Introduction to biomedical signal processing

Book - February 2017

CITATIONS READS
3 10,291

1 author:

Luca Mesin Politecnico di Torino 134 PUBLICATIONS 2,320 CITATIONS

SEE PROFILE

Some of the authors of this publication are also working on these related projects:

Project Epilepsy View project

Informative content of biological signals View project

Contents

Ι	\mathbf{T}	neory	of Signal Processing	1		
1	INT	ΓROD	UCTION TO BIOMEDICAL SIGNALS	3		
	1.1	NOIS	Y SIGNALS	4		
		1.1.1	Introduction to random processes	4		
		1.1.2	Model of noisy signal	11		
		1.1.3	The signal to noise ratio (SNR)	12		
	1.2	FILTE	ERING NOISY SIGNALS	13		
		1.2.1	Standard methods	13		
		1.2.2	Advanced techniques	15		
2	DI	SCRE'	TE SIGNAL PROCESSING	21		
	2.1	DISCI	RETE SIGNALS	21		
	2.2	DISCI	RETE FOURIER TRANSFORM	22		
		2.2.1	Poisson Summation Formula	22		
		2.2.2	DFT	23		
	2.3	DISCI	RETE LINEAR TIME INVARIANT SYSTEMS	27		
	2.4	IMPU	LSE RESPONSE	27		
	2.5	ZTR	ANSFORM	27		
		2.5.1	Properties of Z transform	28		
		2.5.2	Z transform of the step	29		
	2.6	INVERSE OF Z TRANSFORM				
	2.7	NUM	ERICAL SIMULATION	30		
	2.8	NUM	ERICAL FILTERS	33		
		2.8.1	Implementation of numerical filters	34		
		2.8.2	Design of digital filters	40		
		2.8.3	Approximation of dynamical systems	50		
3	SPECTRAL DENSITY ESTIMATION					
	3.1	NON-	PARAMETRIC METHODS FOR PSD ESTIMA-			
		TION	· · · · · · · · · · · · · · · · · · ·	53		
		3.1.1	Spectral density of WSS processes	54		
		3.1.2	Numerical techniques for spectral analysis	56		
		3.1.3	Mutual densities and coherence	69		

	3.2	PARA	METRIC ESTIMATION OF THE PSD	. 71	
		3.2.1	Linear prediction	. 73	
		3.2.2	Regressive models	. 75	
		3.2.3	Applications and generalizations	. 78	
4	TI	Æ ED	EQUENCY REPRESENTATIONS	83	
4	4.1		AR TIME FREQUENCY REPRESENTATIONS.		
	4.1	4.1.1	The Short Time Fourier Transform (STFT)		
		4.1.2	Wavelet Transform (WT)		
	4.2		PRATIC TIME FREQUENCY REPRESENTATION		
	1.2	4.2.1	Properties		
		4.2.2	Quadratic TFR derived from linear TFR		
		4.2.3	E and C domains: Wigner-Ville Transform and	. 00	
		1.2.0	Ambiguity Function	. 99	
		4.2.4	Cohen's class TFR and Choi-Williams kernel		
		4.2.5	Cross time frequency representations		
				. 100	
5			EAR ANALYSIS OF TIME SERIES	115	
	5.1	RAND	OOMNESS AND CHAOS		
		5.1.1	Examples of dynamical systems		
		5.1.2	Fractal Dimension		
		5.1.3	Self-similarity, Hurst Exponent and fractional Brow		
			nian motion		
	5.2		INEAR ANALYSIS OF TIME SERIES		
		5.2.1	Time series embedding		
		5.2.2	Testing with Surrogate Data	. 127	
	5.3		CES OF COMPLEXITY		
		5.3.1	Box counting estimation of fractal dimension		
		5.3.2	Lyapunov exponent		
		5.3.3	Recurrence Plots		
		5.3.4	Entropy estimation	. 136	
6	STA	ATISTI	ICS	141	
	6.1	DESC	RIPTIVE STATISTICS	. 141	
	6.2		ISTICAL INFERENCE		
		6.2.1	Important distributions	. 144	
		6.2.2	Parameter estimation		
		6.2.3	Confidence intervals		
		6.2.4	Test of hypotheses		
		6.2.5	Analysis of variance		
	6.3 ESTIMATION OF THE PROBABILITY DENSITY FU				
		TION			
		6.3.1	Parametric methods		
		6.3.2	Non-parametric methods: unknown PDF distribu-		
			tion	161	

	6.4 6.5		DNESS OF FIT		
II	A	pplica	ations to biomedical signals	165	
7	NON-INVASIVE BIOMEDICAL MEASUREMENTS				
	7.1	ACQU	VISITION OF BIOELECTRIC SIGNALS		
		7.1.1	Electrodes		
		7.1.2	Amplification		
	7.2	NEAR	INFRARED TECHNOLOGY	174	
		7.2.1	Introduction		
		7.2.2	The law of Lambert-Beer	174	
	7.3	ULTR	ASOUND TECHNOLOGY	177	
		7.3.1	Introduction to ultrasounds	177	
		7.3.2	Doppler ultrasound		
		7.3.3	Sound Propagation	. 184	
8	BIC		TRIC SIGNALS	189	
	8.1	THE I	BRAIN AND EEG	189	
		8.1.1	Anatomy and Physiology of the Central Nervous		
			System	189	
		8.1.2	The cells of the nervous system	189	
		8.1.3	Brain anatomy	192	
		8.1.4	Functional properties of cortical columns	196	
		8.1.5	Functional areas of the cerebral cortex	197	
		8.1.6	Electrical activity of the cerebral cortex	198	
		8.1.7	Connections of the cerebral cortex	203	
		8.1.8	The peripheral nervous system	205	
	8.2	THE N	MUSCLES AND EMG	207	
		8.2.1	Striated Muscles	207	
		8.2.2	The electrical command of muscle contraction and		
			electromyography	211	
		8.2.3	Indexes extracted from surface EMG	211	
	8.3	THE I	HEART AND ECG	215	
		8.3.1	Introduction to the anatomy and physiology of the		
			heart	215	
		8.3.2	Origin and interpretation of the electrocardiogram	216	
9	CA	RDIOV	VASCULAR SYSTEM	219	
	9.1	ANAT	OMY AND PHYSIOLOGY	219	
	9.2		DIOVASCULAR AND RESPIRATORY CONTROL		
	9.3		CEREBROVASCULAR SYSTEM		
		9.3.1	The cerebral autoregulation		
			The blood-brain barrier	230	

	9.4	EXAMPLES OF APPLICATIONS	230		
		9.4.1 Multiple data: RR, pressure and respiration	231		
		9.4.2 NIRS data	232		
		9.4.3 TCD data			
10	BIC	OMEDICAL SIGNAL PROCESSING USING MAT-			
	$\mathbf{L}\mathbf{A}\mathbf{I}$	3	237		
	10.1	BASIC COMMANDS	237		
	10.2	SIGNAL PROCESSING TOOLBOX	240		
		10.2.1 Numerical filters	240		
		10.2.2 PSD estimation			
	10.3	TIME-FREQUENCY REPRESENTATION	246		
	10.4	STATISTICS	255		
	10.5	SIMULATION OF DYNAMICAL SYSTEMS	256		
	10.6	COMPLEXITY ANALYSIS	257		
	10.7	Final considerations	257		
\mathbf{A}	Fou	rier transform	259		
В	Lap	lace transform	265		
	-	Bilateral Laplace transform	265		
		Unilateral Laplace transform			
		Bode diagram			
R	efere	nces	274		
Index					