ECG Signal Compression Using Analysis by Synthesis Coding

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1. Introduction

- 每一筆ECG取樣率在250~500Hz且用12 bits的解析度
- ECG需要長時間12-24小時的紀錄
- 在傳輸和儲存時資料太過龐大
- 在這提出一個有損的壓縮技術，並且在重建時保留有價值的特徵

1. Introduction

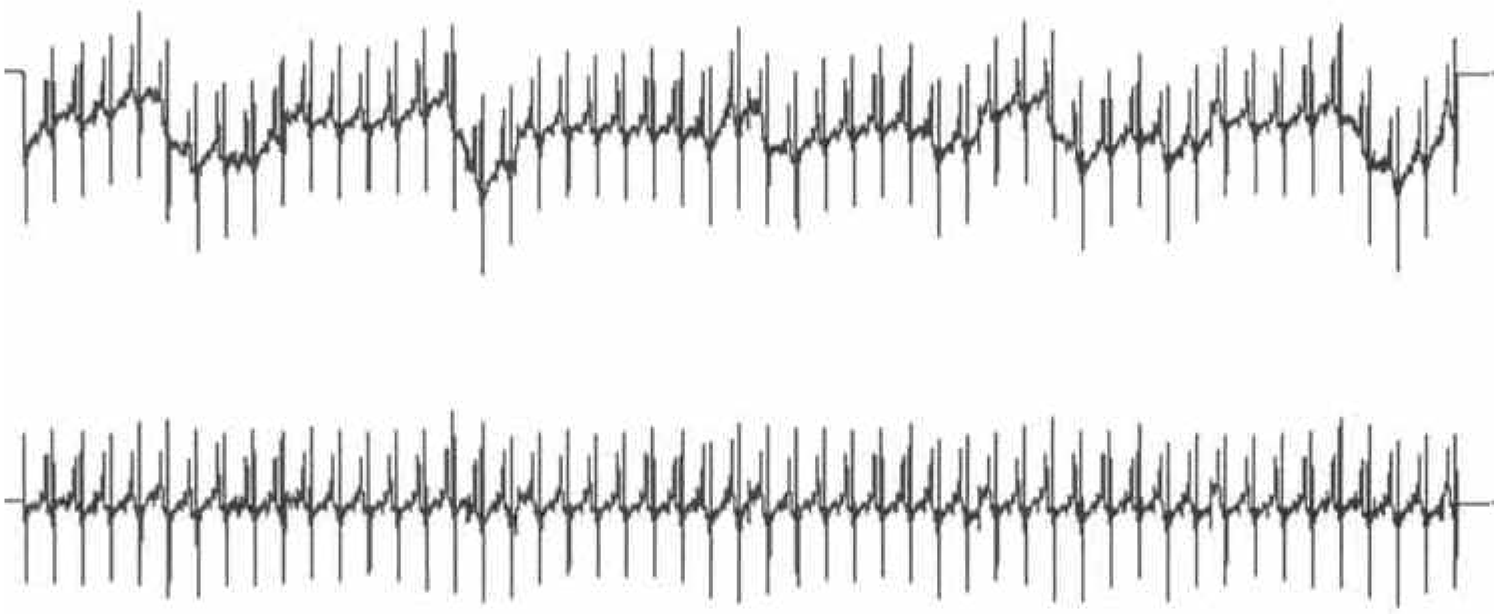
- 一直以來用來計算失真的方法大多使用 percentage rms difference(PRD)
- 失真度的評價在壓縮技術中是不可或缺的
- 在這我們使用了PRD以及weighted diagnostic distortion(WDD)

1. Introduction

- 提出的方法是 analysis by synthesis ECG compressor(ASEC)
- 以合成做分析編碼由心跳組成的碼簿、長期與短期的預測和適應性的殘值量化所構成

2. The Distortion Measures

- 基線飄移移除



2. The Distortion Measures

- 失真尺度

PRD

$$PRD = \sqrt{\frac{\sum_{n=1}^{N}\left(x(n)-\tilde{x}(n)\right)^2}{\sum_{n=1}^{N}\left(x(n)-\bar{x}(n)\right)^2}} \times 100$$

$x(n)$ 原始訊號

$\tilde{x}(n)$ 重建訊號

$\bar{x}(n)$ x(n)的平均

N 取樣點的長度

2. The Distortion Measures

- 失真尺度

WDD

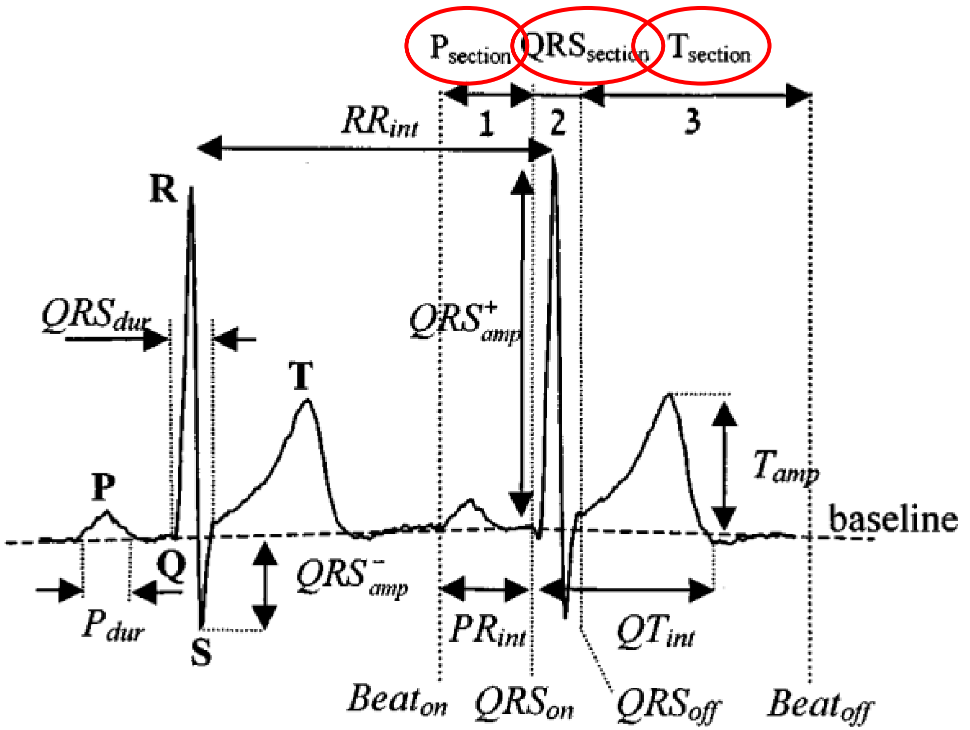


Fig. 1. Some of the diagnostic features used by the WDD (and beat segmentation).

2. The Distortion Measures

- 失真尺度

WDD

$$\beta^T = [\beta_1, \beta_2, \ldots, \beta_p] \quad \text{原始訊號}$$

$$\hat{\beta}^T = [\hat{\beta}_1, \hat{\beta}_2, \ldots, \hat{\beta}_p] \quad \text{重建訊號}$$

$$\Delta\beta^T = [\beta_1, \beta_2, \ldots, \beta_p] \quad \beta^T \text{與} \hat{\beta}^T \text{的差}$$

$$\text{WDD}(\beta, \hat{\beta}) = \Delta\beta \cdot \frac{\Lambda}{tr[\Lambda]} \cdot \Delta\beta \times 100$$

權重值

2. The Distortion Measures

- 每一個心跳都有相似的波形，所以可以用long-trem prediction(LTP)

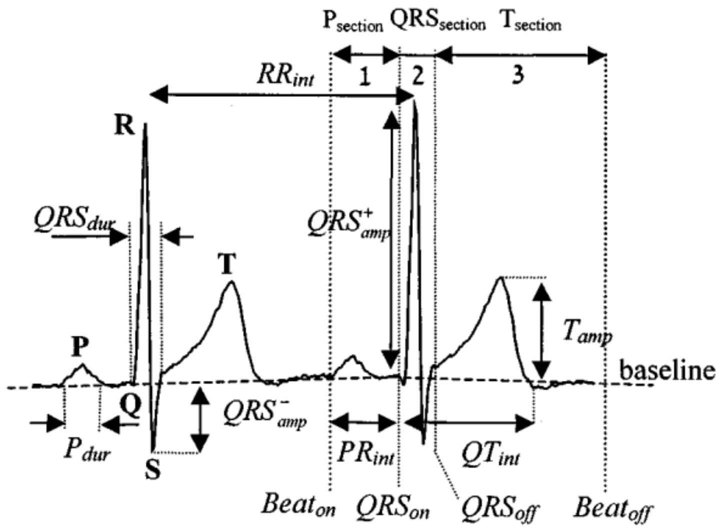


Fig. 1. Some of the diagnostic features used by the WDD (and beat segmentation).

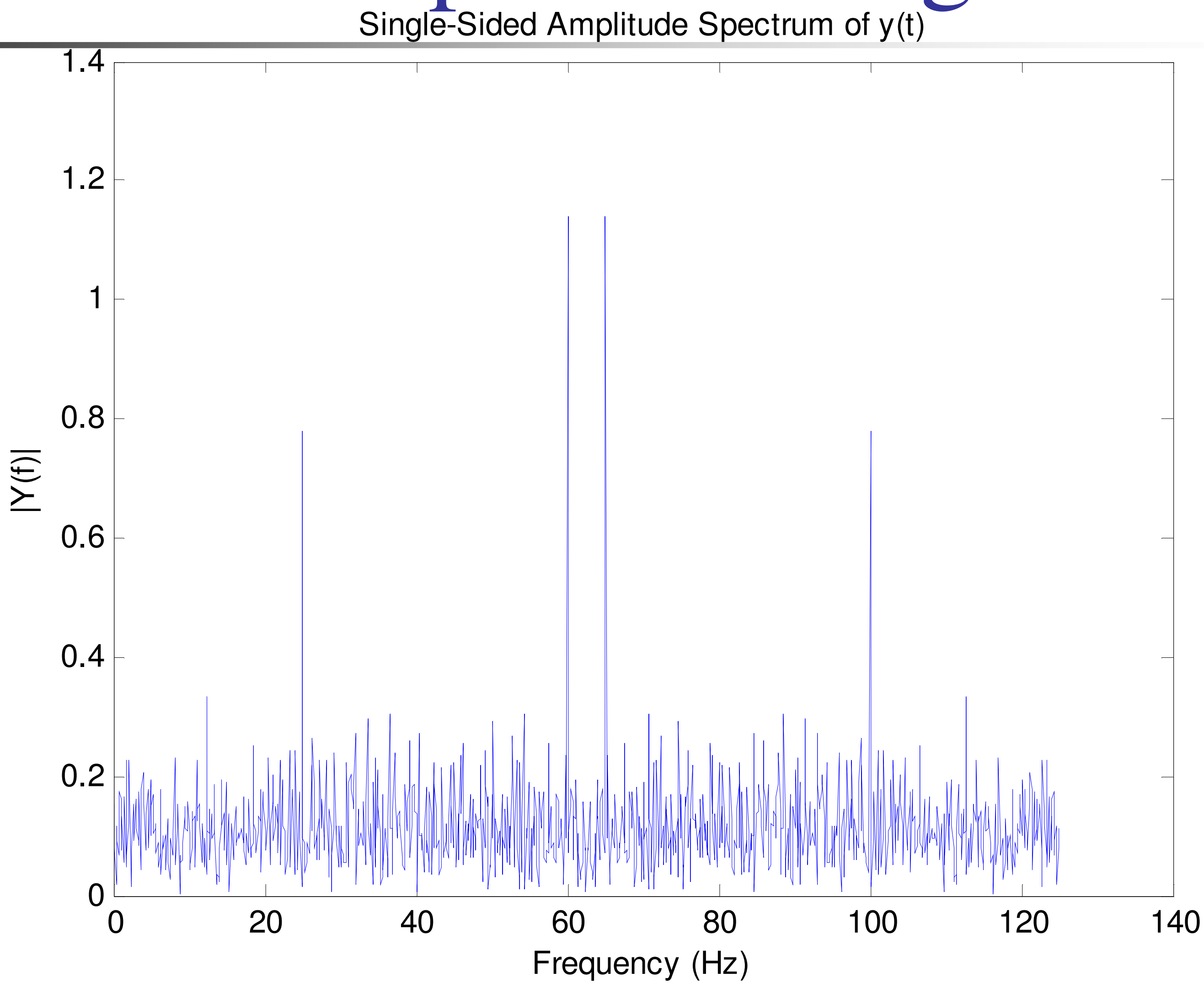
3. The Compression Algorithm

A. The Preprocessing Stage

將心跳切割成$P_{section}$, $QRS_{section}$, $T_{section}$

- $P_{section}$和$T_{section}$使用0.01-50Hz bandpass FIR filter
- $QRS_{section}$使用0.1-100Hz bandpass FIR filter

3. The Compression Algorithm



3. The Compression Algorithm

B. The Encoding System

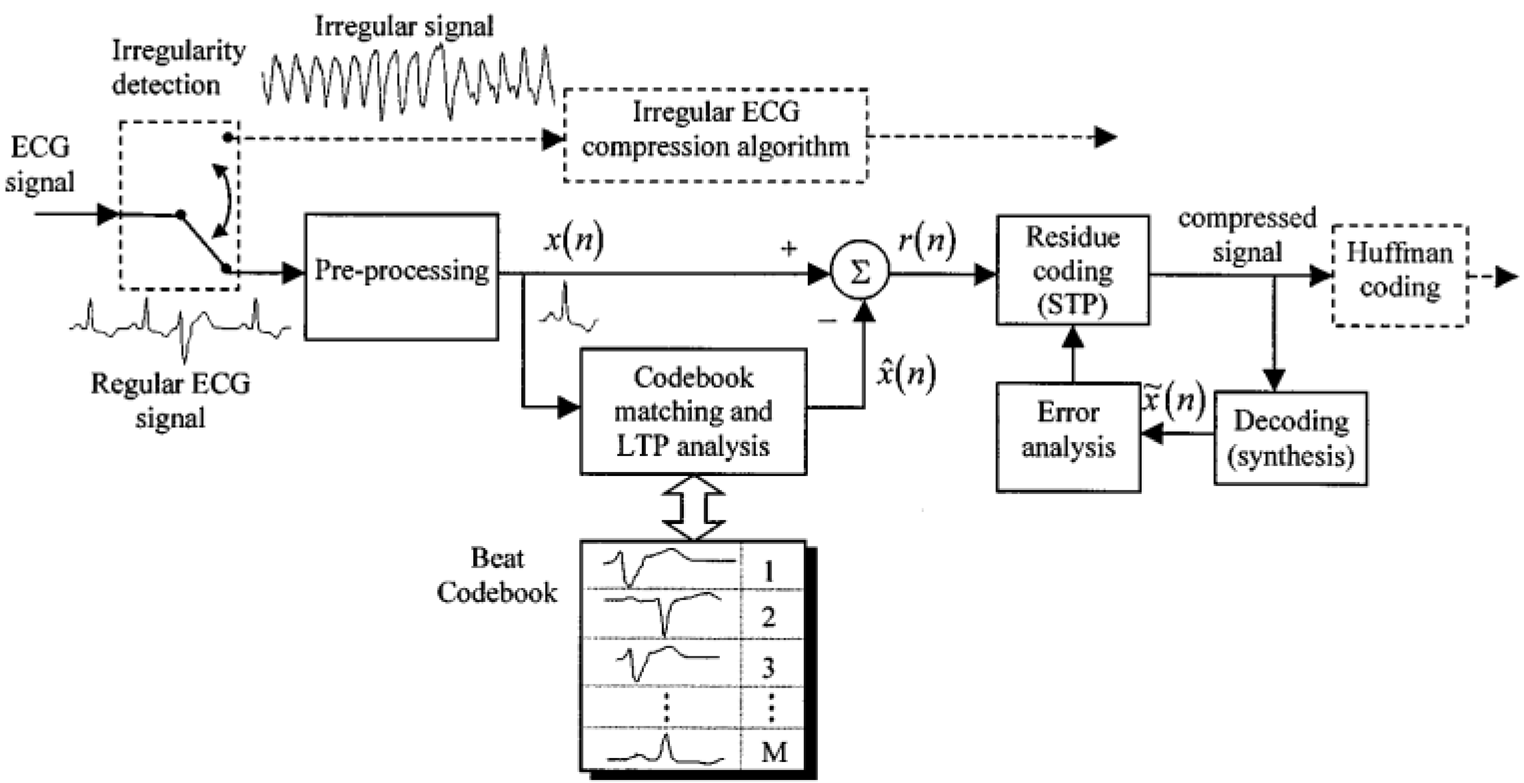


Fig. 2. General scheme of the ASEC. Huffman coding (which was not implemented) can improve the results by approximately 10%.

3. The Compression Algorithm

B. The Encoding System

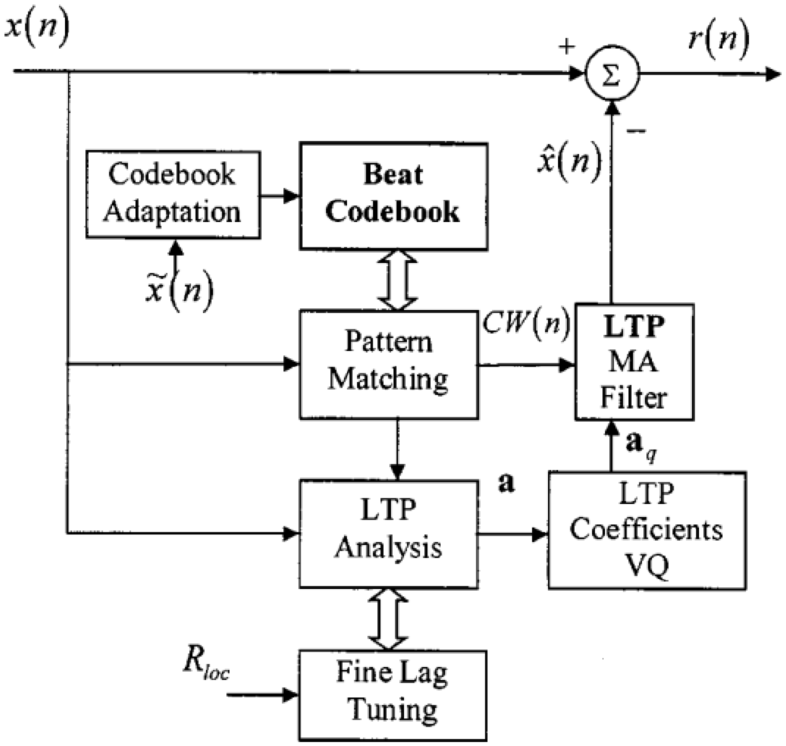


Fig. 3. The process of codebook matching, LTP analysis, and residue signal production.

3. The Compression Algorithm

B. The Encoding System

$$CW_j^k = \theta \cdot CW_j^{k-1} + (1-\theta)\tilde{x}$$

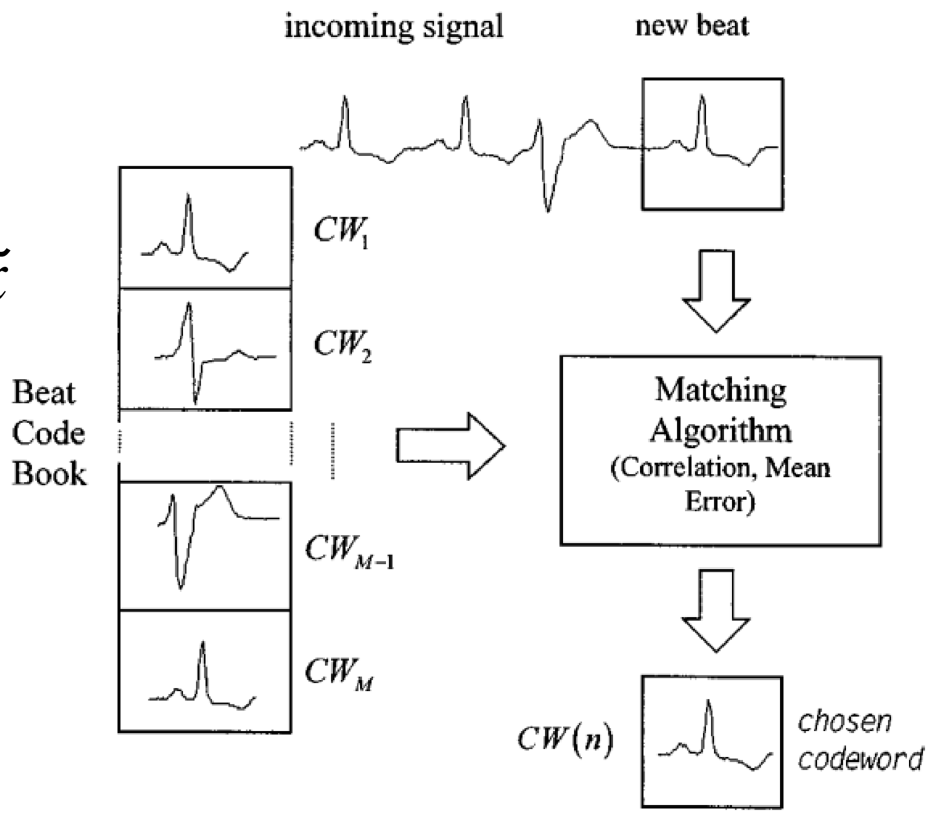


Fig. 4. Beat codeword selection process.

3. The Compression Algorithm

B. The Encoding System

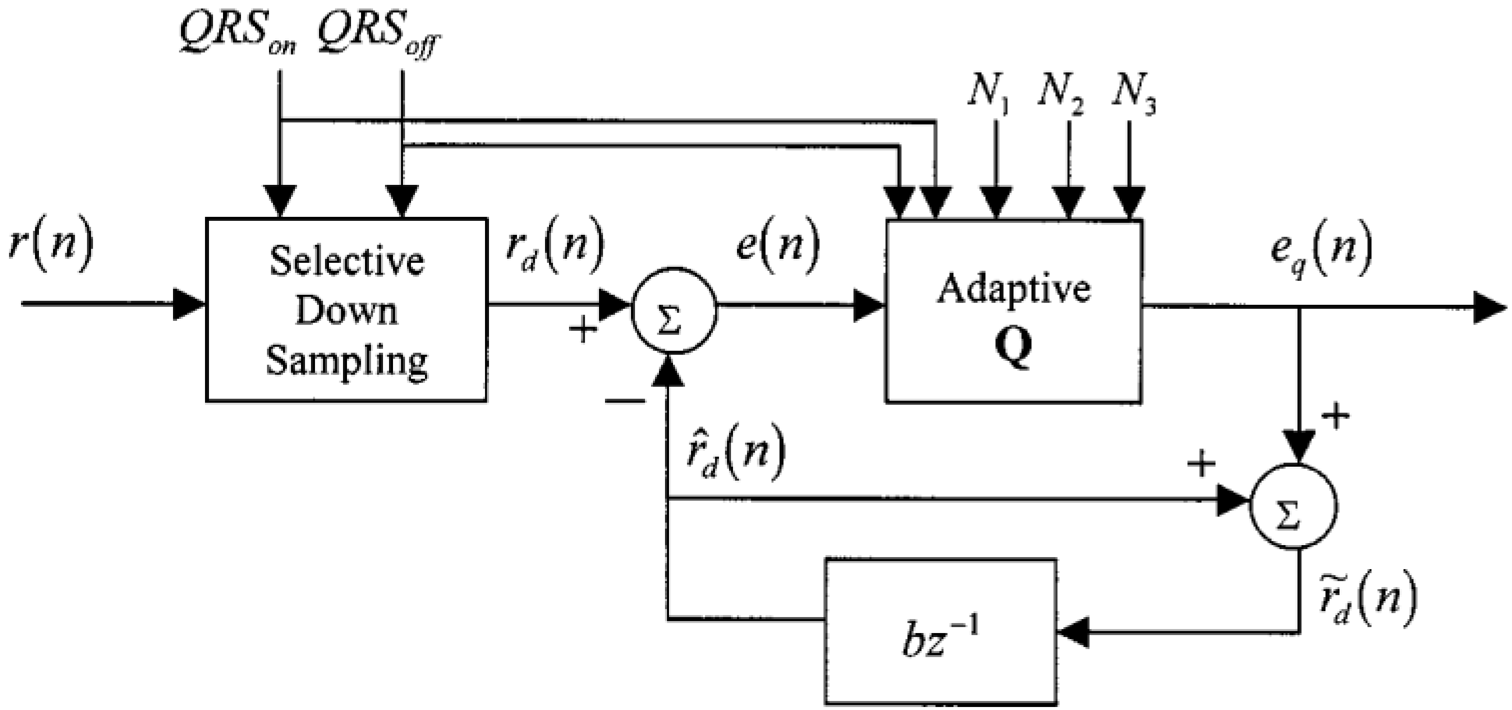


Fig. 5. The residual encoder.

3. The Compression Algorithm

B. The Encoding System

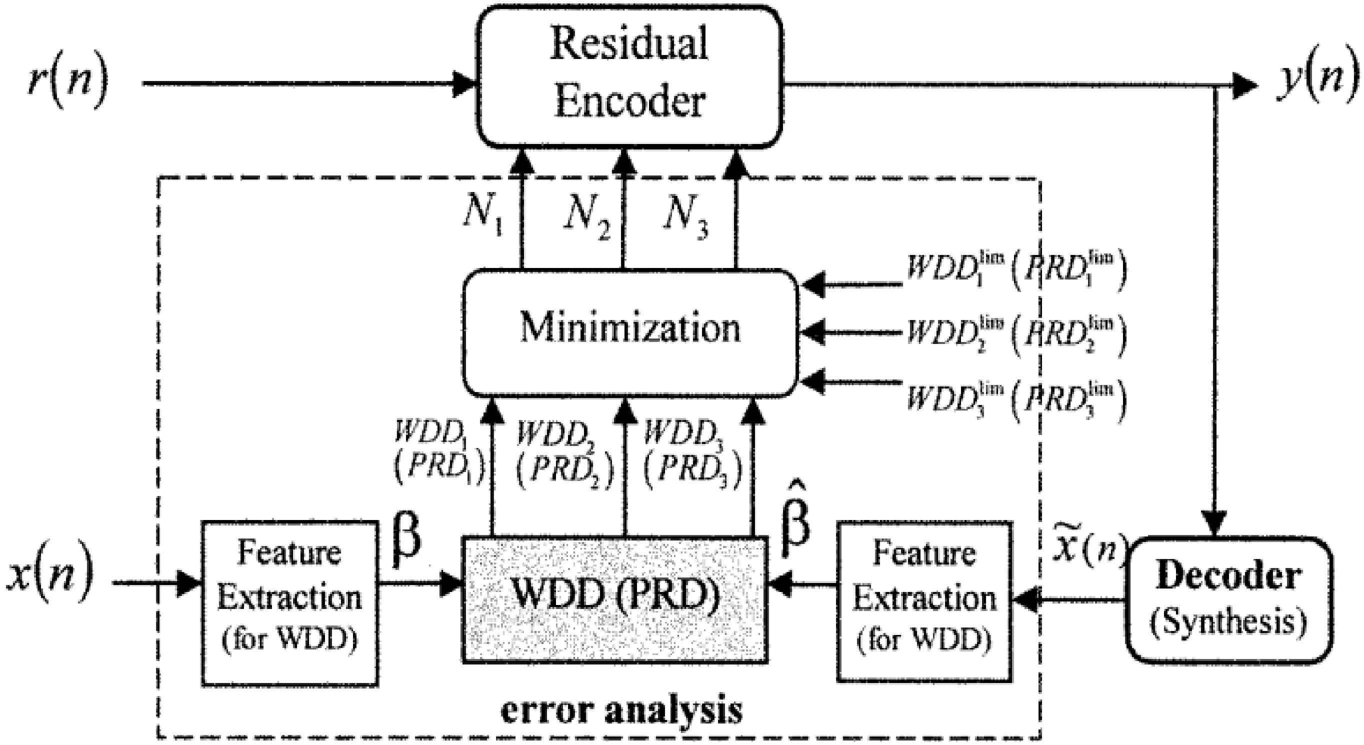


Fig. 6. The block diagram of the error analysis by synthesis subsystem (using WDD or PRD measure).

3. The Compression Algorithm

C. The Decoding System

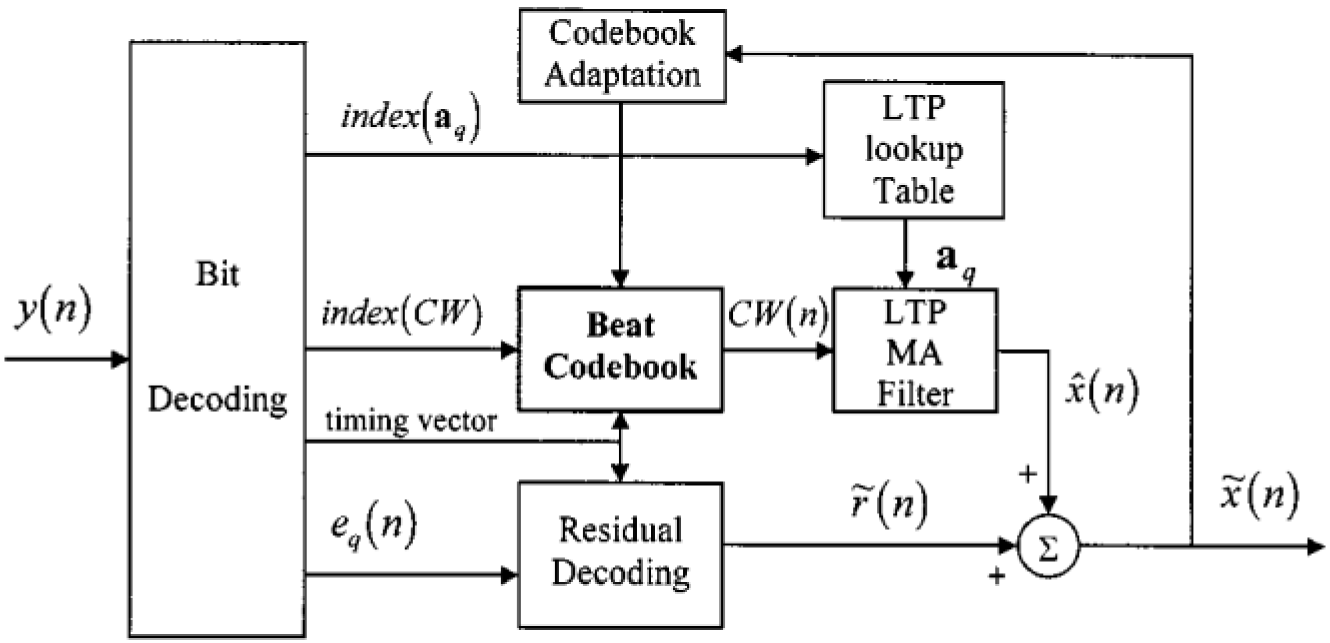


Fig. 7. The decoding system.

4. Results and Discussion

- MIT-BIH Arrhythmia database
- 比較目標
  - AZTEC
  - SAPA2
  - LTP

4. Results and Discussion

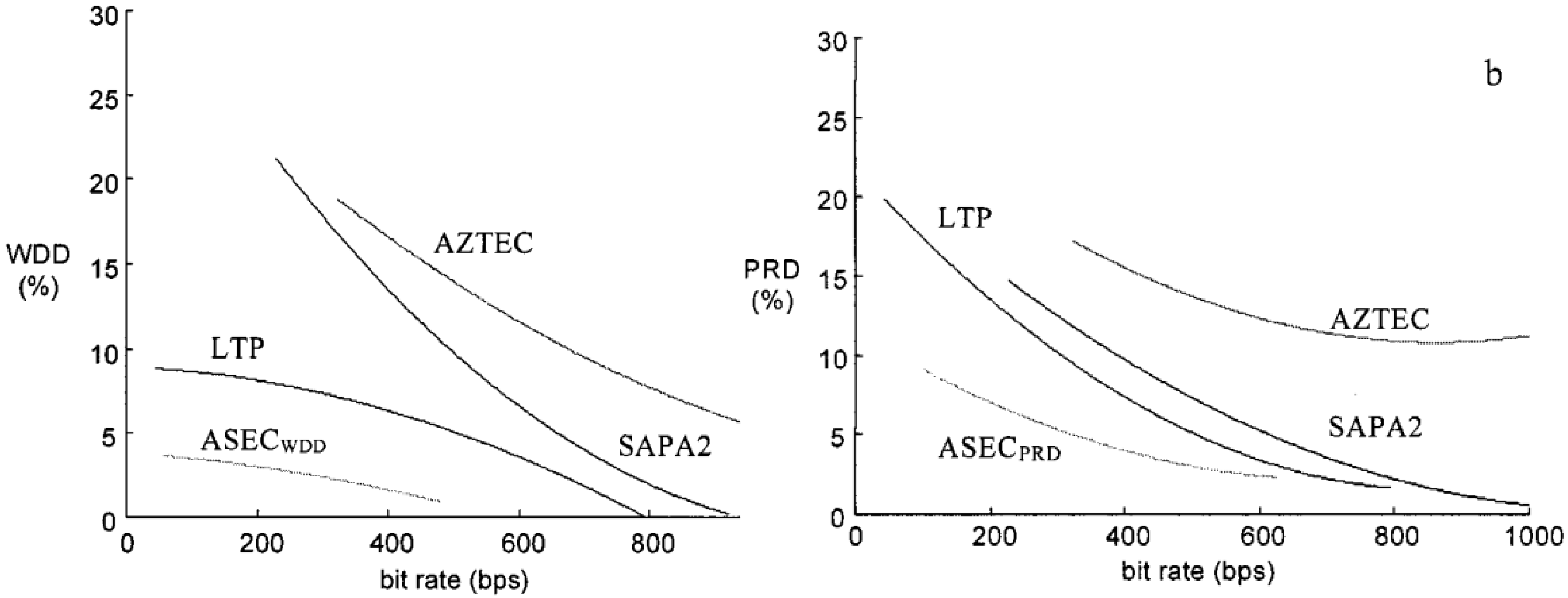


Fig. 10. The distortion-rate curves of the algorithms: $ASEC_{WDD}$, $ASEC_{PRD}$, LTP, SAPA2, and AZTEC. (a) with WDD measure. Standard deviations: $ASEC_{WDD}$ = 2.32, LTP = 4.75, SAPA2 = 3.58, AZTEC = 6.45, (b) with PRD measure. Standard deviations: $ASEC_{PRD}$ = 1.43, LTP = 4.92, SAPA2 = 3.06, AZTEC = 3.61.

4. Results and Discussion

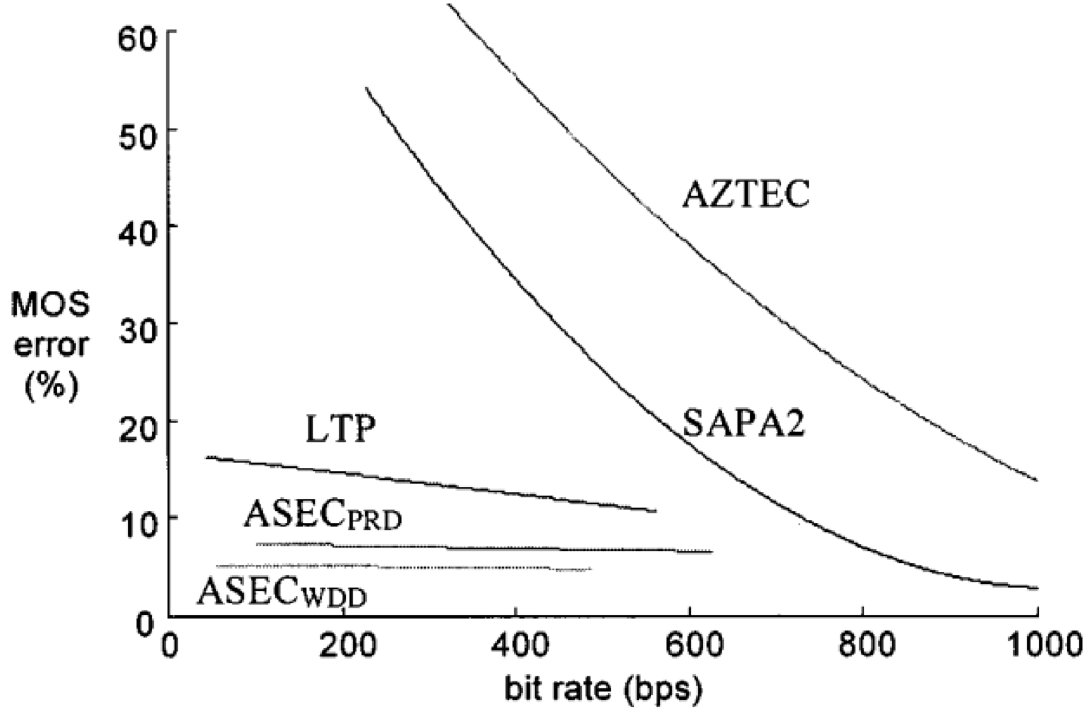


Fig. 11. The distortion-rate curves of the algorithms: $\mathrm{ASEC_{WDD}}$, $\mathrm{ASEC_{PRD}}$, LTP, SAPA2, and AZTEC. with **MOS error**. Standard deviations: $\mathrm{ASEC_{WDD}} = 3.46$, $\mathrm{ASEC_{PRD}} = 3.84$, LTP $= 9.3$, SAPA2 $= 9.8$, AZTEC $= 14.83$.