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Design Group

應用於心電訊號之低複雜度免反矩陣運算演算法與可變尺寸之正交多重匹配追蹤演算法
Low-Complexity Compressed Sensing with Variable Orthogonal Multi-Matching Pursuit and Partially Known Support for ECG Signals

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作品摘要

本晶片應用於無線體域網路（WSBN）偵測心電訊號之低複雜度壓縮感測技術，實現了我們所提出應用在解碼端還原心電訊號之可變尺寸之正交多重匹配追蹤演算法。此演算法結合了正交匹配追蹤演算法（OMP）與多重正交匹配追蹤演算法（OMMP）之優點，除了減少遞迴次數以及運算複雜度還能夠有效的提升還原效能。除此之外，針對正交匹配追蹤相關的演算法最為複雜的運算為偽逆矩陣的運算，我們提出了免反矩陣運算的還原方式，利用 QR 分解來避免反矩陣運算，相較於傳統求解壓縮感測訊號之正交匹配追蹤演算法，不僅有較低的複雜度，還可以有性能上的改善。實作上，我們用台積電 90 奈米製程實作。為了節省硬體，透過排程與分享來達成記憶體共用，總共使用了 9 顆記憶體區塊，我們也使用了 16 顆 CORDIC 來運算 4*4 矩陣的 QR 分解，並利用小的 QR 分解單元的排序處理來實現大型感測矩陣的 QR 分解運算以節省硬體複雜度。晶片面積（chip area）為 3.61mm^2 且 gate-count 為 308K。由晶片量測分析結果可知，我們的設計符合極高硬體使用效率且低功耗需求。

Abstract

We present the implementation of low-complexity compressed sensing (CS) techniques for monitoring electrocardiogram (ECG) signals in wireless body sensor network (WBSN). First, the partially known support set (PKS) exploiting the wavelet property and the variable orthogonal multi-matching pursuit (vOMMP) algorithm are proposed in order to enhance reconstruction performance and to reduce computation time. Furthermore, the computation-intensive pseudo-inverse operation for signal reconstruction is simplified by the matrix-inversion-free (MIF) technique based on QR decomposition. The performance and complexity comparisons manifest the advantages of our proposed techniques. The vOMMP MIF CS decoder is implemented in 90nm CMOS technology. With scheduling and hardware sharing to achieve complexity reduction, 9 SRAM modules are used. We use 16 CORDIC operating blocks to operate 4×4 QR decomposition, and the QR decomposition of the large sensing matrix is accomplished by sequential 4×4 QR decomposition. The chip area is 3.61mm^2 with 308K gates. From the measurement result, the energy consumption is 3.97μJ with 0.7V supply voltage to restore the 128-point ECG waveform sampled by 300Hz frequency. Compared to prior chip implementations, our design shows good hardware efficiency and is suitable for low-energy applications.