Tutorial 34: 2D Projection Images and Camera Coordinate System Reconstruction

2017-05-15: Tim C. Lueth, MIMED - Technische Universität München, Germany (URL: http://www.mimed.de) - Last Change: 2017-07-25

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Motivation for this tutorial: (Originally SolidGeometry 3.8 required)

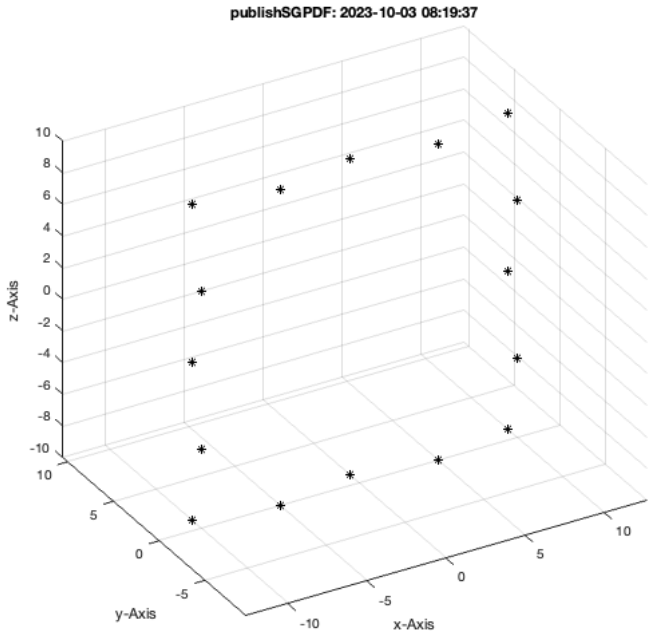
Many surgical procedures in orthopedics are not based on three-dimensional CT or MRI image data but on C-arm images. These C-arm images are 2D projection images of a spatial region of the patient. In this, the most important strategies for the conversion of volume images to projection images are presented. It is also explained how the position of the X-ray camera can be calculated from projection images, if one knows the exact location of objects in space and the 2D image. The research area is also called Camera Calibration.

ATTENTION >>> The Publishermode changes the aspect ratio of figures, therefor it is strongly recommended to copy lines from this tutorial instead of just executing the publishabe example

1. Create a number of random points around the center

The following commands could be typed in absolute in the same way as part

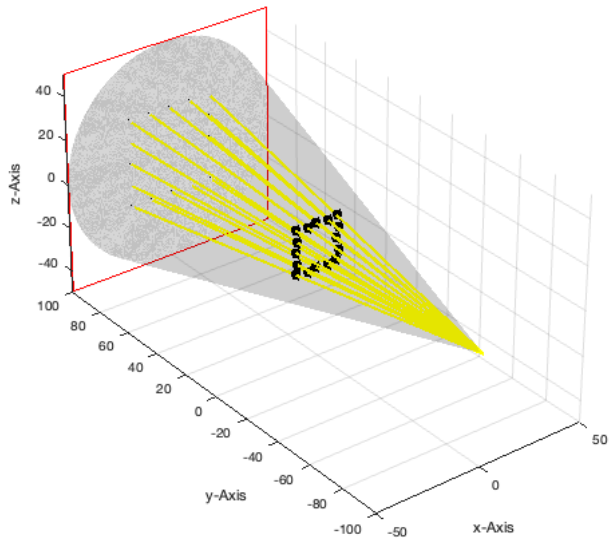
```
SGfigure; view(-30,30); xlabel 'x-Axis', ylabel 'y-Axis', zlabel 'z-Axis';
VL=50*rand(10,3)-25; VL(:,2)=1*rand(10,1)';
% VL=VLsample(9)
VL=VLsample(11); VL=VLtransT(VL,TofR(rot(-pi/20,0,pi/20)));
VL=VLsample(12);
VLplot(VL,'k*');
```



2. Create an X-ray image by using the camera parameter of Matlab

The x-ray source is at position [0 100 0]; The target is at [0 +100 0] The screen has a size of 100x100 The scaling factor is 4, i.e. the pixel size if 025 x 0.25 mm

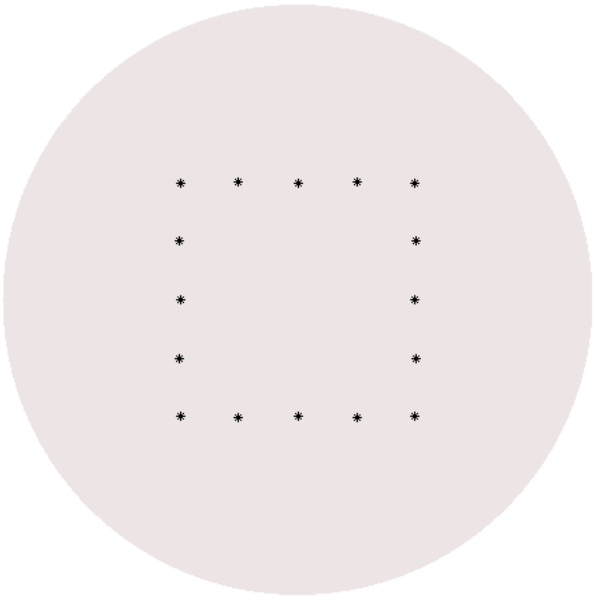
```
imageofVLprojection(VL,[100 100],[0 -100 0],[0 100 0],4);
set(gca,'Projection','perspective');    % this line is only required because of publishing function
```



show the image

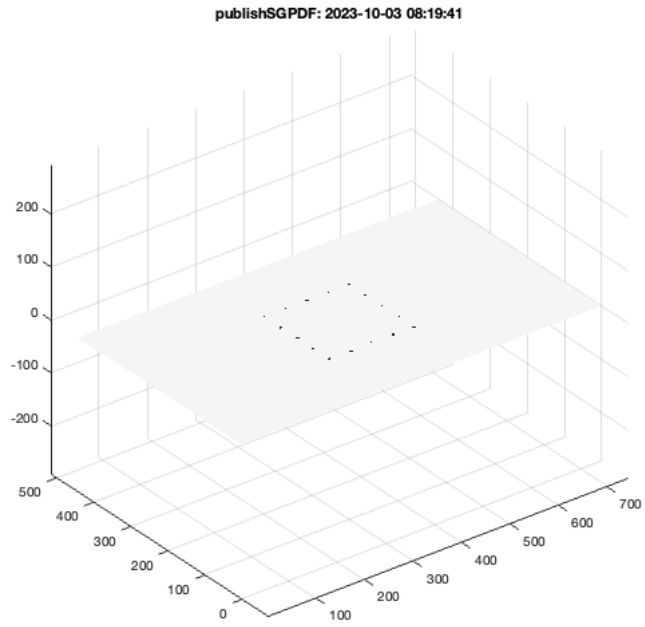
```
I=imageofVLprojection(VL,[100 100],[0 -100 0],[0 100 0],4);
set(gca,'Projection','perspective');    % this line is only required because of publishing function
whos I                                  % this line is only required because of publishing function
```

```
  Name        Size               Bytes  Class     Attributes

  I         440x744            2618880  double
```



```
SGfigure
imwarpT(I);
```

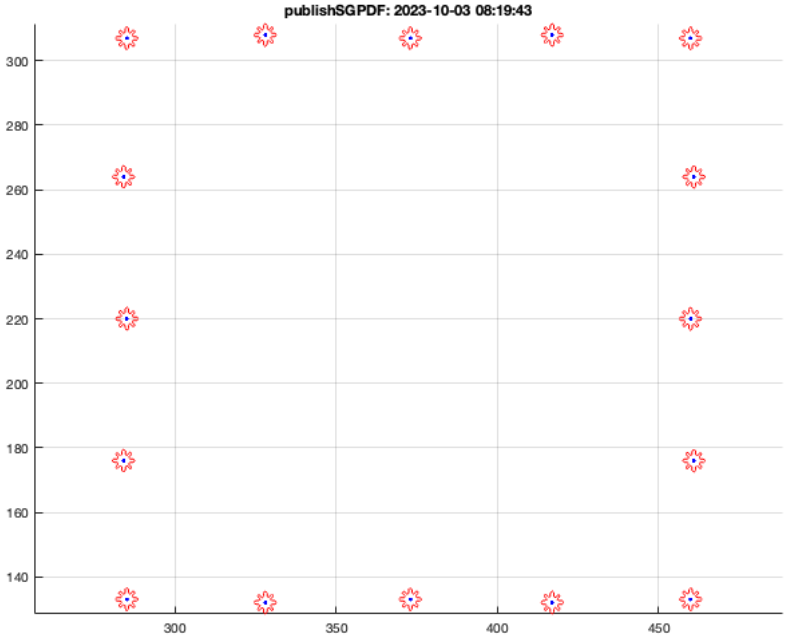
```
ans =
  Figure (1: AOI Matlab Solid Modeler app_2012_11_09) with properties:

      Number: 1
        Name: 'AOI Matlab Solid Modeler app_2012_11_09'
       Color: [1 1 0.9000]
    Position: [31 803 960 540]
       Units: 'pixels'

  Use GET to show all properties
```



3. Find the marker points in the image

```
SGfigure;
CPL=CPLcontourc(I,1); % Contour segmentation on image base
CPLplot(CPL,'r-');
PL=centerCPL(CPL)
PLplot(PL,'b.',4);
size(I,2)                              % this line is only required because of publishing function
```

```
PL =
   284   264
   284   176
   461   264
   461   176
   285   307
   285   220
   285   133
   460   307
   460   220
   460   133
   328   308
   328   132
   417   308
   417   132
   373   307
   373   133
ans =
   744
```

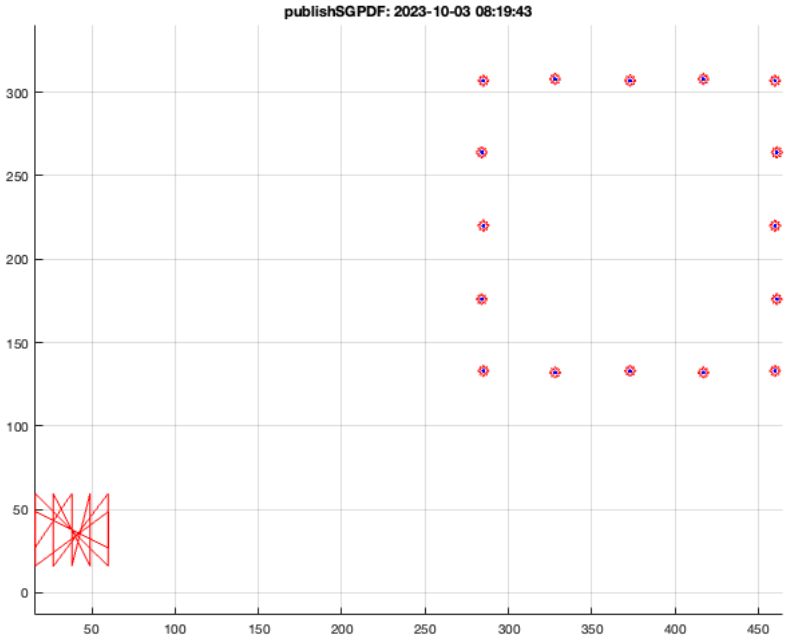


turn the coordinate

```
PL(:,2)=-PL(:,2)+size(I,2)   % flip up and down (y-axis)
PL=(PL-1)-size(I)/2          % Move coordinate into center
PL=PL/4                      % Scale using pixle size
CPLplot(PL,'r-');
```

```
PL =
   284   480
   284   568
   461   480
   461   568
   285   437
   285   524
   285   611
   460   437
   460   524
   460   611
   328   436
   328   612
   417   436
   417   612
   373   437
   373   611
PL =
    63   107
    63   195
```

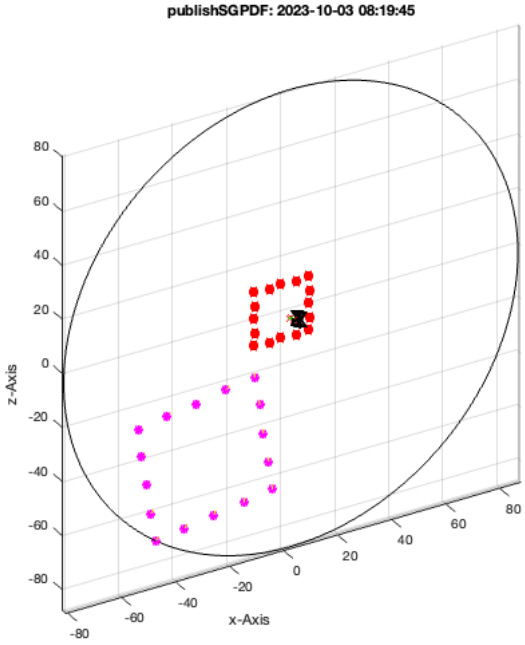
```
   240   107
   240   195
    64    64
    64   151
    64   238
   239    64
   239   151
   239   238
   107    63
   107   239
   196    63
   196   239
   152    64
   152   238
PL =
   15.7500   26.7500
   15.7500   48.7500
   60.0000   26.7500
   60.0000   48.7500
   16.0000   16.0000
   16.0000   37.7500
   16.0000   59.5000
   59.7500   16.0000
   59.7500   37.7500
   59.7500   59.5000
   26.7500   15.7500
   26.7500   59.7500
   49.0000   15.7500
   49.0000   59.7500
   38.0000   16.0000
   38.0000   59.5000
```



Some knowledge on corresponding axis

```
TofcamVLPL(sortrows(VL,[1 3]),sortrows(PL,[1 2]))
```

```
K =
   -1.1927   -0.1958   26.3421
    0.0000    0.8946   26.0685
    0.0000   -0.0000    0.5765
s =
    1.7345
ans =
    0.9888    0.1491   -0.0042    3.4747
    0.0048   -0.0036    1.0000   -0.9897
    0.1491   -0.9888   -0.0042   -3.5332
         0         0         0    1.0000
```



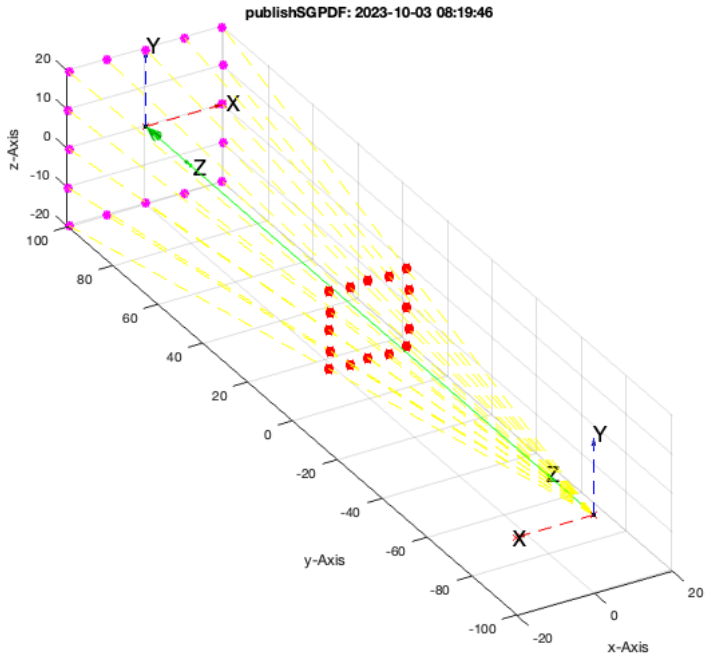
3. Calculate the Point Position of a X-Ray Camera

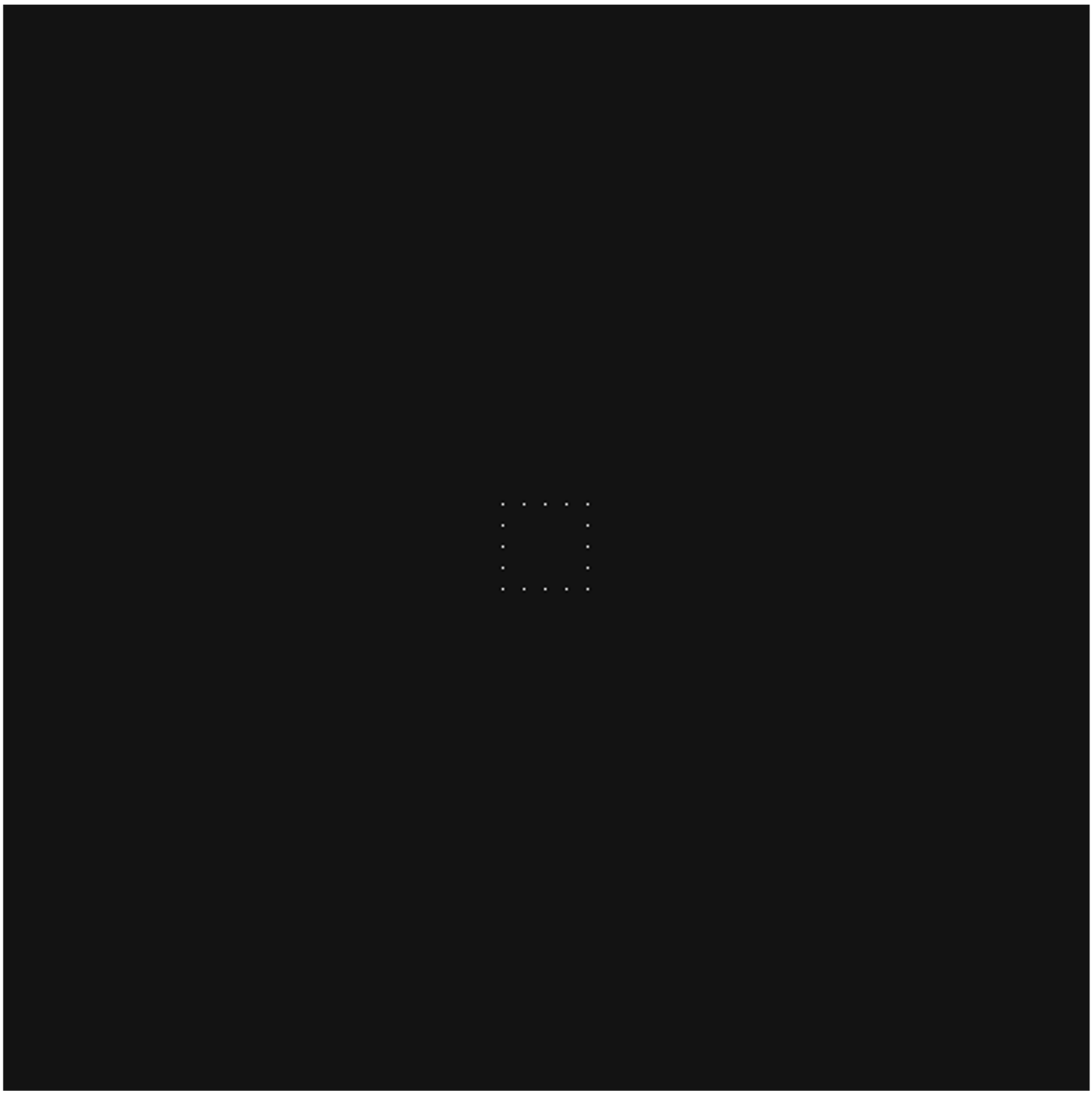
The x-ray source is at position [0 100 0]; The target is at [0 +100 0]

```
PLofVLprojection(VL,[0 -100 0],[0 100 0]);
PL=PLofVLprojection(VL,[0 -100 0],[0 100 0])
```

```
  Name        Size              Bytes  Class     Attributes

  I         512x512           2097152  double

  Name        Size              Bytes  Class     Attributes

  I         512x512           2097152  double

PL =
  -19.8020  -19.8020
  -10.0000  -20.0000
         0  -19.8020
   10.0000  -20.0000
   19.8020  -19.8020
   20.0000  -10.0000
   19.8020         0
   20.0000   10.0000
   19.8020   19.8020
   10.0000   20.0000
```

```
         0   19.8020
  -10.0000   20.0000
  -19.8020   19.8020
  -20.0000   10.0000
  -19.8020         0
  -20.0000  -10.0000
```

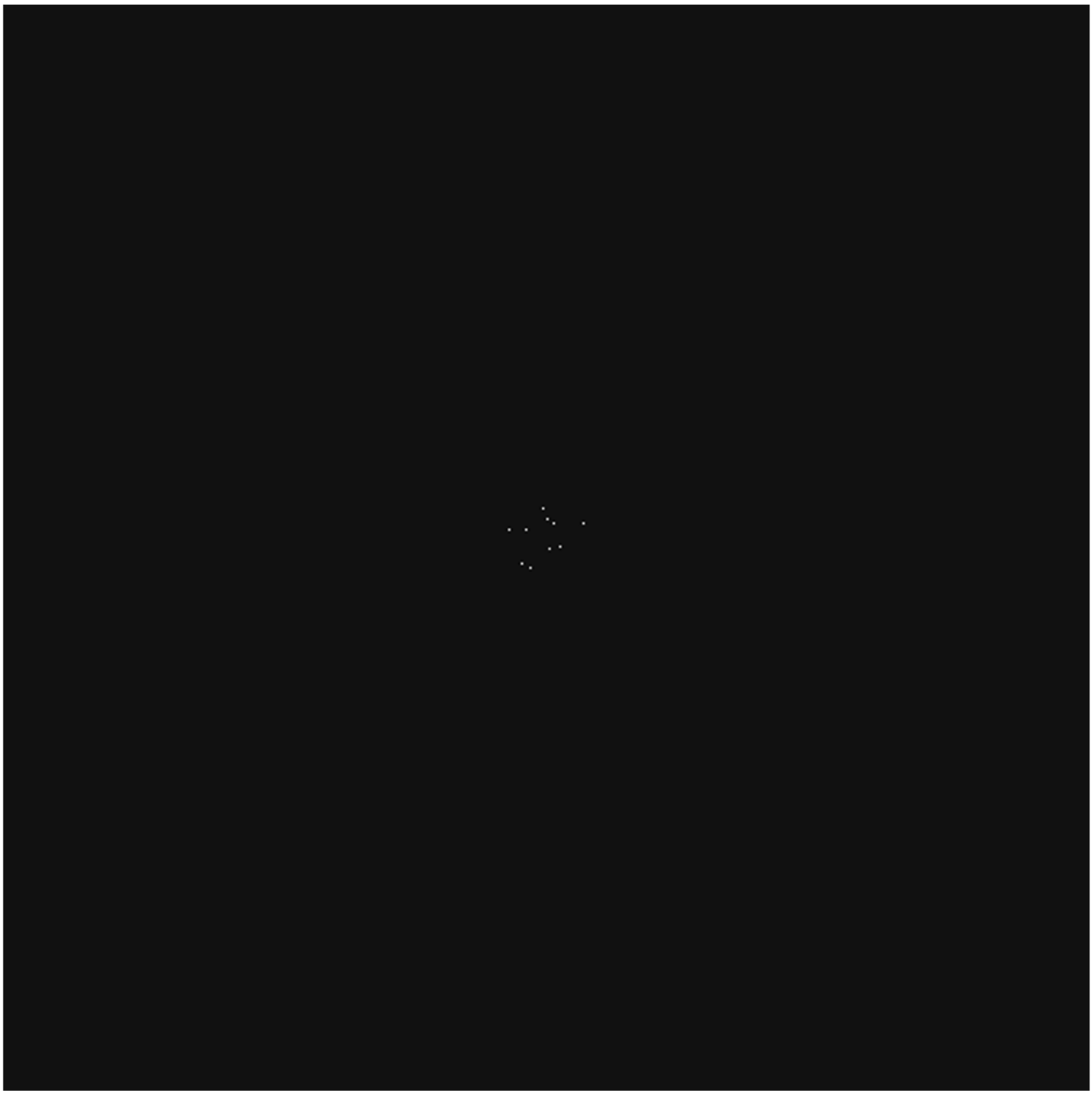




5. Comparision of point lists created by numerical projection or projection image reconstruction

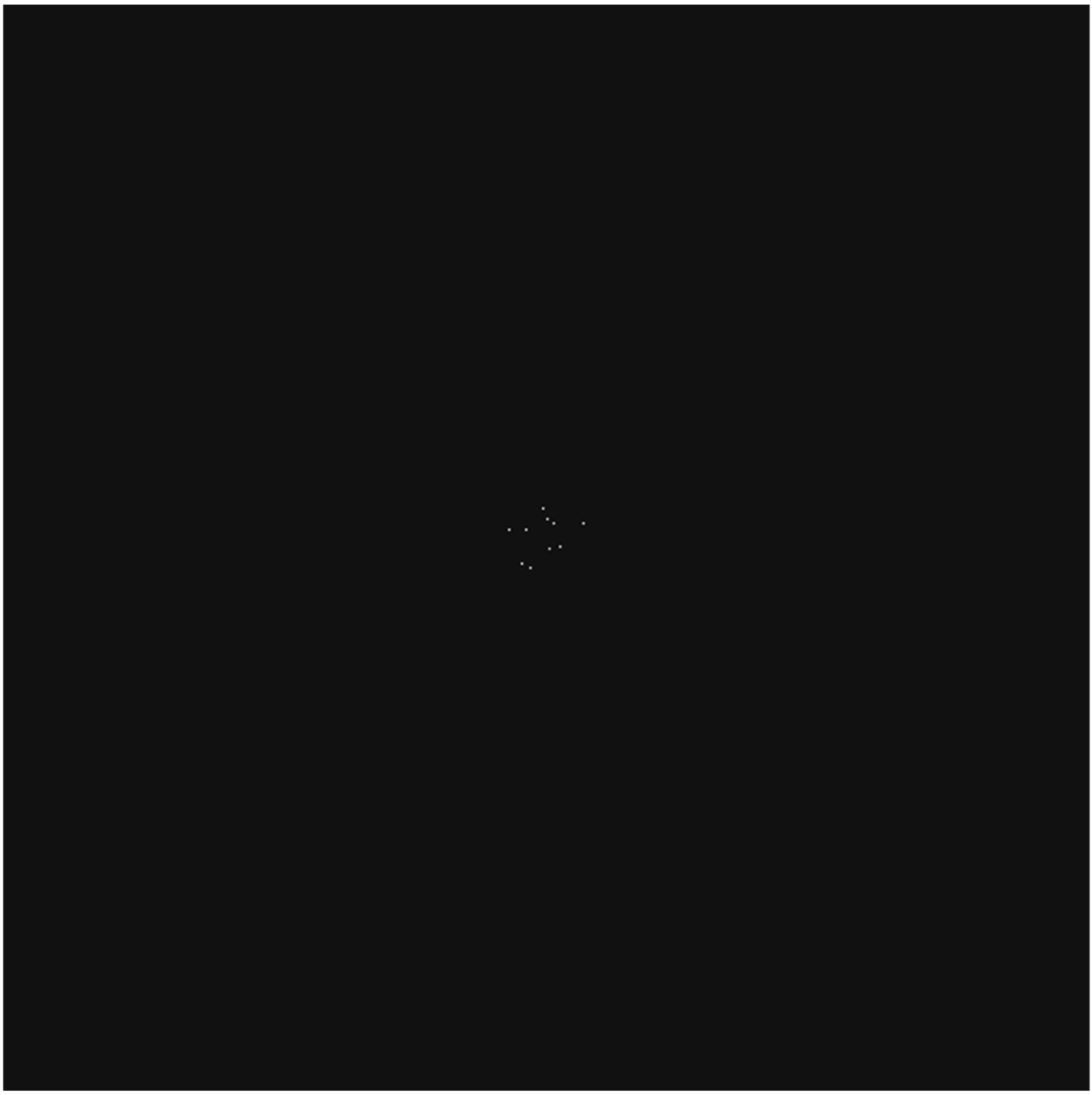
```
VL=20*rand(10,3)-10; VL(:,2)=5*rand(10,1)';
I=imageofVLprojection(VL,[100 100],[0 -100 0],[0 100 0],4);
[sortrows(PLofimcontourc(I,true,1/4)) sortrows(PLofVLprojection(VL,[0 -100 0],[0 100 0]))]
```

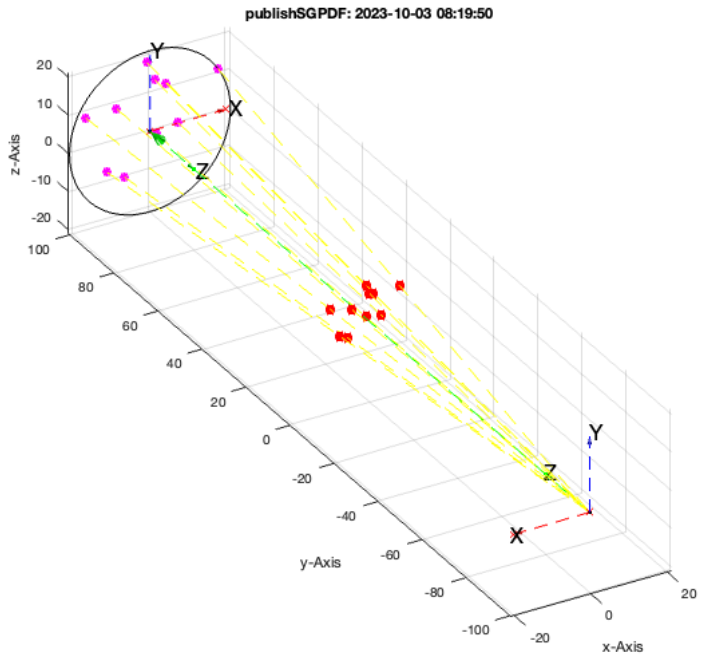
```
  Name        Size               Bytes  Class     Attributes

  I         512x512            2097152  double

ans =
  -17.1250    8.3750  -16.8123    8.2529
  -11.6250   -7.6250  -11.2556   -7.5212
   -8.8750    8.3750   -8.6804    8.2927
   -6.8750  -10.1250   -6.6762  -10.1249
   -1.1250   18.1250   -0.7593   18.2097
    0.8750   13.1250    1.2352   13.0986
    1.3750   -1.1250    1.6112   -1.0634
    3.8750   11.3750    4.2393   11.3588
    7.1250    0.1250    7.2909    0.2278
   17.6250   11.3750   17.8217   11.3458
```



```
TofcamVLPL(sortrows(VL,[1 3]),sortrows(PLofVLprojection(VL,[0 -100 0],[0 100 0]),[1 2]))
```

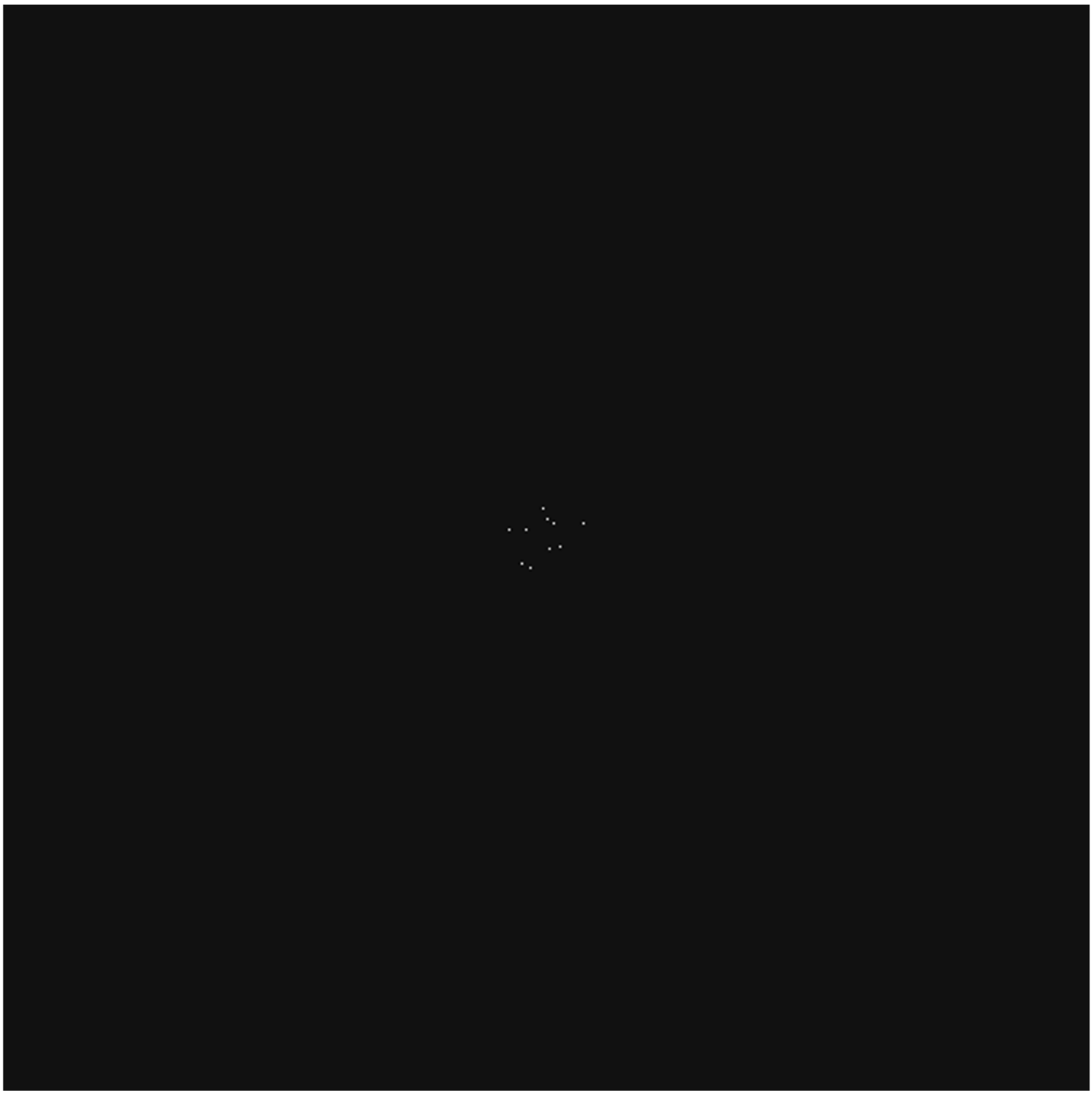
```
  Name        Size              Bytes  Class     Attributes

  I         512x512           2097152  double

K =
    1.0000   -0.0000    0.0000
         0    1.0000    0.0000
   -0.0000   -0.0000    0.0050
s =
   200
ans =
   -1.0000         0         0    0.0000
         0         0    1.0000 -100.0000
         0    1.0000         0    0.0000
         0         0         0    1.0000
```

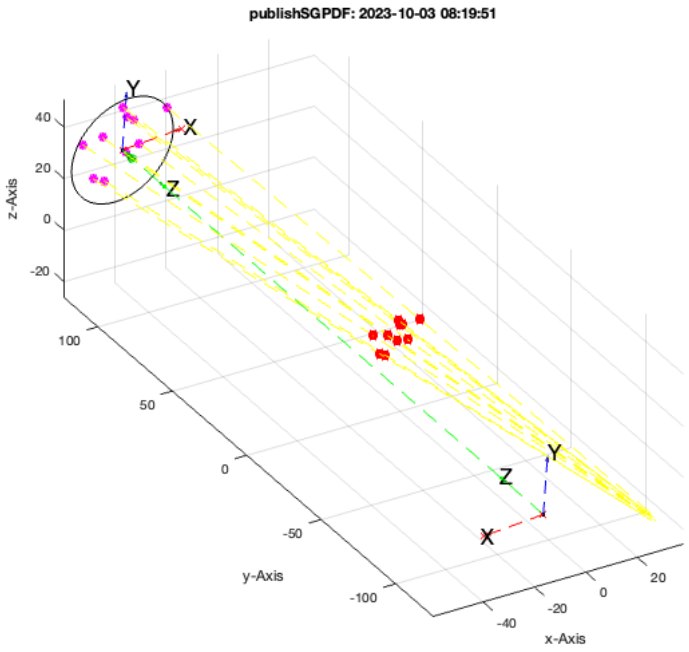





```
TofcamVLPL(sortrows(VL,[1 3]),sortrows(PLofimcontourc(I,true,1/4),[1 2]))
```

```
K =
   -0.9896   -0.0043   -0.1179
    0.0000    0.9930    0.1179
   -0.0000   -0.0000    0.0041
s =
  245.0885
ans =
   -0.9953    0.0047   -0.0971  -14.9715
   -0.0970   -0.1112    0.9890 -122.5733
   -0.0061    0.9938    0.1112   -0.6167
         0         0         0    1.0000
```





Final Remarks

```
close all
VLFLlicense
```

```
This VLFL-Lib, Rel.  (2023-Oct-03), is for limited non commercial educational use only!
Licensee: Tim Lueth (Development Version)!
Please contact Tim Lueth, Professor at TU Munich, Germany!
WARNING: This VLFL-Lib (Rel. ) license will exceed at 06-Jul-2078 08:19:53!
Executed 03-Oct-2023 08:19:55 by 'timlueth' on a MACI64 using Mac OSX 13.6 | R2023a Update 5 | SG-Lib 5.4
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database_toolbox
distrib_computing_toolbox
fixed_point_toolbox
image_toolbox
map_toolbox
matlab
simmechanics
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================================================================================================================
```

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