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Computer Application to ECG Signal Processing+

Mitsuharu Okajima, M.D.*

1. Introduction

Electrocardiographic (ECG) signals, the heart waves in a rather simple pattern and with much regularity synchronized to every heart beat, have long been one of the most suitable targets for computer processing in bio-medical field. Our experiences in computer application to ECG signal processing and diagnostic interpretation in various aspects in the last two decades will be reviewed with some forecasting for the directions in the years to come.

2. Computer Interpretation of Routine Electrocardiogram

ECG signals in digital form after A-D conversion are processed by fiducial points detection program and P, QRS and T waves identified. Amplitudes, widths, slopes and other parameters are determined with these waves, which are then used in classifying each case of ECGs into various clinically defined categories through deterministic (branching) logics.

This kind of pattern recognition procedures are now being carried out in clinical examination routinely. Minicomputer systems are utilized in stand-alone unit and also in telephone-service systems. However, currently popular systems are self-contained microcomputer electrocardiograph which is as small as a brief-case and still includes almost every function of larger systems.

3. Long-term Electrocardiography (Ambulatory ECG, Holter System) and Its Computerization

A cassette-tape recorder is carried on by the patient with his ECG signals recorded on it continuously throughout his daily life during day and night. The tape then undergoes replaying in a much faster speed (60~240 times) than while recording and ECG signals on the tape are displayed on CRT for Human eye observation.

Computers are taking over this tedious and exhausting observation job, aiming full automation of signal processing and interpretation of long-term electrocardiogram. Future goal is "built-in" microcomputer in the recorder to be carried by patients and incoming ECG signals are processed in real-time, with warning and therapeutic functions (implantable CCU device).

4. Production of Body Surface Potential Map

A different representation of ECG other than conventional time-axis curve is isopoten-

* Laboratory of Medical Engineering and Computer Science School of Medicine, Fujita-Gakuen Health University

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tial contour line mapping on the body surface. This is produced by collecting instantaneous amplitudes of ECG curve from numerous body surface points.

By utilizing multiple amplifiers, multiplexing systems and microcomputer, the body surface map is now produced as a clinical examination. ECG signal processing procedures in this map production is somewhat like wave recognition mentioned earlier in 1. The amplitude of each body surface point is stored on memory so that reference to the past map will be done at will. Pattern subtraction between maps is one of its uses.

5. Forward and Inverse Problems in Electrocardiogram

ECG curve is a physical outcome derived from current generators in the heart and transfered to the body surface. If one is given with geometry and electrical characteristics of the heart and the torso, patterns of ECG curve can be calculated mathematically. This is forward problem, i.e., outcome is derived from its source.

On the other hand, mathematical estimation of electrical source in the heart (current generators in the myocardium or potential distribution on the epicardium) has also been tried based on the body surface potential distribution. This is inverse problem, i.e. source is to be decided from outcome. The solution requires various complicated mathematics including integral equations, finite element method and boundary element method. However, ease of use of large computer in these days is helping promote the inverse problem studies.