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BCA Honours | Semester VI | BCA6EJ304(1)

Applied Digital Image Processing

Module 4 Comprehensive Notes

Module 4: Remote Sensing and Industrial Quality Inspection

Remote sensing captures planetary surface imagery from satellite platforms, while industrial machine vision automates quality inspection on manufacturing assembly lines.

4.1 Remote Sensing Image Analysis and Vegetation Indices

Satellite sensors (Landsat, Sentinel) capture imagery across multiple electromagnetic spectral bands: Visible, Near-Infrared (NIR), Shortwave-Infrared (SWIR), and Thermal:

- **Normalized Difference Vegetation Index (NDVI):** Exploits high chlorophyll absorption in the red band and strong cellular scattering in the NIR band:

$$\text{NDVI} = \frac{\text{NIR} - \text{Red}}{\text{NIR} + \text{Red}}$$

Where: Dense healthy vegetation yields values approaching $+0.8$, bare soil yields near 0, and open water bodies produce negative values.

- **Land Use and Land Cover (LULC) Classification:** Supervised classification categorizing terrain into urban, agricultural, forest, and water bodies using Maximum Likelihood or Random Forest classifiers.

4.2 Industrial Machine Vision Quality Inspection

High-speed industrial machine vision systems operate in real-time along conveyor lines:

Industrial Domain	Machine Vision Task	Inspection Methodology and Defect Criteria
Semiconductor & PCB	Automated Optical Inspection (AOI)	Golden-template subtraction and morphological edge checks detecting solder bridging, component misalignment, and missing pins.
Pharmaceutical Packaging	Blister Pack Inspection	Blob analysis verifying tablet presence, color uniformity, and detecting crushed pills in high-speed packaging lines.
Automotive Stamping	Surface Defect Detection	Deflectometry and dark-field illumination detecting micro-cracks, scratches, and dings on polished sheet metal.

Advanced Theoretical Foundations & Industrial Systems Synthesis

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- **Time Complexity Optimization versus Spatial Footprint:** In high-throughput algorithmic pipelines handling Module 4 Core Concepts and Methods, pre-computing intermediate lookup tables, spatial indices, and hashing structures achieves near-instantaneous $O(1)$ query latency, but inflates the physical memory footprint. Conversely, in-place algorithms minimize RAM utilization at the cost of higher CPU cycle counts. Modern architectures dynamically calibrate memory allocations using memory-mapped files and cache-aware structures.
- **Concurrency Scalability versus Thread Contention:** While multi-core hardware allows horizontal execution, concurrent modifications to shared state structures create severe lock contention, thread synchronization bottlenecks, and cache line invalidation storms. High-performance frameworks deploy lock-free algorithms, optimistic concurrency control, and atomic compare-and-swap (CAS) primitives.
- **Algorithmic Determinism versus Heuristic Scalability:** Exact mathematical algorithms frequently encounter NP-hard combinatorial barriers as problem dimensions scale. Contemporary systems bridge this gap by deploying bounded approximation algorithms and meta-heuristics that produce near-optimal solutions within guaranteed execution time windows.

2. Empirical Comparative Framework

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