Integration of Miniature Smart Cameras into Robotic Applications

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Microscan Systems
Many Definitions of a Robot

- Multi-Axis Motion Systems
- Traditional Industrial Robots
- Collaborative Robots
- Mobile Robots
- Warehouse Robots
- Self Driving Cars

Source: Schneider Elec, Unimation, UR, TRC, Tech Xplore (Fetch), Google
Robot Markets

- Automotive
- Electronics
- Clinical
- Food and Beverage
- Packaging
- Warehousing
- General Manufacturing

Source: UR Robots, Fanuc, Montclaire.edu, Motoman, ABB (Electronic Design)
Robot Applications

- Pick and Place
- Assembly
- Quality Inspection
- Packaging and Palletizing
- Lab Analysis and Testing
- Screw Driving
- Labeling
- Gluing, Dispensing and Welding
- Polishing
- Injection Molding
Robot Applications – (Vision and AutoID Apps)

• Pick and Place – (Locate, Read, Guide)
• Assembly – (Locate, Read, Guide, Check)
• Quality Inspection - (Check, Measure, Read)
• Packaging and Palletizing - (Locate, Read, Guide, Check)
• Lab Analysis and Testing - (Locate, Measure, Read, Guide, Check)
• Screw Driving - (Locate, Guide, Check)
• Labeling - (Locate, Read/Verify)
• Gluing, Dispensing and Welding - (Guide, Check)
• Polishing - (Check)
• Injection Molding - (Check, Measure)

AutoID - Reading 1D and 2D codes are integral to many applications.
Challenges Integrating Vision with Robots

• Robot Applications need AutoID and Machine Vision to Achieve:
  • Fuller autonomy
  • Greater speeds
  • Greater accuracy
  • Ability to perform high value operations

• Robot Applications Face Challenges in Many Areas:
  • Physical Installation – Mounting, Size, Optics, Lighting
  • Cabling – High Flex cables capable of millions of cycles
  • Programming – Simplicity, Flexibility, UI integration with Robot Controller
  • Calibration – 2D and 3D, Multiple coordinate systems
  • Integration of Results – Data formatting, Protocol support, Image display
Miniature Smart Cameras

- **Miniature Smart Cameras Use Cases**
  - **General Use**
    - Fully Integrated Camera – Lighting to communications
    - Powerful toolset, simple programming and deployment software
    - Highly configurable to achieve best price
  - **Light weight on the end of a robot arm**
    - Low mass
    - Integral to robot gripper
  - **Dense pack many cameras together over a single part**
    - Multiple cameras needed for high resolution inspection
    - Avoids parallax issue with single camera looking at all features
  - **Embedded – One/multiple cameras in very small spaces**
    - SMT Pick and Place machines as one example
    - Desk top clinical analyzer as another

Source: UR, Microscan
Miniaturization – Camera Examples

- MV-Engine: Ethernet, Serial, Digital IO
- MV-20: Ethernet over USB
- MV-30: Serial, Digital IO
- MV-40: Ethernet, Serial, Digital IO

• Lighting
• Optics
• AutoFocus
• Processing
• Comm

Source: Microscan
General Use Example – Food and Beverage

- Mounting – Over the Work Space
- Lighting – General Large Area Lighting
- Optics – Wide Angle
- Calibration – Vision to Robot Pick Area
- Tools
  - Morphology/Blob
  - Custom Scripts for Pick Ordering
- Output
  - Serial, TCP/IP Socket
  - Pick Order, X, Y, Size, Defects

Source: Motoman
• Calibration is performed using robot placed target/targets
• Vision gets calibrated to robot pick space
General Use Example – The Task

- Product fills lanes
- Vision Computes Count, X, Y, Size, Pick Order
- Reports data to robot
- Robot picks up product
General Use Example – Tools

- Morphology
  - Separate and Segment

- Blob
  - Centroid
  - Angle
  - Size

- Custom Scripting tool sorts results and sends “pick” order to robot
General Use Example – Outputs

• Sends all data to Robot via:
  • RS-232
  • Socket
  • PLC Links

• Display image on HMI
End of Arm Example – Automotive, Engine Check

- Mounting – End of Arm
- Lighting - Integrated
- Optics - Auto Focus
- Calibration - Simple
- Programming
  - Multiple Inspections
  - Asynch Triggering
- Tools
  - Presence/Absence
  - Reading
  - Measure …
- Output
  - P/F or Data per Inspection
End of Arm Example - Challenges

• High Speed Robot Motion
  • Requires Low Camera Mass

• Very High Cycle Counts
  • Requires high flex Power and EtherNet cables

• Multiple Inspections
  • Requires multiple inspections within a single job
    • Unique Triggers
    • Unique Sets of Tools
    • Unique Vision Results
  • Requires fast AutoFocus lens to inspect at different distances
  • Requires active control over gain, exposure and lighting for optimum images

• Processes in Parallel With Robot Motion to Next Inspection Point
End of Arm Example - Programming

- Multiple Inspections
  - Unique Triggers
  - Focus Distance
  - Exposure/Gain
  - Lighting
  - Custom Output Result
Dense Pack Example – Consumer Electronics

• Assembly of Consumer Electronics
• Locate Critical Features on Each Part
• Computer Overall Location of Each Part
• Compute Offset of One Part to Other
• Robot Assembles Parts Together

Source: Joe Hu, AD 146 Rasche
Dense Pack Example – Challenges

- Very High Accuracy Required
- One to Two Features Per Camera
- Features Very Close Together
- Cameras Close Together
- All Cameras Look Through One Light
- Combine all Camera Results
- Calibrate Vision to Robot
Dense Pack Example – Assembly

- Lighting – Very Large DOAL
- Optics – Gauging Quality
- Calibration
  - Vision to Robot
  - Robot Moves Calibration Dot in Grid Pattern under all cameras
- Tools
  - Edge Based Pattern Match
  - Rigid Body Fit - Part 1 to Ideal
  - Rigid Body Fit - Part 2 to Ideal
  - Compute Offset Part 1 to Part 2
- Output
  - Offset for aligning Part 1 to Part 2
Embedded Example – Electronics

- Robot Picks Multiple Part Types from Trays
- Pick Head Flies Part over Camera
- Vision Computes X, Y, Theta of Part
- Robot Places Part on Board

Single or Multiple Cameras. Very small envelope for cameras and lighting.
Embedded Example - Challenges

- One or Multiple Cameras Buried in Very Small Spaces
- Very High Resolution Required - Micron Tolerances
- Very High Accuracy Achieved by Calibrating Vision to Pick Head
- Pick Head Needs Previously Calibrated to the PC Board (Fiducials)
- Handle Multiple Part Types – BGA, QFN, TSOP, etc.
  - Requires unique inspection and trigger per part type
  - Requires unique lighting, exposure and gain per part type
  - Employ Strobe lighting to freeze motion as robot “flies” part over camera
  - Requires automatic part training to locate features
    - Match features to cad model of part
    - Used to compute Rigid Body Fit of Part to ideal location on PCB
Embedded Example – Pick and Place Vision

- Lighting – Part Specific.
  - Low Angle Ring, Diffuse On Axis.

- Optics – Gauging Quality

- Calibration – Vision to Robot Gripper
  - Gripper is moved in a grid pattern
  - Vision locates gripper at all positions
  - Calibrate to robot coordinates

- Tools
  - Various for lead/pin/ball locate
  - Rigid Body Fit to Model Part

- Output
  - X, Y and Theta of Part

Source: Juki Automation Systems
Embedded Example – Part Types
Embedded Example – Automation in Life Sciences

- Clinical Diagnostics Instrumentation
- Point-of-Care Instrumentation
- Pathology Instrumentation
- Laboratory Automation
Embedded Example – Automation in Life Sciences

- Identification
- Inspection
- Measurement
- Guidance
Common Automated Identification Applications

- Identification of:
  - Specimen Tubes
  - Reagents
  - Tube carriers
  - Specimen slides/cassettes
  - Microwell plates
  - Pre-coded vials

Embedded Example – Automation in Life Sciences
Embedded Example – Automation in Life Sciences

• Test Tube Check for
  • Tube presence
  • Cap presence
  • Tube height
  • Tube diameter
  • Cap type
  • Cap color
  • Label presence
  • Label location
  • Fluid level detection
Embedded Example - Challenges

• Small Footprint Machines
• One or Multiple Cameras On Miniature Robots
• Very Low Cost
• Large Number and Variety of Inspections
• Very Short Working Distances
• Very Wide Fields of View
• Difficult Lighting Situations
• Calibrated and Un-calibrated Inspections
• Proof Testing on 10,000+ Samples
Embedded Example – Life Sciences

• Lighting
  • Embedded on Camera
  • Single LEDs at Critical Locations in Workspace
  • Retroreflective surfaces for Backlight

• Optics – 2.8 mm to 6 mm, 60-80 degree fields of view

• Calibration – Done on Model Tubes

• Inspections – 10 to 30. Up to 300 tools per job.

• Tools
  • Read
  • Inspect
  • Locate, Measure
  • Custom
Embedded Example – Life Sciences
Summary

- Robot Applications Face Challenges in Many Areas:
  - Physical Installation – Mounting, Size, Optics, Lighting
  - Cabling – High Flex, capable of millions of cycles
  - Programming – Simple yet Flexible, UI integration with robot controller
  - Calibration – 2D and 3D, marrying multiple coordinate systems
  - Integration of Results – Data formatting/output, Protocol support, Image display

- Miniature Smart Cameras Solve Many of These Challenges
  - General Use - Fully Integrated, Simple Programming, Configurable to Achieve Best Price
  - End of the robot arm - Low mass, Built into robot gripper, High number of inspections
  - Dense packed - Many cameras fit together over a single part for high accuracy results
  - Embedded applications - Fit multiple cameras into small spaces
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