Instruction Manual: Multimodal Analysis

Integration of Xsens, Noraxon EMG, and Force Sensor

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1. Xsens System Placement (Kinematics)

The Xsens Awinda system uses wireless IMU sensors (MTw) to capture orientation in space. The precision of the biomechanical model depends critically on the alignment of the sensor axes with the bone segments.

1.1. Key Sensor Placement (Views)

The official Xsens protocol for the "Unified Rajagopal" biomechanical model has been followed. The three main views of the instrumented subject are shown below.

Figure 1: Posterior View. Pelvis sensor centered on the sacrum.

Figure 2: Anterior View. Sternum sensor flat and centered.

Figure 3: Lateral View. Humeral and radial sensors aligned.

1.2. Anatomical Landmarks

- **Pelvis:** Over the sacrum, on the midline between the posterior superior iliac spines (See Fig. 1).
- **Torso (Sternum):** Flat part of the sternum, avoiding the xiphoid process to reduce breathing artifacts (See Fig. 2).
- **Humerus (Arm):** Outer lateral face, on the muscle belly between the deltoid and the elbow.
- **Radius (Forearm):** Flat dorsal face, near the wrist (styloid process), avoiding excessive skin rotation (See Fig. 3).
- **Hand:** Dorsum of the hand, firmly fixed with tape or a glove.

Note: Sensors must be secured with the provided velcro straps, ensuring there is no slipping during fast movements.

2. Noraxon EMG Sensor Placement

Placement follows the SENIAM standard to ensure study repeatability. The main agonist and stabilizer muscles involved in the cutting task are monitored.

2.1. Skin Preparation Protocol

Clean the area with isopropyl alcohol and shave if necessary to ensure an impedance $< 5k\Omega$. *Place the dual electrodes on the muscle belly, parallel to the fibers.*

2.2. Electrode Location (Views)

The placement areas for the right hemibody are detailed below.

Figure 4: Anterior View. Biceps and Pectoralis.

Figure 5: Lateral View. Triceps and Middle Deltoid.

Figure 6: Posterior View. Trapezius and Latissimus Dorsi.

3. Sensor Mapping

3.1. Channel Configuration (Acquisition Order)

The assignment of sensor IDs corresponds strictly to the column order generated by the Noraxon acquisition system (CSV V1).

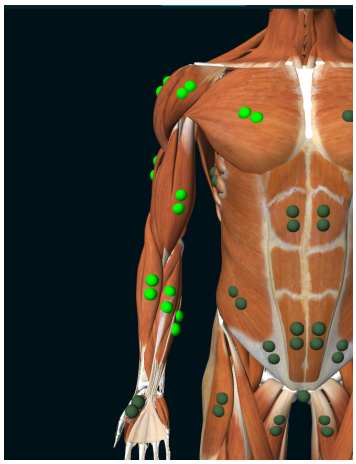

Figure 7: EMG channel configuration (Part 1).

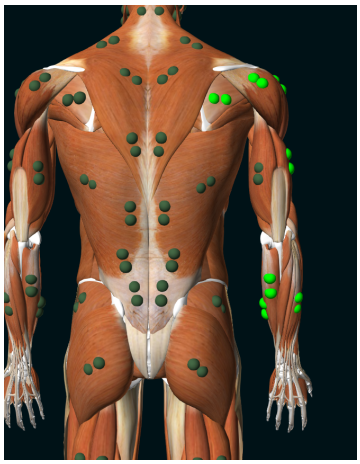

Figure 8: EMG channel configuration (Part 2).

Sensor ID	Muscle (CSV Label)	Main Biomechanical Function
1	Brachioradialis	Elbow flexion (Neutral position)
2	Extensor Carpi Ulnaris	Extension and ulnar deviation
3	Flexor Carpi Ulnaris	Flexion and ulnar deviation
4	Extensor Digitorum	Finger and wrist extension
5	Biceps Brachii	Elbow flexion and supination
6	Triceps Brachii (Lateral)	Elbow extension
7	Anterior Deltoid	Shoulder flexion (Frontal elevation)
8	Posterior Deltoid	Shoulder extension (Retraction)
9	Middle Deltoid	Shoulder abduction (Lateral elevation)
10	Pectoralis Major	Horizontal adduction / Internal rotation
11	Infraspinatus	External rotation (Rotator cuff)
12	Flexor Carpi Radialis	Flexion and radial deviation

Table 1: EMG sensor mapping according to recording order (V1).

3.2. Integration with Inertial Sensors (Layer 3)

Xsens sensors are placed on bone segments, avoiding direct contact with EMG cables or sensors to prevent movement artifacts.

Sensor ID	Segment	Critical Location
10B41517	**Pelvis**	Sacrum (L5/S1). Fundamental for OpenSim.
10B4151A	**Sternum**	Flat chest.
10B4151C	**Right Arm**	Outer lateral face (between Biceps/Triceps).
10B4215D	**Right Forearm**	Wrist (Dorsal/Watch).
10B41515	**Right Hand**	Dorsum of the hand (Over glove if present).
10B414FE	**Left Arm**	Symmetrical to the right.
10B414FF	**Left Forearm**	Symmetrical to the right.

Table 2: Xsens Sensor Map with Hardware IDs.

4. Recording and Synchronization Protocol

Data fusion strictly depends on compliance with the following steps:

4.1. Software Preparation

- Open **MT Manager** and start recording.
- Open **Noraxon MR3** and start recording.
- Start the **OnRobot Force Sensor** software.

4.2. The Synchronization

Before starting the cutting task, the operator must:

1. Remain motionless for 10 seconds, this is for the calibration of the IMU sensors.
2. Perform three **sharp and fast strikes** on the force sensor with the knife.
3. The impact must simultaneously record a peak in force, an artifact in the EMG, and an acceleration peak in the hand (Xsens).

4.3. Execution

Perform the cut continuously. Upon completion, save the files with the same nomenclature (e.g. `V1_force.csv`, `V1_emg.csv`) adapting it to the execution code.

5. Automatic Analysis (Pipeline)

Once the data is obtained, the Python environment is used to:

1. **Conversion:** Generate the `.sto` file from the Xsens binaries.
2. **Fusion:** Execute `fusion_multimodal.py` to align the signals at $T = 0$.
3. **Analysis:** Generate the linear envelopes (6 Hz) and the SNR report.