1224183359520394 … 0.030011816671178262 0.0]
 [0.26976696731919364 1.121523079792877 … 0.030222386835033997 0.0]
 [0.2699456793827502 1.120639311203193 … 0.030427131752582215 0.0]
 [0.27012244493306486 1.119766795475741 … 0.0306261951652648 0.0]
 [0.2702972547286862 1.1189053049511206 … 0.030819717019344592 0.0]
 [0.2704701019341333 1.1180546190177771 … 0.03100783346590539 0.0]
 [0.27064098211989585 1.117214524112002 … 0.031190676860851956 0.0]
 [0.27080989326243393 1.1163848137179326 … 0.03136837576491001 0.0]
 [0.27097683574417825 1.1155652883675529 … 0.031541054943626225 0.0]
```

[13]:
```
anim = @animate for i in 1:length(pos)
    plt = scatter(5,xlim=(-1.5,1.5),ylim=(-1.5,1.5), c=:red, aspect_ratio =␣
↪1,legend=false, framestyle=:origin)
    pst = pst=reshape(pos[i],(3,6))
    scatter!(x_coor',y_coor', markersize=20,aspect_ratio = 1 )
```

```
    scatter!(plt,pst[1,1:5],pst[2,1:5] ,markersize=20,c=:blue, legend=false)
    scatter!(plt,[pst[1,6]],[pst[2,6]] ,markersize=20,c=:red,legend=false)
    annotate!([(pst[1,6]-0.05, pst[2,6], text("Leader",24))])
    scatter!(size=(800,800))
end
```



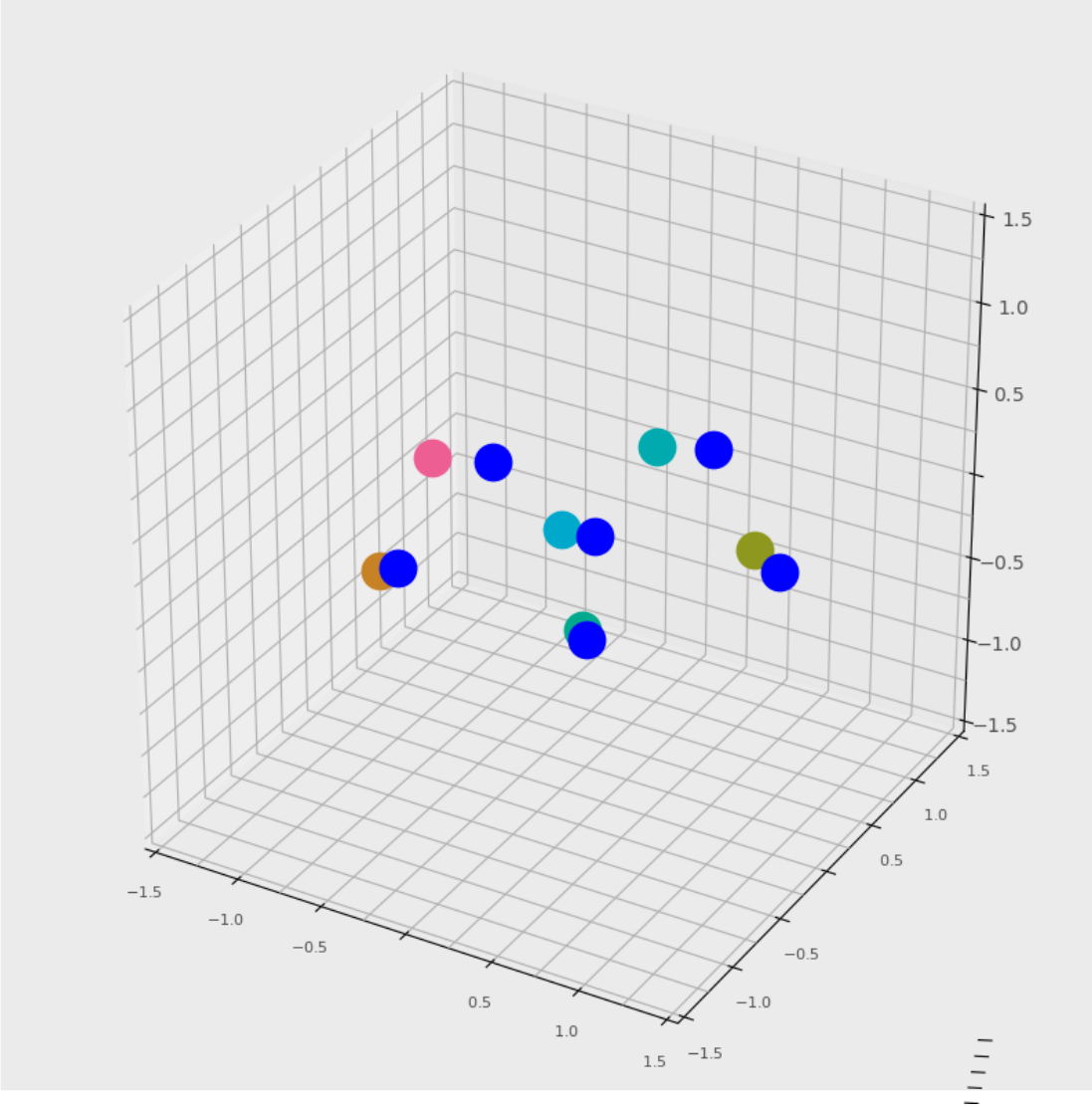
[13]:
```
Animation("/tmp/jl_tUEQdb", ["000001.png", "000002.png", "000003.png",
"000004.png", "000005.png", "000006.png", "000007.png", "000008.png",
"000009.png", "000010.png"  …  "000092.png", "000093.png", "000094.png",
"000095.png", "000096.png", "000097.png", "000098.png", "000099.png",
"000100.png", "000101.png"])
```

[14]:
```
gif(anim,fps=10)
```

```
 Info: Saved animation to
   fn = /home/bbm/Documents/research/FormationControl/tmp.gif
 @ Plots /home/bbm/.julia/packages/Plots/LWw1t/src/animation.jl:104
```

[14]:
```
Plots.AnimatedGif("/home/bbm/Documents/research/FormationControl/tmp.gif")
```

[15]:
```
anim = @animate for i in 1:length(pos)
    plt = scatter(5,xlim=(-1.5,1.5),ylim=(-1.5,1.5), zlim=(-1.5,1.5),c=:
↪red,legend=false, framestyle=:origin)
    pst = pst=reshape(pos[i],(3,6))
    scatter!(x_coor',y_coor', z_coor', markersize=20 )
    scatter!(plt,pst[1,:],pst[2,:] , pst[3,:],markersize=20,c=:blue,␣
↪legend=false)
    scatter!(size=(800,800))
end
```



[15]:
```
Animation("/tmp/jl_sEspuA", ["000001.png", "000002.png", "000003.png",
"000004.png", "000005.png", "000006.png", "000007.png", "000008.png",
"000009.png", "000010.png"  …  "000092.png", "000093.png", "000094.png",
"000095.png", "000096.png", "000097.png", "000098.png", "000099.png",
"000100.png", "000101.png"])
```

[16]:
```
gif(anim,fps=10)
```

```
Info: Saved animation to
  fn = /home/bbm/Documents/research/FormationControl/tmp.gif
@ Plots /home/bbm/.julia/packages/Plots/LWw1t/src/animation.jl:104
```

[16]:
```
Plots.AnimatedGif("/home/bbm/Documents/research/FormationControl/tmp.gif")
```

0.1 Formation Acquistion

[20]:
```
function Desired_velocity(t,q)
     = [0,0,1];
    vt = [1;cos(t);0] # it is cost along y axis
    n = 6
    vr = zeros(n,3);
    # print(size(q))
    q = q';
    buff = reshape(q[n,:],(1,3))
    zqwe = kron(ones(6,1),buff);
    qr = q - zqwe;

    for i = 1:n
        vr[i,:] = cross( ,qr[i,:]);
    end
    return kron(ones(n,1),vt)+reshape(vr',(:,1))
end
```

[20]:
```
Desired_velocity (generic function with 1 method)
```

[21]:
```
function form_with_vel(du,u,p,t)
    n = p.n
    kv = p.kv
    Adj = p.Adj
    d = p.d
    u = reshape(u,(3,:))

    z = zeros(2*n-3,1)
    R = zeros(2*n-3,3*n)
```

```
    e = zeros(n,n)

    ord = 1
    for i=1:n-1
        for j=i+1:n
            e[i,j] = sqrt((u[:,i]-u[:,j])'*(u[:,i]-u[:,j]))-d[i,j]
            # print("i =",i,"j=",j,"\n")
            if Adj[i,j] == 1
                z[ord] = e[i,j]*(e[i,j]+2*d[i,j]);
                R[ord,3*i-2:3*i] = (u[:,i]-u[:,j])';
                R[ord,3*j-2:3*j] = (u[:,j]-u[:,i])';
                ord = ord+1;
            end
        end
    end
    vd = Desired_velocity(t,u);
    control =  -kv * R' * z + vd
    control = reshape(control,(1,:))
    du .= control;
end
```

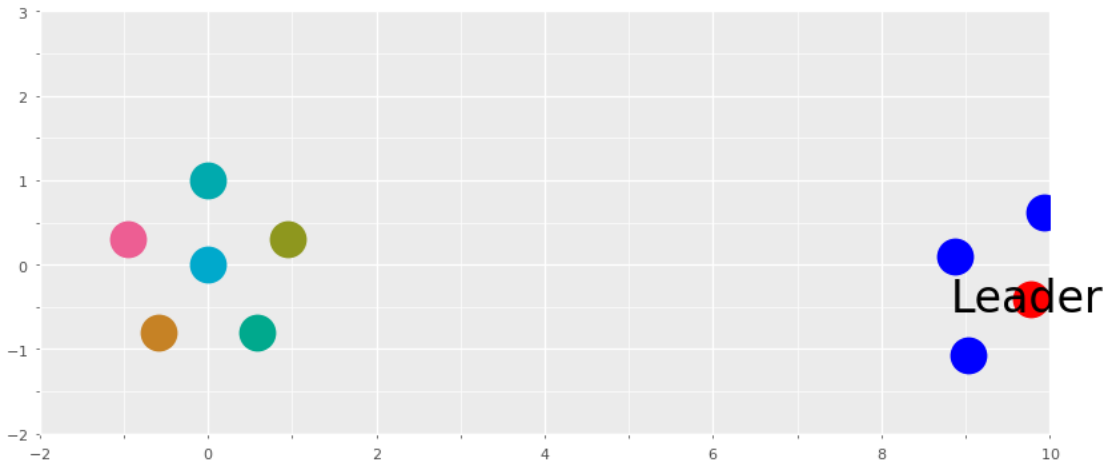
[21]:
```
form_with_vel (generic function with 1 method)
```

[22]:
```
prob2= ODEProblem(form_with_vel,q_0_vec,time_span,p)

sol2 = solve(prob2,saveat=0.1)

pos2 = sol2.u
```

[22]:
```
101-element Array{Array{Float64,2},1}:
 [0.3147 1.4058 … -0.0782 0.0]
 [0.2585877489032584 1.5498331540580363 … 0.027768571847526048 0.0]
 [0.20176198507722604 1.6742920620109476 … 0.13571157083282565 0.0]
 [0.14600504603814507 1.778809385556364 … 0.2438023528493907 0.0]
 [0.0930044551333009 1.8631214199214459 … 0.35043446784338017 0.0]
 [0.04435122037772749 1.9270879657693636 … 0.4541703784909652 0.0]
 [0.0015323942756549048 1.9706979380386478 … 0.5537196065968468 0.0]
 [-0.03406927945007219 1.9940841016838609 … 0.647914799781772 0.0]
 [-0.06118578557013045 1.9975228846933892 … 0.7357065887535489 0.0]
 [-0.0786695919498487 1.9814335219844719 … 0.8161620753113588 0.0]
 [-0.08549343959196985 1.9463869239501903 … 0.8884529169783595 0.0]
 [-0.08076040447401704 1.8930956478380543 … 0.9518617931276299 0.0]
 [-0.06371040048317184 1.8224072976122991 … 1.00578627632593 0.0]

 [8.0395471407798 -0.2588396730077755 … 0.6408812801661242 0.0]
 [8.232754447859941 -0.40575068470419856 … 0.5520397645926393 0.0]
 [8.431149895465657 -0.5471753516120196 … 0.45901533318051674 0.0]
```

```
[8.633768678478036 -0.6816394380453502 … 0.36275920148259466 0.0]
[8.839608732905006 -0.8077848321851198 … 0.26423375652814324 0.0]
[9.047630969858158 -0.9243700025242326 … 0.1644124712612649 0.0]
[9.256759275552744 -1.0302699978675742 … 0.06427990454089175 0.0]
[9.465880511307693 -1.1244764473320115 … -0.03516829885921875 0.0]
[9.67384451354559 -1.2060975603463866 … -0.13292540825047386 0.0]
[9.879498583044935 -1.274352488135437 … -0.22798402333990386 0.0]
[10.081865266779777 -1.3285583091246578 … -0.3194038861251736 0.0]
[10.279944462165043 -1.3681905320720333 … -0.40627411198279956 0.0]
```

[29]:
```
anim2 = @animate for i in 1:length(pos2)
    plt = scatter(5,xlim=(-2,12),ylim=(-2,3), c=:red, aspect_ratio =␣
↪1,legend=false)
    pst = pst=reshape(pos2[i],(3,6))
    scatter!(x_coor',y_coor', markersize=20,aspect_ratio = 1 )
    scatter!(plt,pst[1,1:5],pst[2,1:5] ,markersize=20,c=:blue, legend=false)
    scatter!(plt,[pst[1,6]],[pst[2,6]] ,markersize=20,c=:red,legend=false)
    annotate!([(pst[1,6]-0.05, pst[2,6], text("Leader",24))])
    scatter!(size=(800,800))
end
```



[29]:
```
Animation("/tmp/jl_9Tx1wy", ["000001.png", "000002.png", "000003.png",
"000004.png", "000005.png", "000006.png", "000007.png", "000008.png",
"000009.png", "000010.png"  …  "000092.png", "000093.png", "000094.png",
"000095.png", "000096.png", "000097.png", "000098.png", "000099.png",
"000100.png", "000101.png"])
```

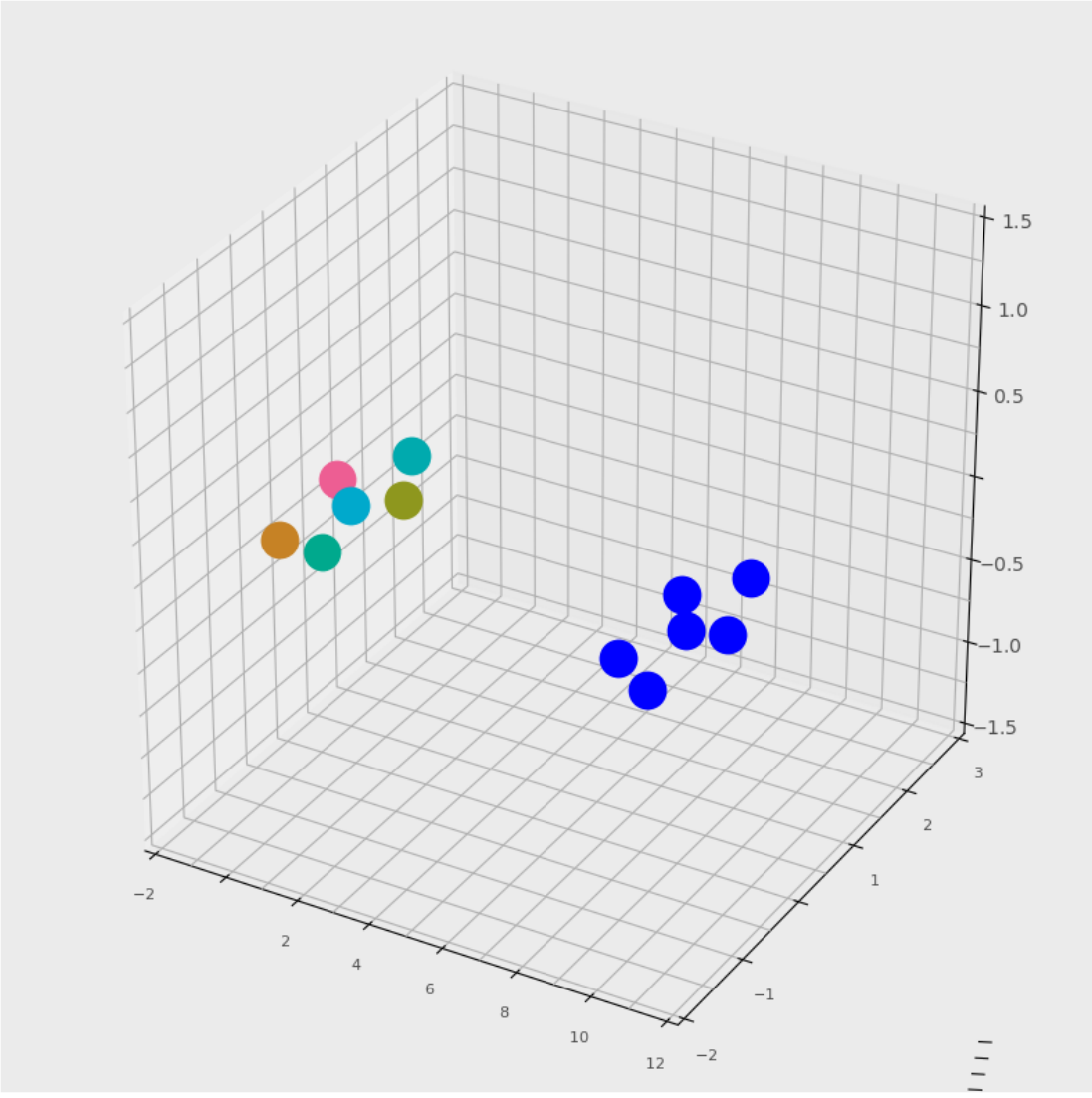
[31]:
```
gif(anim2,fps=10)
```

```
Info: Saved animation to
  fn = /home/bbm/Documents/research/FormationControl/tmp.gif
```

```
@ Plots /home/bbm/.julia/packages/Plots/LWw1t/src/animation.jl:104
```

[31]:
```
Plots.AnimatedGif("/home/bbm/Documents/research/FormationControl/tmp.gif")
```

[32]:
```
anim3 = @animate for i in 1:length(pos2)
    plt = scatter(5,xlim=(-2,12),ylim=(-2,3), zlim=(-1.5,1.5),c=:
↪red,legend=false, framestyle=:origin)
    pst = pst=reshape(pos2[i],(3,6))
    scatter!(x_coor',y_coor', z_coor', markersize=20 )
    scatter!(plt,pst[1,:],pst[2,:] , pst[3,:],markersize=20,c=:blue,␣
↪legend=false)
    scatter!(size=(800,800))
end
```



[32]:
```
Animation("/tmp/jl_Mz9c0s", ["000001.png", "000002.png", "000003.png",
"000004.png", "000005.png", "000006.png", "000007.png", "000008.png",
"000009.png", "000010.png"  …  "000092.png", "000093.png", "000094.png",
"000095.png", "000096.png", "000097.png", "000098.png", "000099.png",
"000100.png", "000101.png"])
```

[33]:
```
gif(anim3,fps=10)
```

```
Info: Saved animation to
  fn = /home/bbm/Documents/research/FormationControl/tmp.gif
@ Plots /home/bbm/.julia/packages/Plots/LWw1t/src/animation.jl:104
```

[33]:
```
Plots.AnimatedGif("/home/bbm/Documents/research/FormationControl/tmp.gif")
```

[ ]:
```

```