Supplementary Material for "WVD-MODWT: An Enhanced Wigner-Ville Distribution for the Automated Control of Human-Machine Interaction-based Systems"

The supplementary material includes additional figures for further explanation of the proposed method. Table I presents the list of mathematical terms used in this paper with their description. Fig. 1 present the enhanced TFRs generated by the proposed WVD-MODWT method for different sample eye movements of Dataset-I. Fig. 2 shows the enhanced TFRs for different sample gestures after applying the proposed WVD-MODWT method. Table II and Table III present the classification performance of the WVD with cross-term interference evaluated separately on Dataset-I and Dataset-II. Fig. 3 present the confusion matrices for the classification results of Dataset-I and Dataset-II utilizing WVD with cross-term interference.

TABLE I
DESCRIPTION OF THE MATHEMATICAL TERMS UTILIZED.

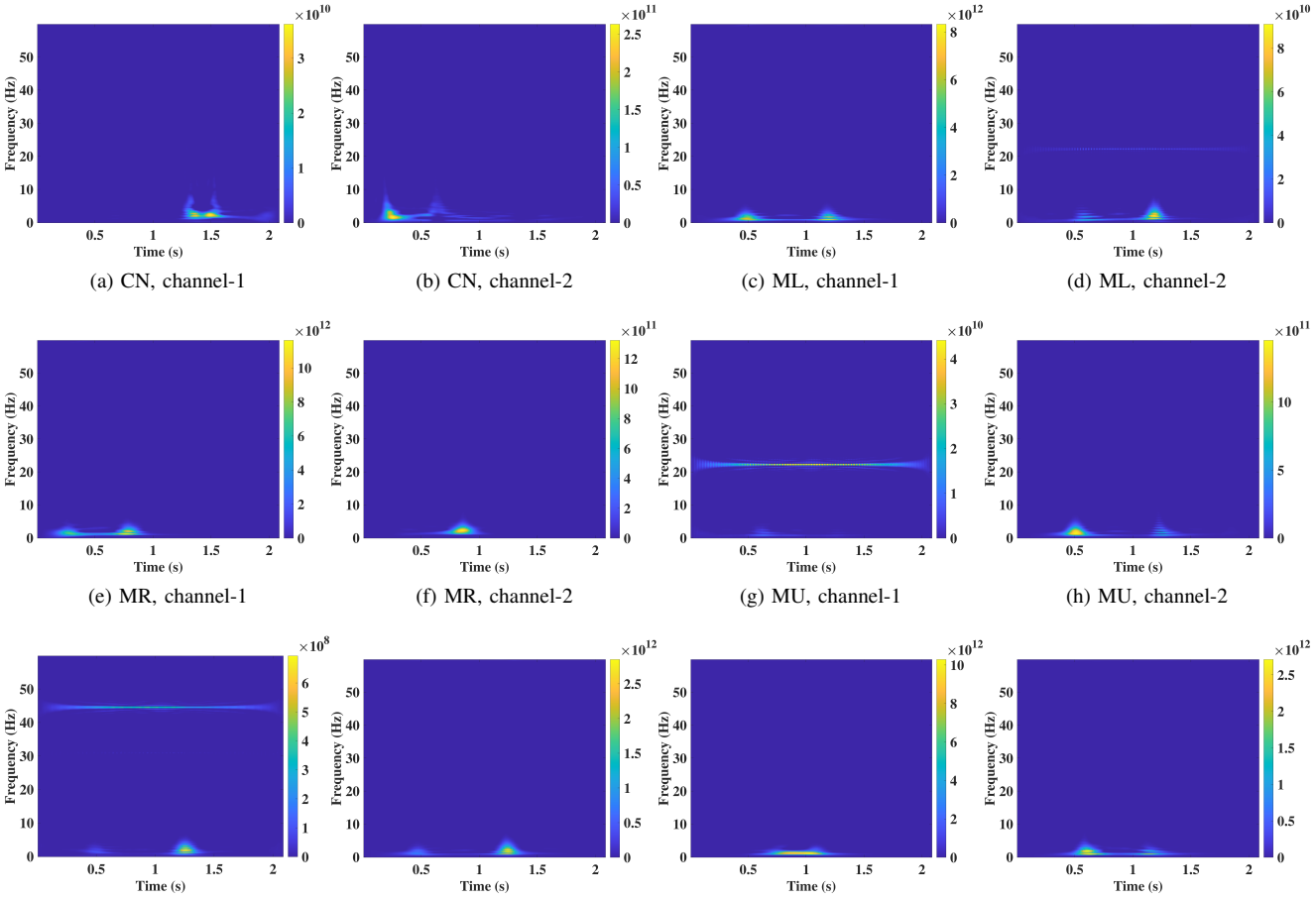
Mathematical terms	Description
$\Phi_x(t,f)$	WVD of a signal $x(t)$
$x_a(t)$	Analytic representation of $x(t)$
τ	Time lag parameter
$\mathcal{H}[\cdot]$	Hilbert transform operator
$\mathcal{X}(f)$	Spectral response of signal $x(t)$
$x_m(t)$	Multi-component signal
$\Phi_{x_1}(t,f)$ and $\Phi_{x_2}(t,f)$	WVDs of signals $x_1(t)$ and $x_2(t)$, respectively
$\Phi_{x_1x_2}(t,f)$	Cross-WVD of signals
x_{a_1} and x_{a_2}	Analytic representations of x_1 and x_2, respectively
(C)	Wavelet coefficient
(U)	Scaling coefficient
$\hat{p}_{j,k}$ and $\hat{q}_{j,k}$	Wavelet (high-pass) and scaling (low-pass) filters corresponding to the j^{th} decomposition level of the MODWT, respectively
$\Phi_x[i,l]$	WVD of signal $x[i]$ consisting of I samples
$\Phi_x^T[i,l]$	Time samples-based enhanced WVD
$\Phi_x^F[i,l]$	Frequency indices-based enhanced WVD
$\Phi_x^E[i,l]$	Cross-terms-free WVD

TABLE II
RESULTS OF VARIOUS PERFORMANCE MEASURES FOR THE WVD WITH CROSS-TERM INTERFERENCE ON DATASET-I.

Indices	CN	MD	ML	MP	MR	MU	Macro	Micro accuracy
Accuracy	99.33	100	99.33	98	98.83	99.17	99.11	97.33
Precision	98.98	100	98.98	94.90	95.15	96.12	97.35	
Recall	97	100	97	93	98	99	97.33	
F1-score	97.98	100	97.98	93.94	96.55	97.54	97.33	

TABLE III
RESULTS OF VARIOUS PERFORMANCE MEASURES FOR THE WVD WITH CROSS-TERM INTERFERENCE ON DATASET-II.

Indices	CF	CL	FF	SH	WE	WF	FM	FS	Macro	Micro accuracy
Accuracy	99.47	99.76	98.94	99.38	97.76	98.02	98.94	99.05	98.92	95.66
Precision	98.51	98.74	95.24	97.17	89.72	92.75	96.05	97.35	95.69	
Recall	97.21	99.44	96.75	97.62	92.07	92.11	95.11	95.04	95.67	
F1-score	97.86	99.09	95.99	97.39	90.88	92.43	95.57	96.18	95.67	



(a) CN, channel-1 (b) CN, channel-2 (c) ML, channel-1 (d) ML, channel-2

(e) MR, channel-1 (f) MR, channel-2 (g) MU, channel-1 (h) MU, channel-2

(i) MD, channel-1 (j) MD, channel-2 (k) MP, channel-1 (l) MP, channel-2

Fig. 1. WVD-MODWT generated TFRs for representative eye movement samples from Dataset-I.

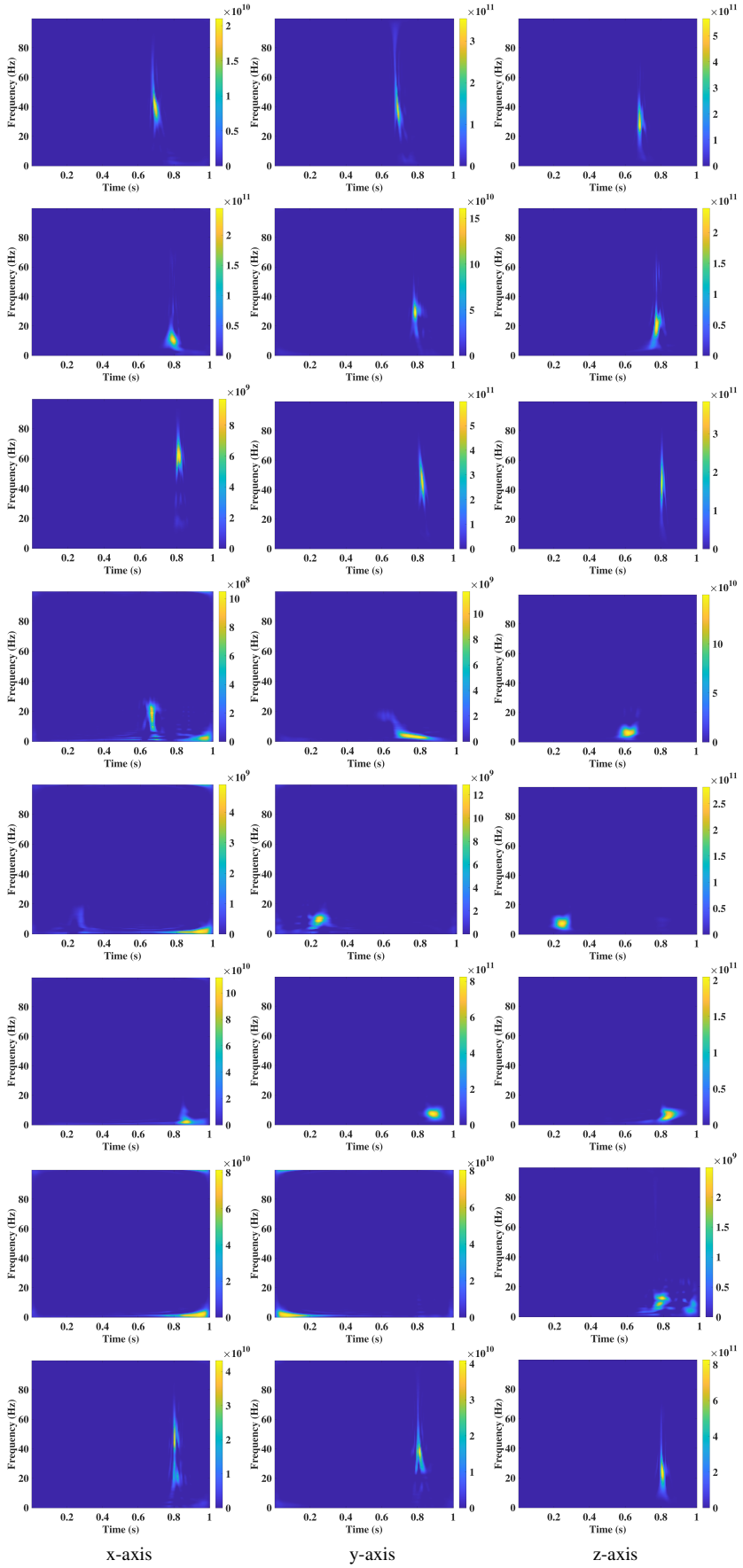
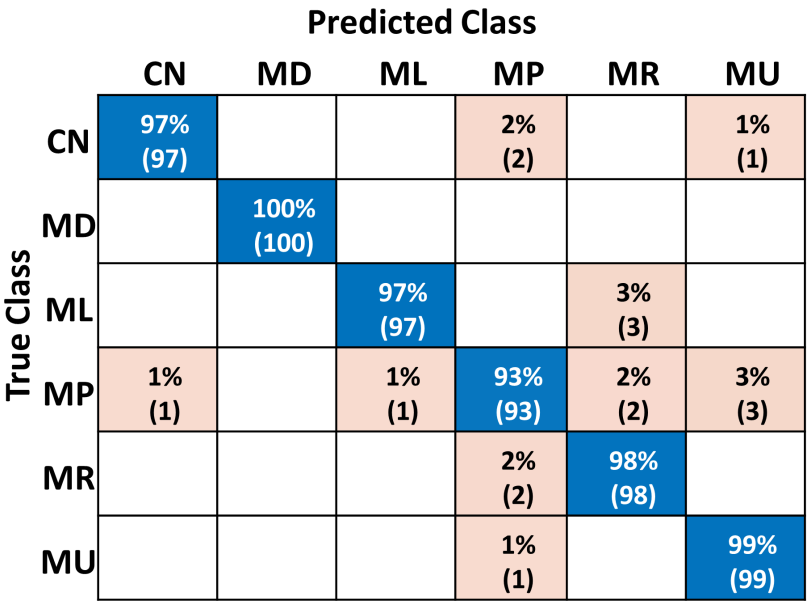
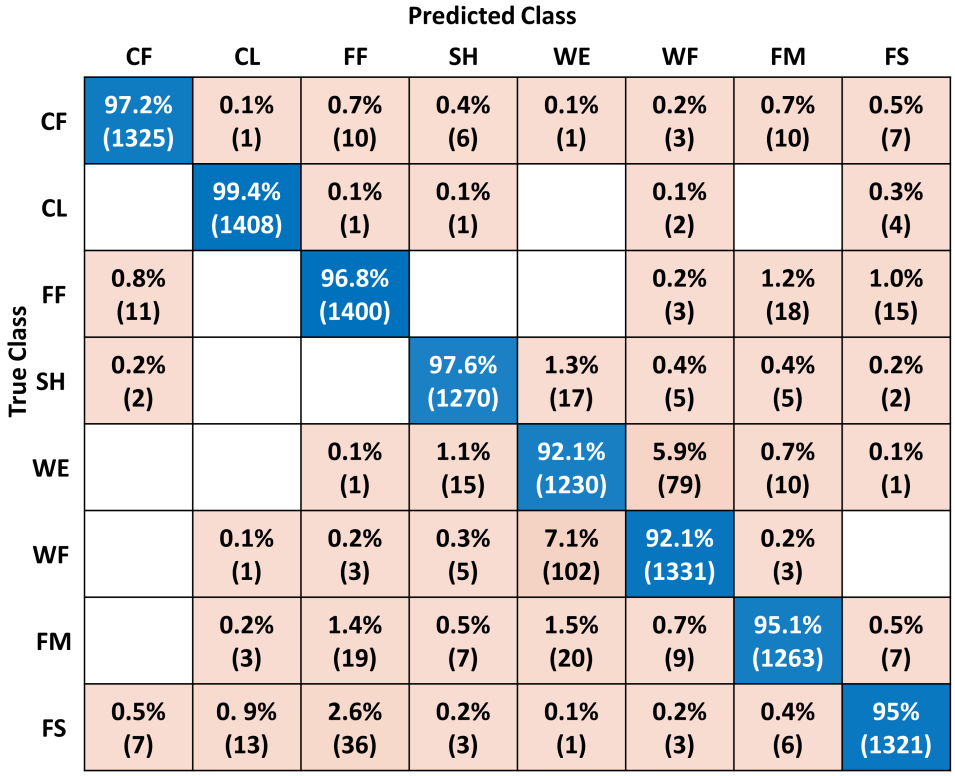


Fig. 2. WVD-MODWT generated TFRs along x, y, and z-axis for representative gesture samples from Dataset-II, arranged sequentially from top to bottom as: CF, CL, FF, SH, WE, WF, FM, and FS.



(a)



(b)

Fig. 3. Confusion matrices for the classification results of (a) Dataset-I (Automated eye movement classification using EMG signals) and (b) Dataset-II (Automated hand gesture recognition using MMG signals) utilizing WVD with cross-term interference.