nano-tera.ch
swiss scientific initiative in health / security / environment systems

UltrasoundToGo RTD 2016

FNSNF

Safe and Optimal Deployment of 3D Ultrasound Application on Kalray MPPA-256 Platform

ÉCOLE POLYTECHNIQUE FÉDÉRALE DE LAUSANNE

Stefanos Skalistis, Ahmet Caner Yüzügüler and Alena Simalatsar

Rigorous System Design Laboratory (RiSD), EPFL

Introduction

The optimal deployment of data streaming application onto many-core architecture is a multi-criteria optimization problem [1]. We solve this problem for 3D Ultrasound (US) application [2] with its most computationally demanding ***beamforming*** part being executed on MPPA-256 many-core chip with high degree of parallelization. The amount of shared memory on each cluster is limited (~1MB for application data), therefore we choose suitable optimal configurations of the US system.

Safe and optimal US application deployment

Steps of Ultrasound processing

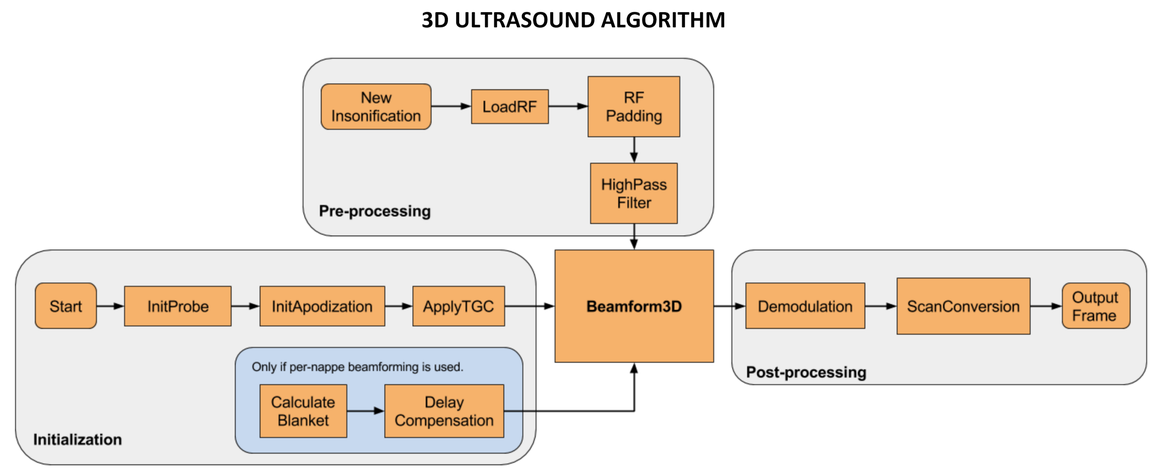
- Generated of RF data by Field II simulation
- Initialization of essential US coefficients
- Highpass filtering of incoming RF data
- 3D beamforming by apodization and summing:
  - Beamforming is done nappe-by-nappe [3]
  - Delays are calculated on-the-fly by steering method
- Demodulation, scan conversion & visualization

Kalray MPPA-256 platform:

- Host processor Intel with 4GB DDR memory
- 2 IO clusters with 4 cores and 4GB of memory
- Many-core MPPA-256 chip:
  - 256 cores (400 MHz) in 16 clusters
  - 2MB shared scratchpad memory
  - 2D-torus NoC

Software Implementation

- Initialization & pre-processing on Host
- Reference delays computed on IO clusters
- RF data partitioned on IO cluster
- Beamforming efficiently parallelized on compute clusters of Kalray MPPA-256 chip
- Output image is aggregated on IO clusters
- Scan conversion is done on Host



Two memory-wise optimal configurations

- Probe = 12 x 12 array;
- Volume depth = 4.5cm
- φ,ϑ ∈ [-38°, 38°];
- fc = 4Mhz;
- fs = 200MHz

- Probe = 64 x 64 array;
- Volume depth = 4.5cm
- φ,ϑ ∈ [-38°, 38°];
- fc = 4Mhz;
- fs = 12MHz

A blanket of echo signals that need to be stored on each cluster:

Memory required by one blanket is ~ 1MB

Time running the whole application of the host processor (1 thread):

➢~ 30s ➢~ 13 minutes

Time when Beamforming is running on the Kalray MPPA-256 chip:

➢~ 0.5s ➢~ 14s

Conclusion

- The memory usage is a trade-off between the probe size and sampling frequency
- The computation time is proportional to the probe-size and does not depend on the sampling frequency
- The acceleration gain in average is about 55 times

Acknowledgment

This research work was funded by the Swiss Confederation through the UltrasoundToGo project of the Nano-Tera.ch initiative.

[1] Tendulkar, Pranav, et al. "Many-Core Scheduling of Data Parallel Applications using SMT Solvers." Digital System Design (DSD), 2014 17th Euromicro Conference on. IEEE, 2014.
[2] Ibrahim, Aya, et al. "Assessment of Image Quality vs. Computation Cost for Different Parameterizations of Ultrasound Imaging Pipelines.“ Medical Cyber-Physical Systems (MCPS) Workshop, 2015
[3] Pirmin Vogel, Andrea Bartolini, Luca Benini, "Efficient Parallel Beamforming for 3D Ultrasound Imaging", GLSVLSI'14, May 21–23, 2014, Houston, Texas, USA.