

**ESCOLA TÈCNICA SUPERIOR D'ENGINYERS
INDUSTRIALS DE BARCELONA (UPC)**

Institut de Cibernètica

**NOVES TÈCNIQUES EN L'ANÀLISI DEL
SENYAL ELECTROCARDIOGRÀFIC:
APLICACIÓ A L'ECG D'ALTA
RESOLUCIÓ.**

Autor: Raimon Jané Campos
Director: Antonio Bayes

Juny 1989

REFERÈNCIES

- Belforte G., De Mori R. i Ferraris F. (1979), "A contribution to the automatic processing of electrocardiograms using syntactic methods", *IEEE Trans. Biomed. Eng.*, vol. BME-26, n. 3.
- Bendat J.S. i Piersol A.G. (1986), "Random Data. Analysis and Measurements Procedures", *John Wiley & Sons*, New York.
- Berberi E.J., Lazzara R., El-Sherif N. i Scherlag B.J. (1975), "Extracardiac recordings of His-Purkinje activity during conduction disorders and junctional rhythms", *Circulation*, vol. 51, pp. 802-810.
- Berberi E.J., Scherlag B.J. i Hope R.R. (1978), "Recording from the body surface of arrhythmogenic ventricular activity during the ST segment", *Am. J. Cardiol.*, vol. 41, pp. 697-702.
- Berberi E.J. i Lazzara R. (1988), "An introduction to high-resolution ECG recordings of cardiac late potentials", *Arch. Intern. Med.*, vol. 148, pp. 1859-1863.
- Birman K.P. (1982), "Rule-based learning for more accurate ECG analysis", *IEEE Trans. Pattern Analysis and Machine Intelligence*, vol. PAMI-4, n. 4, pp. 369-380.
- Birman K.P. (1983), "Using SEEK for multichannel pattern recognition", *Comput. Biom. Res.*, vol. 16, pp. 311-333.
- Boineau J.P. i Cox J.L. (1973), "A slow ventricular activation in acute myocardial infarction: A source of reentrant ventricular contractions", *Circulation*, vol. 48, pp. 702-713.
- Bolton M.P. i Coleman J.D. (1981), "Detection of QRS complexes in ECG signals and evaluation of instantaneous heart rate", en *Proceedings of changes in health care instrumentation due to microprocessor technology*, North-Holland. IFIP, pp. 249-256.
- Börjesson P.O., Pahlm O., Sörnmo L. i Nygard M.E. (1982), "Adaptive QRS detection based on maximum -a-posteriori estimation", *IEEE Trans. Biomed. Eng.*, vol. BME-29, pp. 341-351.

- Breithardt G., Becker R., Seipel L., Abendroth R.-R. i Ostermeyer J.** (1981), "Non-invasive detection of late potentials in man -a new marker for ventricular tachycardia", *Eur. Heart J.*, vol. 2, pp. 1-11.
- Breithardt G., Schwarzmaier J. i Boggrefe M.** (1983), "Prognostic significance of late ventricular potentials after acute myocardial infarction", *Eur. Heart J.*, vol. 4, pp. 487-495.
- Burbank D.P. i Webster J.G.** (1978), "Reducing skin potential motion artefact by skin abrasion". *Med. Biol. Eng. Comp.*, vol 16, pp. 31-38.
- Carter G.C.** (1981 a), "Time delay estimation for passive sonar signal processing", *IEEE Trans. Acoustic, Speech, and Signal Processing*, vol. ASSP-29, n. 3, pp. 463-470.
- Carter G.C.** (1981 b), "Time delay estimation (Guest editorial), Special Issue on Time Delay Estimation", *IEEE Trans. Acoustic, Speech, and Signal Processing*, vol. ASSP-29, n. 3.
- Craelius W., Restivo M., Assadi M.A., i El-Sherif N.** (1986), "Criteria for optimal averaging of cardiac signals", *IEEE Trans. Biomed. Eng.*, vol. BME-33, n. 3, pp. 957-966.
- Denes P., Santarelli P. i Hauser R.G.** (1983), "Quantitative analysis of the high frequency components of the terminal portion of the body surface QRS in normal subjects and in patients with ventricular tachycardia", *Circulation*, vol. 67, pp. 1129-1138.
- Dennis A.R., Ross D.L. i Richards D.A.** (1986), "Effect of antiarrhythmic therapy on delayed potentials detected by the signal-averaged electrocardiogram in patients with ventricular tachycardia after acute myocardial infarction", *Am. J. Cardiol.*, vol. 58, pp. 261-265.
- Devlin P., Moody G. i Mark R.** (1982), "Design and evaluation of a modular real-time QRS detector", *Proc. 35th Ann. Conf. on Engineering in Medicine and Biology, Bethesda, U.S.A.*, vol. 40.

- Dillman R., Judell N. i Kuo S.** (1978), "Replacement of AZTEC by correlation for more accurate VPB detection", *Computers in Cardiology, IEEE Computer Society Press*, pp. 29-32.
- Einthoven W., Fahr G. i deWaart A.** (1913), "Uber die richtung und die manifeste grosse der poententialschwankungen in menschlischen herren und uber den einfluss der herzlage auf die form des electrokardiogaams", *Pfluegers Arch. Gesamte Physiol. Menschen Tiere*, vol. 150, pp. 275-315.
- Fontaine G., Guiraudon G. i Frank R.** (1978), "Modern concepts of ventricular tachycardia ", *Eur. J. Cardiol.*, vol. 8, pp. 565.
- Fraden J. i Neuman M.R.** (1980), "QRS wave detection", *Med. Biol. Eng. Comp.*, vol. 18, pp. 125-132.
- Gritzali F.** (1988), "Towards a generalized scheme for QRS detection in ECG waveforms", *Signal Processing*, vol. 15, pp. 183-192.
- Harris F.J.** (1978), "On the use of windows for harmonic analysis with the discrete Fourier transform", *Proceedings of the IEEE*, vol. 66, n. 1, pp. 51-83.
- Helstrom, C.W.** (1968), "Statistical theory of signal detection", segona edició, *Pergamon Press*, Oxford.
- Holsinger W.P., Kempner K.M. i Miller M.H.** (1971), "A QRS preprocessor based on digital differentiation", *IEEE Trans. Biomed. Eng.*, vol. BME-18, pp. 212-217.
- Ianniello J.P.** (1982), "Time delay estimation via cross-correlation in the presence of large estimation errors", *IEEE Trans. Acoustic, Speech, and Signal Processing*, vol. ASSP-30, n. 6, pp. 998-1003.
- Jané R., Caminal P., Rix H., Thierry E., i Laguna P.** (1988), "Improved alignment methods in ECG signal averaging: application to late potentials detection", *en Computers in Cardiology, IEEE Computer Society Press*, Washington
- Jesus S. i Rix H.** (1985) , "ECG analysis by averaging and beat-to-beat approaches: improvements and discussion", *Proceedings of XIV International Conference on Medical and Biological Engineering*, Espoo, Finland, pp. 1462-1463.

Josephson M.E., Horowitz L.N. i Farshidi A. (1978), "Continuous local electrical activity: A mechanism of recurrent ventricular tachycardia", *Circulation*, vol. 57, pp. 658-665.

Knapp C.H. i Carter G.C. (1976), "The generalized correlation method for estimation of time delay", *IEEE Trans. Acoustic, Speech, and Signal Processing*, vol. ASSP-24, n. 4, pp. 320-327.

Koeleman A.S.M., van den Akker T.J., Ros H.H., Janssen R.J., i Rompelman O. (1984), "Estimation accuracy of P wave and QRS complex occurrence times in the ECG: The accuracy for simplified theoretical and computer simulated waveforms", *Signal Processing*, vol. 7, n. 4, pp. 389-405.

Kunt M., Rey H. i Ligtenberg A. (1982), "Preprocessing of electrocardiograms by digital techniques", *Signal Processing*, vol. 4, pp. 215-222.

Ligtenberg A. i Kunt M. (1983), "A robust-digital QRS detection algorithm for arrhythmia monitoring", *Comp. Biomed. Res.*, vol. 16, pp. 273-286.

Lynn P.A. (1977), "Online digital filters for biological signals: some fast designs for a small computer", *Med. Biol. Eng. Comp.*, vol. 15, pp. 534-540.

Lynn P.A. (1982), "An Introduction to the Analysis and processing of Signals", segona edició, *Macmillan Education Ltd*, London.

Max J. (1972), "Traitement du signal et applications aux mesures physiques", *Masson Éditeurs*, Paris.

Murthy I.S.N. i Rangaraj M.R. (1979), "New concepts for PVC detection", *IEEE Trans. Biomed. Eng.*, vol. BME-26, pp. 409-416.

Nygards M.-E. i Sörnmo L. (1983), "Delineation of the QRS complex using the envelope of the e.c.g.", *Med. Biol. Eng. Comp.*, vol. 21, pp. 538-547.

Oeff M., Leitner E. R., Sthapit R., Breithardt G., Borggrefe M., Karbenn U., Meinertz T., Zotz R., Clas W., Hombach V. i Höpp W. (1986), "Methods for non-invasive detection of ventricular late potentials -a comparative multicenter study", *Eur. Heart J.*, vol. 7, pp. 25-33.

- Okada M. (1979), "A digital filter for the QRS complex detection.", *IEEE Trans. Biomed. Eng.*, vol. BME-26, pp. 700-703.
- Oppenheim A.V. i Schafer R.W. (1975), "Digital Signal Processing", *Prentice-Hall, Inc. New Jersey*.
- Pahlm O., Jonson B., Werner O., Johansson K. i Petersson K. (1981), "Computer-aided analysis of long-term ECG recordings", *Europ. Heart J.*, vol. 2, pp. 487-498.
- Pahlm O. i Sörnmo L. (1984), "Software QRS detection in ambulatory monitoring - a review", *Med. Biol. Eng. Comp.*, vol. 22, pp. 289-297.
- Pan J. i Tompkins W.J. (1985), "A real-time QRS detection algorithm", *IEEE Trans. Biomed. Eng.*, vol. BME-32, n. 3, pp. 230-236.
- Papakonstantinou G., Skordalakis E. i Gritzali F. (1986), "An attribute grammar for QRS detection", *Pattern Recognition*, vol. 19, n. 4, pp. 297-303.
- Peper A., Jonges R., Lasekoot T.G. i Grimbergen C. (1982), "Separation of His-Purkinje potentials from coinciding atrium signals: Removal of the P-wave from the electrocardiogram", *Med. Biol. Eng. Comp.*, vol. 20, pp. 195-201.
- Rabiner L.R. i Schafer R.W. (1978), "Digital processing of speech signals", *Prentice-Hall*.
- Reddy G.R. i Rao V.V. (1987), "Signal delay and waveform estimation through differential cepstrum averaging", *IEEE Trans. Acoustic, Speech, and Signal Processing*, vol. ASSP-35, n. 10, pp. 1487-1489.
- Rix H. i Jesus S. (1984), "Estimation du retard entre signaux de même forme", *C.R. Académie des Sciences*, t. 229 série II, n. 8, pp. 399-404.
- Rodriguez M.A., Williams R.H. i Carlow T.J. (1981) "Signal delay and waveform estimation using unwrapped phase averaging", *IEEE Trans. Acoustic, Speech, and Signal Processing*, vol. ASSP-29, n. 3, pp. 508-513.
- Rompelman O. i Ros H.H. (1986), "Coherent averaging technique: A tutorial review. Part 1: Noise reduction and the equivalent filter. Part 2: Trigger jitter,

- overlapping responses and non-periodic stimulation", *J. Biomed. Eng.*, vol. 8, pp. 24-35.
- Rozanski J.J., Mortara D. i Myerburg R.J. (1981), "Body surface detection of delayed depolarizations in patients with recurrent ventricular tachycardia and left ventricular aneurysm", *Circulation*, vol. 63, pp. 1172-1178.
- Scherlag B.J., Lau S.H., Helfant R.H., Berkowitz B., Stein E. i Domato A.N. (1969), "Catheter technique for recording His bundle activity in man", *Circulation*, vol. 39, pp. 13.
- Shah P.M., Arnold J.M., Haberern N.A., Bliss D.T., McClelland K.M. i Clarke W.B. (1977), "Automatic real time arrhythmia monitoring in the intensive care unit", *Am. J. Cardiol.*, vol. 39, pp. 701-708.
- Skordalakis E. i Papakonstantinou G. (1984) "Toward an attribute grammar for the description of ECG Waveforms". *Proceedings of seventh International Conference on Pattern Recognition*, Vol.2, Montreal 1984.
- Tam H.W. i Webster J.G. (1977), "Minimizing Electrode Motion Artifact by Skin Abrasion". *IEEE Trans. on Biomed. Engin.*, vol. BME-24. n. 2, pp. 134-139.
- Thakor N.V. (1984), "From Holter monitors to automatic defibrilators: Developments in ambulatory arrhythmia monitoring", *IEEE Trans. Biomed. Eng.*, vol. BME-31, n. 12, pp. 770-778.
- Thakor N.V. i Webster J.G. (1985) "Electrode studies for the long-term ambulatory ECG". *Med. Biol. Eng. Comp.*, vol. 23, pp. 116-121.
- Thakor N.V., Webster J.G. i Tompkins W.J. (1984), "Estimation of QRS complex power spectra for design of a QRS filter", *IEEE Trans. Biomed. Eng.*, vol. BME-31, n. 11, pp. 702-705.
- Tompkins W.J. i Webster J.G. (1981), "Design of microcomputer-based medical instrumentation", *Prentice-Hall, Inc. New Jersey*.
- Tompkins, W.J. (1985), "Patient Worn, Intelligent Arrhythmia System". *IEEE Engineering in Medicine and Biology Magazine*.

- Tremblay G. i LeBlanc A.R.** (1985), "Near -optimal signal preprocessor for positive cardiac arrhythmia identification", *IEEE Trans. Biomed. Eng.*, vol. BME-32, n. 2, pp. 141-151.
- Udupa J.K. i Murthy I.S.N.** (1980), "Syntactic approach to ECG rhythm analysis", *IEEE Trans. Biomed. Eng.*, vol. BME-27, n. 7.
- Uijen G.J.H., de Weerd J.P.C. i Vendrik A.J.H.** (1979), "Accuracy of QRS detection in relation to the analysis of high-frequency components in the electrocardiogram", *Med. Biol. Eng. Comp.*, vol. 17, pp. 492-502.
- Urkowitz H.** (1967), "Energy detection of unknown deterministic signals", *Proceedings of the IEEE* vol. 55, n. 4, pp. 523-531.
- Usui S. i Amidror I.** (1982), "Digital Low-Pass Differentiation for Biological Signal Processing", *IEEE Trans. Biomed. Eng.*, vol. BME-29, n. 10, pp. 686-693.
- Vincent R., English M.J., Woollons D.J., Carrol D., Werneck S., Marriott T.H. i Chamberlain D.A.** (1981), "Surface his bundle potentials and other low amplitude cardiac signals by signal averaging", *en Signal Averaging Technique in Clinical Cardiology. Ed. V. Hombach i H.H. Hilger. F.K. Schattauer Verlag. Stuttgart.*
- Yegnanarayana B., Sreekant J. i Rangarajan A.** (1985), "Waveform estimation using group delay processing", *IEEE Trans. Acoustic, Speech, and Signal Processing*, vol. ASSP-33, n. 8, pp. 832-836.