A. More about Nancy

How to drive the data driven animation

Nancy was animated using Matlab code adapted from code supplied by the vendor, (version 1.0, XM MT9-B © 2003, Xsens Technologies B.V.author, Per Slycke). Two changes were made to the code. The first change extended the animation from a five-segment upper body model to a ten-segment whole body model. The second improvement allowed the IMUs to be attached to the body segments in the most practical places to avoid skin artefacts. In the original code the IMUs had to be precisely placed with the local z-axis of each IMU aligned with the subject's antero-posterior (AP) axis in the anatomical position. The original code posed problems for the IMU that was to be attached to the posterior aspect of the sacrum. The original code was also undesirable because it required the IMU, to be attached to the anterior surface of biceps brachii, which could exacerbate skin artefacts.

First each IMU was mapped to the subject's limbs by a constant rotation matrix. Mapping was completed with the subject standing stationary in a calibration position at the start of the test. The anatomical position (subject standing upright with arms straight down beside the body and palms facing forward) was used as the calibration position. The IMUs provided information about the local limb orientation. To produce a data driven animation each limb segment was linked to the known location of its proximal joint centre. The animation had to have an external constraint; in this case the C6-7 cervical joint centre, was constrained to a fixed location. This gave the appearance of the subject being suspended from this joint, or being 'hung from a coat hanger'. Other constraints such as not allowing the feet to slip against the floor or additional global measurements might have been used to obtain a global trajectory but they were not implemented in the code.

Animation code changes

A brief explanation of some of the software changes follows. If the reader has access to MATLAB, the XSens COM[1] object and 10 IMUs connected to an XBus then this code can be executed.

In the modified code, the first change occurs when five additional data sets, describing the rotation of each IMU are acquired from the five additional IMUs and put in a cell array called **`M_Rsg.(Sensor ID)`**. This happens automatically when the additional IMUs are attached to the XBus Master.

Five additional variables are then defined that represent instantaneous global orientation of the lower body segments: (**`body_partX_rot`**, where X = 8 to 12). Each **`body_partX_rot`** variable contains the coordinates of the vertices of the triangular patches that made up the instantaneous surfaces of each body segment. Five additional joint centres are defined called: **`waist`**, **`left_hip`**, **`left_knee`**,

[1] COM (Component Object Model) refers to both a specification and implementation developed by Microsoft, which provides a framework for integrating components. In this case the COM object is used to communicate with the XBus without the need for serial communication protocol.

`right_hip`, **`right_knee`**. The additional information is passed to a function called **`XM_Nancy_model`** that connects the additional lower limbs to their proximal joint centres, starting at the hip joint centres of the **`sacrum`** body segment.

The IMU to limb segment calibration procedure was re-developed to allow the IMUs to be placed on the flattest part of each body segment. With the subject in the calibration position (anatomical pose) the following procedure is initiated in Matthew's changed code by pressing the 'M' key:

1. The instantaneous raw orientation of each IMU is recorded in a structure called **`ms{x}`** where X takes on a value of 1 to 12. Orientation is recorded as a 3x3 orientation matrix.
2. The heading or the antero-posterior (AP) axis of the subject called **`Thorax_Heading`** is defined by the negative projection of the Thorax IMU local z-axis on the global XY plane. The heading is then stored in a 3x3 rotation matrix describing a rotation about the global Z-axis.
3. A calibration matrix is then defined called **`m_def{X}`** for each limb segment. It is formed by the matrix multiplication of the inverse of **`ms{x}`** by the inverse of the **`Thorax_Heading`**.
4. Subsequent IMU raw orientation data are multiplied by the calibration matrix **`m_def{X}`** before being used to drive the motion of the body model segments.

Assumptions of IMU motion capture

The first assumption made was that the heading of the z-axis of the IMU attached between the subject's shoulder blades was aligned with the heading of the anterior-posterior (AP) axes of the subject's body segments while standing in the anatomical position. (In this thesis heading generally refers to the projection of a vector onto the horizontal plane.) Therefore, immediately after calibration of the subject, multiplication of IMU raw orientation by the calibration matrix, (**`m_def{X}`**) should have resulted in the identity matrix with an additional heading correction about the global Z-axis. The additional heading correction brought the headings of the limb segments in line with the AP axis of the subject. The additional heading correction was required because unlike the old IMU placement, the new placement of the IMUs did not physically align the IMU headings.

If the headings of the limb segments are inconsistent (because a heading correction is not made) then although a subject will be accurately represented in the calibrated position, subsequent limb rotations might be animated about the wrong local limb axes.

The second assumption made was that the body model accurately represented the subject's dimensions and that the calibrated position adopted by the subject was accurate. The code improvements worked because the points that made up the graphical representation of each body segment were defined so that in the anatomical position, the orientation of the limb was described by the identity matrix plus a heading correction based on the AP axis of the subject's thorax.