

# Project Proposal: MicroStructure Vision

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## Comparative Evaluation of Classical Computer Vision Algorithms for Automated Metallographic Grain Analysis

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### Problem Statement

Metallographic grain analysis is critical for evaluating metal mechanical properties (strength, hardness, ductility), but traditional manual analysis is subjective, time-consuming, and prone to inter-operator variability. This project addresses automated grain segmentation and measurement using classical computer vision—specifically comparing two algorithms to determine which performs better for different microstructure types.

### Motivation

Accurate grain size measurement is essential in automotive, aerospace, and manufacturing quality control. While deep learning shows promise, it requires large annotated datasets and significant computational resources. Classical CV methods offer interpretability, efficiency, reproducibility, and natural alignment with grain formation physics (Watershed mimics crystal growth).

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### Solution Implemented

A Streamlit web application comparing two segmentation approaches:

Algorithm	Method	Best For
<b>Threshold + Connected Components</b>	Otsu's thresholding → morphological closing → component labeling	High-contrast, complete boundaries
<b>Marker-based Watershed</b>	Distance transform → marker extraction → watershed flooding	Partial boundaries, complex structures

Key Features:

- Dual Algorithm Execution — Side-by-side comparison of both methods
- ASTM E112 Metrics — Grain count, G-number calculation:  $G = 3.322 \times \log_{10}(N_a) - 2.95$
- Carbon Content Estimation — Dark pixel percentage analysis
- Interactive Visualization — Color-coded grain overlays with view toggle (Original/Segmented/Overlay)
- Ground Truth Validation — IoU computation and grain count error against manual annotations