From Pixels to Policy: Research Data Management Strategies for AI-Driven Bacterial Detection in Food Safety Research

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The Challenge: Food Safety Meets AI

Traditional bacterial detection: **24-72 hours** to produce results

AI-driven approach: Detection in **minutes** using YOLOv8 architecture

Target pathogens: **E. coli** and **Salmonella** in food samples

The data challenge: **Massive image datasets (2TB+)** with complex metadata

Our Use Case: YOLOv8 Bacterial Detection System

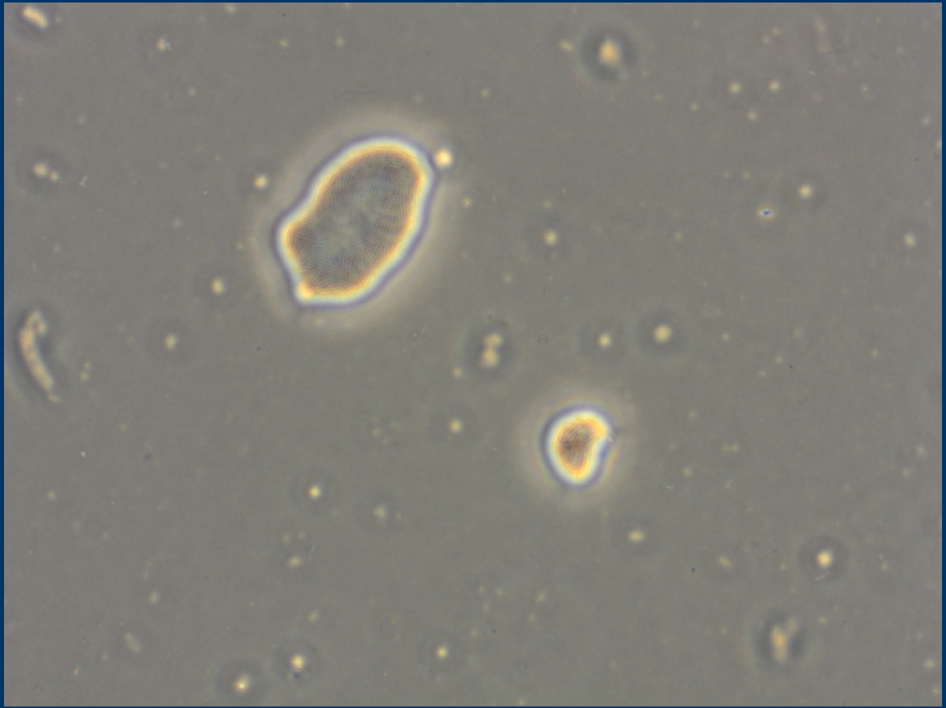
High-resolution microscopic imaging with standardized Gram staining procedures

Mixed cultures with **temporal data (0.5-4 hours)** to capture bacterial growth dynamics

Complex sample preparations (**"with onion" and "without onion"**) to reflect real-world scenarios

Individual images: **50-150 MB each**, cumulative dataset exceeding **2 TB**

Manual annotation: **30-60 minutes per image** requiring expert knowledge



Processing Challenges in AI-Intensive Research

Scale: 2TB+ datasets with individual files exceeding 100MB, overwhelming conventional research infrastructure

Solution: Distributed processing pipeline with parallel image processing nodes

Complexity: Complicated metadata interdependencies capturing sample preparation, imaging parameters, and experimental context

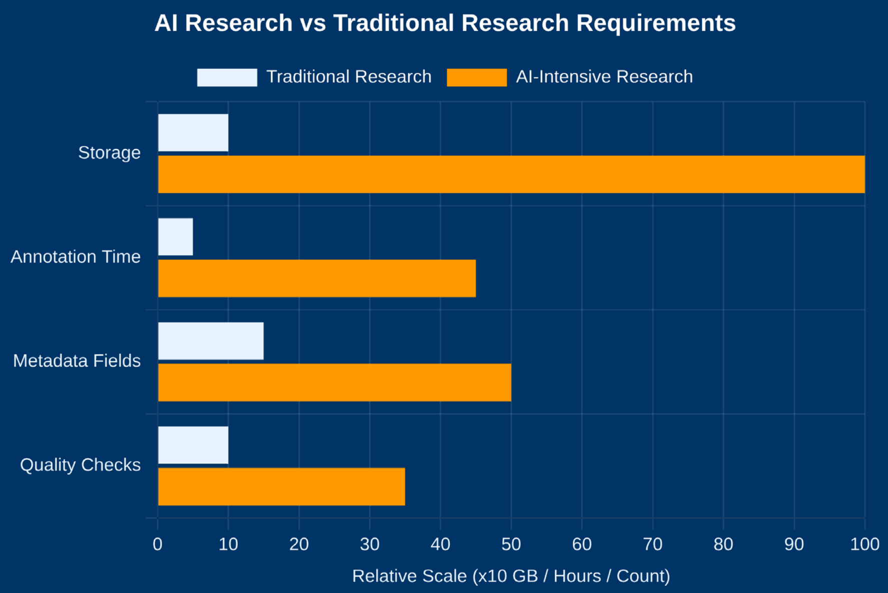
Solution: GPU-accelerated image processing reducing time from hours to minutes

Quality: Balancing biological variability with standardization needs for AI model training

Solution: Automated quality metrics with threshold-based filtering

Version control: Traditional systems inadequate for massive binary files, requiring custom workflows

Solution: Standardized processing workflows with version control



FAIR Implementation Strategies

Findability: Controlled vocabularies, persistent identifiers (DOIs), domain-specific search interfaces

Accessibility: Tiered access control systems, data use agreements, long-term preservation services

Interoperability: Standardized formats (TIFF, PNG), metadata encoding (Dublin Core, DataCite), COCO extensions

Reusability: Comprehensive provenance documentation (PROV-O), Creative Commons licensing, analytical tools

Data Processing Tools & Workflows

Image Processing Tools

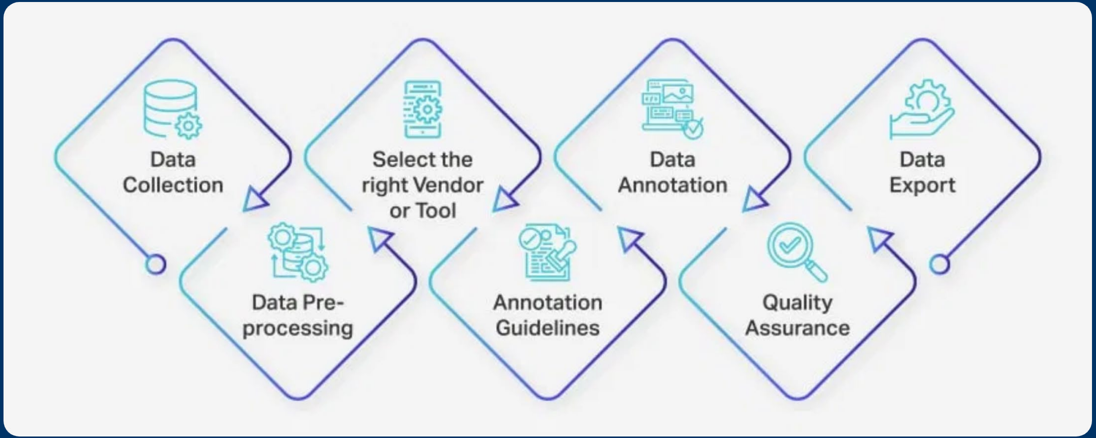
- **OpenCV:** Core library for image preprocessing and enhancement
- **scikit-image:** Quality assessment and feature extraction

Annotation Management

- **LabelImg:** Custom-modified for bacterial annotation
- **CVAT:** Collaborative verification platform

Version Control Systems

- **DVC (Data Version Control):** For large binary files
- **Git LFS:** For metadata and configuration



Lessons

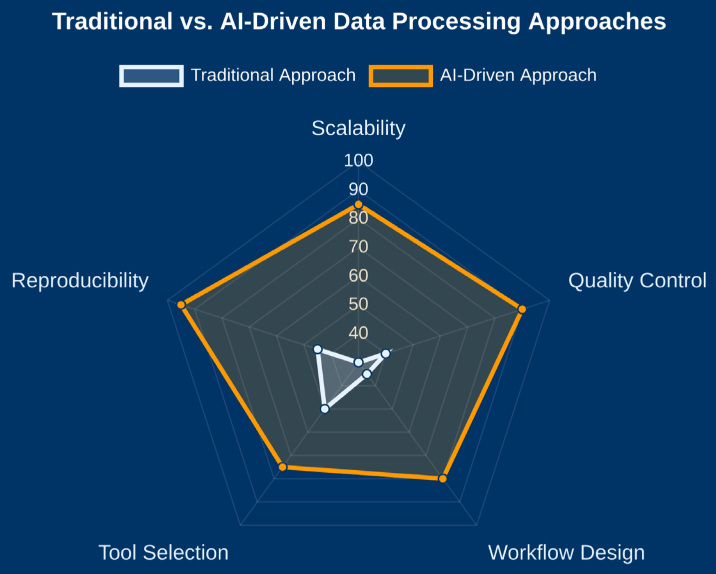
Scale Matters: Traditional data processing tools fail with AI-scale datasets - invest in scalable infrastructure from the start

Quality First: Automated quality control is essential - poor quality data compounds errors throughout the pipeline

Workflow Design: Systematic processing pipelines prevent errors and save time - document every step and automate where possible

Tool Selection: Right tools make the difference between success and failure - evaluate tools based on your specific data characteristics

Reproducibility: Good processing documentation enables scientific reproducibility - version control everything, including processing parameters



Requirements & Recommendations

Standardized Metadata Templates

Machine-readable schemas with automated validation for AI-intensive research

Comprehensive RDM Policies

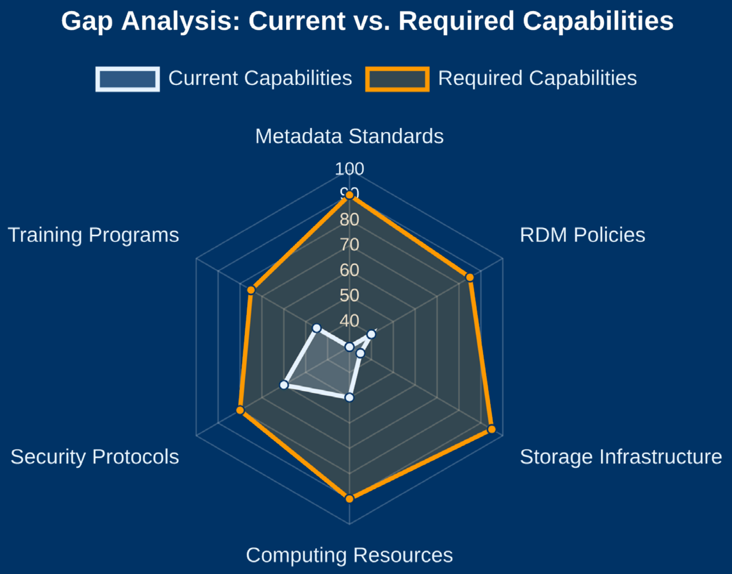
Address data collection, storage, processing, sharing, and preservation throughout research lifecycles

Cyberinfrastructure Development

GPU-accelerated computing, specialized storage systems, and annotation management platforms

Security Infrastructure

Protect sensitive research data while maintaining accessibility for collaborative research



Conclusion & Call to Action

RDM is an **enabler of scientific progress**, not merely an administrative requirement

The stakes extend beyond academia to **public health, food security, and economic stability**

The **window of opportunity is limited** as AI technologies advance rapidly

Sustained commitment needed from research institutions, funding agencies, and the scientific community

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Building the Future

Develop standardized metadata templates

Establish comprehensive RDM policies

Invest in specialized cyberinfrastructure

Collaborate on international standards

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