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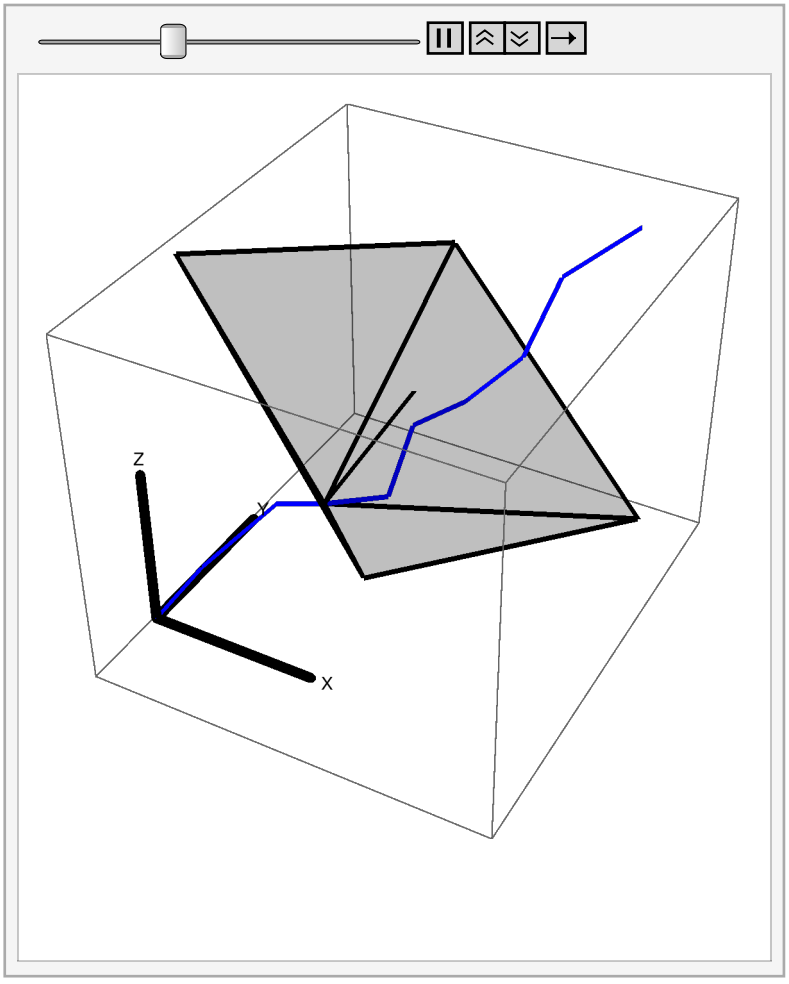
3D Vision Term Project - Dec 2018

Example 4 - Motion of camera on robot

In[4925]:=
```
noOfFrames = 10;
imX = 100;
imY = 100;
aovDeg = 90;
camPos0 = {0, 0, 0};
camTransl = RandomReal[{0, 2}, {noOfFrames - 1, 3}];
camPos = ConstantArray[camPos0, {noOfFrames}] +
   Join[{{0., 0., 0.}}, Accumulate[camTransl]];
camPosPrev = Join[{{-1., 0., 0.}}, camPos[[1 ;; -2]]];
camPosPrevPrev = Join[{{-2., -0.000000001, 0.}}, camPosPrev[[1 ;; -2]]];
vecAngle[u_, v_] := ArcCos[{u}.v / (Norm[u] * Norm[v])][[1]];
vecAngleInDeg[u_, v_] := vecAngle[u, v] * 180 / π;
camRotAngleDegs = Table[-vecAngleInDeg[camPosPrev[[i]] - camPosPrevPrev[[i]],
     camPos[[i]] - camPosPrev[[i]]], {i, noOfFrames}];
camRotAxiss = Table[-Cross[camPosPrev[[i]] - camPosPrevPrev[[i]],
     camPos[[i]] - camPosPrev[[i]]], {i, noOfFrames}];
```

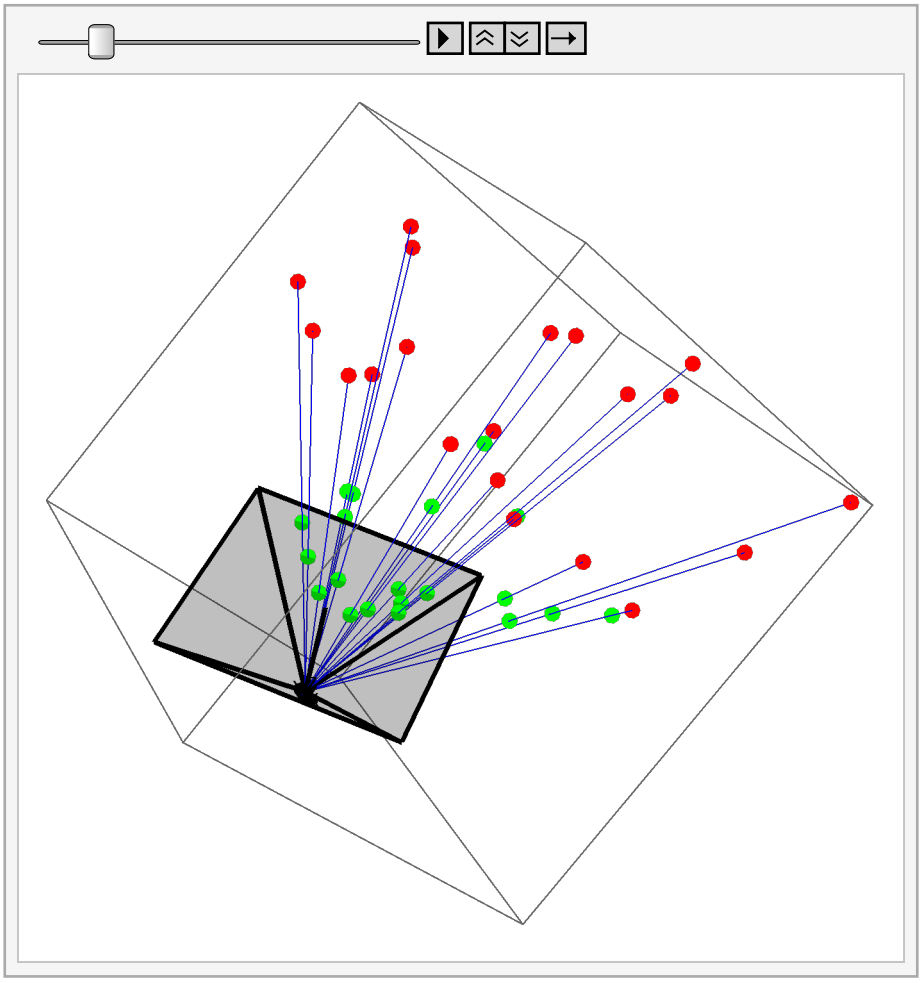
In[4938]:=
```
(* Cameras *)
camFulls = Table[camera[imX, imY, aovDeg, camPos[[i]],
    camRotAngleDegs[[i]], camRotAxiss[[i]]], {i, noOfFrames}];
cams = camFulls[[All, 1]];
fs = camFulls[[All, 2]];
Ks = camFulls[[All, 3]];
Rs = camFulls[[All, 4]];
Ts = camFulls[[All, 5]];
ListAnimate[Table[Show[axes[],
   Graphics3D[
    Table[{Blue, Thick, Line[{camPos[[i - 1]], camPos[[i]]}]}, {i, 2, noOfFrames}]],
   showCam[cams[[i]], fs[[i]] / 10]
  ], {i, 1, noOfFrames}]
]
```

Out[4944]=



In[4945]:=
```
(* Points captured by the cameras *)
camCapturePointss =
  Table[camCapture[points3D, cams[[i]], fs[[i]]], {i, noOfFrames}];
camImgPointss = camCapturePointss[[All, 1]];
camPointsDeprojss = camCapturePointss[[All, 2]];
ListAnimate[Table[Show[axes[],
   Graphics3D[
    Table[{Blue, Thick, Line[{camPos[[i - 1]], camPos[[i]]}]}, {i, 2, noOfFrames}]],
   Graphics3D[{Red, PointSize[0.02], Point[#]}] & /@ points3D,
   Graphics3D[{Green, PointSize[0.02], Point[#]}] & /@ camPointsDeprojss[[i]],
   Graphics3D[{Blue, Line[{camPos[[i]], #}] & /@ points3D}],
   showCam[cams[[i]], fs[[i]]]
  ], {i, 1, noOfFrames}]
]
```

Out[4948]=



In[5289]:=
```
(* Find common points in consecutive frames *)
validPtsIdx = {};
For[i = 1, i ≤ Length[camImgPointss], i++,
  idx = {};
  For[p = 1, p <= Length[camImgPointss[[i]]], p++, If[camImgPointss[[i, p, 1]] > 0 &&
     camImgPointss[[i, p, 1]] < imX && camImgPointss[[i, p, 2]] > 0 &&
     camImgPointss[[i, p, 2]] < imY, idx = Append[idx, p]]
  ];
  validPtsIdx = Append[validPtsIdx, idx];
 ];
validPtsIdx
commonPtsIdx = {};
For[i = 1, i ≤ Length[camImgPointss] - 1, i++,
 commonPtsIdx =
   Append[commonPtsIdx, Intersection[validPtsIdx[[i]], validPtsIdx[[i + 1]]]];
]
commonPtsIdx
```

Out[5291]=
```
{{1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20},
 {5, 6, 10, 11, 12, 13, 16, 18, 19, 20},
 {1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20},
 {2, 4, 5, 7, 9, 12, 14, 15, 16, 17},
 {1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20},
 {5, 6, 10, 11, 13, 16, 18, 19, 20}, {2, 4, 5, 7, 9, 11, 12, 14, 15, 16, 17},
 {1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20},
 {1, 3, 4, 5, 6, 8, 10, 12, 13, 14, 16, 17, 18, 19, 20},
 {1, 2, 3, 4, 5, 7, 8, 9, 12, 14, 15, 16, 17}}
```

Out[5294]=
```
{{5, 6, 10, 11, 12, 13, 16, 18, 19, 20}, {5, 6, 10, 11, 12, 13, 16, 18, 19, 20},
 {2, 4, 5, 7, 9, 12, 14, 15, 16, 17}, {2, 4, 5, 7, 9, 12, 14, 15, 16, 17},
 {5, 6, 10, 11, 13, 16, 18, 19, 20}, {5, 11, 16}, {2, 4, 5, 7, 9, 11, 12, 14, 15, 16, 17},
 {1, 3, 4, 5, 6, 8, 10, 12, 13, 14, 16, 17, 18, 19, 20}, {1, 3, 4, 5, 8, 12, 14, 16, 17}}
```

In[5332]:=
```
pose1 = MapThread[Append,
   {IdentityMatrix[3, WorkingPrecision → MachinePrecision], {0., 0., 0.}}];
{pose2, X} = SLAM[Ks[[1]], camImgPointss[[1, commonPtsIdx[[1]]]], Ks[[2]],
  camImgPointss[[2, commonPtsIdx[[1]]]], camTransl[[1]], pose1]
```

Out[5333]=
```
{{{0.365777, 0.721349, 0.588101, -1.89856},
  {-0.721349, 0.619012, -0.310612, -5.84699 × 10^-13},
  {-0.588101, -0.310612, 0.746765, 1.4595 × 10^-12}},
 {{-13.1533, -57.4739, 175.976}, {-59.4381, -73.0332, 179.02},
  {-85.0016, 30.3223, 119.332}, {-21.1333, -85.4791, 197.819},
  {14.8949, -43.1642, 186.906}, {-62.8267, -59.9477, 121.775},
  {-8.24741, -21.7607, 119.251}, {-69.5375, -6.63656, 138.006},
  {-80.7541, 73.414, 129.324}, {-90.7416, -21.8206, 117.092}}}
```

In[5334]:=
```
pose2 = (Append[pose2, {0., 0., 0., 1.}].Append[pose1, {0., 0., 0., 1.}])[[1 ;; 3]];
Rs[[2]].Ts[[2]]
pose2 // MatrixForm
```

Out[5335]=
$$\text{TransformationFunction}\left[\left(\begin{array}{ccc|c} 0.365777 & 0.721349 & 0.588101 & -1.89856 \\ -0.721349 & 0.619012 & -0.310612 & 1.11022\times10^{-16} \\ -0.588101 & -0.310612 & 0.746765 & 0. \\ \hline 0. & 0. & 0. & 1. \end{array}\right)\right]$$

Out[5336]//MatrixForm=
$$\begin{pmatrix} 0.365777 & 0.721349 & 0.588101 & -1.89856 \\ -0.721349 & 0.619012 & -0.310612 & -5.84699\times10^{-13} \\ -0.588101 & -0.310612 & 0.746765 & 1.4595\times10^{-12} \end{pmatrix}$$

In[5338]:=
```
{pose3, X} = SLAM[Ks[[2]], camImgPointss[[2, commonPtsIdx[[2]]]],
  Ks[[3]], camImgPointss[[3, commonPtsIdx[[2]]]], camTransl[[2]], pose2]
```

Out[5338]=
```
{{{-0.23196, 0.748233, 0.621564, -1.98394},
  {-0.734743, -0.553523, 0.392129, 1.46034},
  {-0.637454, 0.365731, -0.678154, 1.13135}},
 {{-3.69024, -12.9419, 45.9692}, {-18.5948, -20.6983, 55.5746},
  {-10.6311, 5.53001, 15.7402}, {-6.69253, -23.9039, 60.0823},
  {2.83948, -7.022, 39.6044}, {-22.7272, -19.7003, 43.8634},
  {-1.86162, -2.31597, 24.0146}, {-13.805, 0.484695, 27.7517},
  {4.10877, -1.64352, -5.15719}, {-27.1321, -4.86069, 35.2986}}}
```

In[5339]:=
```
pose3 = (Append[pose3, {0., 0., 0., 1.}].Append[pose2, {0., 0., 0., 1.}])[[1 ;; 3]];
Rs[[3]].Ts[[3]]
pose3 // MatrixForm
```

Out[5340]=
$$\text{TransformationFunction}\left[\left(\begin{array}{ccc|c} 0.990125 & -0.102776 & -0.095337 & -1.43195 \\ 0.10008 & 0.994443 & -0.0326566 & -3.3504 \\ 0.0981636 & 0.0227929 & 0.994909 & -2.80448 \\ \hline 0. & 0. & 0. & 1. \end{array}\right)\right]$$

Out[5341]//MatrixForm=
$$\begin{pmatrix} -0.990125 & 0.102776 & 0.095337 & -1.54355 \\ -0.10008 & -0.994443 & 0.0326566 & 2.85529 \\ -0.0981636 & -0.0227929 & -0.994909 & 2.34159 \end{pmatrix}$$

In[5342]:=
```
(* Perform SLAM for each consecutive pair of cameras *)
pose1 = MapThread[Append,
   {IdentityMatrix[3, WorkingPrecision → MachinePrecision], {0., 0., 0.}}];
poses = {pose1};
Xs = {};
For[i = 1, i < noOfFrames, i++,
  {pose2, X} = SLAM[Ks[[i]], camImgPointss[[i, commonPtsIdx[[i]]]], Ks[[i + 1]],
    camImgPointss[[i + 1, commonPtsIdx[[i]]]], camTransl[[i]], poses[[i]]];
  poses = Append[poses, (Append[pose2, {0., 0., 0., 1.}].
       Append[poses[[i]], {0., 0., 0., 1.}])[[1 ;; 3]]]
 ];
```

In[5099]:=
```
Dimensions[poses]
```

Out[5099]=
```
{10, 3, 4}
```

In[5346]:=
```
For[i = 1, i < noOfFrames, i++, Print[i];
 Print["Actual"];
 Print[N[Rs[[i]].Ts[[i]]][[1, 1 ;; 3]] // MatrixForm];
 Print["Predicted"];
 Print[poses[[i]] // MatrixForm];
 Print[]]
```

1

Actual

$$\begin{pmatrix} 1. & 0. & 0. & 0. \\ 0. & 1. & 0. & 0. \\ 0. & 0. & 1. & 0. \end{pmatrix}$$

Predicted

$$\begin{pmatrix} 1. & 0. & 0. & 0. \\ 0. & 1. & 0. & 0. \\ 0. & 0. & 1. & 0. \end{pmatrix}$$

2

Actual

$$\begin{pmatrix} 0.365777 & 0.721349 & 0.588101 & -1.89856 \\ -0.721349 & 0.619012 & -0.310612 & 1.11022 \times 10^{-16} \\ -0.588101 & -0.310612 & 0.746765 & 0. \end{pmatrix}$$

Predicted

$$\begin{pmatrix} 0.365777 & 0.721349 & 0.588101 & -1.89856 \\ -0.721349 & 0.619012 & -0.310612 & -5.84699 \times 10^{-13} \\ -0.588101 & -0.310612 & 0.746765 & 1.4595 \times 10^{-12} \end{pmatrix}$$

3

Actual

$$\begin{pmatrix} 0.990125 & -0.102776 & -0.095337 & -1.43195 \\ 0.10008 & 0.994443 & -0.0326566 & -3.3504 \\ 0.0981636 & 0.0227929 & 0.994909 & -2.80448 \end{pmatrix}$$

Predicted

$$\begin{pmatrix} -0.990125 & 0.102776 & 0.095337 & -1.54355 \\ -0.10008 & -0.994443 & 0.0326566 & 2.85529 \\ -0.0981636 & -0.0227929 & -0.994909 & 2.34159 \end{pmatrix}$$

4

Actual

$$\begin{pmatrix} 0.794894 & -0.450628 & -0.406299 & 0.227693 \\ 0.337645 & 0.884896 & -0.320865 & -3.66936 \\ 0.504123 & 0.117869 & 0.855551 & -4.286 \end{pmatrix}$$

Predicted

$$\begin{pmatrix} -0.794894 & 0.450628 & 0.406299 & -3.95836 \\ -0.337645 & -0.884896 & 0.320865 & 0.71711 \\ -0.504123 & -0.117869 & -0.855551 & 1.28701 \end{pmatrix}$$

5

Actual

$$\begin{pmatrix} 0.96763 & -0.154475 & 0.199575 & -4.69821 \\ 0.131131 & 0.983403 & 0.125392 & -5.3842 \\ -0.215633 & -0.0951627 & 0.971826 & -1.5012 \end{pmatrix}$$

Predicted

$$\begin{pmatrix} 0.662854 & 0.699388 & 0.267358 & -0.0403922 \\ 0.699388 & -0.705841 & 0.11245 & 4.46544 \\ 0.267358 & 0.11245 & -0.957013 & 3.58381 \end{pmatrix}$$

6

Actual

$$\begin{pmatrix} 0.496954 & 0.288998 & 0.81824 & -8.2048 \\ -0.451666 & 0.891268 & -0.0404745 & -2.25067 \\ -0.740969 & -0.349458 & 0.57345 & 2.87498 \end{pmatrix}$$

Predicted

$$\begin{pmatrix} -0.496954 & 0.451666 & 0.740969 & -3.43295 \\ -0.288998 & -0.891268 & 0.349458 & 0.994256 \\ -0.81824 & 0.0404745 & -0.57345 & -1.57023 \end{pmatrix}$$

7

Actual

$$\begin{pmatrix} 0.70709 & -0.291599 & -0.6442 & 0.884413 \\ 0.363805 & 0.931211 & -0.0221937 & -7.5843 \\ 0.606357 & -0.21867 & 0.764535 & -7.35493 \end{pmatrix}$$

Predicted

$$\begin{pmatrix} -0.800205 & -0.597332 & -0.0535366 & -1.66516 \\ -0.168085 & 0.309068 & -0.936069 & 0.106922 \\ 0.57569 & -0.740048 & -0.34772 & 5.28272 \end{pmatrix}$$

8

Actual

$$\begin{pmatrix} 0.980452 & 0.0453209 & 0.191469 & -9.59335 \\ -0.047318 & 0.998863 & 0.00586874 & -5.83333 \\ -0.190985 & -0.0148139 & 0.981481 & -5.855 \end{pmatrix}$$

Predicted

$$\begin{pmatrix} -0.0909981 & -0.751526 & -0.653397 & 0.840239 \\ -0.0302339 & 0.657902 & -0.752497 & -0.206993 \\ 0.995392 & -0.048721 & -0.0825894 & 4.74308 \end{pmatrix}$$

9

Actual

$$\begin{pmatrix} 0.820186 & 0.495755 & 0.285521 & -13.3164 \\ -0.346553 & 0.827627 & -0.441514 & 0.537002 \\ -0.455187 & 0.263176 & 0.850613 & -6.1536 \end{pmatrix}$$

Predicted

$$\begin{pmatrix} 0.0216655 & -0.366619 & -0.930119 & 0.0103899 \\ -0.367876 & 0.862142 & -0.348394 & -2.90247 \\ 0.929622 & 0.349717 & -0.116192 & 2.16226 \end{pmatrix}$$