3D Surface Inspection

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360 Million
Factory Workers Worldwide*

35 Million
Visual Inspectors*

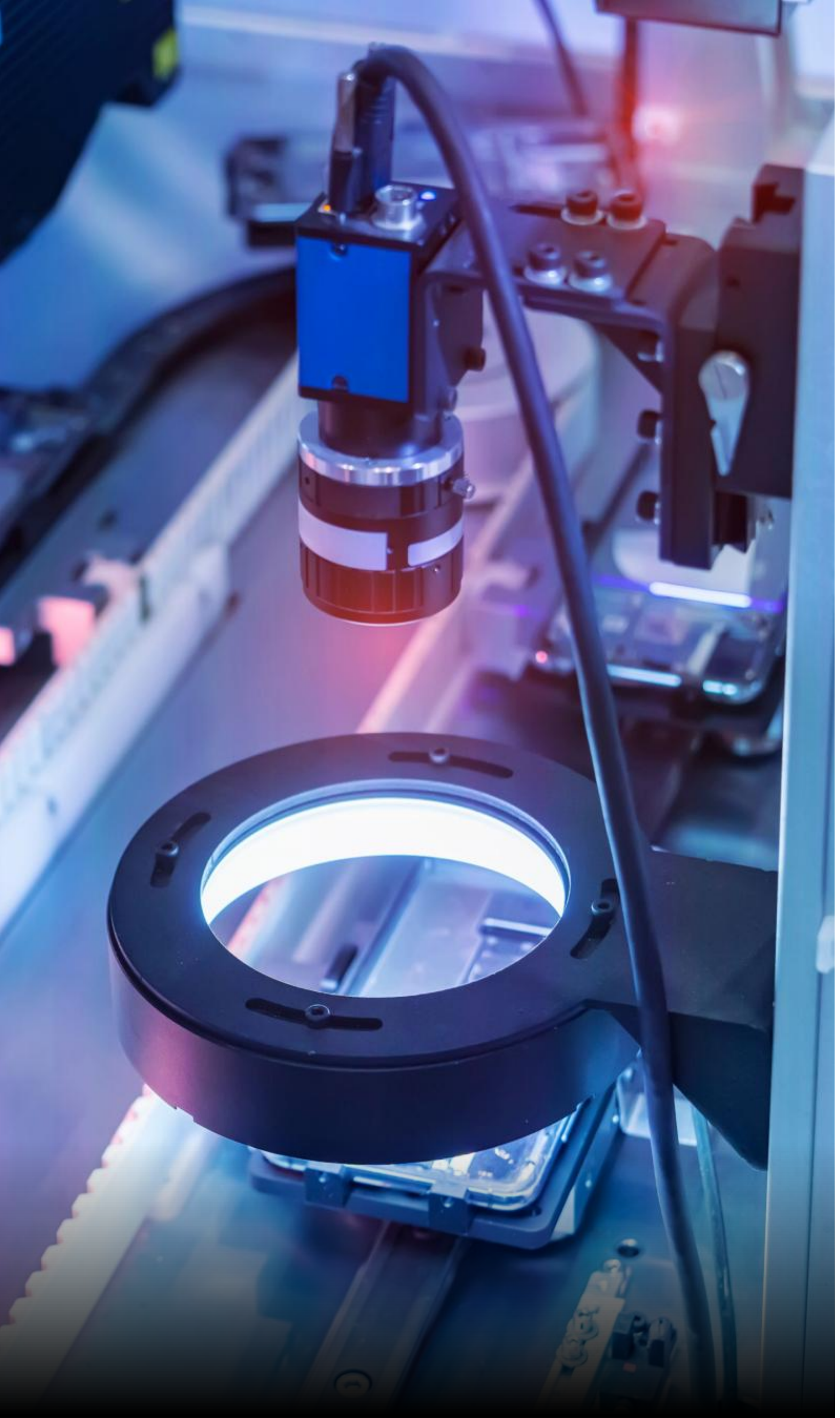
The Challenge

Materials: Existing technologies struggle with shiny and transparent materials (existing 2D cameras, structured light and laser scanning)

Latency: Capturing and transmitting large amounts of image and video data puts load on the network and creates latency for real time detection

Reliability: Modern manufacturing now includes a composite of different textured materials like metals and plastics reducing the reliability of AI defect detection and **requiring human** inspection

*International Labor Organization and World Bank



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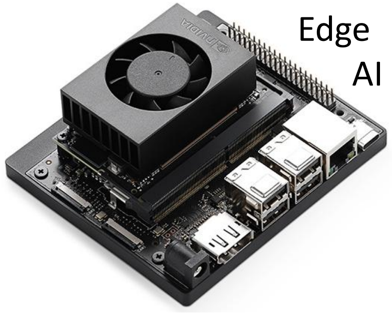
Automating Inspection

- Precise surface metrological data can now be captured from even very shiny or transparent materials like polished metal, carbon fibre, gloss paint and glass.
- Move to 100% inspection with repeatable results efficiently with AI processing on the edge.



Edge AI

Coded Lighting

Industrial Camera

Specular Metrology

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Use Cases

High quality stationary scanning

- Detailed 3D surface direction, color and reflectivity
- Pattern matching for fixturing, gap analysis and external shape
- Inspect multiple material types in the same pass
- High speed modes (30fps+)

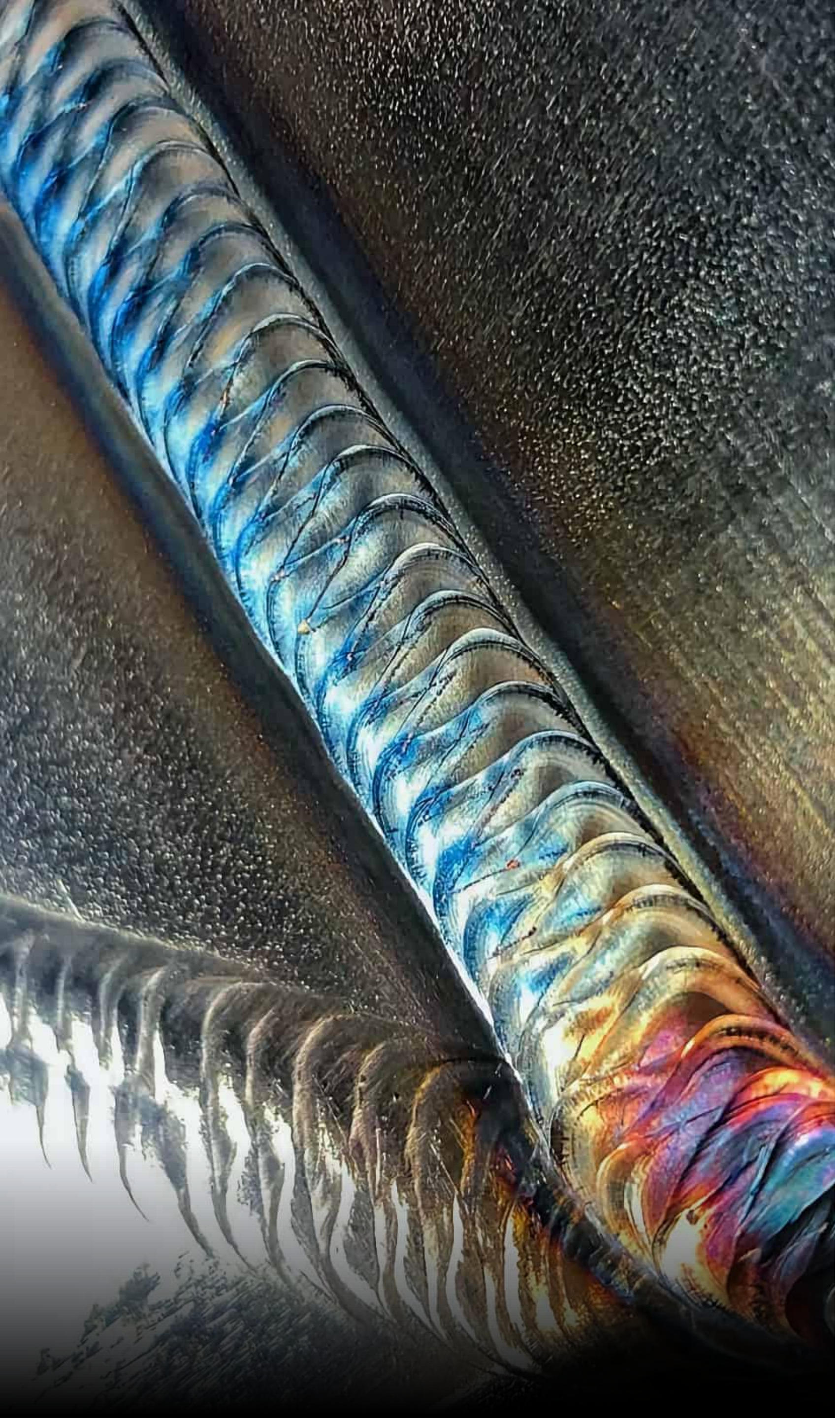
Scanning moving parts and materials

- Real time analysis to accept or reject parts
- Find defects reliably and repeatably
- Set tolerance thresholds for acceptable and unacceptable size or number of defects

Manual Automotive Paint & Glass Inspection

Manual Aluminum Extrusion Inspection

Smartphone Manual Inspection



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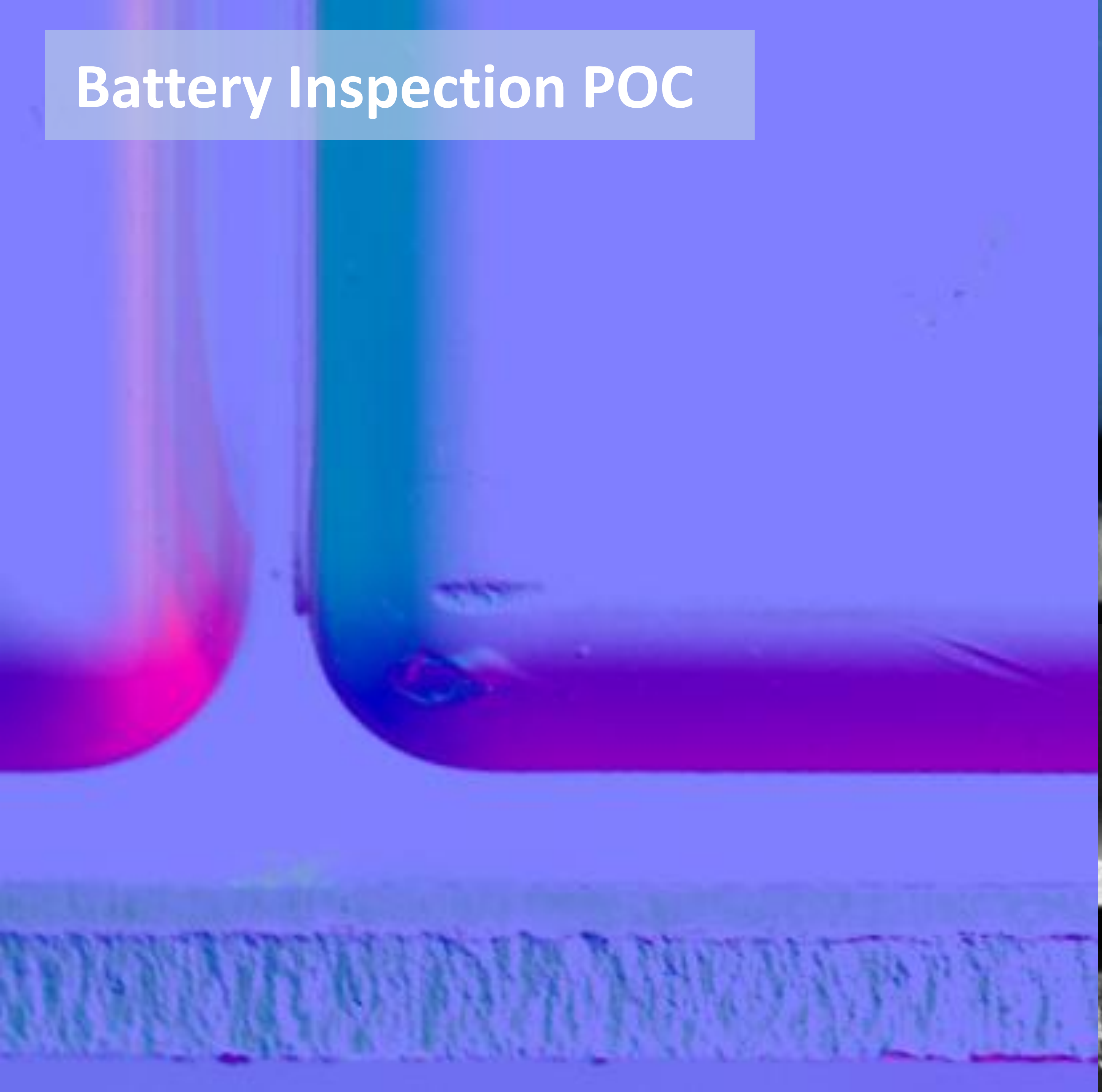
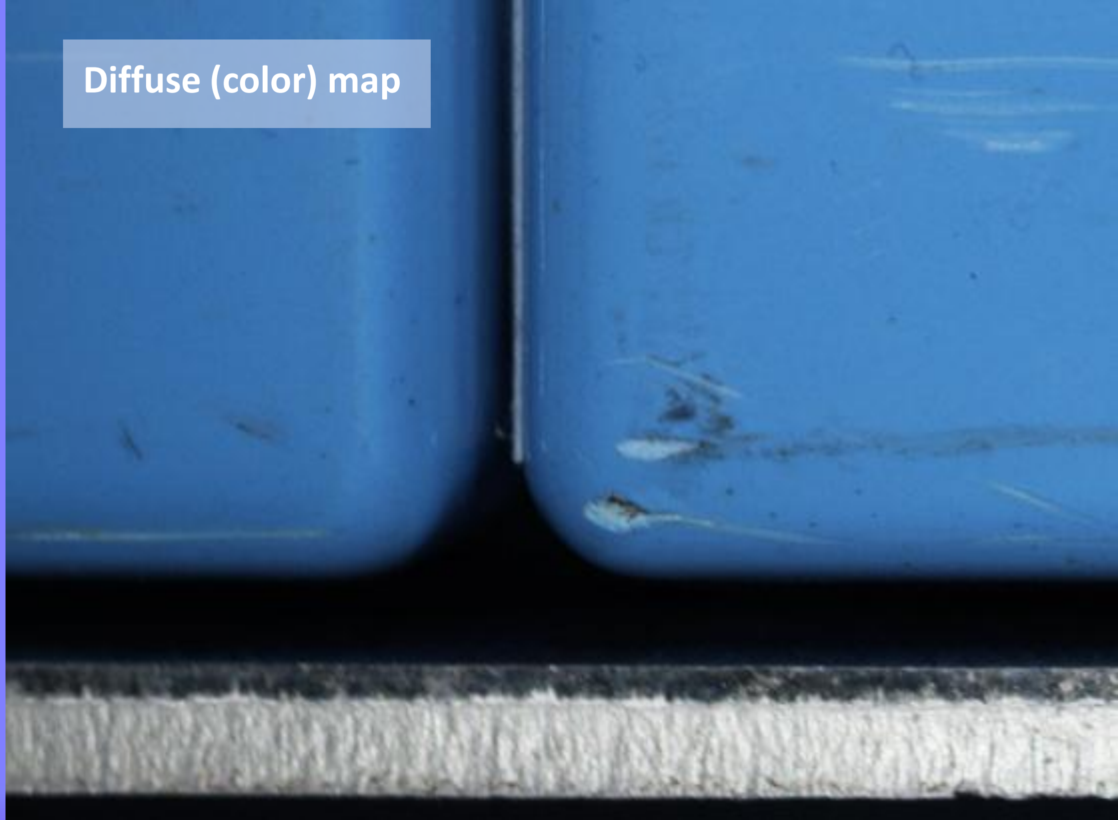
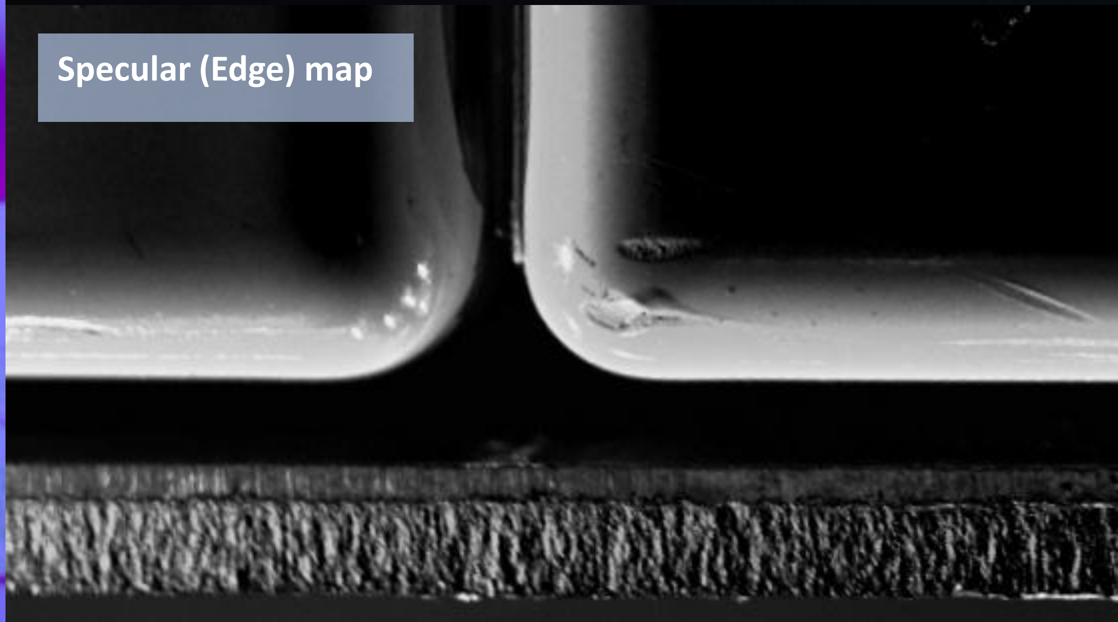
Materials & Defect Types

- Paint, glass, metal, plastic - **Scratch depths and lengths**
- Paint, coatings, metal, carbon fiber - **Dents and gaps**
- Plastic and metal combination - **Measure gaps and fit**
- Stamped metal - **Contour dimensions**
- Stamped metal - **Measure burrs and edge shape**
- Motherboard inspection – **Parts and solder joints**

Battery Inspection POC

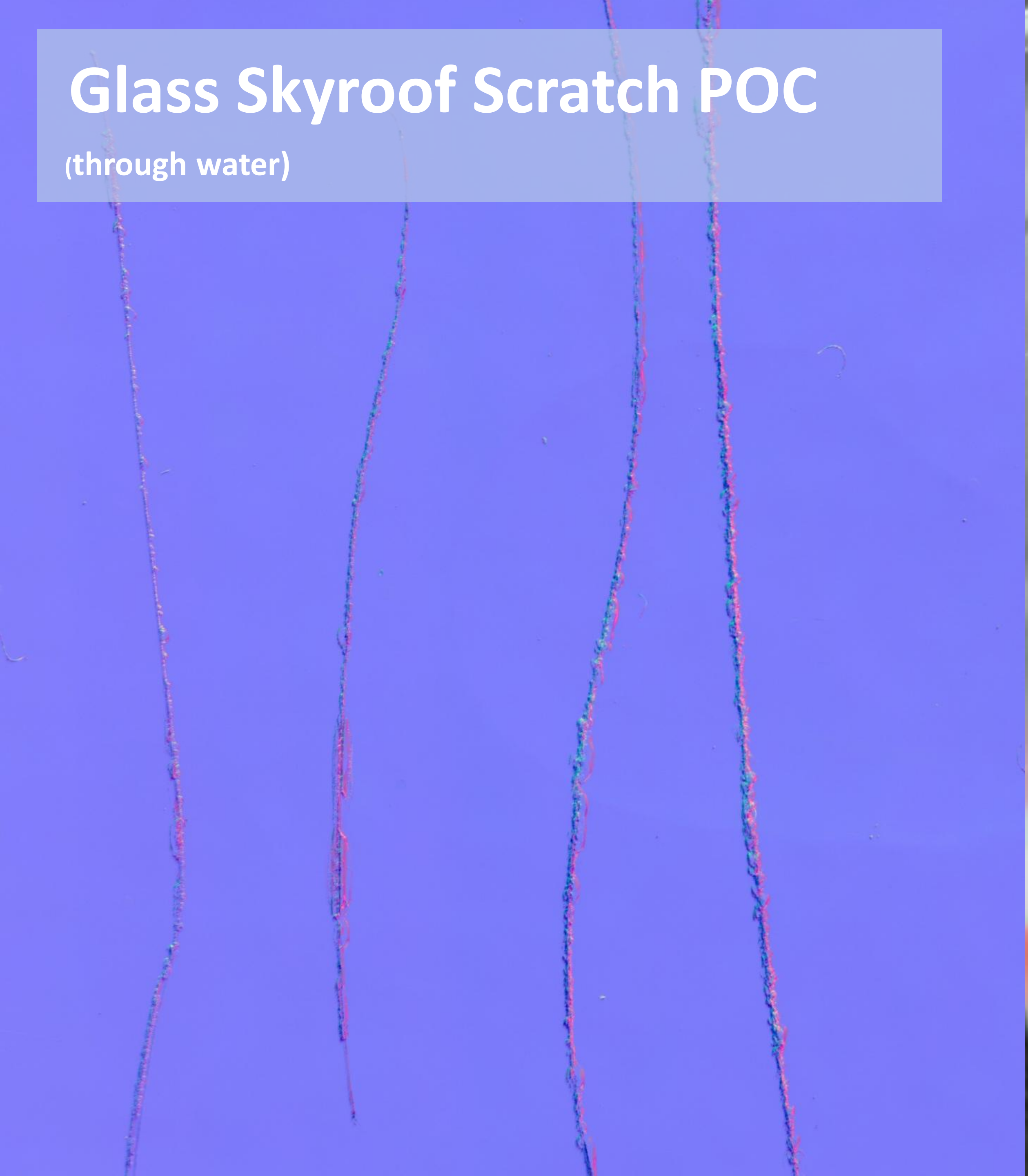




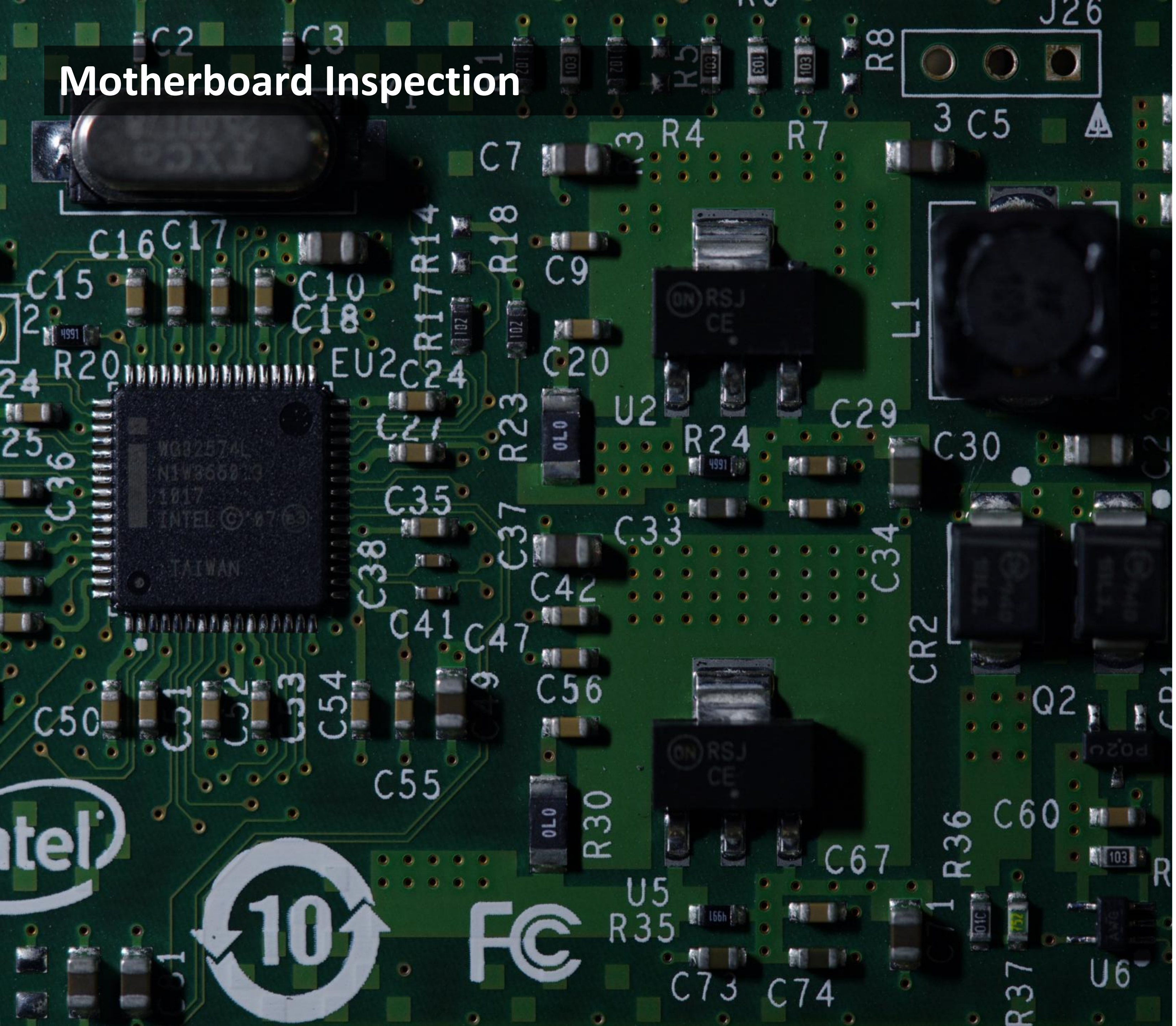


Glass Skyroof Scratch POC

(through water)

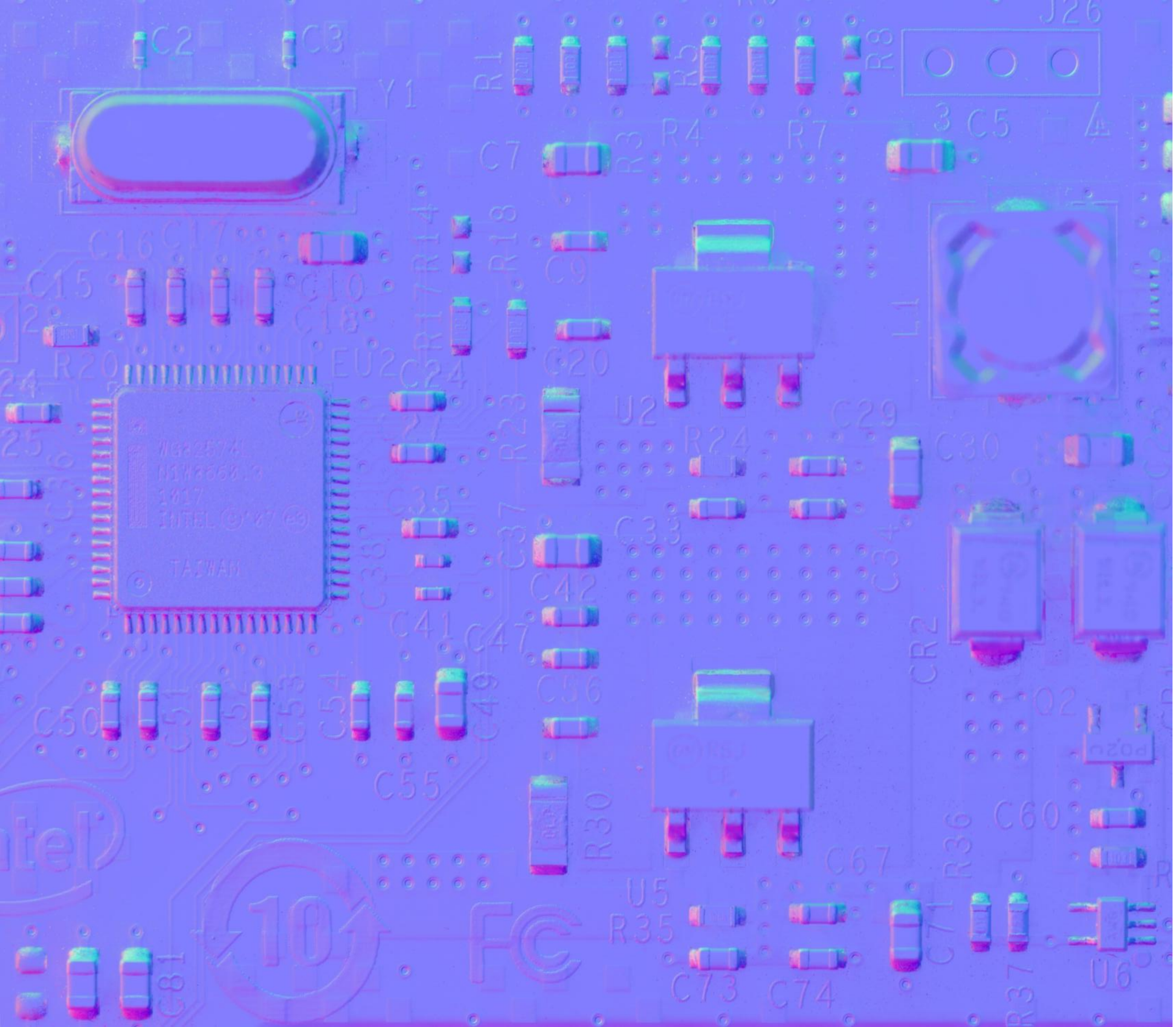


Motherboard Inspection



Traditional image for processing with machine vision

This gets split into layers of information!

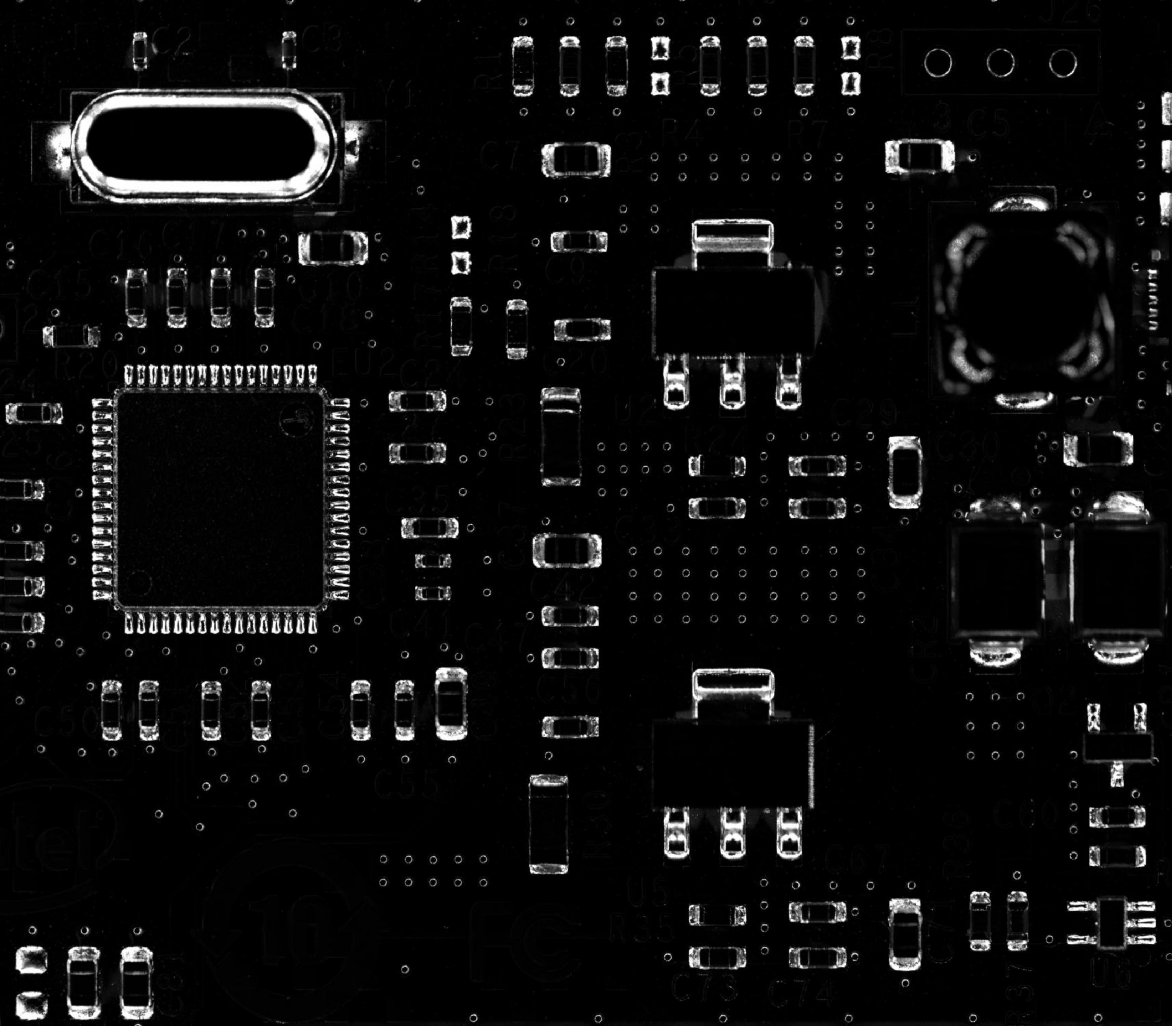


Layer 1

Normal map showing 3D surface angle isolated

20 micron thickness of silk screen ink is detectable.

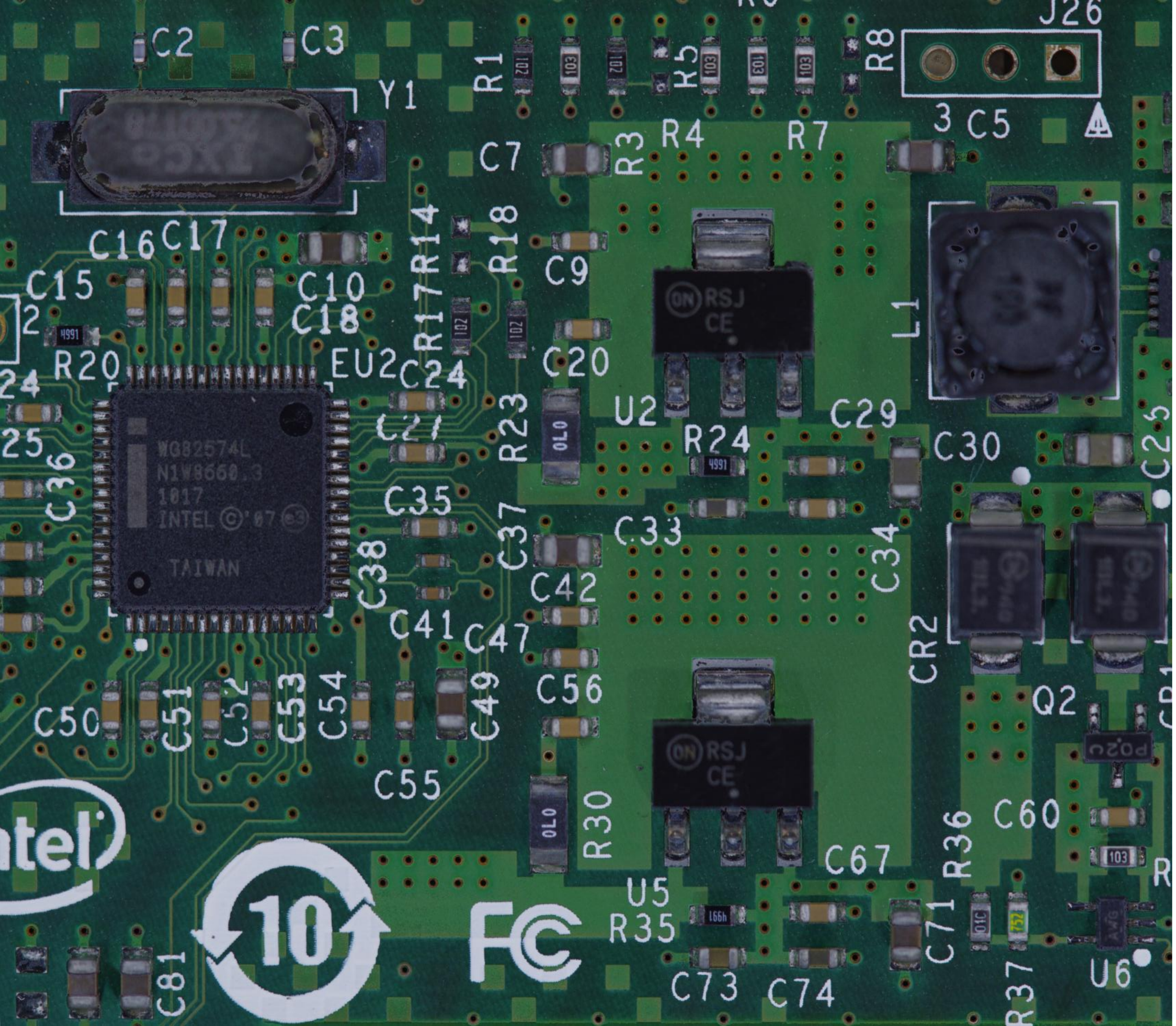
Ideal for checking part placement and structures like via’s



Layer 2

Specular/Edge map isolated

It’s clear where solder has been correctly applied to determine if contacts are wet or dry



Layer 3

Diffuse image isolated

Majority of reflections and shadows removed

Ideal for checking 2D codes and OCR

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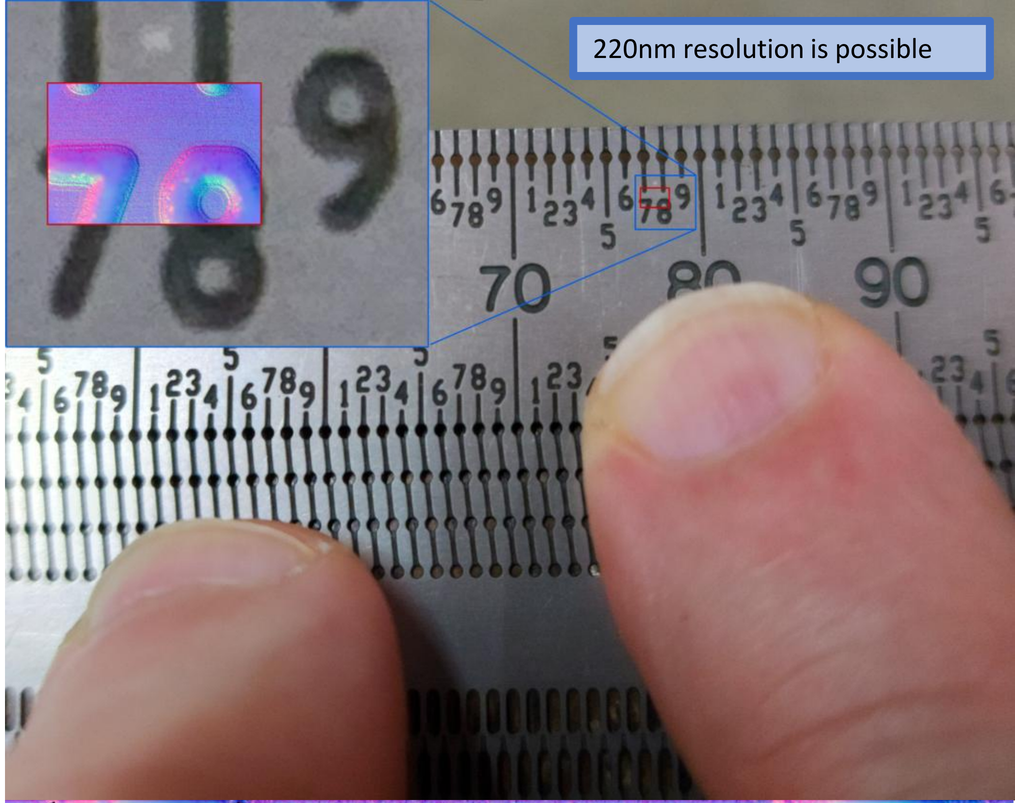
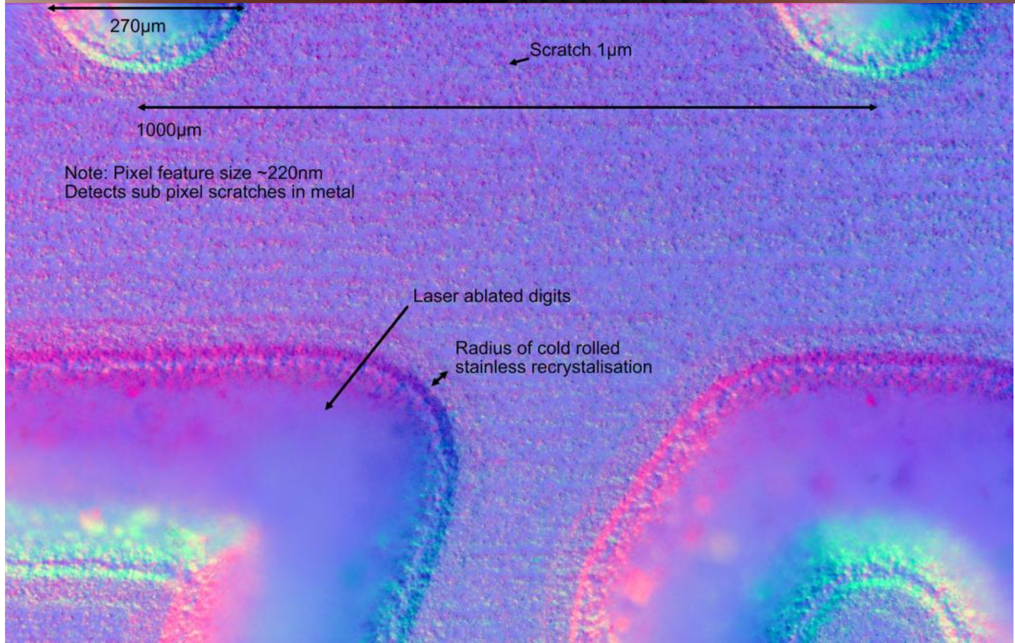
Technical Details

- Performance and usage
- Overview of the technique
- Comparison to existing technologies

Performance

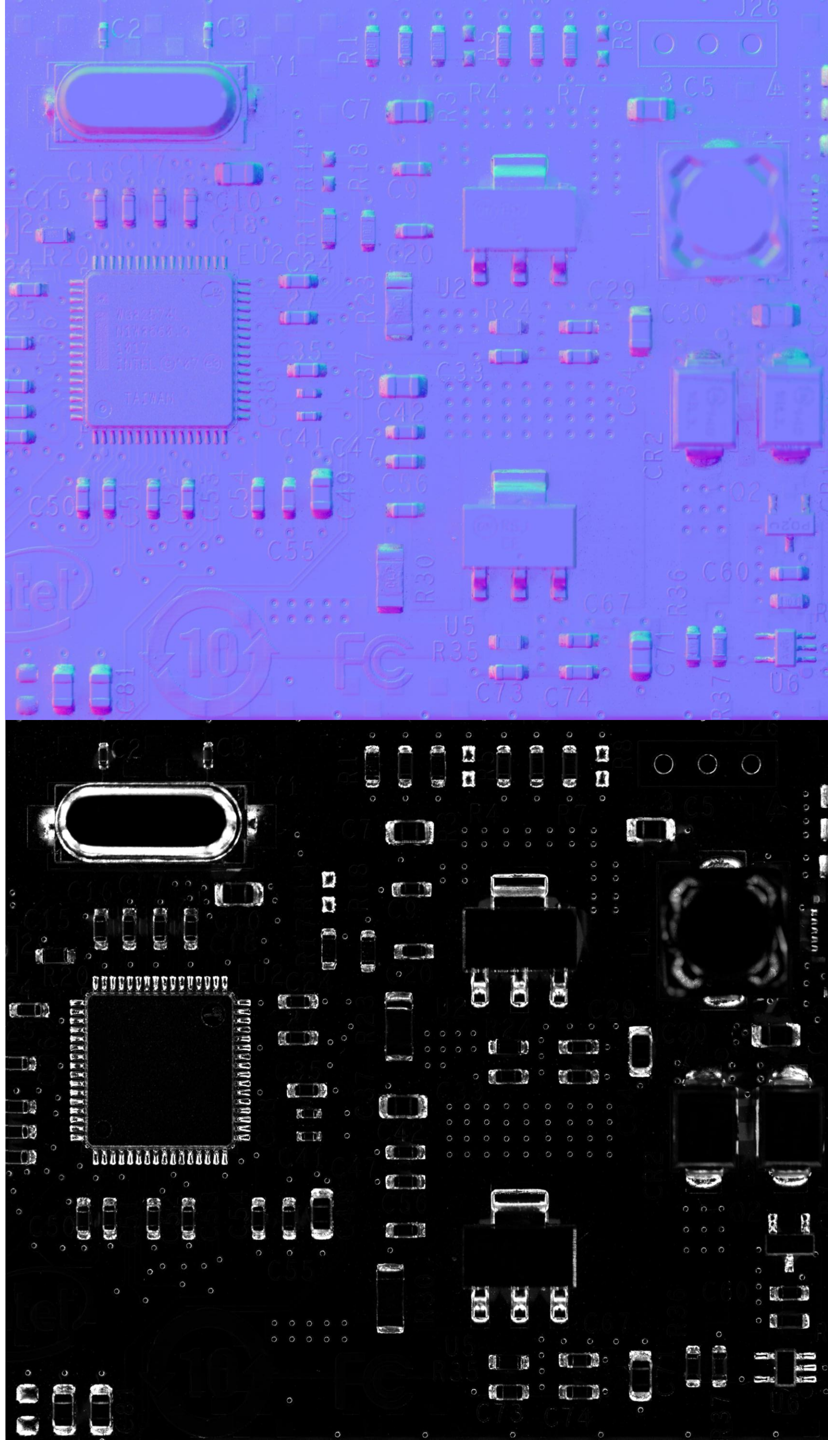
- This approach works for sub micron per pixel up to cm per pixel use cases. The change to the system is the lens, camera and LED’s used
- Separating images into AI actionable data with;
    1. Diffuse/Color
    2. 3D surface normal
    3. Heightmap (estimated)
    4. Specular/Edge map
- Large working area subjects like vehicle sections can be imaged. Combining 3DGS and CAD data for objects with many surfaces like complete vehicles
- This process is a full frame capture and is very fast (limited by camera/bus speed) and as a result can process moving subjects





Capabilities

- Patented process to calculate per pixel 3D surface details along with diffuse, specular, hyperspectral colors and polarized light response
- Mathematical pipeline to reverse the light transport functions
- Low light requirement, large working distance, no-contact scanning, ultra high resolution
- Detection of specular materials allows unique capabilities like the detection of a motherboard having solder present
- Extremely sensitive 3D surface detail can find changes in height caused by layers of ink such as silk screen printing on motherboards



Technology comparison to Specular Metrology

Structured light

- Hexagon, Keyence, MicroEpsilon, Zeiss, Artec 3D, FARO
- Limited accuracy due to spot size
- Challenges with dark and surfaces with multiple colors

Interferometry

- Zygo, Bruker, Keyence, OptoTech
- Ideal for small amounts of surface variation like optical surfaces

Confocal

- Olympus, Keyence, Zeiss, Leica, Nikon, Bruker
- Slow to scan and small scanning area
- Challenging to scan very shiny surfaces

Photometric Stereo

- Generally limited to matte, monochrome surfaces
- Gelsight works with any surface but required gel pads and surface contact

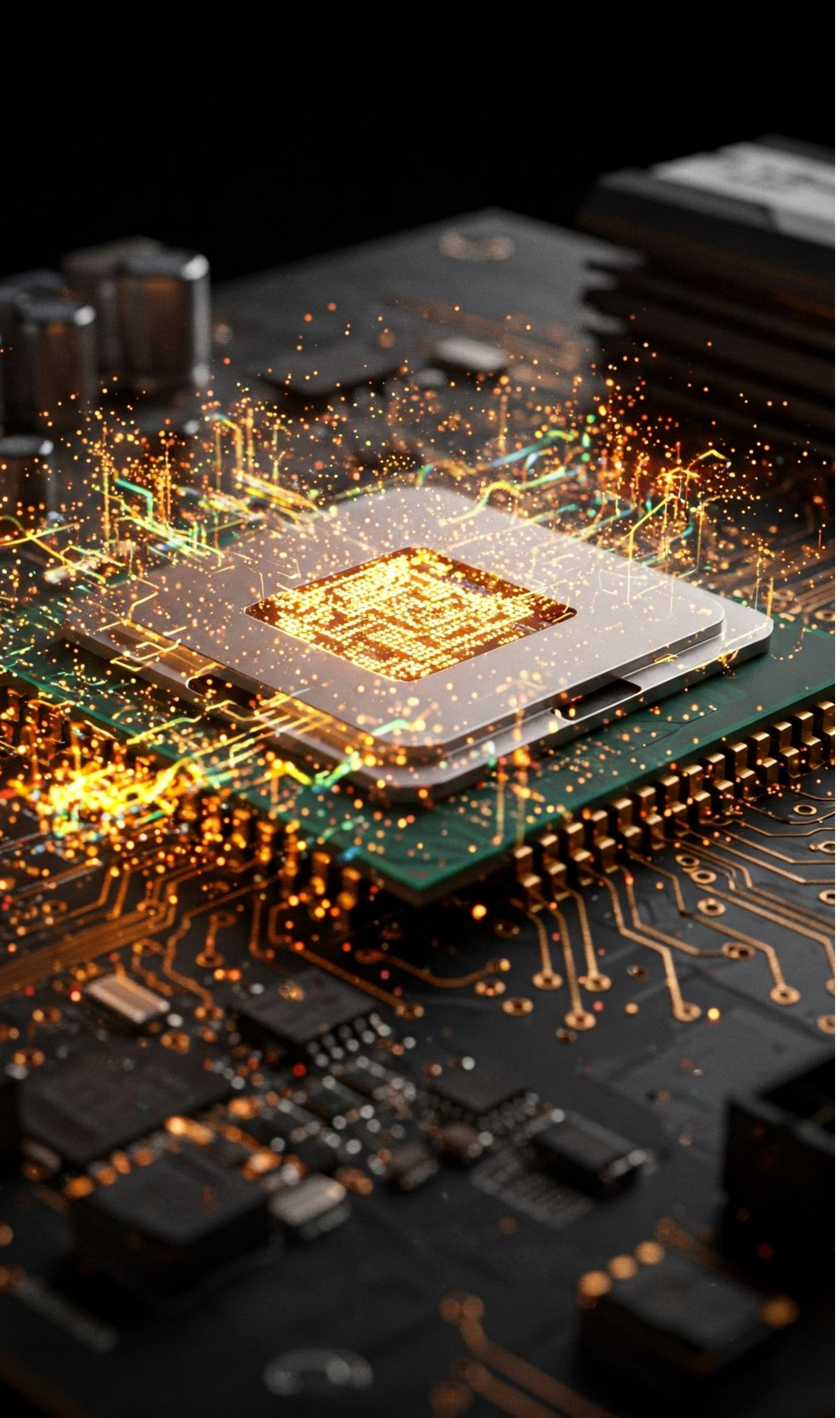
	Confocal Laser Microscopy	Structured Light Scanning	Interferometry (WLI/CSI)	Photometric Stereo	Specular Metrology
Principle	Pinhole spatial filtering + Z-scanning	Projecting patterns, triangulation	Interference of light waves	Multiple lights, single viewpoint	Multiple lights, single viewpoint
Surface Area	Small (stitching for larger)	Medium to Large (stitching for larger)	Small (stitching for larger)	Small (stitching for larger)	Small to Large
Accuracy (Vertical)	Good (nm to µm)	Lower (tens of µm to mm)	Excellent (sub-nm to nm)	Good for texture (µm), variable for form	Good (nm to µm)
Accuracy (Lateral)	High (sub-µm)	Medium (tens of µm to mm)	Medium (sub-µm to µm)	High for texture (µm)	Micron
Scanning Speed	Moderate (can be slow for large areas)	Very Fast (for given field of view)	Moderate (vertical scan adds time)	Fast acquisition, processing time varies	Fast Acquisition, fast processing
Surface Roughness	Handles moderate roughness	Affected by reflectivity/absorption (black)	Best for smooth to moderate roughness	Good for reflective, struggled with textured and colored surfaces	Excellent for reflective, transparent, textured and colored surfaces
Steep Slopes	Can handle steeper slopes	Can handle complex shapes	Limited by objective NA	Good for localized slopes (texture)	Good for localized slopes (texture)
Vibration Sensitivity	Moderate	Low	High	Low (for image capture), processing stable	High (software stabilisation) Includes factory deployments on moving production lines
Contact	Non-contact	Non-contact	Non-contact	Non-contact (except tactile versions)	Non-Contact

Acquisition & Processing Time

Technique	Typical New Equipment Cost Range	Key Operational Cost Drivers
Confocal Laser Microscopy (CLM)	Basic: ~$100k. High-end/Super-res: $500k - >$1M+.[47]	High annual maintenance contracts ($18k-$60k+) [48], software licenses, consumables (dyes, objectives), skilled personnel/training ($40-$775 training, $50-$170/hr staff).[48]
Structured Light Scanning (SLS)	Entry/Hobbyist: <$1k-$5k.[51] Pro/Industrial: $5k - $100k+.[51] Industrial 3D Vision: $3k-$60k+.[53]	Software licenses (e.g., Artec Studio $1.7k/yr or $4.3k lifetime [76]), skilled personnel for complex tasks/modeling, training ($1.5k-$2.9k per course [77]), scanning spray ($40/can [51]), service provider fees if outsourced ($50-$200/hr [74]).
Interferometry	Basic lab: Few $k - $15k+.[55] High-precision metrology: Tens to hundreds of $k+.[57]	High-quality reference optics, laser maintenance, software, skilled personnel, calibration, potential for high OpEx in large research facilities (e.g., LIGO [79]). Service contracts (5-10% of equip. value/yr [82]).
Photometric Stereo (PS) Imaging	Hardware can be low-cost.[62] Integrated industrial 3D Vision systems: $3k-$60k+.[53]	Software (commercial libraries or custom dev), lighting controllers, potentially GPU/FPGA, expertise for algorithm/DL model development & training.[3]

Cost Comparison

Technique	Typical Acquisition Time	Typical Processing Time	Key Influencing Factors (Acquisition & Processing)
Confocal Laser Microscopy (LSCM/Resonant/SDCM)	LSCM: Seconds/slice to hours (large volume, Z-stacks).[2] Resonant/SDCM: Milliseconds/frame to seconds/volume, potentially video rate.[2]	Minutes to hours, dataset and algorithm dependent.[2] Real-time for some digital holography emulations.[41]	Scanning mechanism (point, line, disk), sample size/complexity, Z-depth, resolution, averaging, laser power, detector speed, data volume, algorithm complexity, compute power.
Structured Light Scanning (SLS)	Microseconds to seconds per view/pattern set.[5] Minutes to hours for full object capture (multiple views).[5]	Seconds to hours for point cloud/mesh.[34] Days for parametric CAD models.[34]	Number of patterns, camera FPS, FOV, object size/complexity, surface properties, number of views, algorithm efficiency (phase unwrapping, registration, meshing), PC specs.
Interferometry (PSI/CSI/Dynamic/DHM)	PSI: ~0.5s per measurement.[20] Dynamic/DHM: Microseconds to 10 ms (100 Hz) per frame.[19] CSI: Seconds to minutes (Z-scan dependent).	Milliseconds to minutes, technique and data dependent. Real-time for some dynamic/DHM systems.[20] Potentially longer for complex phase unwrapping/noise.	Technique type, camera speed, phase shift speed, environmental stability (for non-dynamic), Z-scan range (CSI), data volume, phase analysis algorithm complexity, compute power.
Photometric Stereo (PS) Imaging	Milliseconds per image; total depends on number of lights (e.g., 4 lights x ms/image). Real-time systems ~100 ms per 3D frame (10 Hz).[38] Industrial systems can capture individual images at 180 FPS.[25]	Milliseconds to seconds per 3D frame with hardware acceleration (FPGA/GPU).[25] Longer for complex BRDF modeling or CPU-based integration. Training DL models is offline and time-consuming.[3]	Number of light sources, camera FPS, exposure time, light/camera sync speed, image resolution, reflectance model complexity, normal integration algorithm, CPU/GPU/FPGA resources.



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About Umajin

- Solutions are built on the Umajin Platform
- High performance native runtime engine
- Flexible cloud framework
- Designed for accelerated 3D and AI
- Full OS services on iOS, MacOS, Android, Windows, Linux, Meta Horizons OS & AndroidXR

Umajin Platform Context:
Low code tools for AI/ Spatial Application Development

- Umajin combines a 3D low-code editor, multi user capabilities, cloud content management, and cloud servers providing workflows, connectors, and services orchestration
- Powered by a native 3D rendering engine supporting animation, 3D digital twins, XR content, rich network, I/O, math, simulation, database, security and GUI capabilities
- Modular architecture designed to support new technologies as building blocks of functionality ***(REST calls, JS code, SPIRV code, AI models, micro services, native DLL's, Python runtime access)***
- Designed for goal directed development and performance. Encodes what the users want to achieve and the high-level actions without branching and ambiguity.
- Umajin runtime engine allows solutions to be directly deployed onto devices while ensuring best practice security and governance for Windows, MacOS, iOS, Android, AndroidXR, HorizonsOS & Linux
- Umajin orchestrates and optimizes workload deployment across local, edge, and cloud infrastructure

AR Digital Twins with Umajin Spatial

- Digital Twins allow us to track and locate defects directly against the CAD data for the products being manufactured

- NVIDIA Omniverse provides a range of powerful tools including utilizing the important new standard for 3D communication between software, OpenUSD

- The Meta Quest3 AR mode allows for high quality composited images with highly readable text and diagrams to be projected onto the real world showing the underlying Digital Twin data

- Visualize on site with Augmented Reality or offsite in VR
  1. Enterprise System Data
  2. IoT & PLC production Data
  3. Specular scanning defect Data
  4. CAD Data