PREDICTION OF LOWER LIMB SEGMENT KINEMATICS FROM FOOT ACCELERATIONS

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INTRODUCTION

Whilst gait analysis has proved useful for clinical applications its use is still limited by the cost of the facilities, the time and resource required for data collection and analysis, and the fact that the data is only a snapshot of how a patient walks under laboratory conditions. We do not know how representative gait assessment in a laboratory is of gait during daily lives. As a result of these limitations there are efforts to develop "wearable" gait laboratories that provide continuous and daily monitoring of gait. The basis of these systems is that a suitably small number of wearable sensors can be used to measure and represent human motion and activity. Through these systems 1000's rather than 10's of gait cycles from real world situations can be assessed and a truly representative quantification of patient gait (and other activities) acquired. Of the technical challenges in this development, the use of as few and simple motion sensors as possible and the extraction of the maximum amount of motion information as possible is paramount. This would lead to small, inexpensive, light weight and therefore acceptable wearable systems, and yet little or no compromise on data quality for gait researchers. The work described here uses acceleration data of the foot to predict sagittal plane foot, shank and thigh kinematics. For the "wearable gait laboratory" concept this emulates the use of accelerometers to measure foot acceleration, but the extraction from that of full lower limb sagittal plane kinematic data.

METHODS

Kinematic data were collected on 8 subjects using the CAST marker system for the foot, shank, thigh and pelvis and 10 Vicon cameras. From the foot markers the acceleration of the foot in two directions were determined. Also, foot, shank and thigh angles in the sagittal plane are calculated. Several different regression techniques were used (eg: Linear regression, Multi Layer Perception, Polynomial, Functional Link and Radial Basis Neural Networks and k-Nearest Neighbours, Generalised Regression Networks), to predict the foot, shank, and thigh motion patterns from the foot acceleration data. Data from 5 gait cycles for each of the 8 subjects was used with a 4-fold Cross-Validation process. The 8 subjects are split to 4 groups of 2, and each time we use 3 groups for training of the regression tools and 1 for testing of the tools. The final errors are calculated from averaging the errors for the 4 runs of the training-testing stages. The errors measured were the used Cross-Correlation coefficient (CC), the Root Mean Square (RMS), the Maximum Absolute Deviation (MAD) and a Thresholded Absolute Deviation (TAD) that represents the percentage of angle error predictions exceeding a user-defined threshold set to *5°*. Table 1 presents these errors for each of the six redicted signals. Figure1 (top) displays single (1 out of the four) repetitions of Cross-Validation (where subjects 7 & 8 are used to test algorithms and all other 1,..,6 are used for training). Figure 1 (bottom) presents the training (top graphs -6 subjects)Figure 3 displays testing of θ_{rf} prediction (r = right leg, l = left leg, f = foot, s = shank, t = = thigh..

	testing stage				training stage			
	CC	RMS	MAD	TAD	CC	RMS	MAD	TAD
θ_{rf}	0.98	9.19	7.72	62.3	0.99	5.31	3.72	25.3
θ_{rs}	0.99	4.27	3.27	20.5	0.99	2.76	1.78	06.9
θ_{rt}	0.98	4.19	3.38	23.3	0.99	2.71	1.91	07.8
θ_{lf}	0.98	7.95	6.36	53.3	0.99	4.77	3.40	24.4
θ_{ls}	0.99	4.11	3.00	16.7	0.99	2.82	1.85	07.4
θ_{lt}	0.98	4.06	3.23	21.7	0.99	2.36	1.66	04.5
avg	0.98	5.62	4.49	32.9	0.99	3.46	2.39	12.7

Table 1: errors in the prediction of segments kinematics from foot accelerations.

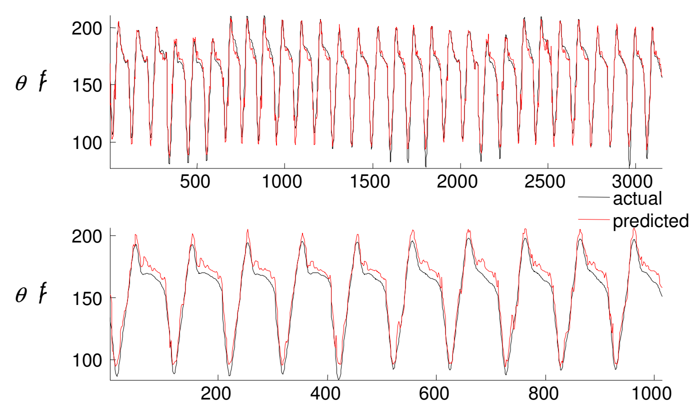

Figure 1: training the algorithms

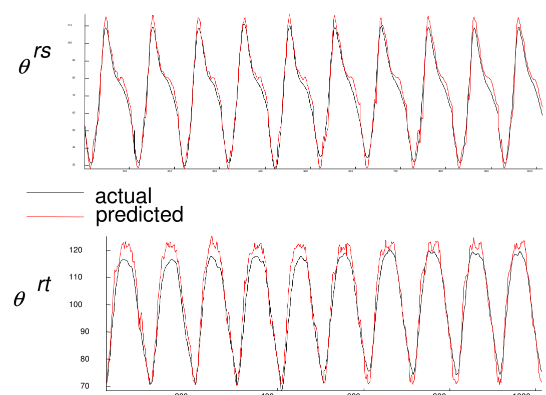

Figure 2: Testing of θ_{rs} and θ_{rt}.

ACKNOWLEDGEMENTS

This project (Real-Prof) was funded by the IST programme of the EU RTD funding (1.2 Million Euros, Jan 2003-Oct 2005).