RESEARCH ACTIVITIES

Self-Reconfigurable Embedded Systems

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Outline

- Self-Reconfigurable Embedded Systems

- Current Research Activities
  - Video Compression: HEVC
  - Radon Transform and Radon-Based 2D Convolutions
  - Smart Antennas
  - Cylinder Pressure Estimation

- Goals
Self-Reconfigurable Embedded Systems

Digital systems can be characterized by a series of properties:

- Energy
- Performance
- Precision,
- Bandwidth, Quality, etc.

Self-Reconfigurable Embedded Systems are self-adaptive systems that can satisfy time-varying requirements, optimizing resources and energy.
Self Reconfigurable Embedded Systems

- **Technology**: Programmable System-on-Chip (SoC): They integrate:
  - **Processing System (PS)**: A dual-core ARM® Cortex™-A9 processor and common peripherals (USB, SD, etc.)
  - **Programmable Logic (PL)**: Reconfigurable fabric (also known as FPGA) that can be reconfigured at run-time.

**Xilinx Zynq-7000 All-Programmable SoC:**

Embedded system with common peripherals, interrupts, and run-time alterable custom hardware.
Current Research Activities

- Video Compression Standard (HEVC) Implementation
  - Self-reconfigurable hardware implementation: Transform (Forward and Inverse), Quantization, Intra-Prediction
  - Products: 1 paper, 1 journal (minor revision).

- Fully-parallel architecture of the HEVC Transform (1D).
  - Block size: 16x16 pixels.
Current Research Activities

- **Radon Transform and Fast Convolutions**
  - Scalable dedicated architectures for Direct/Inverse Radon Transform and for Radon-based 2D Convolution (faster than FFT methods)
  - Products: 2 conf. papers, 2 journals, 1 journal under review, one patent.

2D Radon-based Convolution for prime-sized images:
Current Research Activities

- **Smart Antennas**
  - Implementation of switched-beam smart antennas using self-reconfigurable architectures to steer the beamformer in a particular direction at run-time, and to respond to arithmetic overflow by updating the numerical format.
  - Products: 1 conference paper, 1 journal under review

![Diagram of Smart Antennas](image-url)

\[ RL_P = \left\lfloor \log_2 BO \right\rfloor + \left\lfloor \log_2 (M/L) \right\rfloor + 3 \]
Current Research Activities

- **Cylinder Pressure Estimation**
  - Closed Cylinder Engine: Based on Real pressure data, \( dQ_{HR} \) is computed for various load and rpm conditions. Then, a model for \( dQ_{HR} \) is derived.
  - Then, Pressure can be estimated with the \( dQ_{HR} \) model (hopefully for many load and rpm conditions).

\[
P(n+1) = P(n) + \Delta \theta \left[ \frac{(\gamma - 1) dQ_{HR}}{V(n)} \frac{dV}{d\theta} |_n - \gamma \frac{P(n) dV}{V(n)} \frac{d\theta}{d\theta} |_n - \frac{(\gamma - 1) dQ_{HT}}{V(n)} \frac{d\theta}{d\theta} |_n \right]
\]

- Hardware implementation: It uses Dual Fixed-Point Arithmetic that provides a compromise between Floating Point Arithmetic (high hardware usage) and Fixed Point (reduced range of numerical values).
Goals

- Apply for funding to the following entities:
  - Army Research Laboratory (ARL): Switched-beam Smart Antennas
  - Office of Naval Research (ONR): Dynamic biomimetic sensors.
  - NSF: Distributed Video Analysis using fast 2D Convolutions based on reconfigurable Radon Transforms and HEVC decoder/encoder
  - Chrysler, Ford: Instantaneous Pressure estimation using self-reconfigurable embedded systems.