**Using the Inverse Kinematics code with Electromagnetic sensor data**

Note: This guide was originally prepared to be used with the trakSTAR system, but should be easily adaptable to any other EM sensor system.

The following files will be necessary for the Inverse Kinematics program to work:

1. trakSTARunits2SIunits.m
2. stylus.m
3. sensAng2RU.m
4. R2abg\_7DOF.m
5. R2abg.m
6. pre\_P2R.m
7. pre\_L2R.m
8. pre\_ICR.m
9. P2R.m
10. MatMult3.m
11. L2R.m
12. ICR.m
13. CalibrationL.m
14. CalibrationP.m
15. aer2R.m
16. data files (described below)

The program works under the assumption that the data is formatted in a particular way. If your data is not initially in this format, you will need to alter the data such that it will work with the code. The description of this format is listed below for both the Landmark Calibration and Posture Calibration methods. After the data files are acquired from trakSTAR or a similar apparatus, import the files into MATLAB as a delimited numeric matrix, with unimportable cells replaced by NaN. Once imported, save them each as .mat files.

**Landmark Calibration:**

You will need four data files (Mmat, CALmat, Gmat, and s\_opt).

* **Mmat** is an Nx43 matrix of trakSTAR data recorded as the subject made a number of movements throughout the experiment. It contains the data that will be analyzed, and is the only one of the four data files that will not be part of calibration.
  + As with all of the Nx43 Matrices, the 43 columns in Mmat represent the following:

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | … | 43 |
| Sensor # | X position of sensor | Y position of sensor | Z position of sensor | Azimuth angle of sensor | Elevation angle of sensor | Roll  angle of sensor | (repeat for sensors 2-6) | timestamp |

* + If using trakSTAR, hit the MARK key to signal important points in the data (i.e. MARK #1 represents shoulder abduction). In the processed data, these MARK points will show up as NaN rows.
* **CALmat**: for Landmark Calibration, this is an Nx43 matrix that contains the data describing the sensor position and landmark position when each of the landmarks are touched with the stylus. As the landmarks are touched with the stylus, hit the MARK key. NOTE: the landmarks must be marked in the following order:

|  |  |
| --- | --- |
| **Abbreviation** | **Description** |
| C7 | Processus Spinosus (spinous process) of the 7th cervical vertebra |
| T8 | Processus Spinosus (spinous process) of the 8th thoracic vertebra |
| IJ | Deepest point of Incisura Jugularis (suprasternal notch) |
| PX | Processus Xiphoideus (xiphoid process), most caudal point on the sternum |
| EL | Most caudal point on lateral epicondyle |
| EM | Most caudal point on medial epicondyle |
| RS | Most caudal-lateral point on the radial styloid |
| US | Most caudal-medial point on the ulnar styloid |
| MC2h | Dorsal projection of midpoint of head of second metacarpal |
| MC3h | Dorsal projection of midpoint of head of third metacarpal |
| MC4h | Dorsal projection of midpoint of head of fourth metacarpal |
| MC3b | Dorsal projection of midpoint of base of third metacarpal |

(For a detailed explanation of the Calibration procedure, see the Inverse Kinematics Paper)

* **Gmat**: an Nx43 matrix containing the data necessary to calculate the center of rotation for the glenohumeral joint. (If not using the Landmark Calibration method, this must be an empty matrix []). To obtain this matrix, have the patient perform the following movements after the program begins: from NP to 90 degree abduction; then back to NP; then to 90 degree flexion; then back to NP; to full extension; then back to NP
* **S\_opt:** This is a 3-element vector describing the position of the tip of the stylus in the frame of the sensor. If no calibration was performed, the default should be [0;0;0]. To calibrate the stylus, get an Nx8 matrix by attaching 1 sensor to the end of a stylus. Keep the tip (non-sensor side) of the stylus in place as you rotate the sensor side of the stylus freely. Then in order to properly calibrate the s\_opt vector:
  1. Open the file pre\_ICR and read the information of CASE 1.
  2. The Nx8 calibration movement data matrix, which will be used as the mat input, should be run through the trakSTARunits2SIunits function.
  3. Run the pre\_ICR function with the mat input. The output of pCR is the desired s\_opt vector.

**Posture Calibration:**

You will need four data files (Mmat, CALmat, Gmat, and s\_opt).

* **Mmat:** same as described above.
* **CALmat:** For Posture Calibration, this is an Nx43 matrix that contains data taken at the moment of the posture calibration. This is done by lining up all of the Body Coordinate Systems of the upper limb in Neutral Position (from anatomical position, flex elbow 90 degrees and pronate forearm 90 degrees). When they are aligned, hit the MARK key on trakSTAR.
* **Gmat:** for posture calibration, Gmat is an empty matrix: [ ].
* **S\_opt:** Same as described above.

**Approximation:** In addition to the data files, running this program will also require you to specify an approximation level. (These are built into the function and require no additional files.) Apart from the full 9 Degree of Freedom model of the arm, this program can run a simplified model of the arm with 7 degrees of freedom:

0: Full 9-DOF model, i.e. no approximation

1: 7-DOF model (be = gw = 0 by default, can change within sens2joint.m)

Simply pick the desired approximation and list the corresponding number after the data files in the sens2joint function.

[abg\_s, abg\_e, abg\_w, t] = sens2joint( Mmat, CALmat, Gmat, s\_opt, approx)

**Running the program:** If you have correctly loaded all of the functions and data files, you are ready to run the program. Simply open the sens2joint.m file, and run the program with the data files and the approximation called out as specified. You should get 3 resulting output matrices: abg\_s, abg\_e, abg\_w, (as well as t, which is a time vector for the Mmat file). These abg files are Nx3 and contain alpha, beta, gamma joint angles over time t for shoulder, elbow, and wrist, respectively.

**Changing Shoulder Joint Euler Angles:** Some applications of the software favor a particular order for the Euler angles of the shoulder. These can be selected in R2abg.m or R2abg\_7DOF.m, depending on which approximation you are using. The standard is ZXY, but the equations for YXY are provided. You just need to comment/uncomment the relevant sections.

**Examples:**

Function sens2joint use:

Let's say I want the joint angles using a 7 DOF approximation using Landmark calibration. Let's also assume I don't want to take the time to determine the s\_opt vector. The implementation is as follows:

[abg\_s, abg\_e, abg\_w, t] = sens2joint(Mmat, CALmat, Gmat, [0,0,0], 1);

(Where CALmat is the landmark calibration data matrix)

This would return the desired joint angles.

If I wanted to use Posture calibration for the same approximation instead, then I would implement the function as follows:

[abg\_s, abg\_e, abg\_w, t] = sens2joint(Mmat, CALmat, [], [0,0,0], 1);

(Where CALmat is the posture calibration matrix)

This would return the desired joint angles