An innovative Vision System for Industrial Applications

Ricardo Ribalda Delgado
Supervised by: Prof. Javier Garrido Salas
Creation of the CCD

1969

INVENTORS
W. S. BOYLE
G. E. SMITH

BY
SRI Vision Module
Custom-designed computer vision systems are being applied to specific manufacturing tasks. Current development may lead to general-purpose systems for a broad range of industrial applications.

Gerald J. Agin, 1980

Stanford Research Institute

Computer Vision Today
Computer Vision Today
Computer Vision Today
Computer Vision Today
Computer Vision Today
Computer Vision Today
Industrial Computer Vision

Great computing demands

Low latency

High profit margin

New opportunities every day
Application Development

Multidisciplinary

Uncertain

Closed market

Incomparable results

Single use components
Goals

- General Purpose Computer Vision System
- Reusable parts
- Comparable results
- Wide Spectrum of applications
- Based on Open Source
Requirement Analysis

System on Chip
- Biometric System on Token
  - Texas OMAP4 SOC

FPGA
- Fingerprint Acquisition System
  - Virtex 4 FPGA

CPU + GPU
- Bidimensional Interferometer
  - Nvidia Tesla GPU
System on Chip Computer Vision System

**Application:** Fingerprint matching

**Hardware:** Nokia N800 based on Texas Instruments OMAP 3 SOC

**Software:** NBIS fingerprint processing software

**Goal:** 2 seconds per transaction
# System on Chip Computer Vision System

## Pros
- Auditable Open Source stack
- Integrated DSP
- Mature API
- COTS Hardware

## Cons
- Small selection of sensors
- Limited computer resources
- Non updatable hardware
- No direct access to the sensor
FPGA Computer Vision System

**Application:** Acquisition of fingerprints in 3D

**Sensor:** Vector BCI 6 Mpix Mono

**Hardware:** Custom System based on Virtex 4 FX FPGA

**Software:** Custom Linux Distribution

**Goals:** Low latency auditable
FPGA Computer Vision System
FPGA Computer Vision System

Used on real life
FPGA Computer Vision System

**Pros**

- Image Preprocessing Capabilities
- Low level access to the sensor
- Open Source Stack

**Cons**

- Highly coupled to the selected sensor
- Low Performance CPU
- Custom sensor API
- No Image Processing Software Stack
- Slow Development Cycle
GPU + CPU Computer Vision System

**Application:** Atmospheric research

**Hardware:** x86 + NVIDIA GPU

**Software:** C+CUDA

**Goal:** real time processing
GPU + CPU Computer Vision System
## GPU + CPU Computer Vision System

<table>
<thead>
<tr>
<th>Pros</th>
<th>Cons</th>
</tr>
</thead>
<tbody>
<tr>
<td>Great computing power</td>
<td>Lack of Computer Vision Stack</td>
</tr>
<tr>
<td>High level of parallelization</td>
<td>No image preprocessing</td>
</tr>
<tr>
<td>200x faster than reference implementation</td>
<td>Highly coupled to the selected sensor</td>
</tr>
<tr>
<td>Simple programming (C based)</td>
<td>Nvidia specific programming language</td>
</tr>
</tbody>
</table>

Used on real life
Generic Computer Vision System
Modular Structure

HEAD

Sensor

LVDS

BODY

Image Processing Pipeline

PCle

Processing Unit

PCle

Acceleration Unit

SOFTWARE

User Application

Open Source API

Computer Vision Stack

SOFTWARE

Video4Linux

Linux

OpenCL

Original Contribution
QT5022: head

**CCD:** 1, 3 and 5 sensors

**CMOS:** 2, 4, 8 and 12 Mpix

**Roic:** InGaAs and microbolometer

**Dual eye:** CMOS
Hardware
QT5022: body

Image processing pipeline: Spartan 6 / Kintex
Processing unit: AMD APU
Acceleration unit: GPU
Hardware
Image Processing Pipeline

PCle interface to the Processing Unit

Plenty of resources available

2 implementations:

- Spartan6
- Kintex

Reconfigurable
Frame Generator

Sensor Abstraction
Synchronization
Data readout
Debayer
Fixed Pattern Noise
XForm

Buffer → Interpolation → Remap → Gain

Original Contribution
Data Packer

RGB24
RGB32
BGR24
BGR32
GREY
Y16
Y16_BE
SBGGR8
SGBRG8
SGRGB8
SRGGB8
UYVY
YUYV
RGBPP40
RGBPP80
Hardware
Processing Unit

AMD APU G-T65N:
- 2 x 1.65 GHz x86 cores
- 1x Radeon 6320 GPU

Memory: 4 GiB DDR2 RAM

Dual Port Intel Gigabit Ethernet

Fintek Serial Port

Custom Hardware Monitor
Hardware
Acceleration Unit / OpenCL

Massive number of threads

Hardware agnostic: Implemented by GPU, DSP, CPU or FPGA
Acceleration Unit
Acceleration Unit

![Graph showing acceleration measurements](image)

**Measurements:**
- **RMS(1):** 510.8 mA
- **Avg(1):** 501.5 mA
- **Current:** 510.8 mA to 501.5 mA
- **Mean:** 511.53 mA, 502.20 mA
- **Min:** 507.3 mA, 498.3 mA
- **Max:** 516.5 mA, 506.8 mA
- **Std Dev:** 4.6436 mA, 4.2930 mA
- **Count:** 3, 3

**Timestamp:** TUE JUN 16 14:24:55 2015
Modular Structure
Software
Kernel

All Open Source
(except video drivers)

2 approaches:
- manufacturer tree
- upstream
Video4Linux

- User Space
- Qbuf
- Dqbuf
- Incoming
- Outgoing
- IO
- Read/Write
- Memory Map
- Userptr
- Dmabuf
### Video4Linux

| Red Balance | Blue Balance | Gain | Horizontal Flip | Vertical Flip | Cropped Frames | Writing Frames | Map Frames/Queue | Sensor Type | Bitstream Version | Reset Pipeline | Head12C Address | Head12C Bus | Green Balance | P1 Balance | P2 Balance | Compact Balance | Red Offset | Green Offset | P1 Offset | P2 Offset | Copyright Offset |.writeInt | Set | Get |
|-------------|--------------|------|-----------------|--------------|---------------|----------------|-----------------|-------------|----------------|----------------|----------------|-------------|-------------|-------------|-----------|-------------|-----------|------------|---------------|-----------|-------------|-----------|------------|----------------|---------|-----|-----|
|             |              |      |                 |              |               |                |                 |             |               |                |               |             |             |             |           |             |             |            |             |           |           |                |         |     |     |

### Video4Linux

- **Multitype**
- **Cache**
- **Atomic**
- **Arrays**
- **Events**
- **Error Flags**
Video4Linux

DATA SOURCE
CROP_DEFAULT
CROP_BOUNDS

DATA SINK
COMPOSE_DEFAULT
COMPOSE_BOUNDS

DATA SOURCE
CROP_DEFAULT
CROP_BOUNDS

DATA SINK
COMPOSE_DEFAULT
COMPOSE_BOUNDS

Number_lines = Number_lines1 + Number_lines2 + Number_lines3 + Number_lines4

Figure 9: Example of 4 multiple frames read out
Yocto Project
Computer Vision Stack

IP[y]: Notebook

OpenCL

gstcamer

LINUX TV

HALCON

the Power of Machine Vision

OpenCV

Biometric and Artificial Intelligence Technologies
## Goals Recap

### Pros

- Auditable Open Source stack
- Integrated DSP
- Mature API
- Image Preprocessing Capabilities
- Real time performance
- Highly Parallel Architecture
- Easy Programming
- COTS Hardware

### Cons

- Small selection of sensors
- Limited computer resources
- Non updatable hardware
- No direct access to the sensor
- No Image Preprocessing
- Custom sensor API
- No Image Processing Software Stack
- Slow Development Cycle
Business Model
Applications

Potato Grader  Batch analyzer  Checkweigher  Spectral Camera
Potato Grader
Potato Grader
Potato Grader

28 tons per hour
13 categories
1 mm² resolution
Hyperspectral Camera
Hyperspectral Camera
Hyperspectral Camera
Conclusion and Future Work
Original Contributions
# Gerald J. Agin Alike System

## Pros
- Auditable Open Source stack
- Integrated DSP
- Mature API
- Image Preprocessing Capabilities
- Real time performance
- Highly Parallel Architecture
- Easy Programming
- COTS Hardware

## Cons
- Small selection of sensors
- Limited computer resources
- Non updatable hardware
- No direct access to the sensor
- No image preprocessing
- Custom sensor API
- No Image Processing Software Stack
- Slow Development Cycle
Scientific Communication


Standardization Process


Open Source Contributions

**Linux Kernel**: 172 contributions merged. Including a 9+ year old bug. 2nd Spanish Contributor by number of patches.


**Yocto project**: 17 contributions. Supporting organization of the project.

**v4l-utils/libv4l2**: 7 contributions.

**Flashrom**: Support for the first board with EEprom memory.

**Gerbil**: 2 contributions

**Clpeak**: 2 contributions.

**Video Lan Client**: 1 contribution.
Future Work

Image Processing Pipeline: High Level Synthesis

Processing Unit: Full Open source

Sensor Interface: USB3

Standardisation
Open Discussion
An innovative Vision System for Industrial Applications

Thanks!
Batch Analyzer
Batch Analyzer
Batch Analyzer
Checkweigher
Checkweigher

Detects and separates bags too close to each other
Clock Synchronization

NTP

PTP