

Block of input data initialization

The Lotka—Volterra Attractor & Verner's method of order 6(5) (DVERK)

```
clear
clc
close

a1 = 2.9851;
b1 = 3;
c1 = 2;

fun_DVERK = @(t, x) [x(1) - x(1) * x(2) + c1 * x(1) ^ 2 - a1 * x(3) * x(1) ^ 2;
                     - x(2) + x(1) * x(2);
                     -b1 * x(3) + a1 * x(3) * x(1) ^ 2];

incond_DVERK = [1 1 1];
timeint_DVERK = [0 300];

tau_DVERK = 0.001;

s_stages = 8;
c_vector_DVERK = [0 1/6 4/15 2/3 5/6 1 1/15 1]';

A_matrix_DVERK = [zeros(1,s_stages);
                  1/6 zeros(1,s_stages-1);
                  4/75 16/75 zeros(1,s_stages-2);
                  5/6 -8/3 5/2 zeros(1,s_stages-3);
                  -165/64 55/6 -425/64 85/96 zeros(1,s_stages-4);
                  12/5 -8 4015/612 -11/36 88/255 zeros(1,s_stages-5);
                  -8263/15000 124/75 -643/680 -81/250 2484/10625 0 zeros(1,s_stages-6);
                  3501/1720 -300/43 297275/52632 -319/2322 24068/84065 0 3850/26703
zeros(1,s_stages-7)];;

b_vector_DVERK = [3/40 0 875/2244 23/72 264/1955 0 125/11592 43/616]';

b_hat_vector_DVERK = [13/160 0 2375/5984 5/16 12/85 3/44 0 0]';
```

The TSUCS2 Attractor & Dormand—Prince method of order 5(4) (RK5(4)7M)

```
a2 = 40;
b2 = 1.833;
c2 = 55;
d2 = 0.16;
e2 = 20;
xi2 = 0.65;

fun_DP54 = @(t, x) [a2 * (x(2) - x(1)) + d2 * x(1) * x(3);
                     c2 * x(1) - x(1) * x(3) + e2 * x(2);
                     b2 * x(3) + x(1) * x(2) - xi2 * x(1) ^ 2];

incond_DP54 = [0 1 0];
timeint_DP54 = [0 300];
```

```

tau_DP54 = 0.001;

c_vector_DP54 = [0 1/5 3/10 4/5 8/9 1 1]';

A_matrix_DP54 = [0 0 0 0 0 0 0;
                  1/5 0 0 0 0 0 0;
                  3/40 9/40 0 0 0 0 0;
                  44/45 -56/15 32/9 0 0 0 0;
                  19372/6561 -25360/2187 64448/6561 -212/729 0 0 0;
                  9017/3168 -355/33 46732/5247 49/176 -5103/18656 0 0;
                  35/384 0 500/1113 125/192 -2187/6784 11/84 0];

b_vector_DP54 = [35/384 0 500/1113 125/192 -2187/6784 11/84 0]';

b_hat_vector_DP54 = [5179/57600 0 7571/16695 393/640 -92097/339200 187/2100
1/40]';

```

Block of IVP solution

```
[t_DVERK, xsol_DVERK, ELE_DVERK] = odeEmbeddedGeneral(c_vector_DVERK,
A_matrix_DVERK, b_vector_DVERK, b_hat_vector_DVERK, ...
fun_DVERK, timeint_DVERK, tau_DVERK, incond_DVERK)
```

```

t_DVERK = 300001x1
0
0.001
0.002
0.003
0.004
0.005
0.006
0.007
0.008
0.009
:
xsol_DVERK = 300001x3
1           1           1
0.999015894744055   0.999999507781529   0.999982162479794
0.998033787250472   0.999998032457346   0.99995846192943
0.997053689800704   0.999995576035711   0.999928916469127
0.996075614503824   0.999992140539951   0.999893544357053
0.995099573297578   0.999987728008267   0.999852363987037
0.99412557794945    0.999982340493546   0.999805393886283
0.993153640057726   0.999975980063168   0.999752652713107
0.992183771052576   0.99996864879882   0.999694159254675
0.991215982197123   0.999960348796305   0.999629932424757
:
ELE_DVERK = 300001x1
0
4.47233396150271e-19
4.47233396150271e-19
4.33680868994202e-19
4.20128341838133e-19
4.74338450462408e-19
4.74338450462408e-19
4.74338450462408e-19
4.47233396150271e-19
4.47233396150271e-19

```

```
[t_DP54, xsol_DP54, ELE_DP54] = odeFSALEmbeddedGeneral(c_vector_DP54,
A_matrix_DP54, b_vector_DP54, b_hat_vector_DP54, ...
fun_DP54, timeint_DP54, tau_DP54, incond_DP54)
```

```
t_DP54 = 300001x1
    0
    0.001
    0.002
    0.003
    0.004
    0.005
    0.006
    0.007
    0.008
    0.009
    :
    :
xsol_DP54 = 300001x3
    0           1           0
    0.039622457573753  1.02130165043835  1.98203779158411e-05
    0.0785780543116934  1.04521572478453  7.87307462247841e-05
    0.116995730584252  1.07176153394019  0.000176269739178019
    0.155000275746303  1.10096582055379  0.000312443583641569
    0.192712780886028  1.13286269119574  0.000487707945546123
    0.230251071639839  1.16749357162493  0.000702955777042324
    0.267730122747747  1.20490718455756  0.000959510785967497
    0.305262455936878  1.24515954942398  0.00125912623020745
    0.342958522640375  1.28831400367194  0.00160398881383773
    :
    :
ELE_DP54 = 300001x1
    0
    4.20951647671364e-10
    4.00446041885945e-10
    3.81534180876435e-10
    3.64128535266725e-10
    3.481477202881e-10
    3.33516138751461e-10
    3.2016364917304e-10
    3.08025256017842e-10
    2.97040812194567e-10
    :
```

```
max_ELE_DVERK = max(abs(ELE_DVERK))
```

```
max_ELE_DVERK =
    1.68728963093057e-18
```

```
max_ELE_DP54 = max(abs(ELE_DP54))
```

```
max_ELE_DP54 =
    8.24761348461323e-06
```

Block of visualization of the obtained results

The Lotka—Volterra Attractor

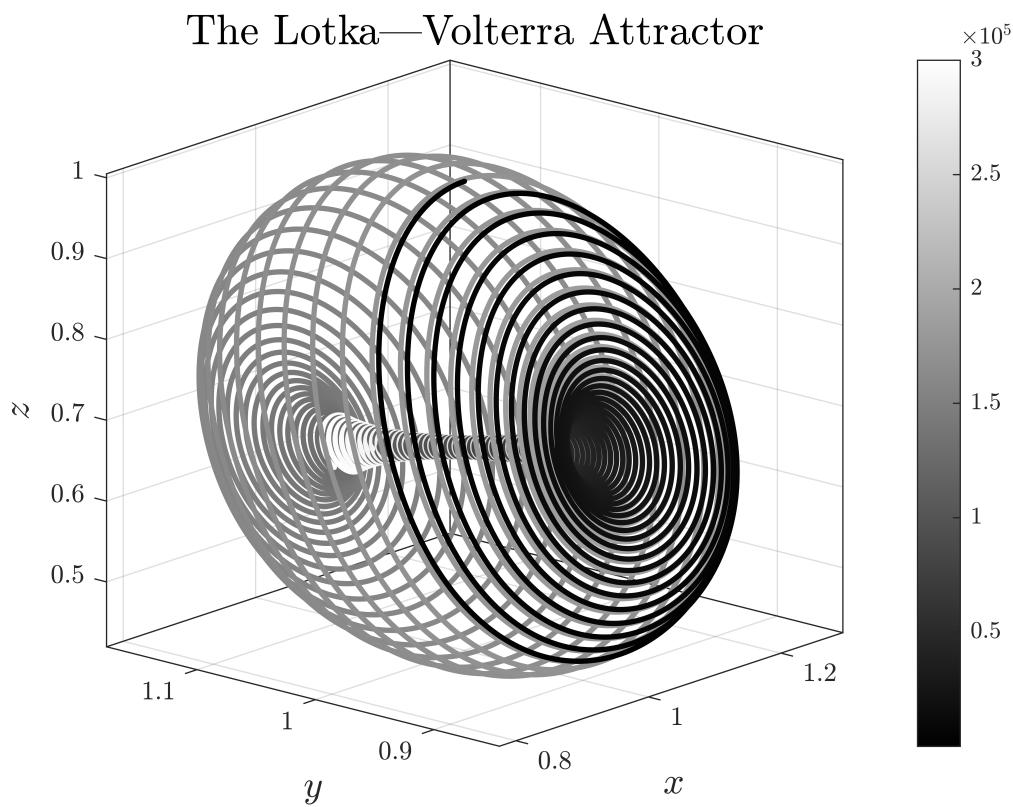
```
set(groot, "defaultAxesTickLabelInterpreter", "latex")
set(groot, "defaultTextInterpreter", "latex")
```

```

set(groot, "defaultLegendInterpreter", "latex")
set(groot, "defaultColorbarTickLabelInterpreter", "latex");

fig1 = figure();
scatter3(xsol_DVERK(:,1), xsol_DVERK(:,2), xsol_DVERK(:,3),
4,1:length(xsol_DVERK(:,1)), 'filled');
colormap gray;
colorbar;
axis tight;
grid on;
box on;
view([-48.822 17.712])
xlabel('$x$', 'FontSize', 14 );
ylabel('$y$', 'FontSize', 14 );
zlabel('$z$', 'FontSize', 14 );
title('The Lotka---Volterra Attractor', 'FontSize', 16);

```



The TSUCS2 Attractor

```

set(groot, "defaultAxesTickLabelInterpreter", "latex")
set(groot, "defaultTextInterpreter", "latex")
set(groot, "defaultLegendInterpreter", "latex")
set(groot, "defaultColorbarTickLabelInterpreter", "latex");

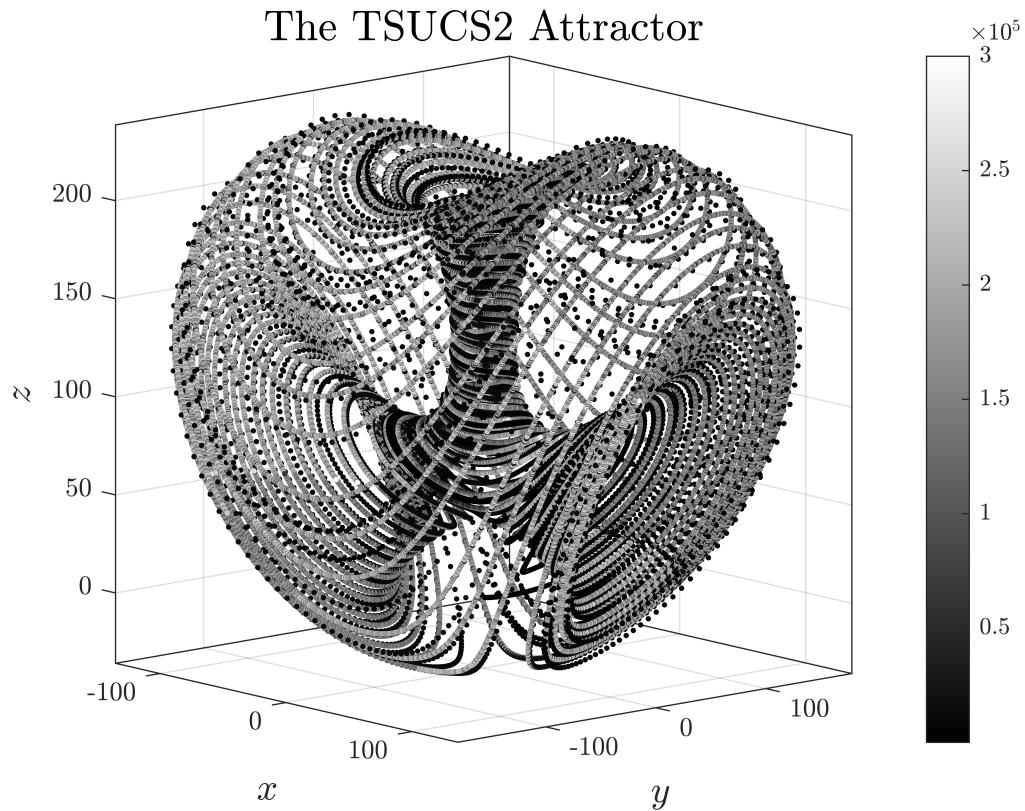
fig2 = figure();
scatter3(xsol_DP54(:,1), xsol_DP54(:,2), xsol_DP54(:,3),
4,1:length(xsol_DP54(:,1)), 'filled');
colormap gray;
colorbar;
axis tight;

```

```

grid on;
box on;
view([49 11]);
xlabel('$x$', 'FontSize', 14 );
ylabel('$y$', 'FontSize', 14 );
zlabel('$z$', 'FontSize', 14 );
title('The TSUCS2 Attractor', 'FontSize', 16);

```



Block of exporting the obtained results

```

exportgraphics(fig1, "images/The_Lotka_Volterra_Attractor.pdf",
"ContentType", "vector")

```

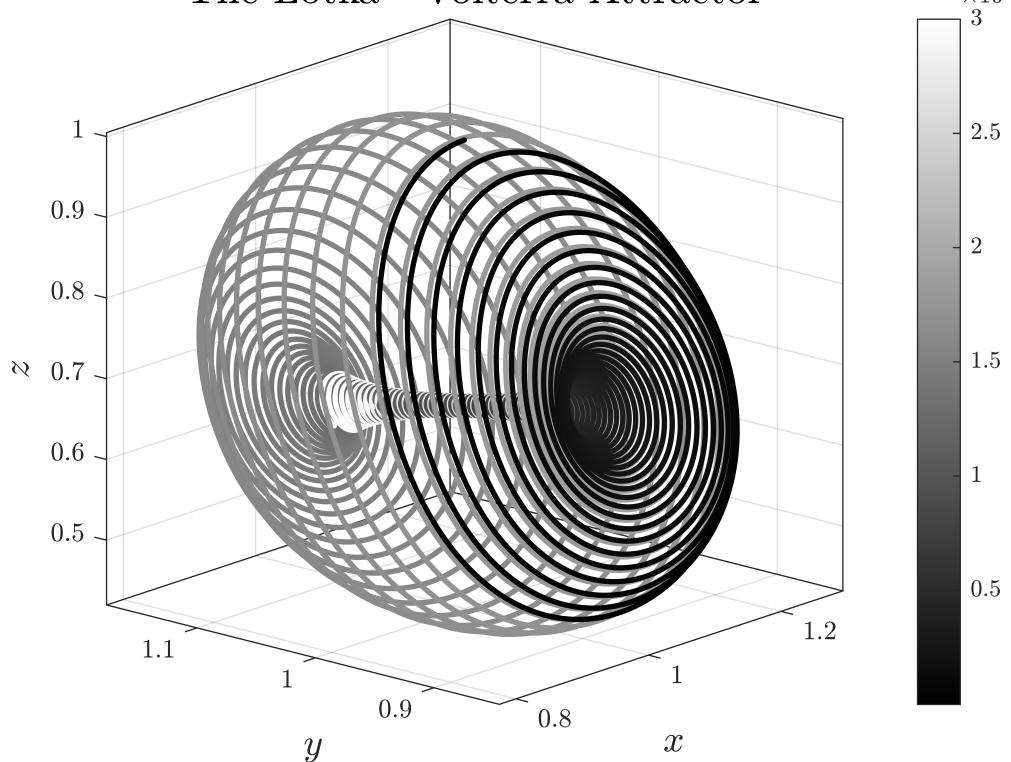
Warning: Vectorized content might take a long time to create, or it might contain unexpected results. Set 'ContentType' to 'image' for better performance. Click here to not see this message again.

```

exportgraphics(fig1, "images/The_Lotka_Volterra_Attractor.png", "Resolution",
1200)

```

The Lotka—Volterra Attractor

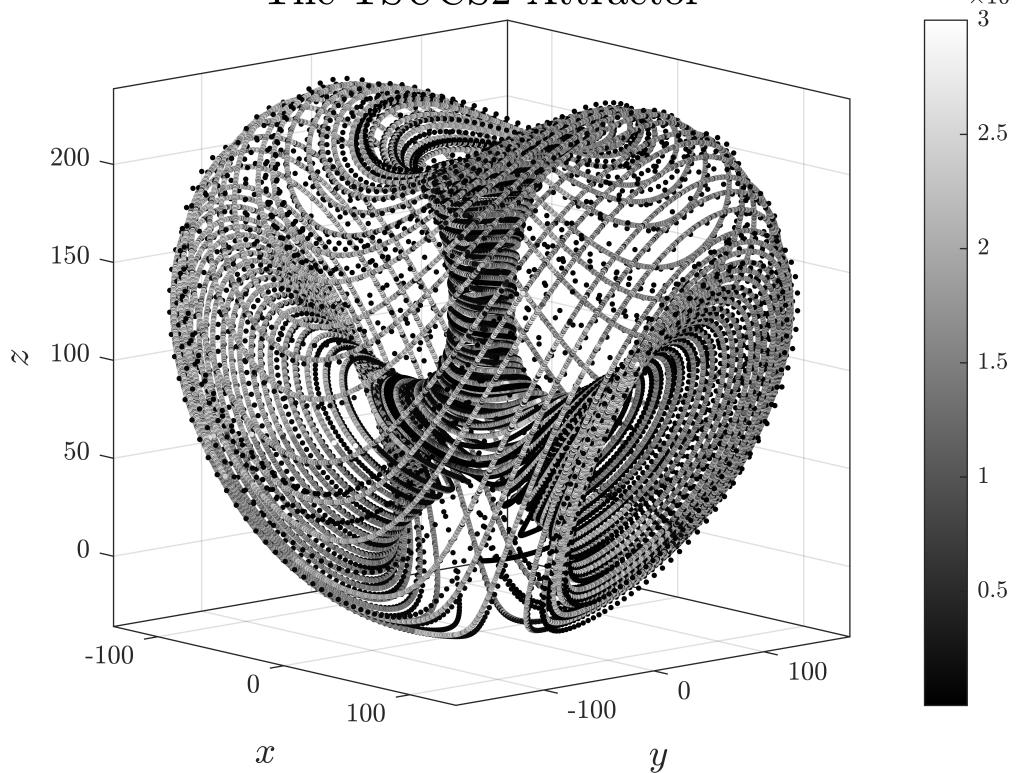


```
exportgraphics(fig2, "images/The_TSUCS2_Attractor.pdf", "ContentType", "vector")
```

Warning: Vectorized content might take a long time to create, or it might contain unexpected results. Set 'ContentType' to 'image' for better performance. Click here to not see this message again.

```
exportgraphics(fig2, "images/The_TSUCS2_Attractor.png", "Resolution", 1200)
```

The TSUCS2 Attractor



```
save("results.mat")
```