FPGA in Advanced Vision Applications

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Tools for Measurement, Control and Automated Test

Platform – hardware

Tools for Measurement, Control and Automated Test

Platform - Software

NI InsightCM™ Enterprise

Desktops, Laptops, and Mobile

NI CompactDAQ
PXI and Modular Instruments
NI CompactRIO

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Multicore CPU systems

- Ride the CPU frequency wave
- Automatic hardware acceleration (SSE, Hyperthreading)
- Making software multithreaded
  - OpenMP (multiple cores)
  - MPI (multiple separate machines)
  - Vision Development Module
- Some problems divide well
- Others don’t
FPGAs

- Latency ✓
- Jitter ✓
- Compute power ✓
- Pipelining ✓
- Security ✓
- Weight / Power / Heat ✓
- Complexity ✗
- Raw Clock Rates ✗
- Limited Floating Point support ✗
Latency - Preprocessing

Diagram showing the process with blocks labeled as follows:
- Exp
- Readout
- Processing

The diagram illustrates the loop period with arrows pointing in both directions.
Latency – Co-processing

- Exp
- Readout
- Processing
- Loop Period
Latency – Co-processing

Exp

Readout

Exp

Loop Period

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Complexity

Counter

Analog I/O

I/O with DMA

LabVIEW FPGA

VHD

~4000 lines

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Image Processing and Visualization

- FPGA is directly in the path of the image data
- Processes pixels as they arrive
- May require some buffering—2D kernel operations
- Generates and outputs images directly or send result to host CPU
NI FPGA Hardware

- NI FlexRIO + NI 1483 adapter module
- PCIe-1473R
  - Base, medium or full configuration cameras
  - General purpose digital I/O
- LabVIEW FPGA example programs
  - Area scan and linescan image acquisition
  - Threshold
  - Centroid
  - Bayer decoding
FlexRIO for PXI System Architecture

**I/O**
- FlexRIO Adapter Module
- Camera Link Module

**FPGA**
- FlexRIO FPGA Module
  - Kintex-7 FPGA
  - Up to 2 GB of DRAM
  - PCIe Gen 2 x 8

**Processor**
- PXI Platform
  - Embedded Controllers
  - Synchronization
  - Data streaming
  - Power/cooling

132 DIO

PCIe
Visualization

- Image transformation
  - Image warping, rotation and flip
  - Image compression, encryption, and authentication
- Feature highlighting
  - Filtering
  - Shading correction
- Noise reduction
  - Image averaging
  - Retinex algorithm
Image Processing Functions

FPGAs suitable to improve images and extract basic features

- **Preprocessing**
  - Image transforms
  - Image operators
  - Shading correction
  - Bayer decoding
  - Color space conversion
  - 1D & 2D FFT
  - Filtering (smooth/sharpen)
  - Binary morphology

- **Feature Extraction**
  - Edge, lines corners
  - Binary objects
  - Color

- **Measurements**
  - Centroid
  - Area measurements
Image Processing Functions

FPGAs not suitable for certain high-level algorithms

• Object-level vision functions
  – Pattern matching
  – OCR/OCV
  – Barcode reading
  – Some geometric measurements
  – Classification
High-Speed Control

- FPGA is directly in the path of the image data
- FPGA generates and outputs control commands directly
High-Speed Control

- Laser alignment/steering
  - Beam profile/position measurements
  - Low latency control output

- High-speed sorting
  - Segmentation
  - Measure parameters of contaminant
  - Trigger rejection valves

- In Air Sorting
  - Image and inspect falling product
  - Low jitter requirement for decision making and IO
Example: Medical Imaging

Challenge

Develop the signal processing backend for an Optical Coherence Tomography machine.

High Level Requirements

- Sample at 800 MS/s
- Control fast steering mirrors to perform raster scan imaging in real-time
- Stream image data over the network
FlexRIO Optimized for Deployment

**I/O**
- FlexRIO Adapter Module
- Interchangeable I/O
- Analog, Digital, RF
- Custom I/O with MDK

**FPGA**
- 132 DIO

**Processor**
- Controller for FlexRIO
- Kintex-7 FPGA
- Dual-Core ARM Processor
- High Speed Serial
- NI Linux Real-Time OS
- Optimized for Size, Weight, Power

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OCT Solution with Controller for FlexRIO

NI 5772
2 Ch 800 MS/s
12-bit

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Image Co-processing
Visual Servo Control

- CAPTURED IMAGES
- Move Complete
- Image Capture
- VISION
- Image Feedback
- MOTION
Visual Servo Control: Direct Servo

- Control Loop
  - Position Setpoint
  - Position Feedback
  - 5ms
  - Image Processing
    - Coordinate Transform
    - Camera
  - Image Processing
    - Coordinate Transform
    - Camera

Actuator
IC-3173 EtherCAT Master: Machine Controller

Touchscreen HMI

To the network or PC

To industrial I/O

GigE (PoE)

(EtherCAT)

AKD EtherCAT Servo Drive

(EtherCAT)

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Future Looking Projects Using FPGA Co-processing

System On Module
You Might Want to Use an FPGA for Vision…

- If latency or jitter is critical
- If power consumption is critical
- If you have to speed up throughput
- If you can pipeline your algorithms
- If you have to reduce the amount of data or aggregate multiple high-speed channels
- If you are using algorithms that can take advantage of the FPGA architecture
- If the FPGA is already in the image path
- If any of the above give you a competitive advantage