Machine Vision

Lecture 15

Machine Vision in manufacturing

Outlines

- Tasks
- Why Machine Vision?
- Examples
- Computational requirements and using of DSP
- Inspection of surfaces

Automation & Machine Vision

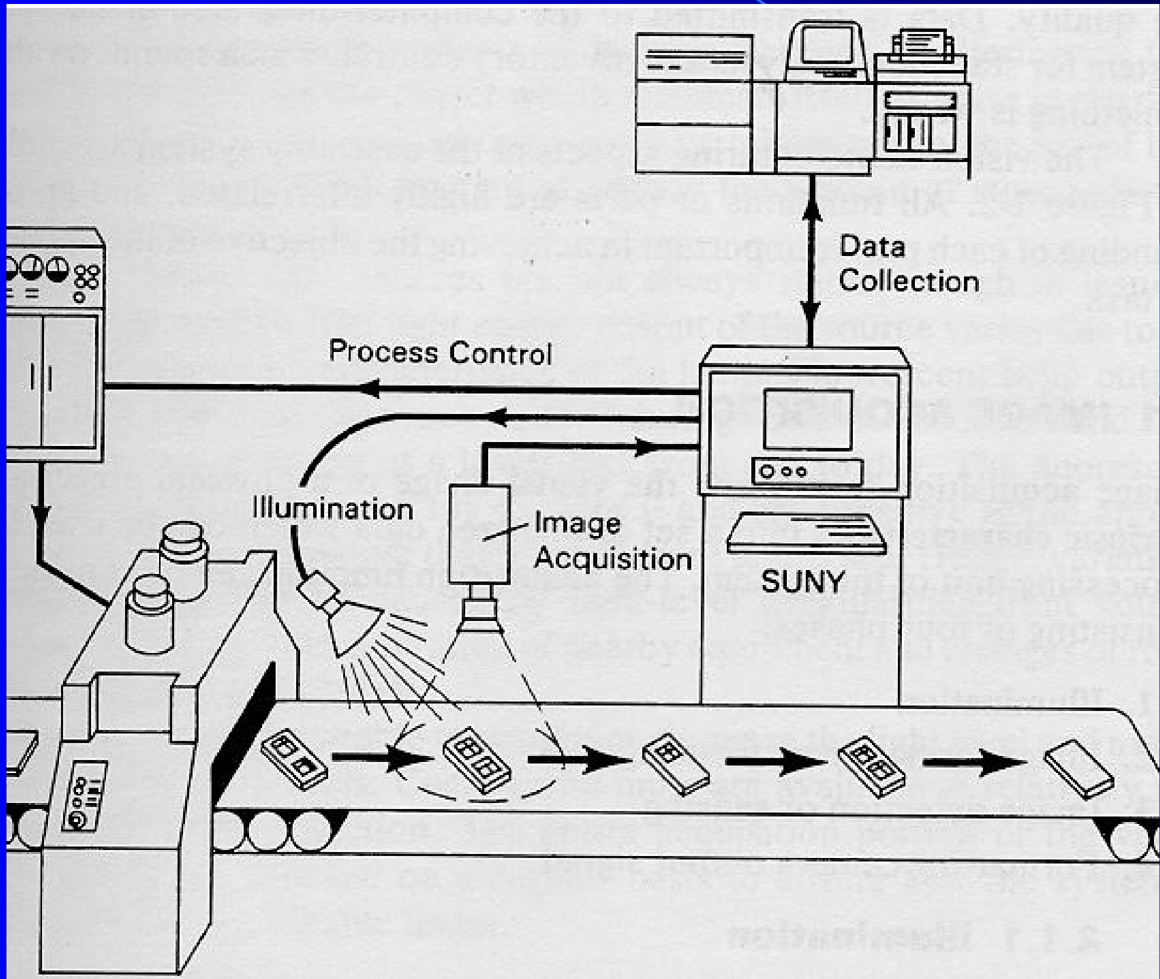
Motoman SP100 robot with vacuum gripper palletizes cases of filters.

Robot and Vision

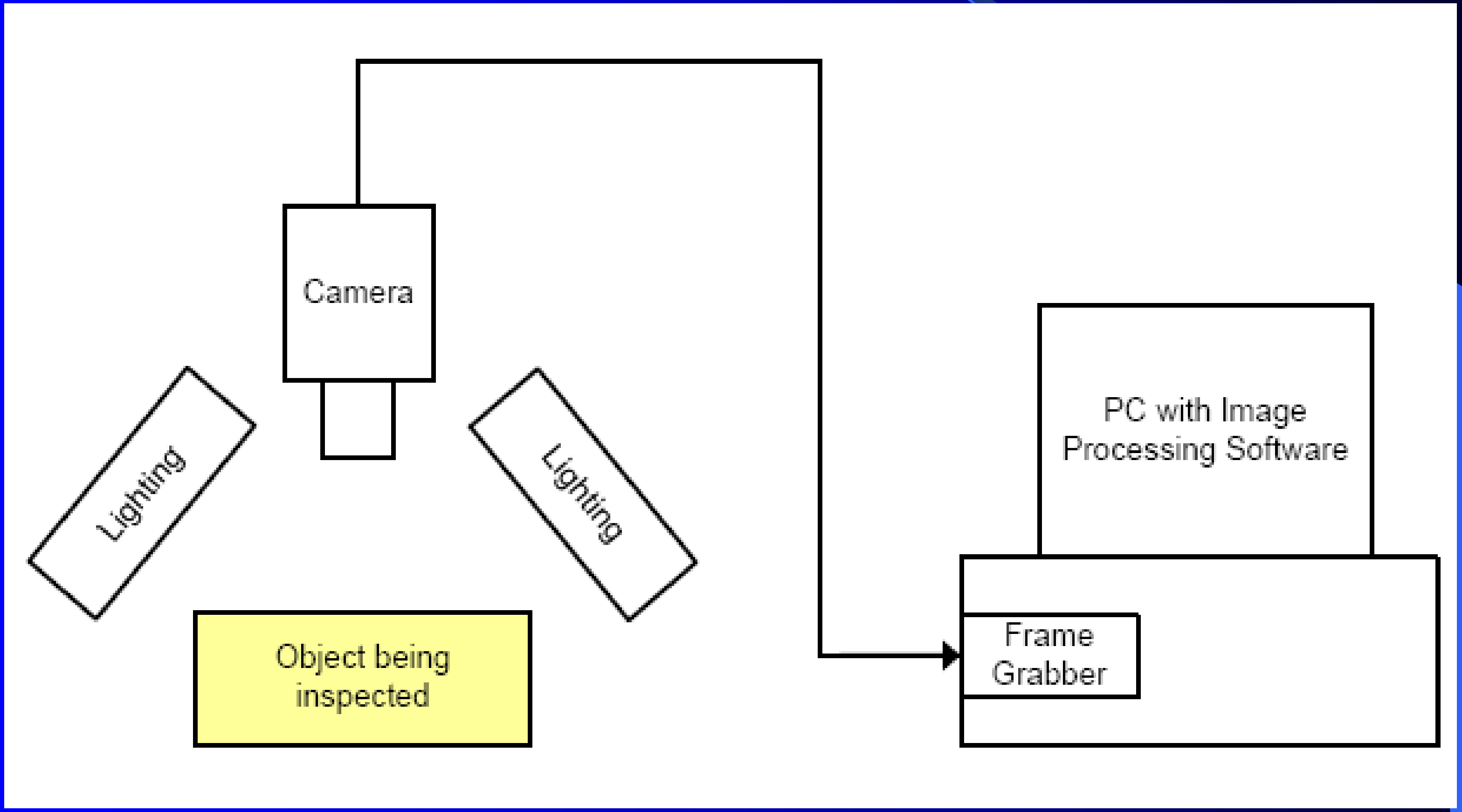
Kinds of tasks in manufacturing for computer vision

- Inspection of product or material
  - Inspection of quality of surface
  - Inspection of structure of material (detail) (e.g., by x-ray)
  - Inspection of quality of color
  - Non-contact measurement
- Assistance in assembling
  - Checking of directions of details
  - Checking of positions of details
  - Checking of relations between details in assembly
- In security systems
- In robotics

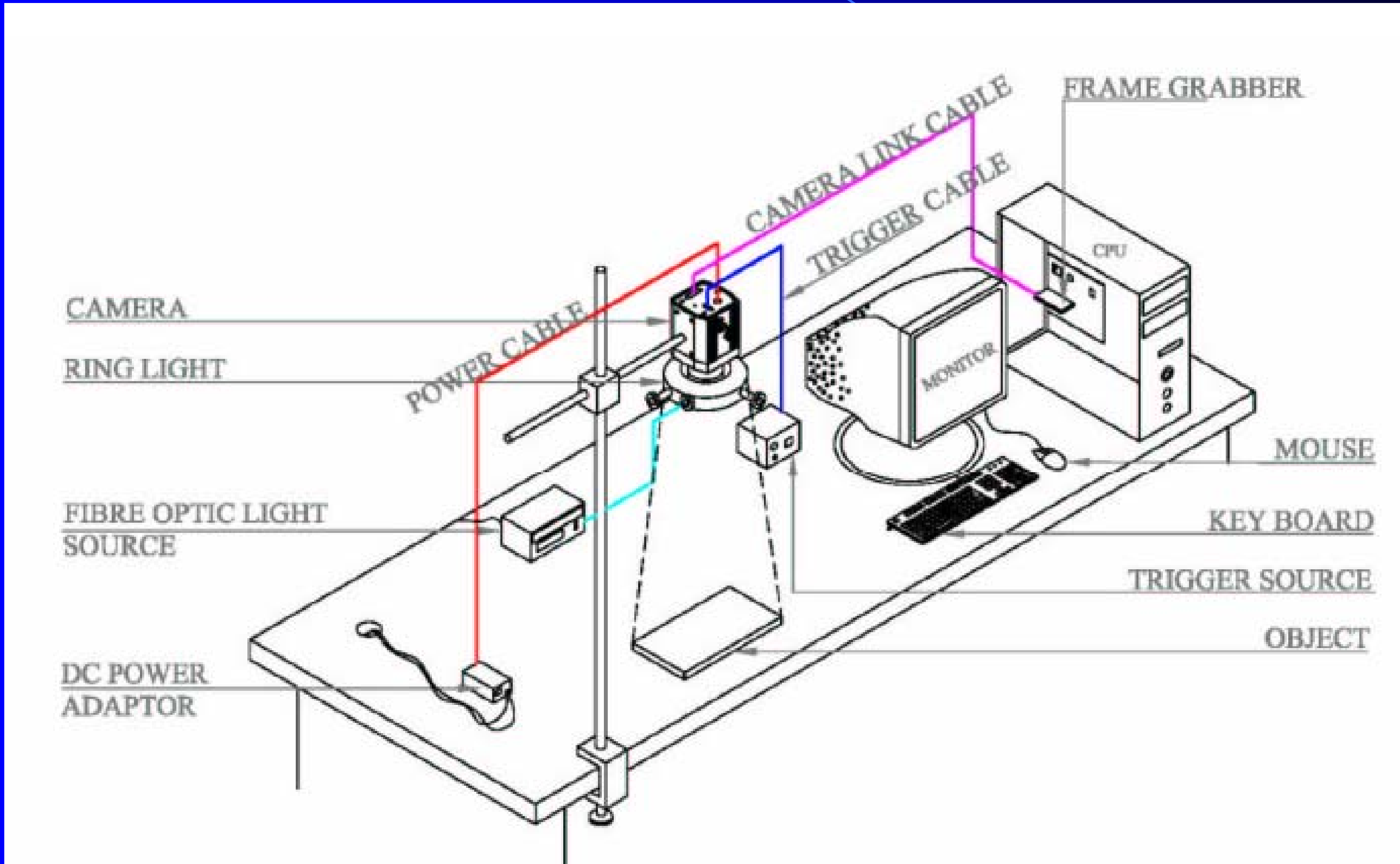
An Industrial Computer Vision System



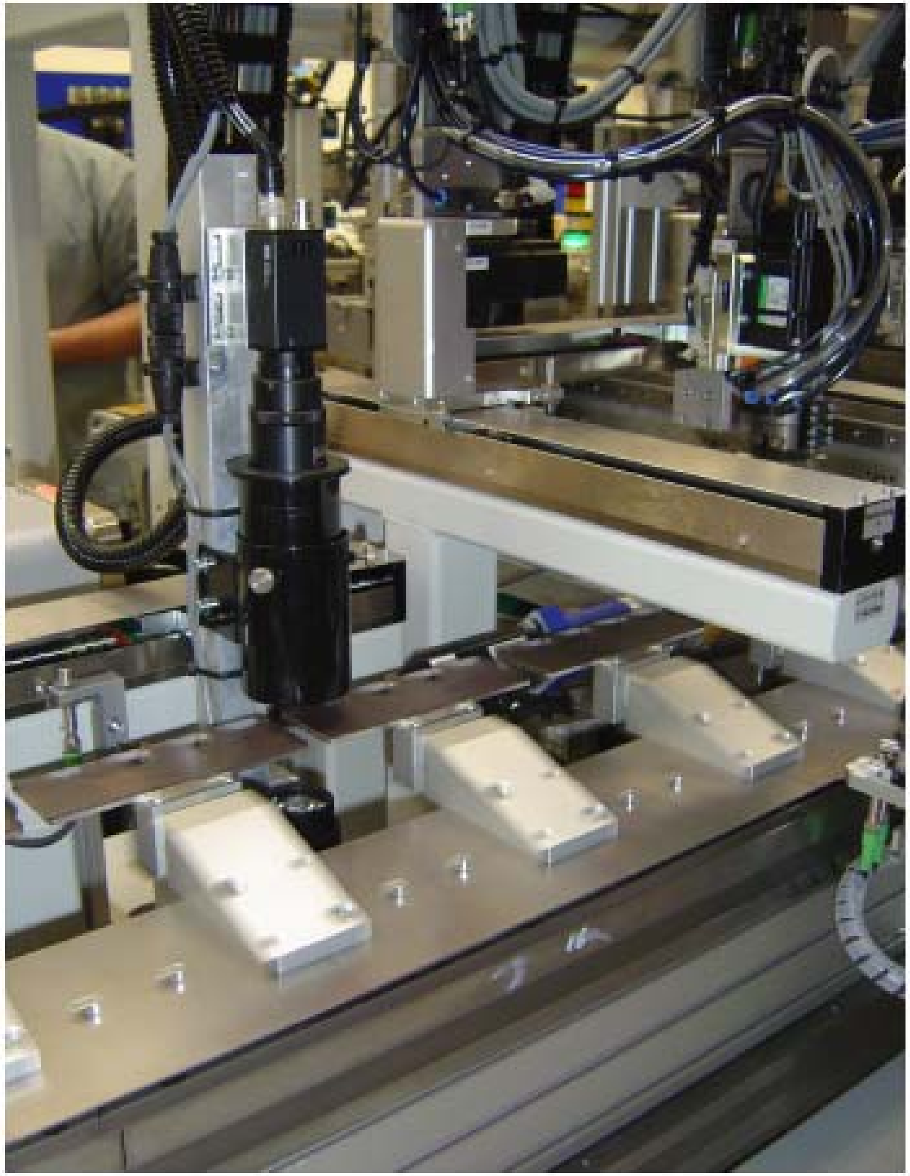
Basic Components in a Typical Configuration



Laboratory Setup



Factory Setup



Why Machine Vision?

- Many production defects are visibly identifiable
- Manual Inspection used to be the only option
- Many limitations and so automation was attempted before technology was ready
- Over the years it has improved to become an essential part of innumerable manufacturing operations

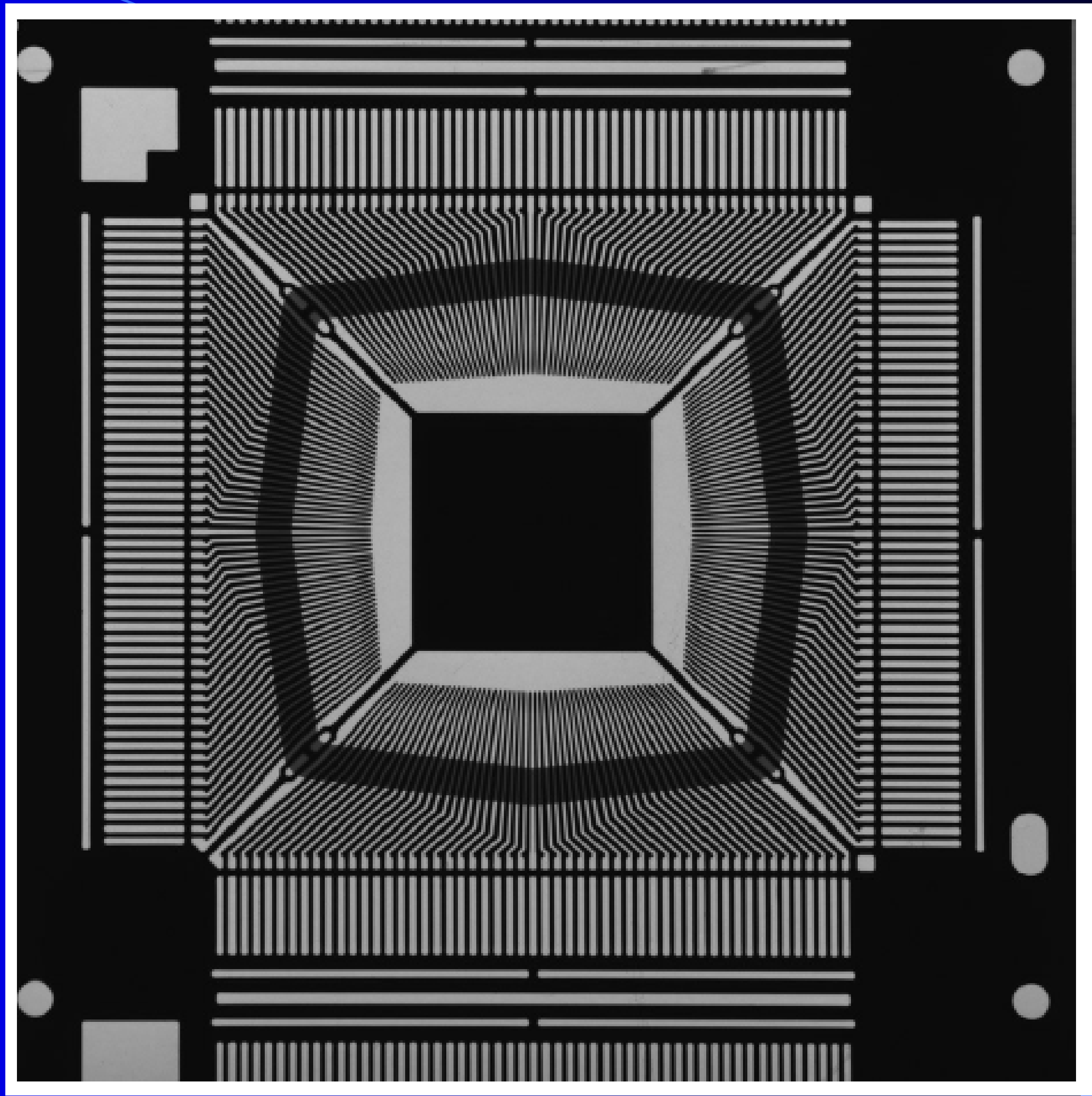
Manual Inspection

Comparison with Manual Inspection

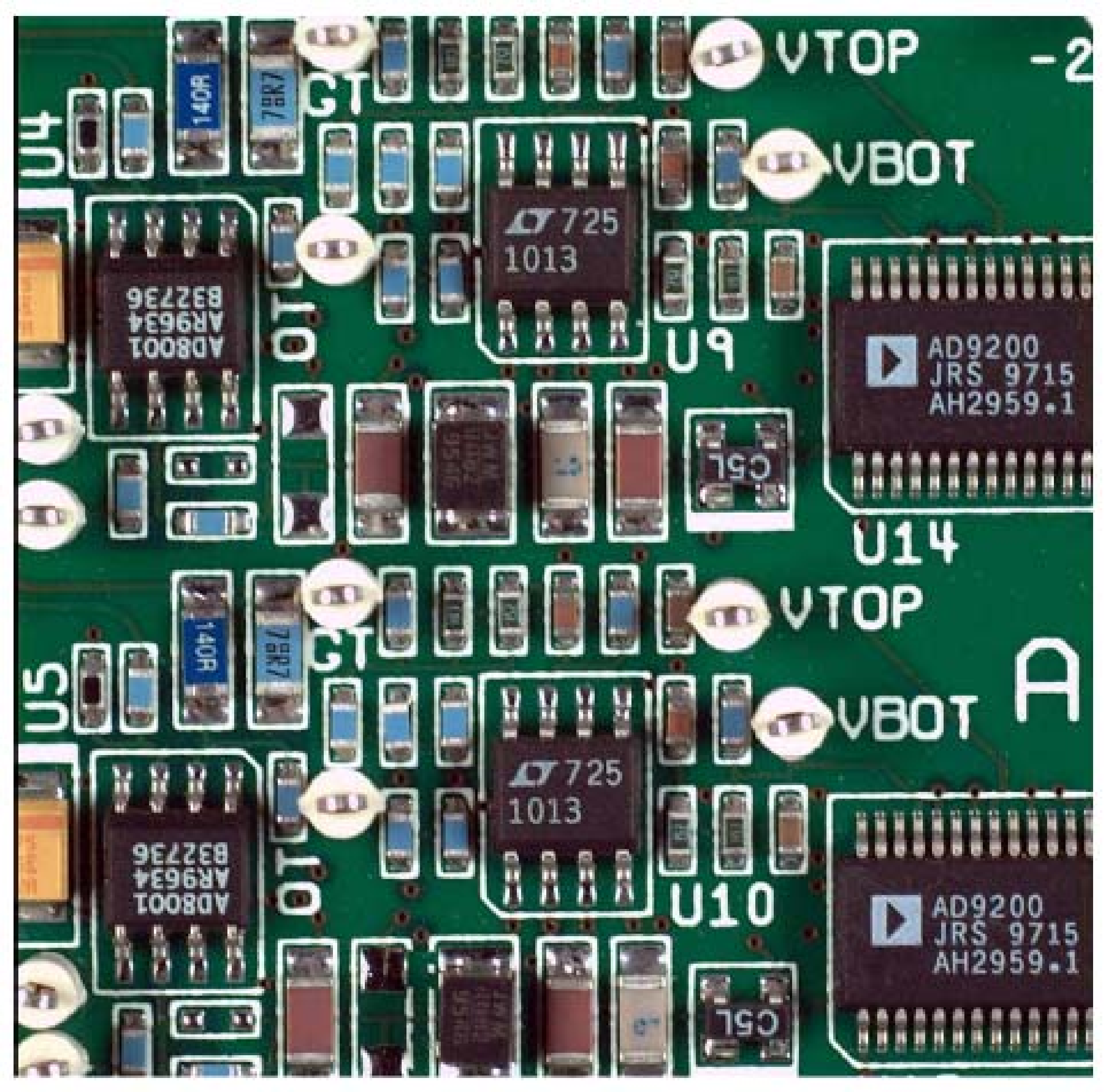
Manual Inspection using Inspectors	Automated Inspection using Machine Vision
Subjective – Operator Dependent	Objective and Repeatable
Error Prone – Fatigue / Attention Span	24x7 Operation with no Errors
Slow – Offline Sample Inspection	Very Fast – 100% Online Inspection

Examples
(developed by Texas Instruments)

Chip Inspection



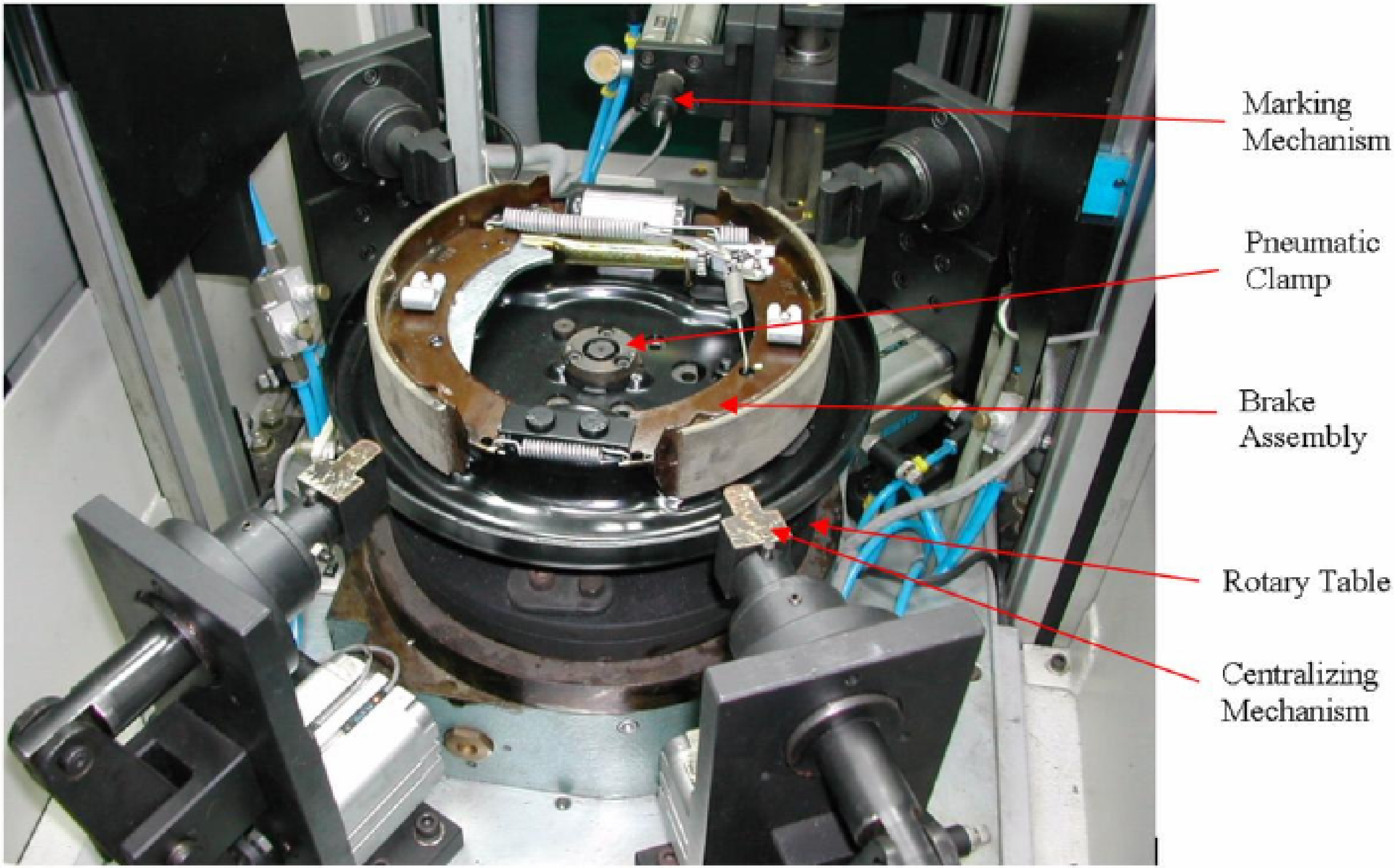
PCB Inspection



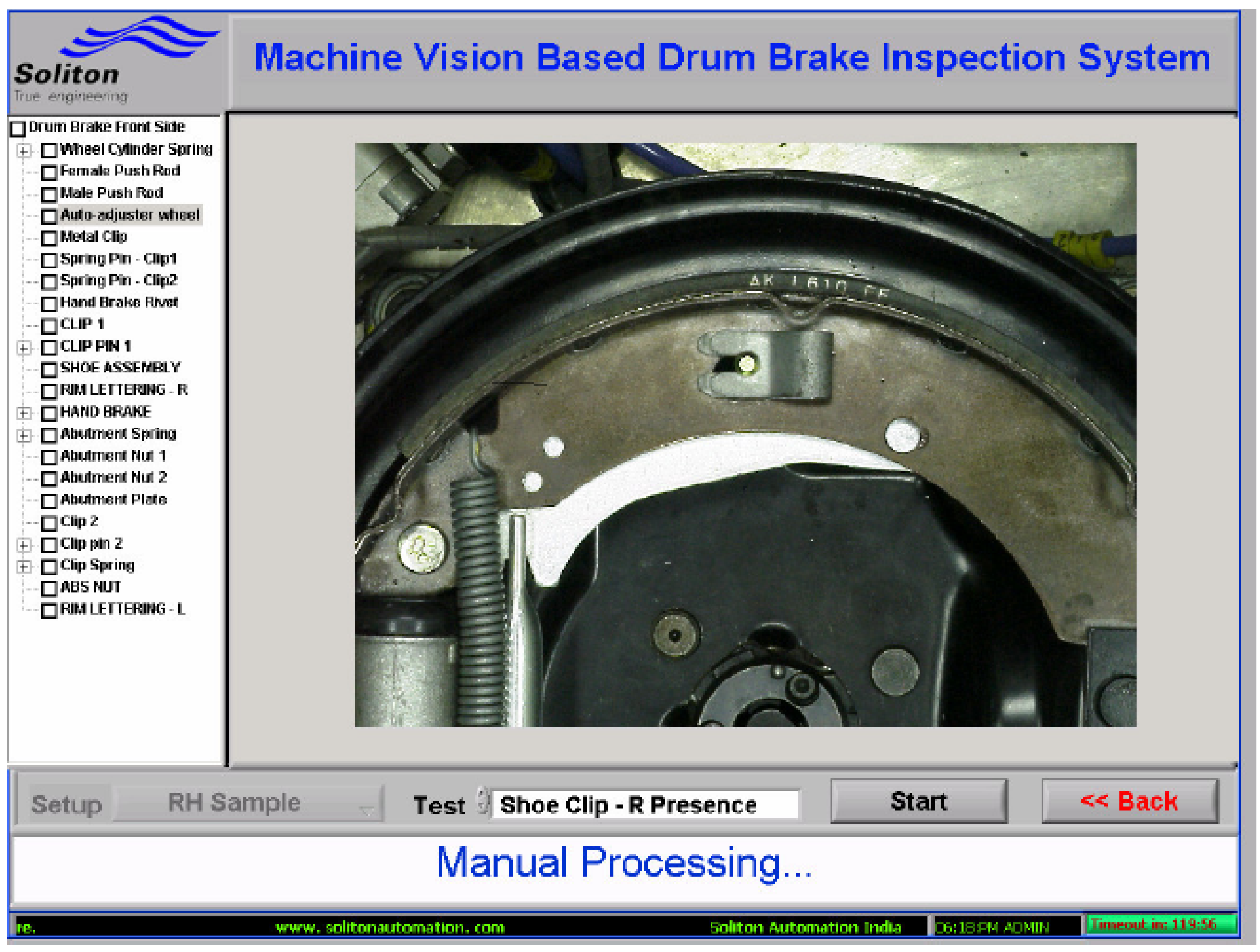
Bottle filling Inspection

Label Inspection

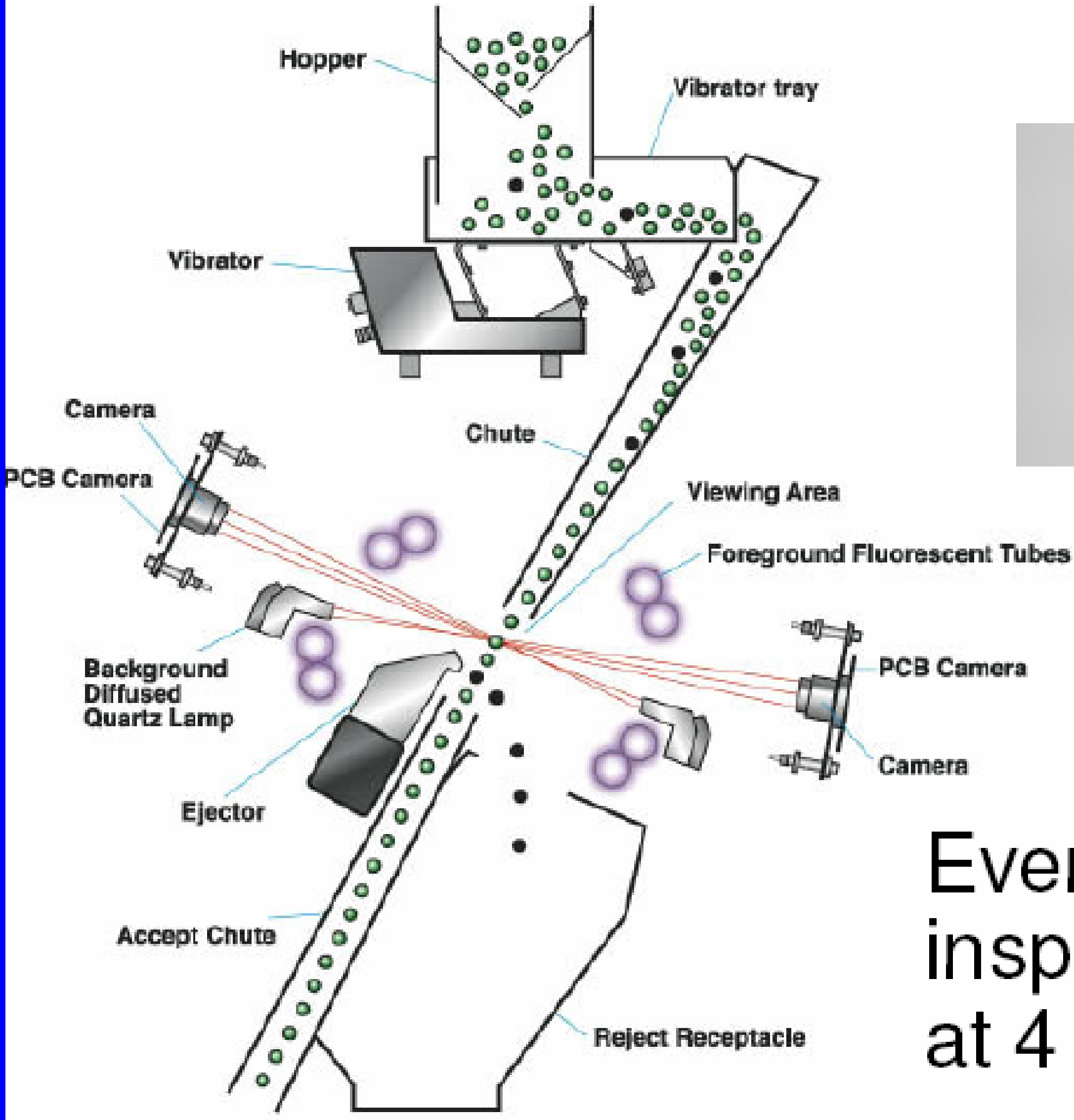
Brake Assembly Inspection

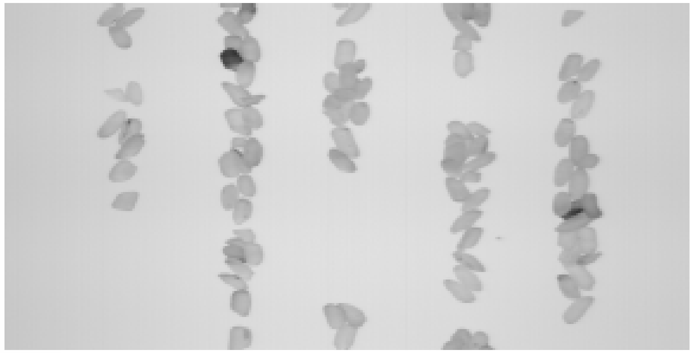


Brake Assembly Inspection (2)



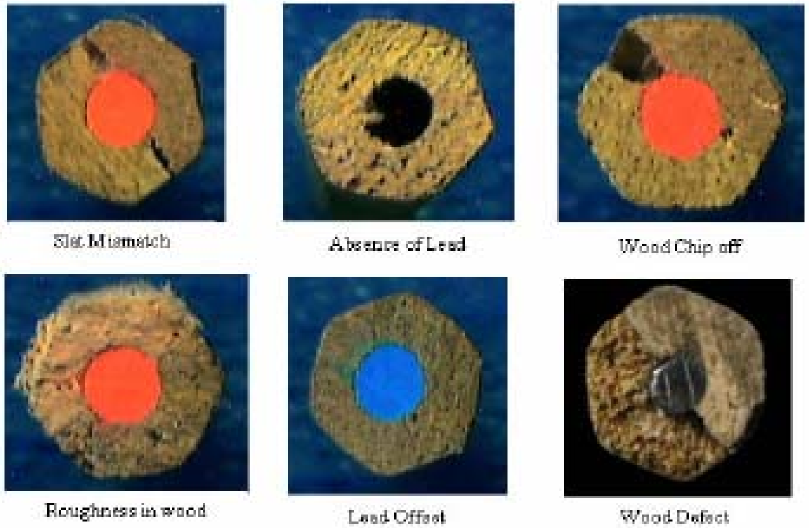
Rice Sorting Machine





Every grain of rice is inspected and sorted at 4 tons/hour

Pencil Sorting Machine



High Speed Deterministic Sorting at 20 Pencils/sec

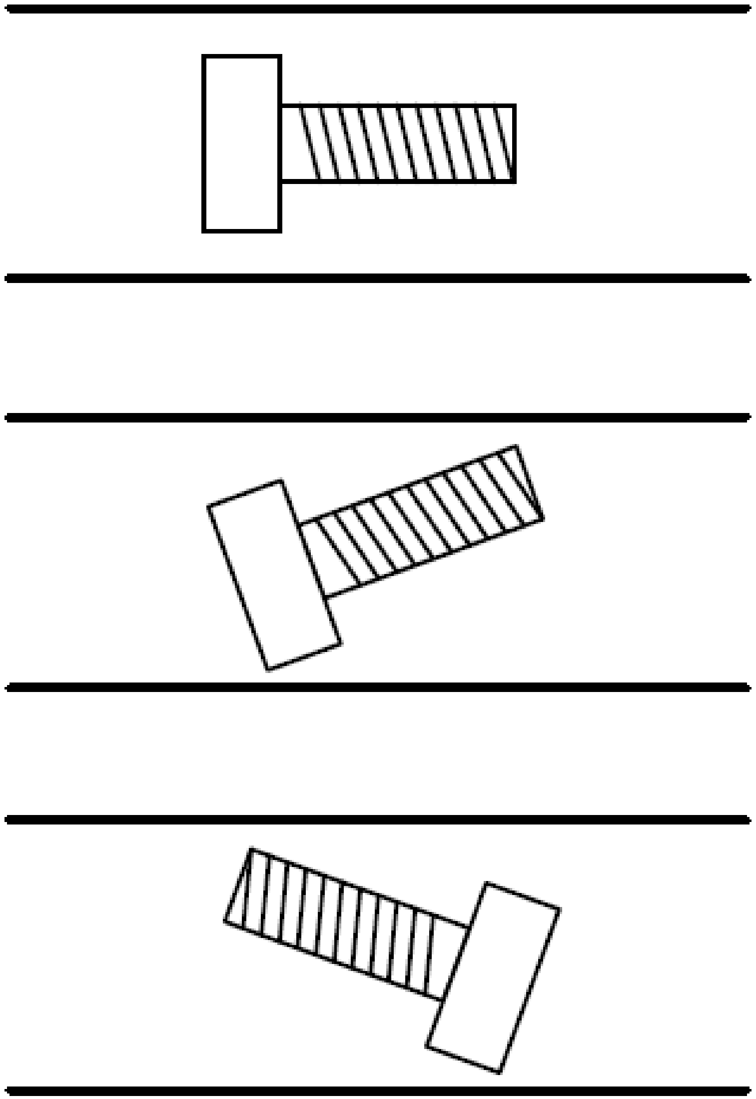
Computational requirements and using of DSP

Image processing

- Computationally very intensive
- Typical processes are filtering and correlations
- Both use multiple and accumulate (MAC) as the basic operations
- Highly suited for DSPs
- Consider an example to understand the computational demands

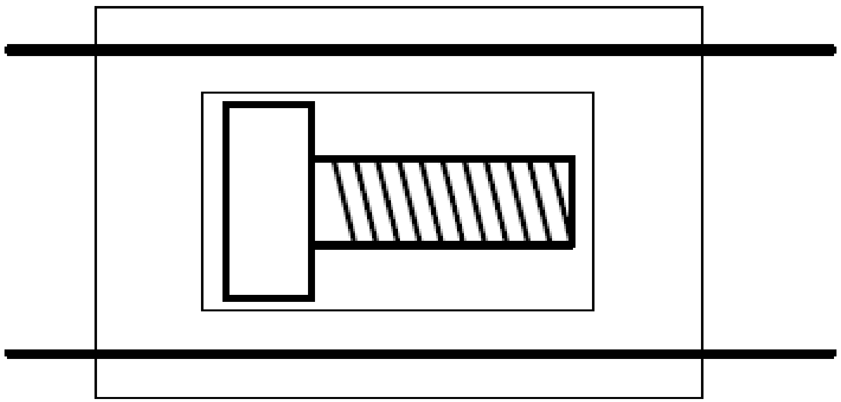
Bolt Inspection

- Automated Assembly Requirements
- Verify
  - Orientation
  - Length
  - Diameter of Head
  - Diameter of Bolt
  - Presence of Thread
  - Thread Pitch



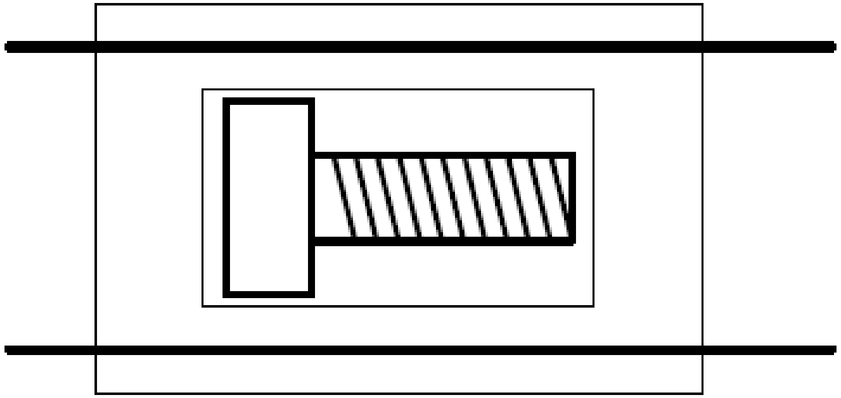
Bolt Inspection 2

- Could use a Pattern Match
- Select the Imaging Area (say 640 x 480 pixels)
- Select the Template (say 400 x 200 pixels)
- Warning – lots of simplifications in what follows!



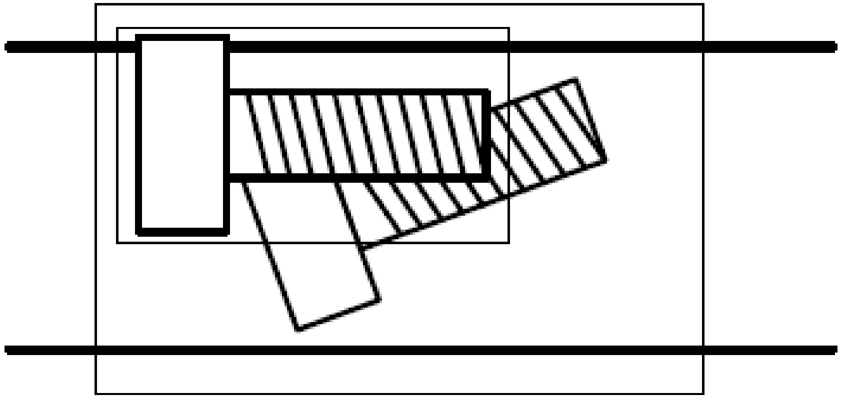
Bolt Inspection 3

- Consider Simple Pixel Correlation
- Search within the area – considering the simplest of constraints
  - 240 x 280 positions
  - 30 angular positions (considering +/- 15 degrees at 1 degree resolution)



Bolt Inspection 4

- Correlation - Multiply and Accumulate (MAC)
- Pattern 400x200=80,000 pixels – 8 bits/pixel
- Repeat for about 2 million positions (240x280x30)



Bolt Inspection

- MAC Operations = 80,000 x 240 x 280 x 30 = 161,000 Million
- Consider DSP with 5,000 MIPS
- Computation Time = 32 seconds!
- Requirement is 10 bolts/second!
- Improved considerably using Pyramid Search Techniques – reduces to millisecs

Computation Speeds and Production Rates

Year	Computation Speed	Production Rates *(assuming roughly 10% improvement / year)*
1995	50 MIPS	1 Parts/Sec
2005	5000 MIPS	3 Parts/Sec

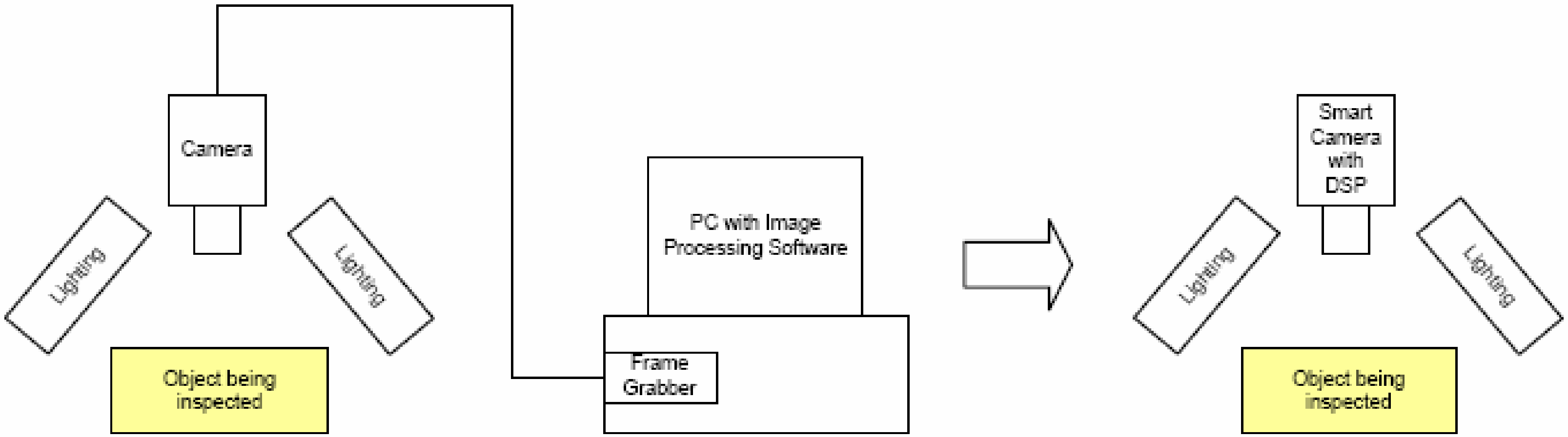
- ❑ Advances in Non-Semiconductor Manufacturing has been "normal"
- ❑ Computing Speeds have grown tremendously making Machine Vision based Automated Inspection possible

DSP Innovations Leveraged for Machine Vision

- Direct Memory Access
  - Machine Vision involves very high data
- rates
- Pipelining and on chip L1 and L2 Cache
- SIMD / VLIW
- Multicore
  - DAVINCI (C64x+ DSP and ARM)

Trends

- More transistors on a chip will drive further integration and lower the size and cost of machine vision solutions
  - Trend is towards Smart Cameras
- The DAVINCI will be very important in Machine Vision

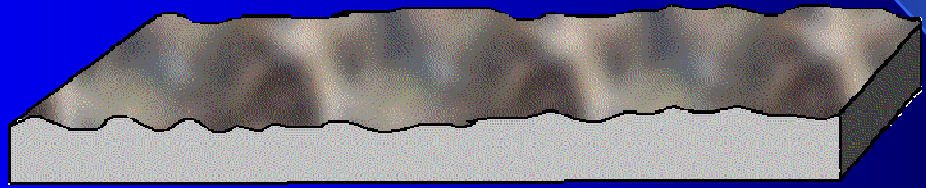


Inspection of surfaces

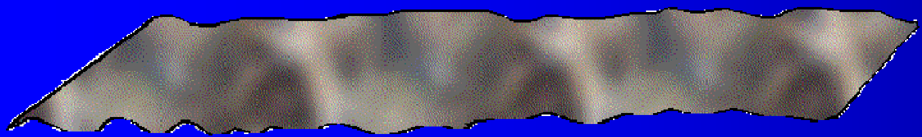
Inspection of Complex Surfaces

(Centre for Innovative Manufacturing &
Machine Vision Systems (CIMMS) UWE, Bristol)

Typical complex surface

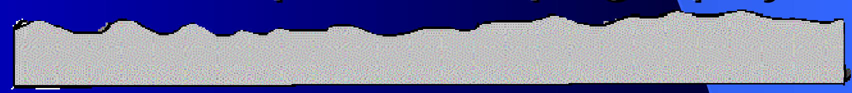


Surface reflectance



(Albedo)

Surface profile/topography



(Bump map)

Photometric Stereo

- Illuminating an object from three different directions produces three different images...

Photometric Stereo

- The observed brightness at a given point is a function of both the reflectivity and the orientation of the surface at that point
- Three images thus give us three equations with three unknowns
- We can solve to isolate both the shape and the reflectance of the surface

Application to surface analysis

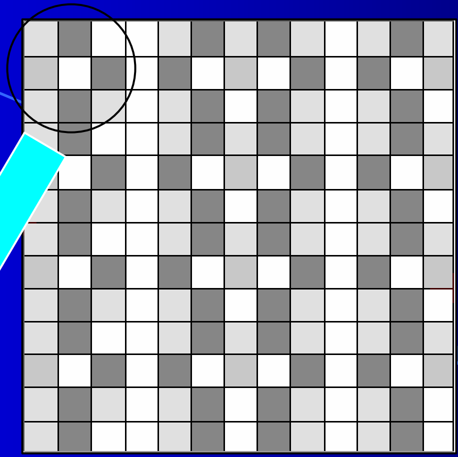
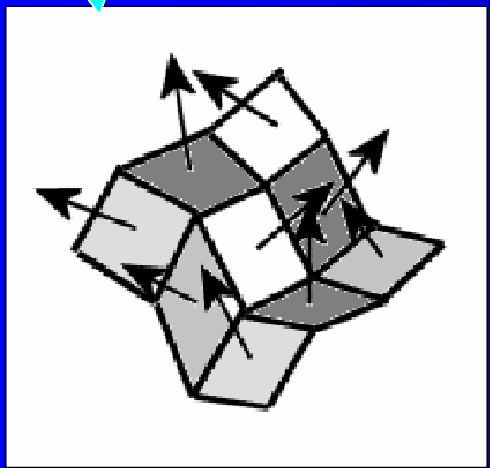
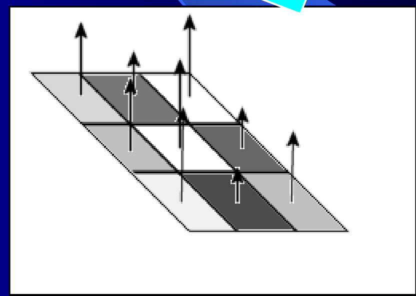


Image of scene as viewed by camera - apparent as a matrix of grey levels

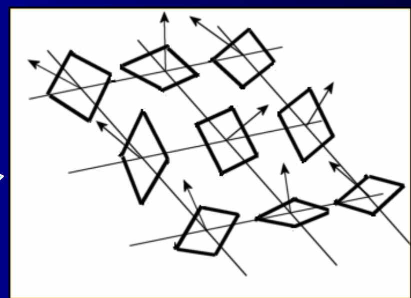
Surface normals recovered as a series of vectors with magnitude and direction



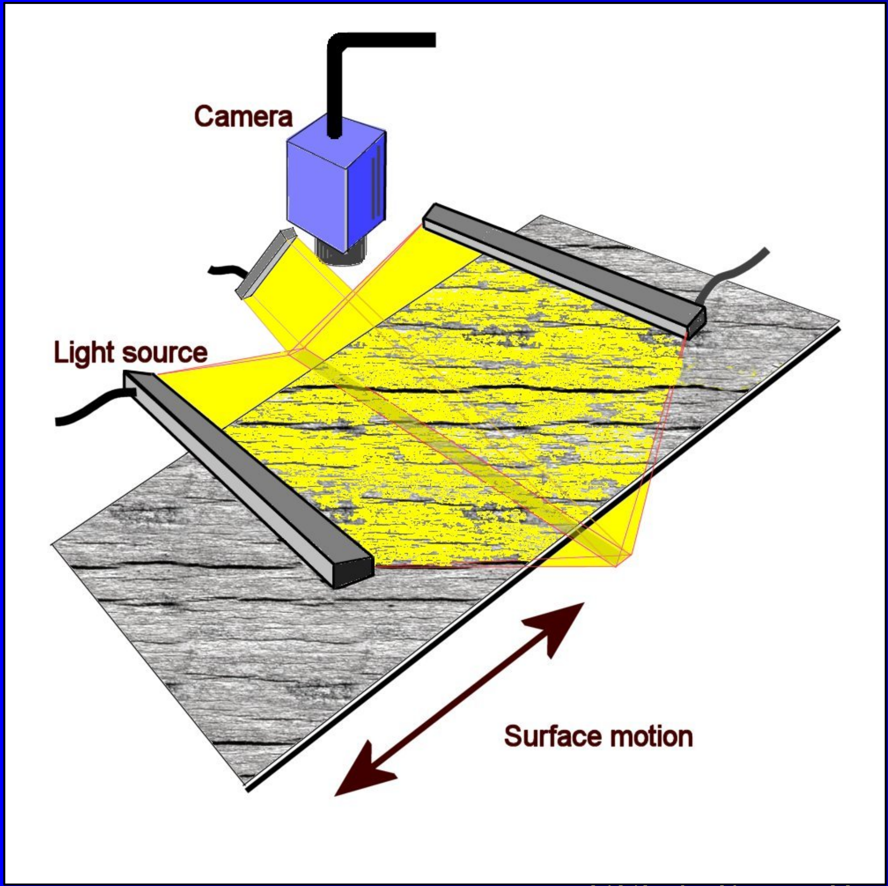
The magnitude of the vectors gives the surface colouring - ‘albedo’

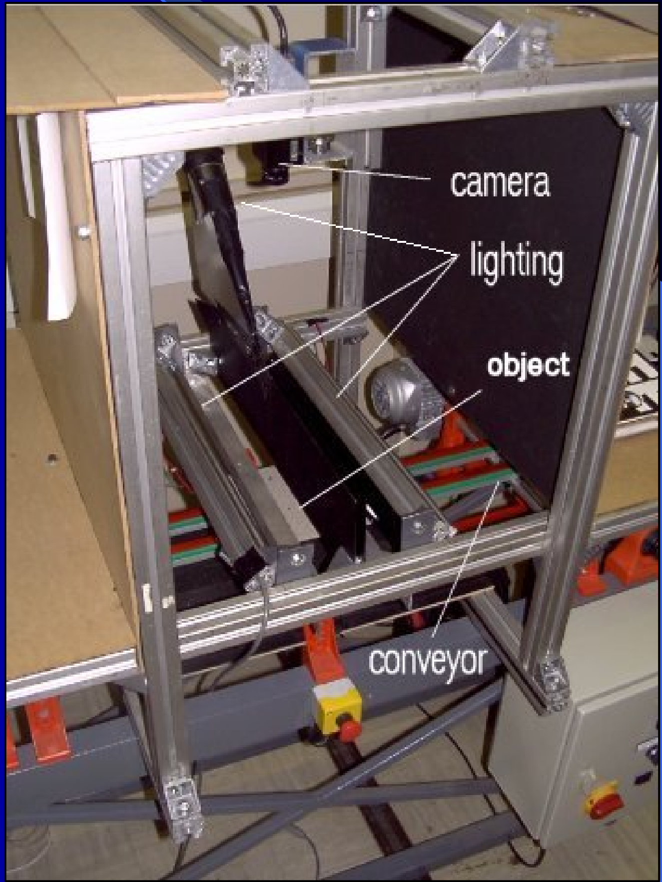


The directions of the normals form the ‘bump map’ - topography

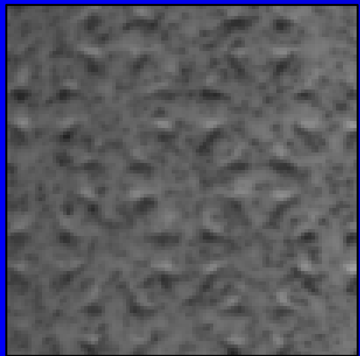


Prototype tile inspection system

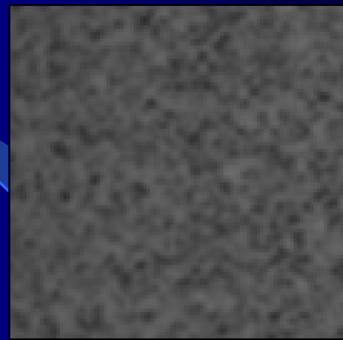




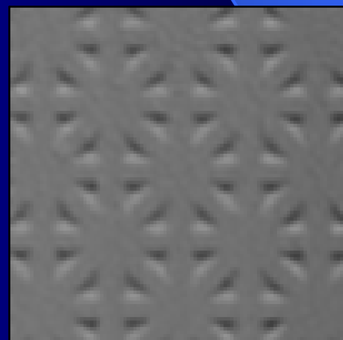
Example Results



Albedo (2D)

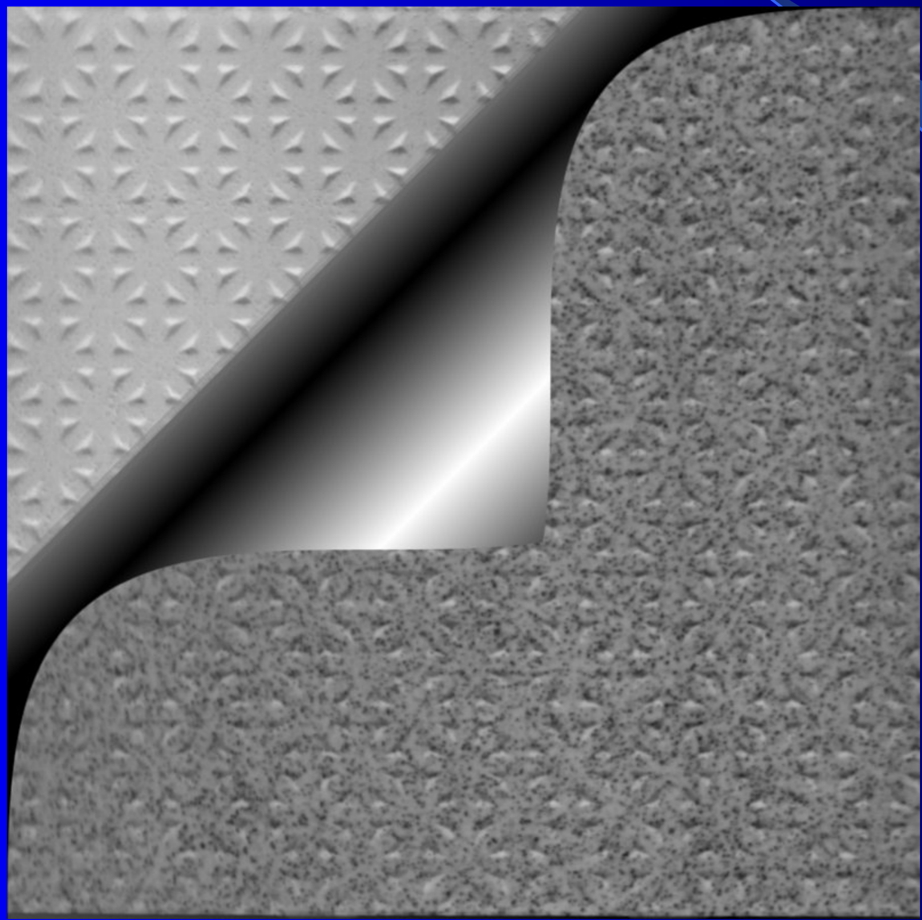


Rendered
Bump Map (3D)

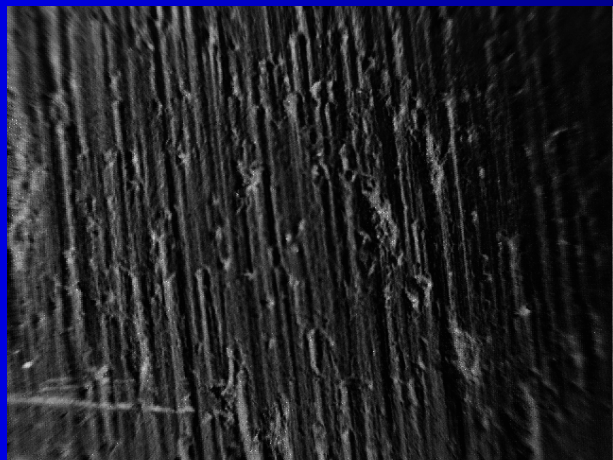


Raw image of surface
Possessing concomitant
2D and 3D features

Isolation of two- and three-dimensional data



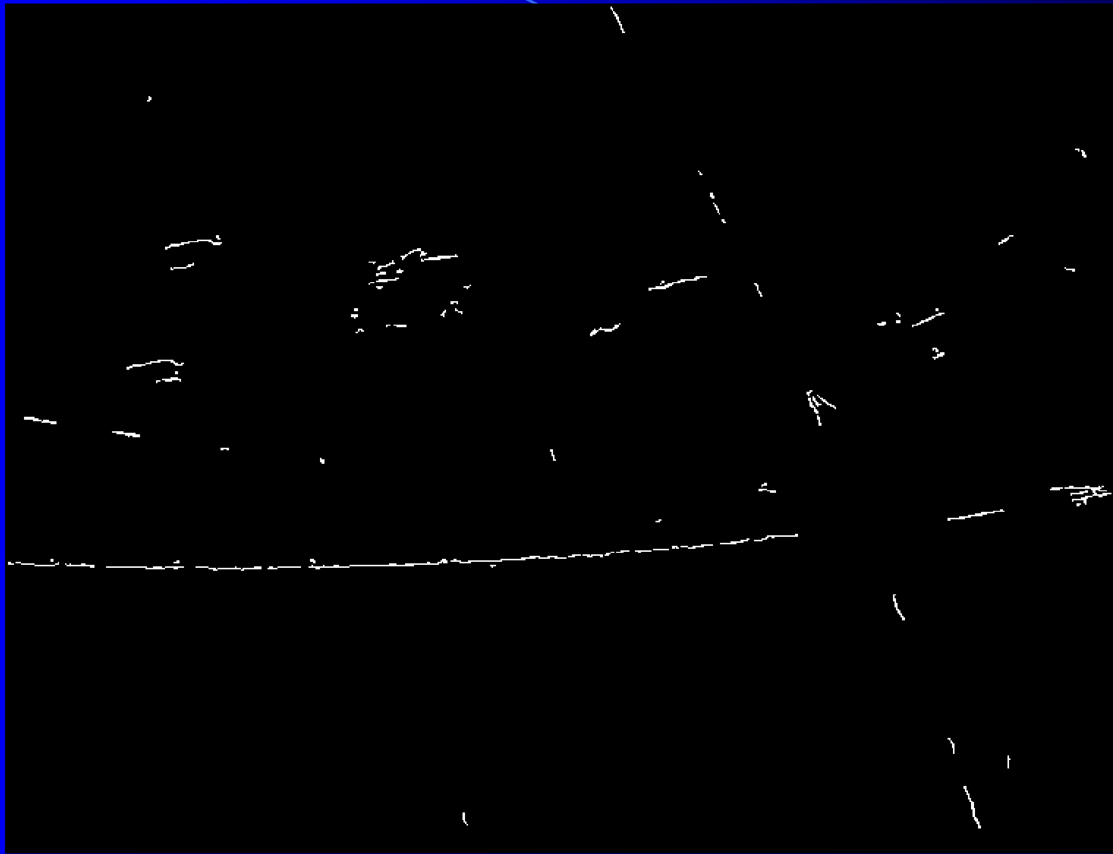
Example of virtual rendering of the captured 3D surface data



Note altered surface appearance as user moves virtual light source

Visual Inspection of Polished Stone (VIPS)

- Aim to develop imaging techniques suitable for the on-line surface inspection of polished stone in the field.
- Classify and quantify surface defects in the presence of acceptable natural stone features.
- Allow potential for closed-loop control of the polishing process.
- Partners in Italy and Portugal.



Problems: - Very large images (64 Mega-pixels)

- Very large indistinct scratches (dia 10 x image)
- Noisy images