Towards an automatic parameter setting for MIMU sensor fusion algorithms

M. Caruso[1], R. Rossanigo[1], A. M. Sabatini[2], M. Knaflitz[1], M. Gazzoni[1], U. Della Croce[3], A. Cereatti[3]
[1] *Politecnico di Torino, Torino, Italy,* [2] *Scuola Superiore Sant'Anna, Pisa, Italy,* [3] *Università degli studi di Sassari, Sassari, Italy*

INTRODUCTION

Magnetic and Inertial Measurement Units (MIMU) are widely used in human movement analysis. MIMU orientation can be determined by combining accelerometer, gyroscope, and magnetometer data in a sensor fusion framework. Any algorithm for orientation estimation requires to define a given number of input parameters. It has been shown that any algorithm performance greatly varies depending on the selection of the parameter values according to both hardware and motion characteristics [1]. It is common practice to choose parameters values as set by the authors in their original implementations or by following a *trial and error* approach [2]. Unfortunately, the latter solutions are time-demanding, require a good level of expertise and do not guarantee for generalization. The aim of this work was to propose a method for sub-optimal parameter values identification based on specific hardware characteristics, different angular rates and types of motion without requiring reference data. The method validity was assessed on a popular complementary filter [2] using data recorded from a motion capture optical system (SP) as reference.

METHODS

The proposed method relies on the hypothesis that the value of the filter parameters minimizing the relative orientation of two MIMUs attached on the same rigid body, can be considered sub-optimal. The method validity was tested on Madgiwck's filter (MAD, [2]) which requires only one parameter to be set (β). Two pairs of MIMUs (Xsens-MTx and APDM-Opal) were aligned on a board equipped with four reflective markers. Reference orientation was obtained from marker trajectories acquired using a 12-camera SP (Vicon T20). A dynamic trial was recorded while an operator continuously changed the board orientation from 0° to 180° and back for five repetitions (2D motion) and then by performing a multi-axis rotation (3D motion). This protocol was executed at three rotation rates (rms 120-260-380 °/s). For each factor (hardware, angular rate, and type of motion), the orientation of each pair of MIMUs was computed for 76 values of β and then compared with SP to obtain the absolute orientation errors. Then, we searched for β* which minimized the relative orientation difference and for the interval of β values which corresponded to the absolute errors within the minimum (*E_min*) + 0,5°.

RESULTS

The values of β interval, *E_min* and β* are listed in Table 1 for both 2D and 3D results. The errors corresponding to β* (*E**) and to the default β=0.1 (*E_def*) set by Madgwick *et al.* in their original Matlab implementation [1-2] are also reported.

Table 1. Results for each condition analyzed (S=slow, M=medium, F=fast, XS=Xsens, AP=APDM).

		2D					3D				
		β interval	E_min	β*	E*	E_def	β interval	E_min	β*	E*	E_def
XS	**S**	0 – 0.0015	2.1°	0.0009	2.2°	4.2°	0 – 0.0498	2.3°	0.0050	2.3°	3.2°
	M	0 – 0.0018	2.0°	0	2.0°	5.0°	0 – 0.0550	2.1°	0.0074	2.1°	3.1°
	F	0 – 0.0020	3.0°	0	3.0°	6.1°	0 – 0.0743	4.9°	0.0273	5.0°	5.7°
AP	**S**	0.0082 – 0.1353	3.4°	0.0821	3.5°	3.6°	0.0101 – 0.0907	2.3°	0.1108	2.9°	2.8°
	M	0.0050 – 0.1827	5.5°	0.0302	5.5°	5.7°	0.0450 – 0.1827	3.5°	0.0608	3.6°	3.5°
	F	0 – 0.0498	6.8°	0.0041	6.9°	7.9°	0.0334 – 0.1496	7.3°	0.2231	8.8°	7.3°

DISCUSSION

Table 1 shows that the intervals of *β* where the errors are minimum were different depending on angular rate values, planarity of motion, and the MIMU model employed. These findings suggest that a fixed value of *β* could be not suitable for all experimental conditions. Moreover, the errors obtained using *β** computed with the novel proposed algorithm were close to *E_min* and the higher difference reached 1.5° for APDM-Fast-3D. For Xsens the errors obtained using *β** were lower than *E_def* in all cases.

This study was partially supported by DoMoMEA grant, Sardegna Ricerche POR FESR 2014/2020.

REFERENCES

[1] Bergamini, et al. *Sensors* 2014; 10: 18625 18649.
[2] Madgwick S. O. H. et al. 2011; ICORR, 2011.