Towards the Design of Dependable Real-Time System for Remote Health Monitoring of Elderly People

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Introduction and Background

- Electrocardiography is a well known method for heart diagnosis
  - Used as one of major diagnosis for conventional health monitoring
- Electrocardiography main processing challenges arise from:
  - High computational demand for processing huge amount of data under:
    - ✓ Strict time constraints
    - ✓ Relatively high sampling frequency
    - ✓ Life critical conditions

Introduction and Background

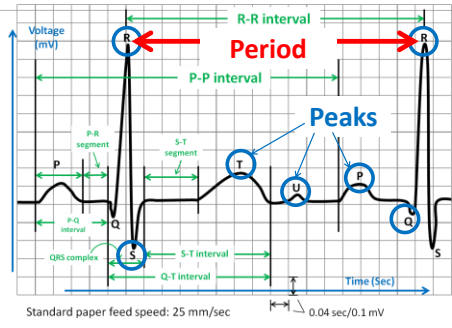

Figure: A typical ECG graph

Introduction and Background

- Most ECG systems use the Pan-Tompkins approach based on the QRS complex
  - Usage of an R-peak as a reference point
  - Accurate detection of the R-peak is a must
    - ➢ R-peak detection might **be inaccurate**

- Traditional techniques **may fail** in detecting serious heart problems

Introduction and Background

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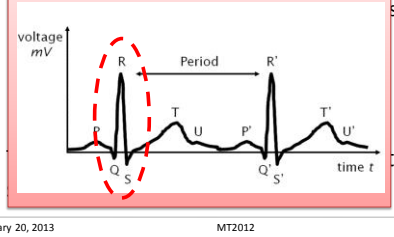

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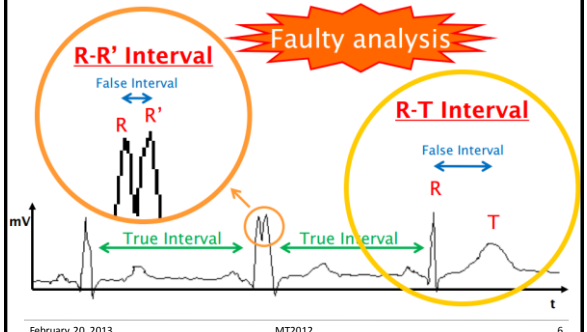


BANSMOM System Architecture

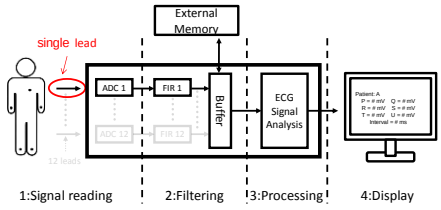
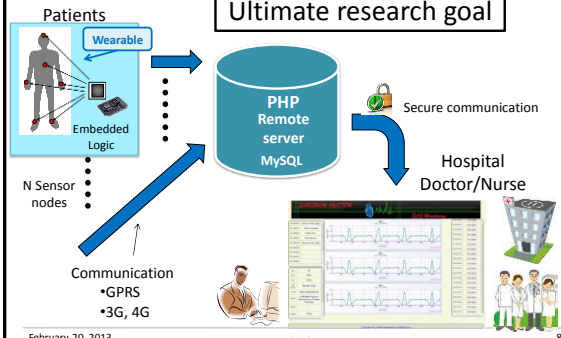


Figure: single lead system architecture

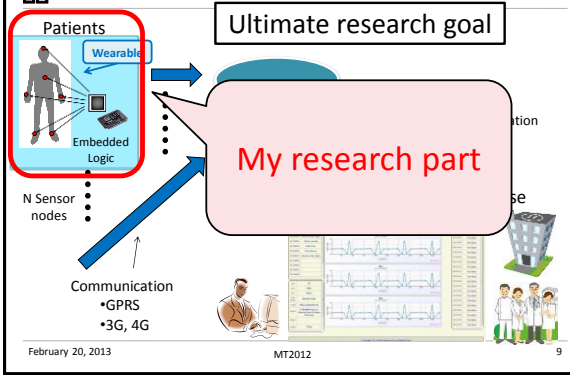
BANSMOM System Architecture

Ultimate research goal



BANSMOM System Architecture

Ultimate research goal



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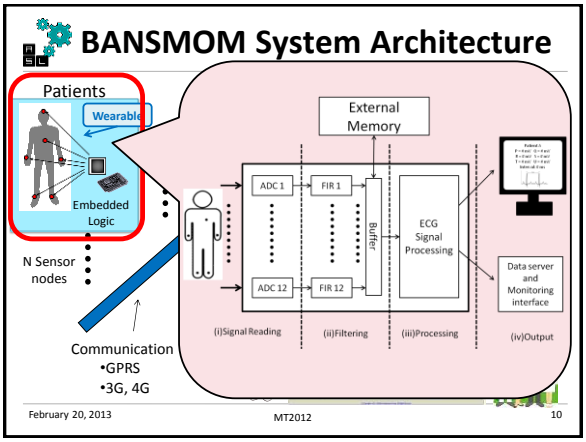

BANSMOM System Architecture

Stratix III DSP Board

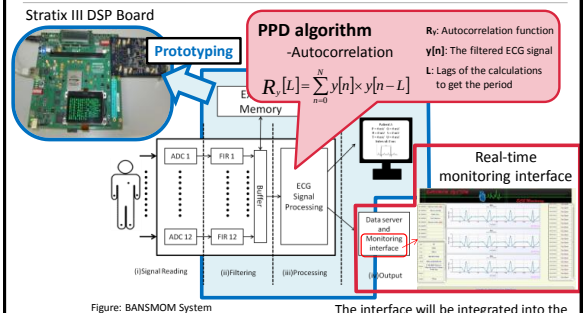

Figure: BANSMOM System Architecture Block Diagram

The interface will be integrated into the processing system in the near future

BANSMOM System Architecture

Stratix III DSP Board

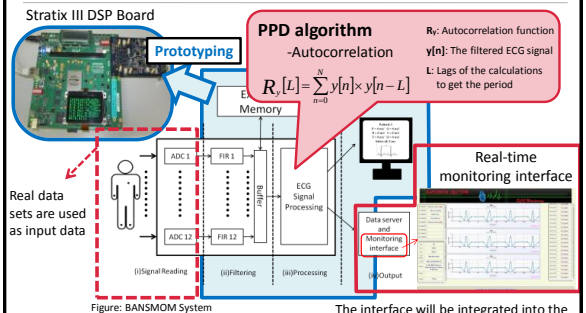

Figure: BANSMOM System Architecture Block Diagram

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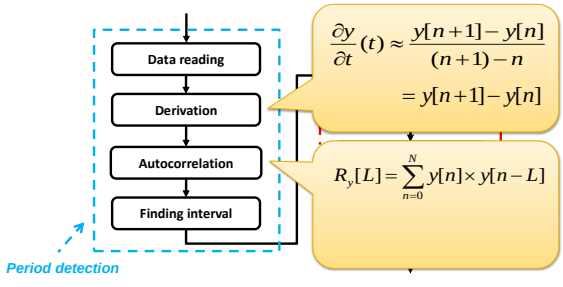
Research Motivation

- Previously developed BANSMOM system has **several limitations**:
  - Few leads support
  - Low hardware usability
  - No DMA and Ethernet Support
  - Does not Support Connection to DB Server in order to monitor data efficiently in real-time

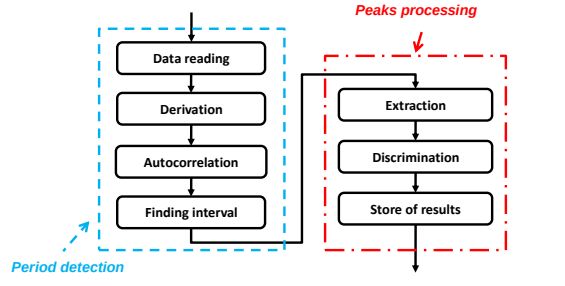
Research Goal

- **Design** and **evaluation** of a high performance **Real-Time multiprocessor SoC system on FPGA** for ECG processing based on Period-Peak Detection Algorithm:
  - ✓ Hardware Optimization
  - ✓ System Integration
  - ✓ Evaluate the optimized system with many different types of sample data

Period-Peak Detection Algorithm



Period-Peak Detection Algorithm



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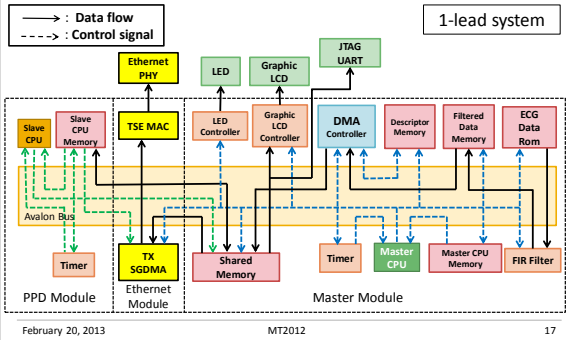

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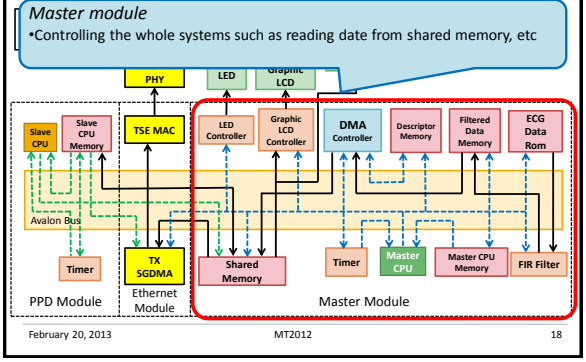

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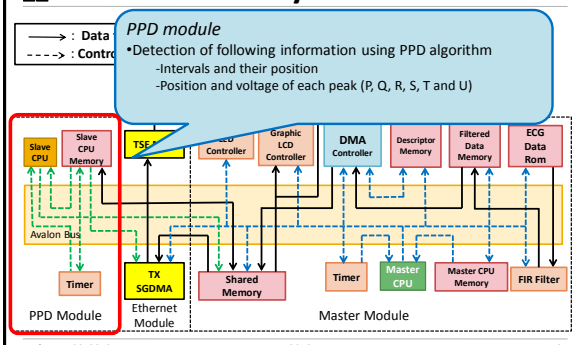

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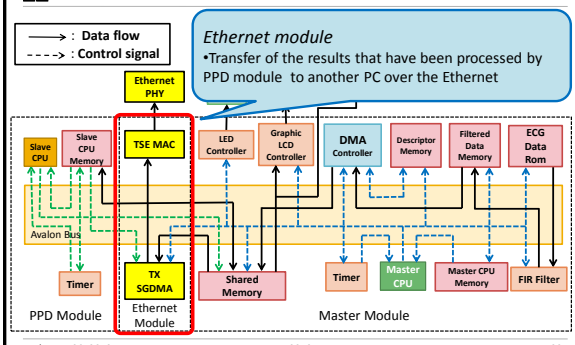

Prototyping and Evaluation Method

- Verilog HDL
- Quartus II, SOPC Builder, and NIOS II IDE
- Target device: Stratix III DSP Board (EP3SL150F1152C2)
- 8 real data sets
  - From MIT-BIH Normal Sinus Rhythm Database
- Evaluation parameters
  - Hardware complexity
  - Execution time
  - Accuracy

HW and SW Complexity

System model	Logic utilization			Block memory bits	Fmax (MHz)	Power (mW)
	Combinational ALUTs	Dedicated Logic registers	Total			
BANSMOM (3-lead system)	24,819	31,087	38%	2,430,216(43%)	99.34	953
OBANSMOM (6-lead system)	52,060	64,066	79%	4,386,330(78%)	86.07	986.88

Main module (lines)	PPD module (lines)								Total (lines)
	Total	Breakdown							
		Reading data	Deriva-tion	Autocor relation	Find interval	Peaks detection	Store result		
696	288	30	6	17	60	126	49		984

Execution Time Evaluation

Database No.	Execution Time (seconds)							
	Phase of Period-Peaks Detection algorithm							Total
	Reading data	Deriva-tion	Autocorre-lation	Finding Intervals	Extraction	Discrimi-nation	Store result	
16265	3.608	0.008	2.087	0.028	0.010	0.001	< 0.001	5.812
16273	2.300	0.009	2.387	0.032	0.010	0.001	< 0.001	4.919
16420	3.363	0.008	2.088	0.028	0.011	0.001	< 0.001	5.903
16773	2.671	0.011	2.985	0.040	0.010	0.001	< 0.001	5.700
16786	1.586	0.011	2.984	0.040	0.010	0.001	< 0.001	4.659
17052	3.225	0.010	2.688	0.037	0.010	0.001	< 0.001	6.035
18177	2.890	0.009	2.386	0.032	0.010	0.001	< 0.001	5.362
18184	1.368	0.010	2.683	0.036	0.007	0.001	< 0.001	4.164

Total processing time < 10 seconds (length of the input data)

Accuracy of PPD Algorithm

- Algorithm has average 69% accuracy
  - In typical normal waveform

Database No.	Detected RR Interval (# of interval)	Failed Detection (# of interval)
16265	14	7 (50%)
16273	13	3 (23%)
16420	14	5 (36%)
16773	10	1 (10%)
16786	10	3 (30%)
17052	9	2 (22%)
18177	15	5 (33%)
18184	8	3 (38%)

Average 31% failure rate

Sample data: *Heart signal of 10 seconds (1,280 samples)*

Sample type: *MIT-BIH Normal Sinus Rhythm*

Conclusion

- Design a high performance Real-Time multiprocessor SoC system on FPGA
  - DMA
  - Ethernet
- Real-Time Parallel processing of ECG signals based on a new Period-Peak Detection Algorithm
- PPD algorithm processing on BANSMOM system has average 69% accuracy
- Designed system occupies about 79% of available LU

Future Work

- Evaluate BANSMOM system with more real data sets
- Study other ECG processing algorithms on BANSMOM system
- Optimize BANSMOM system by adding encryption and compression capability

Thank you for listening