Role of Machine Vision in Monitoring Vehicle and Track Condition

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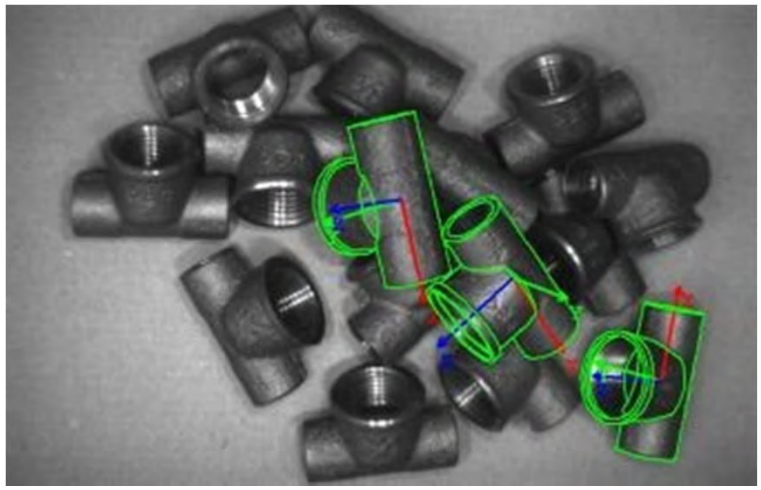
ENSCO Rail
May 19th 2015

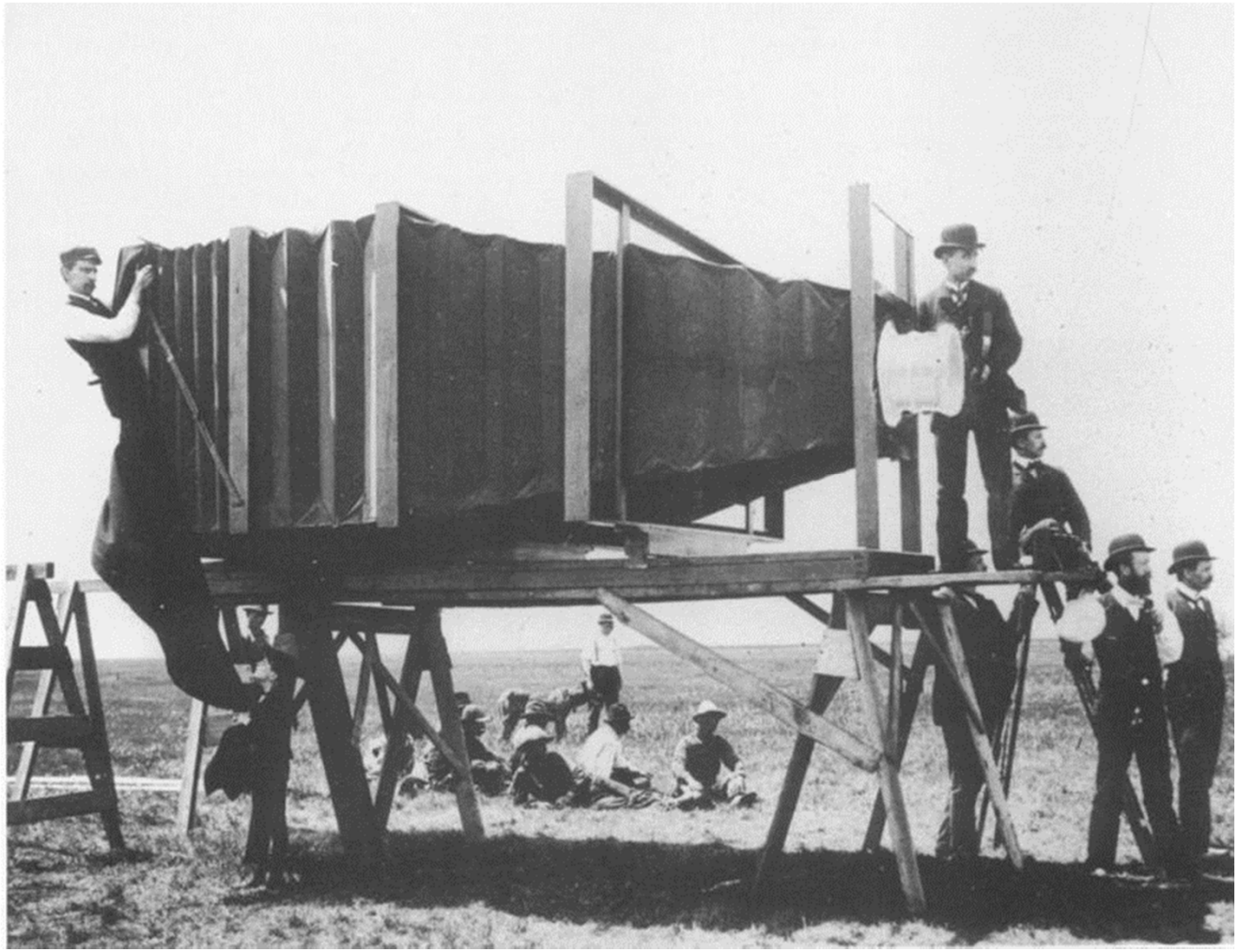
What is Machine Vision?

Machine Vision is **image based** automated inspection in an *industrial* setting.



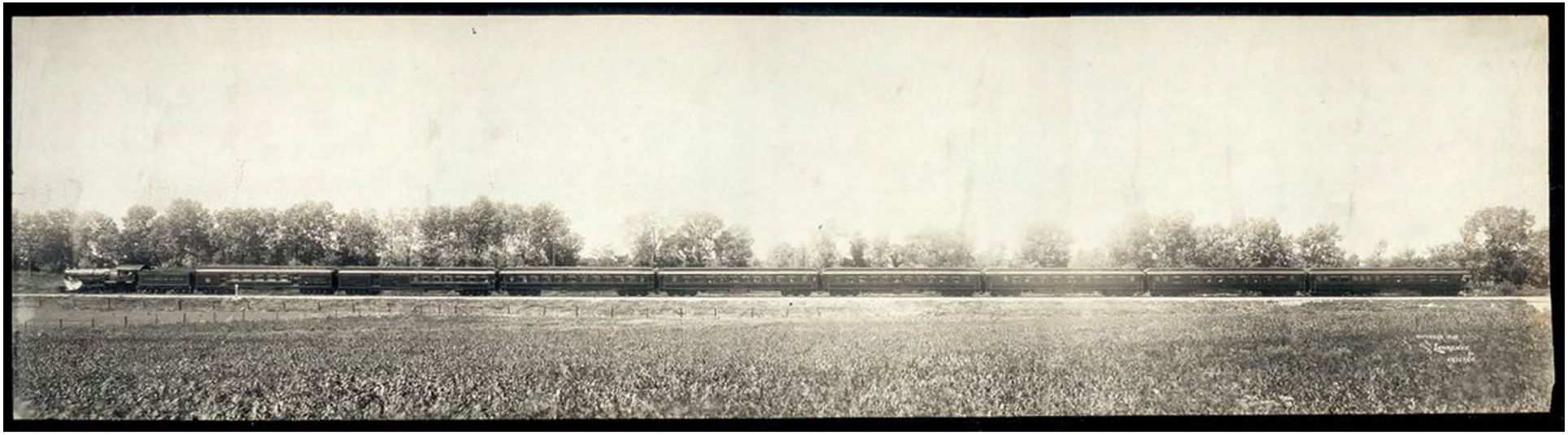
What is *Computer* Vision?

Computer Vision is the broader field of technology focused on acquiring, processing, and analyzing images.

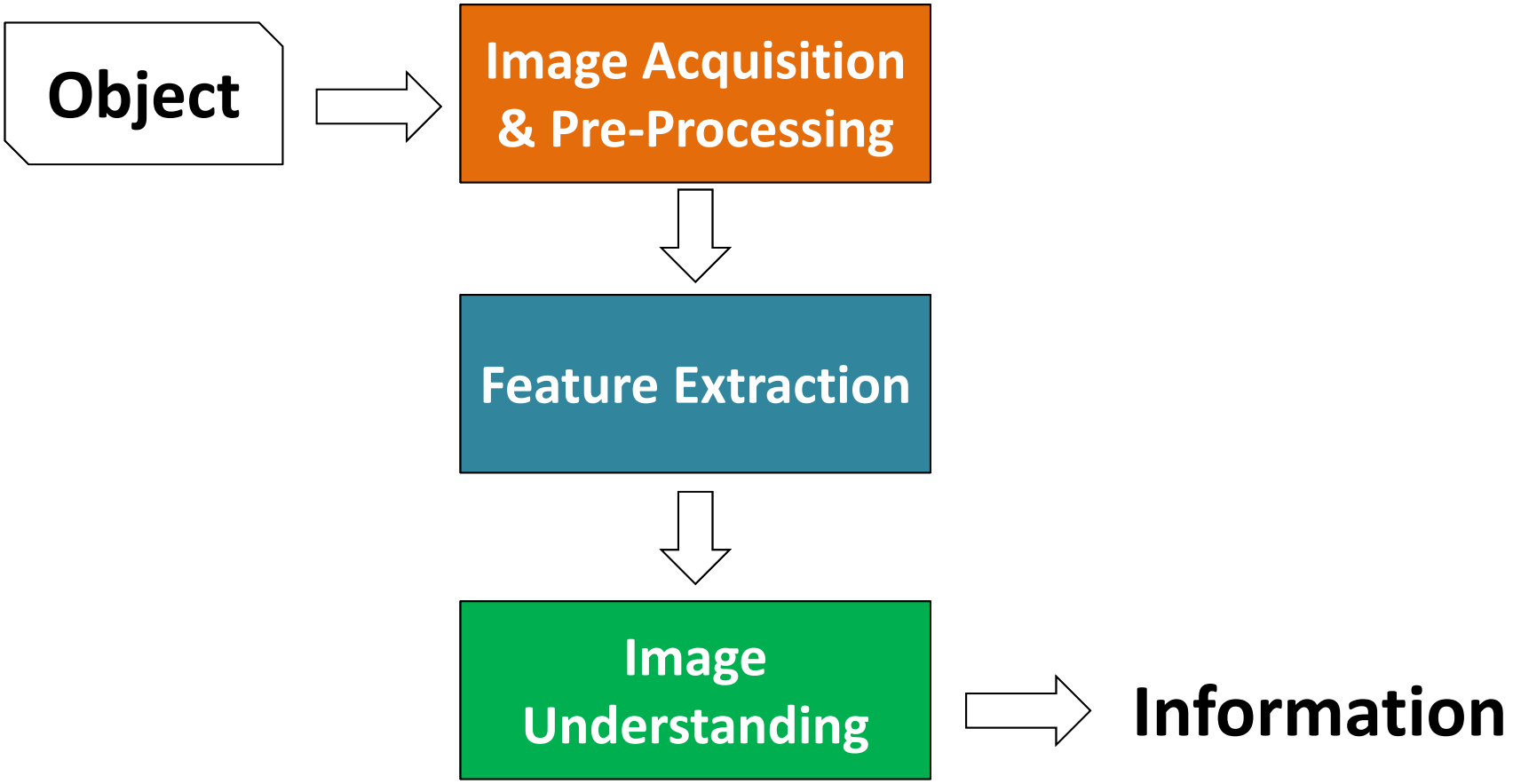


The “Mammoth” Camera commissioned for the Chicago & Alton Railway (1900)

Ref: http://robroy.dyndns.info/lawrence/mammoth.html



Ref: http://www.lomography.com/magazine/246893-george-lawrences-mammoth-camera-from-1900


Object
Image Acquisition & Pre-Processing
Feature Extraction
Image Understanding
Information

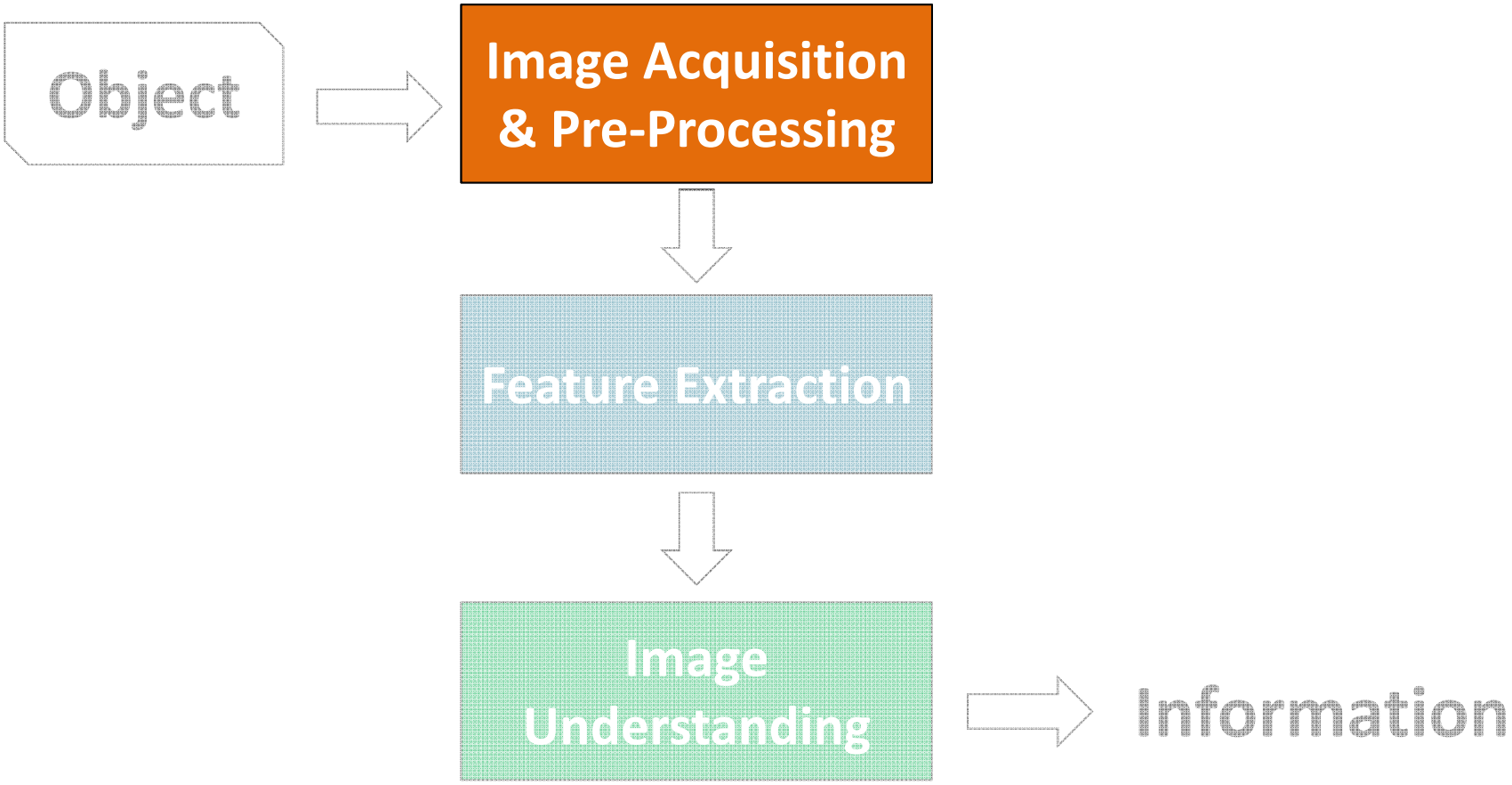

Object
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Image Understanding
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Cameras

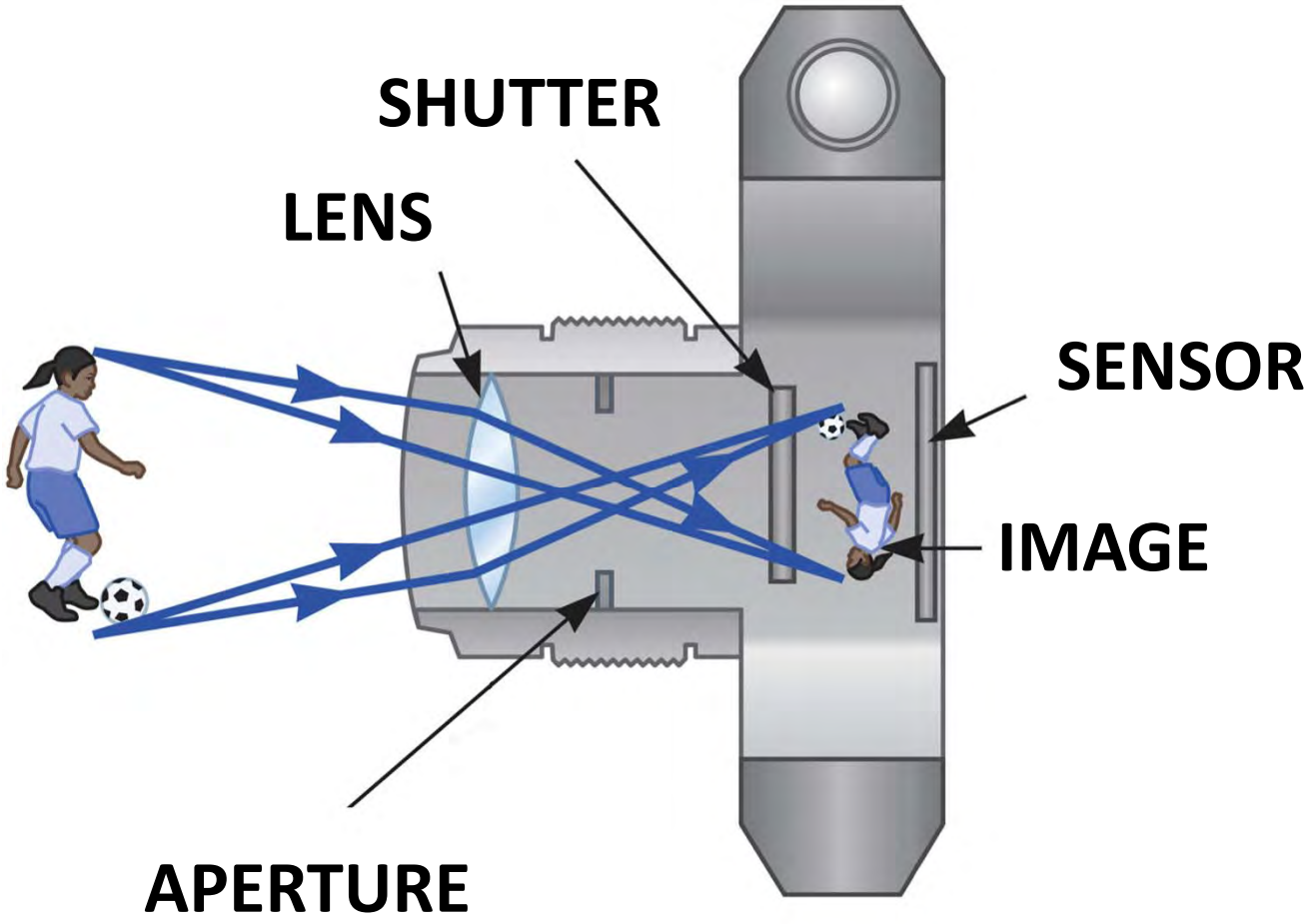
"Line Scan" Cameras
aka "Slit Scan"

Works like your document scanner

"Area Scan" Cameras
aka "Full Frame"

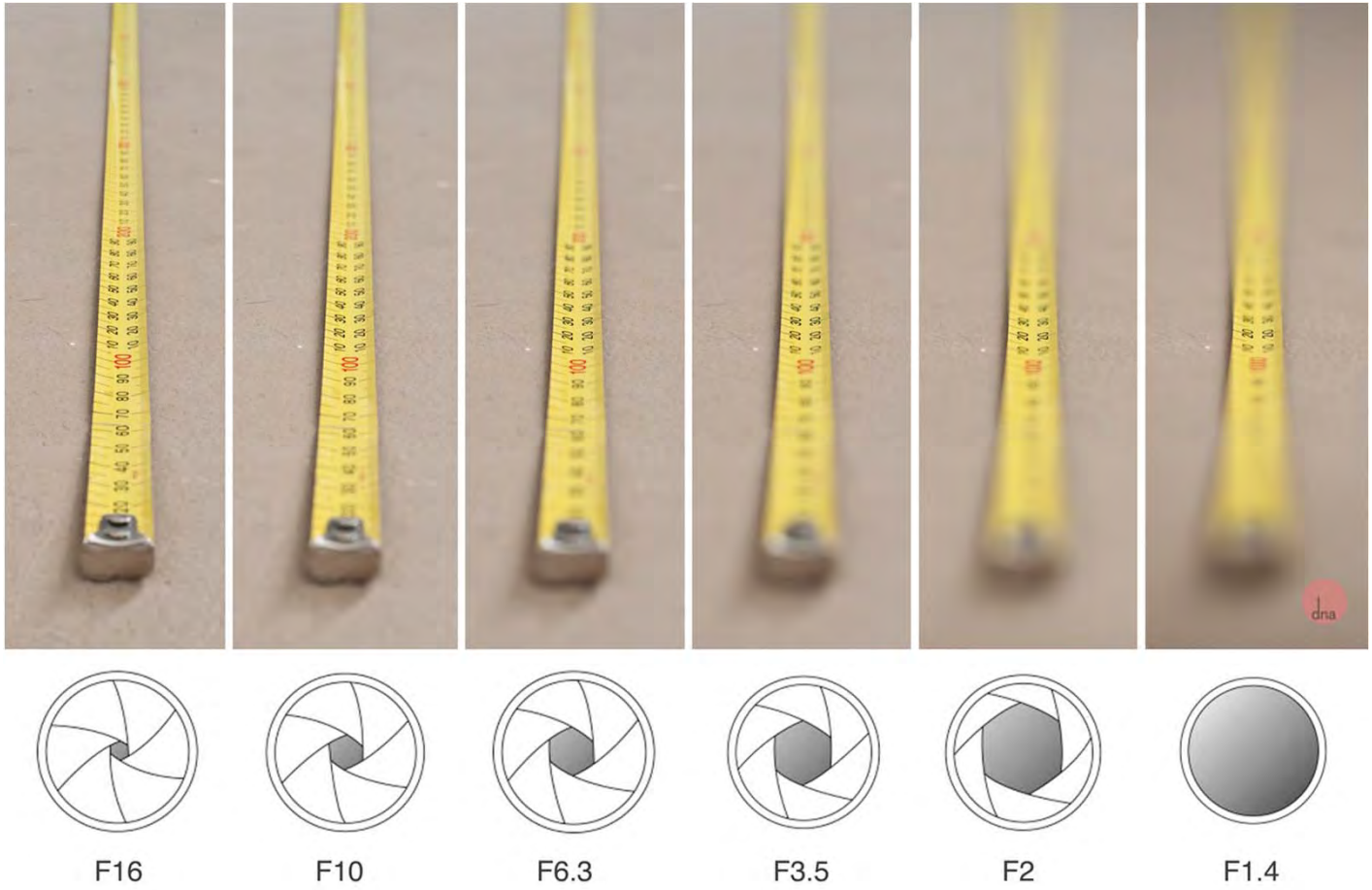
Works like your standard camera

Camera Basics



Ref: http://www.physics.byu.edu/faculty/colton/courses/phy123-fall12/warmups/jitt30a.html

Aperture & Depth of Field



Ref: https://www.ormsdirect.co.za/blog/2012/05/08/what-is-aperture-desmond-louw-explains/

Railway Cameras

What is needed for a railroad application:

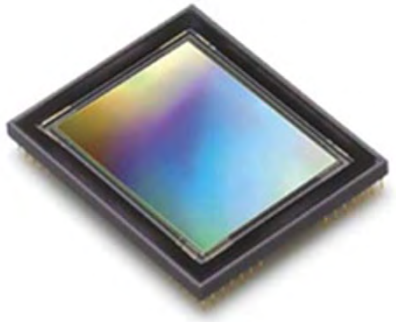
Ideally want **large depth of field (small aperture)** for maximum content in focus.

Want **fast shutter speed** to capture quickly moving objects.

Generally **need lots of light**.

Imagery Sensors

Line Scan Sensor

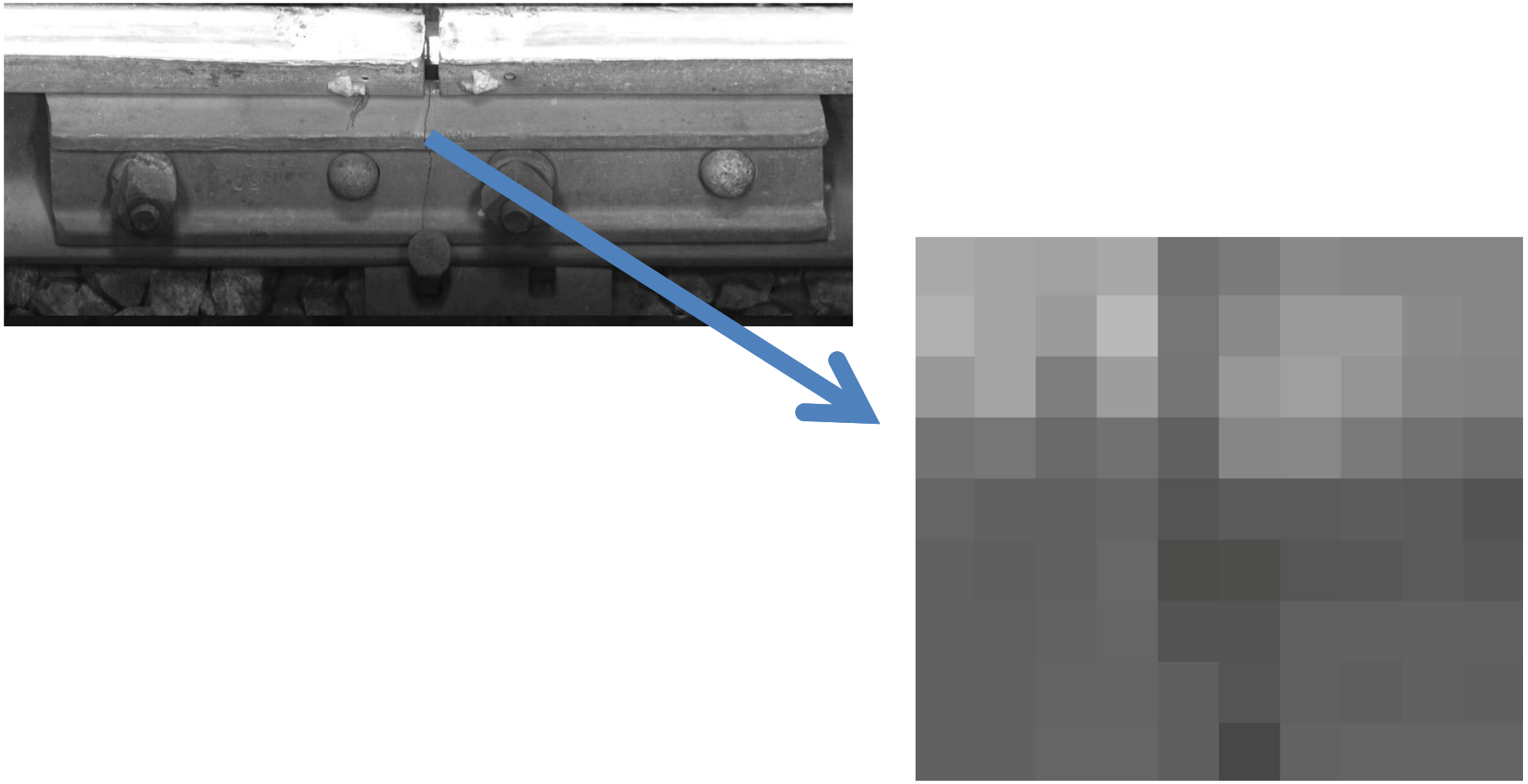


Area Scan Sensor

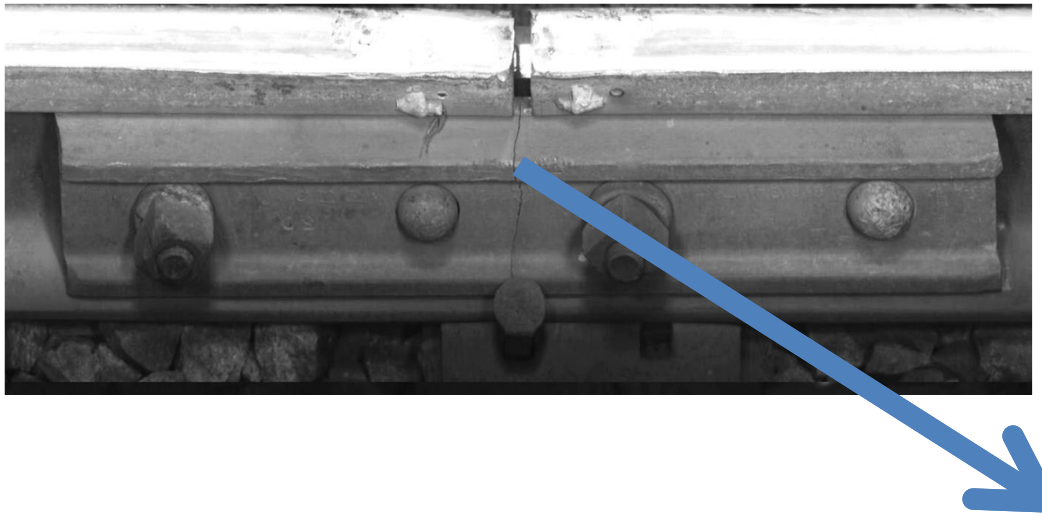
Light is converted to electricity similar to a solar cell.

Imagery sensors are like a grid of very tiny solar cells.

Pixels

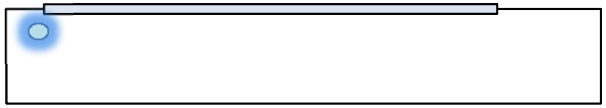


Pixels

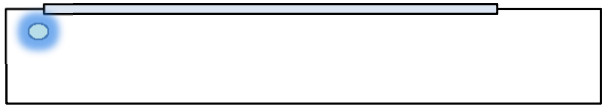


169	164	161	168	113	123	138	134	134	134
176	164	155	185	118	138	154	155	138	134
153	164	126	157	117	151	159	148	134	132
115	118	106	113	97	134	135	122	113	107
101	97	97	100	84	91	90	93	91	83
97	95	97	103	76	78	86	88	90	88
97	96	98	101	83	83	96	96	97	96
97	97	100	100	95	85	96	94	97	95
97	97	101	101	95	71	98	100	99	99

Line Scan Camera



Line Scan Camera



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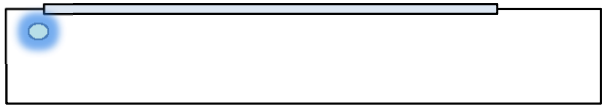

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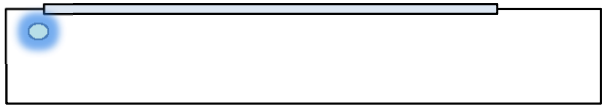
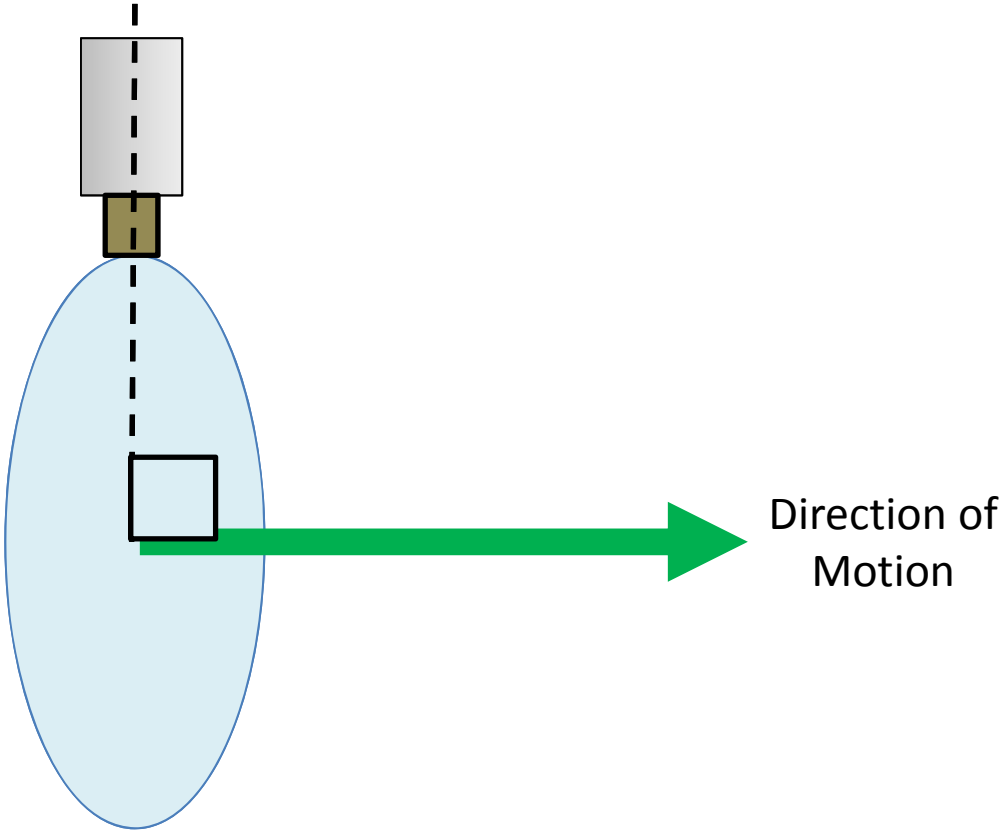
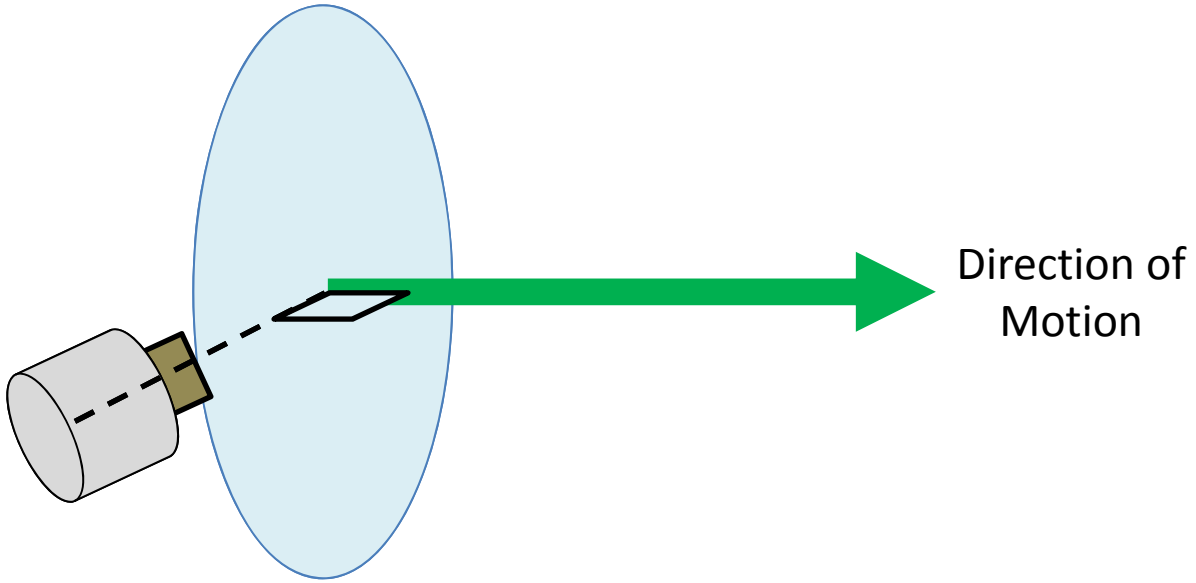


Line Scan Camera



Line scan cameras must be **perpendicular to the trajectory of motion**.

Line Scan Camera

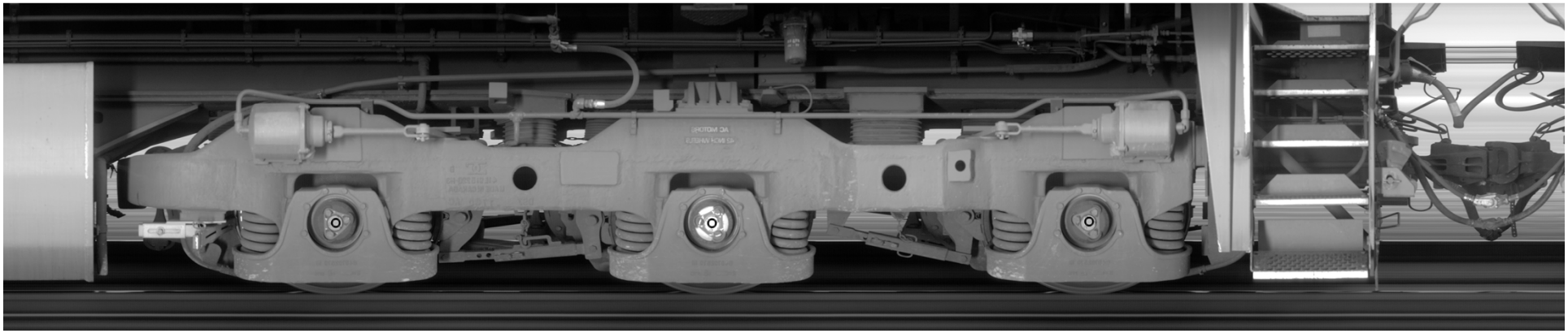


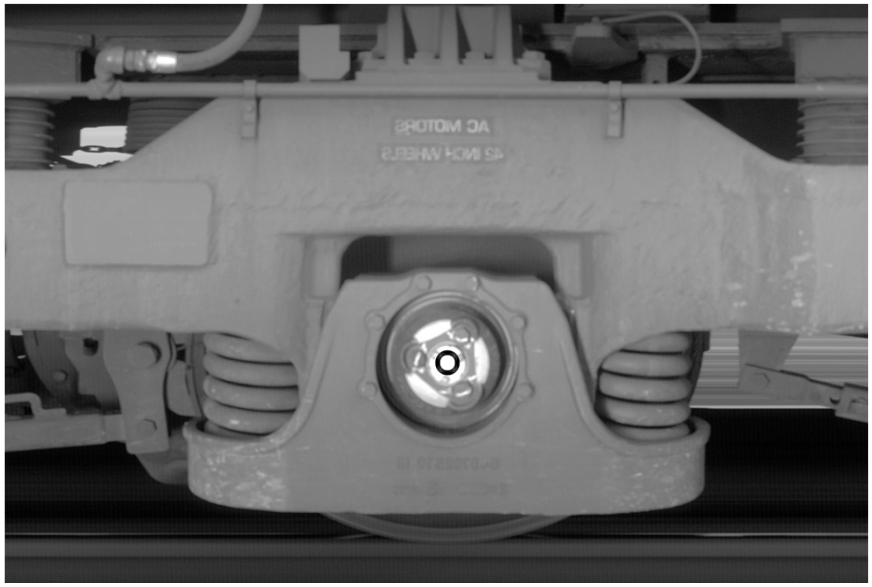
Line scan cameras must be **perpendicular to the trajectory of motion**.

Line Scan Camera

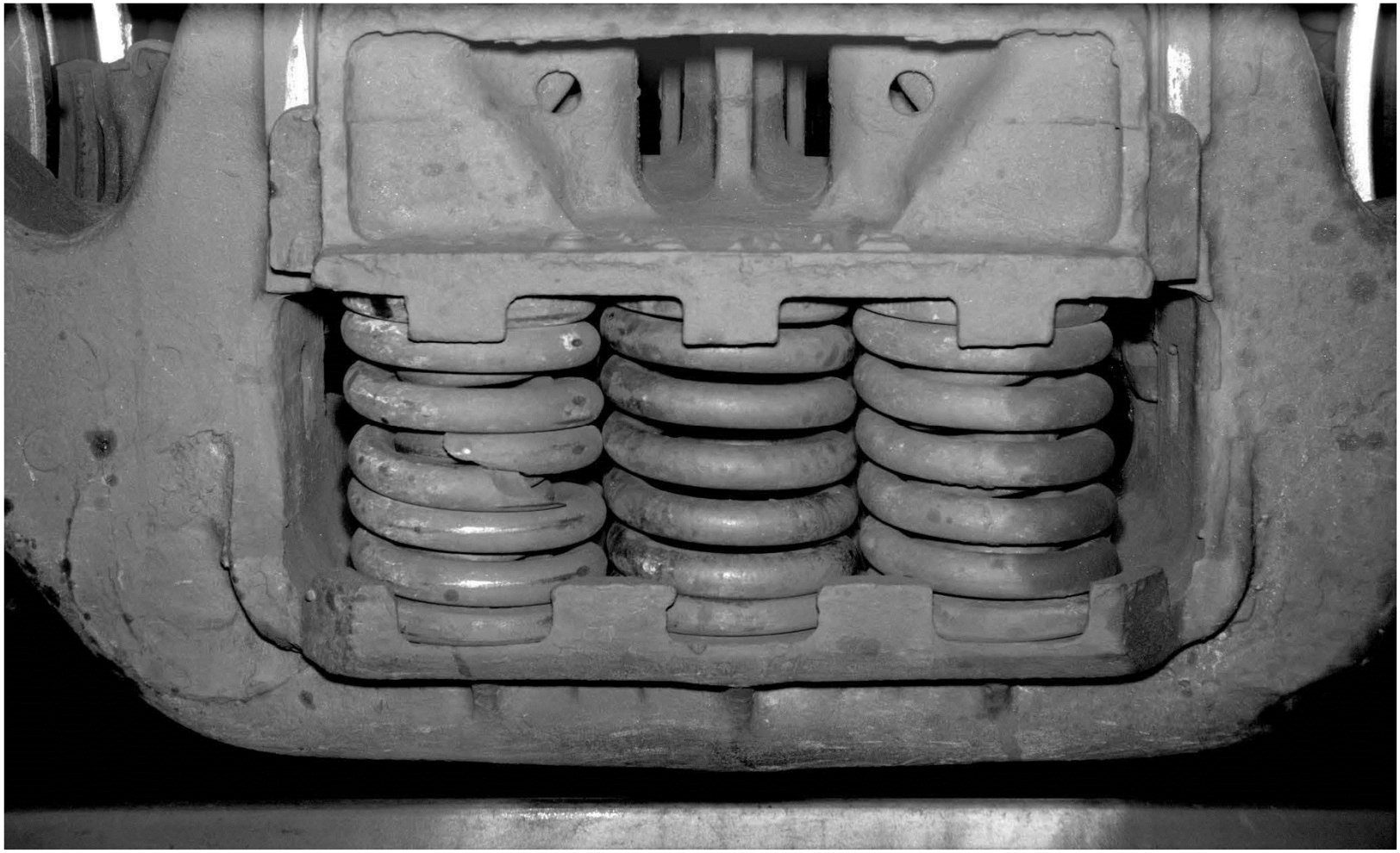
Wheel Sensor

Line Scan Examples

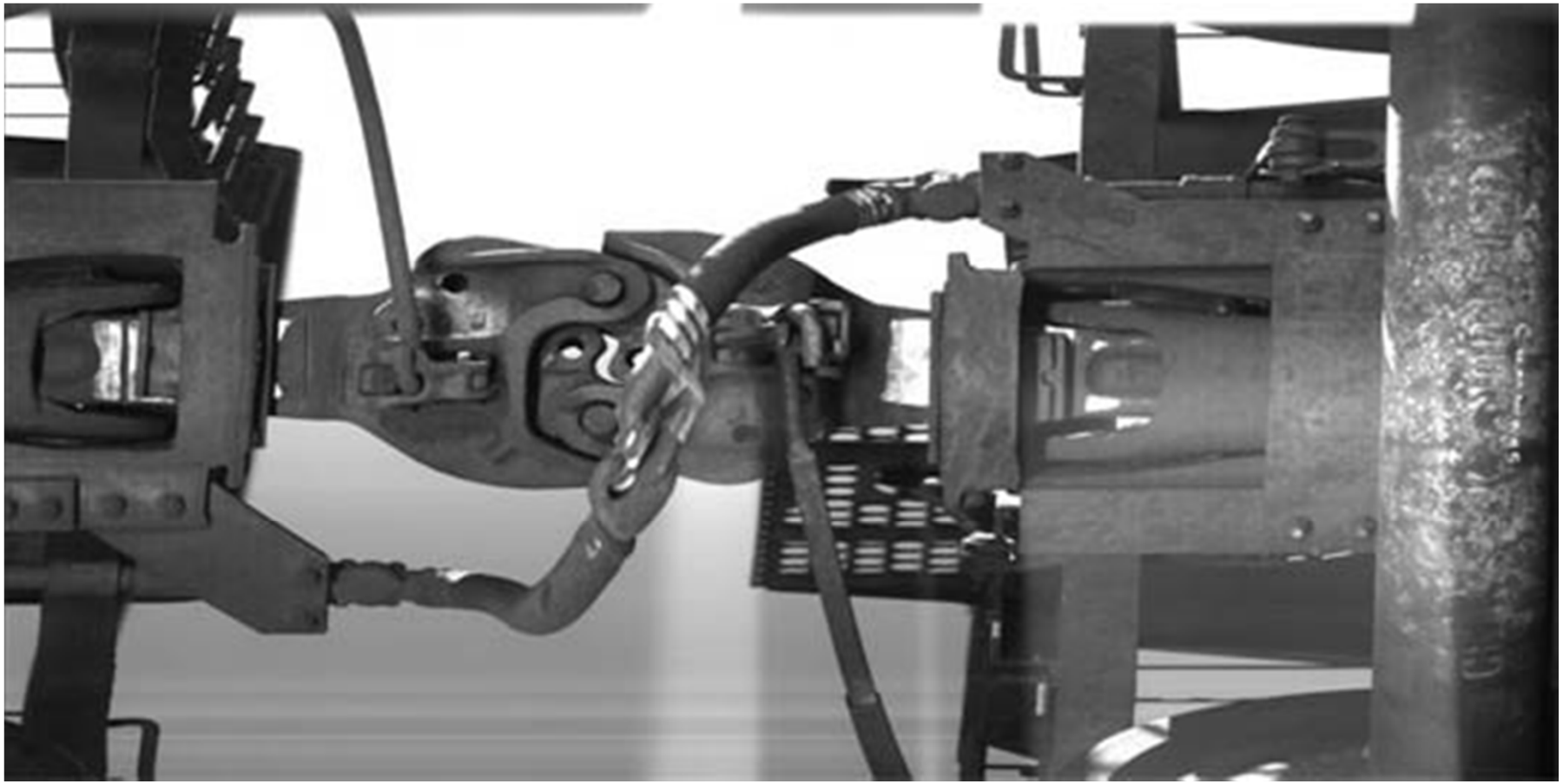




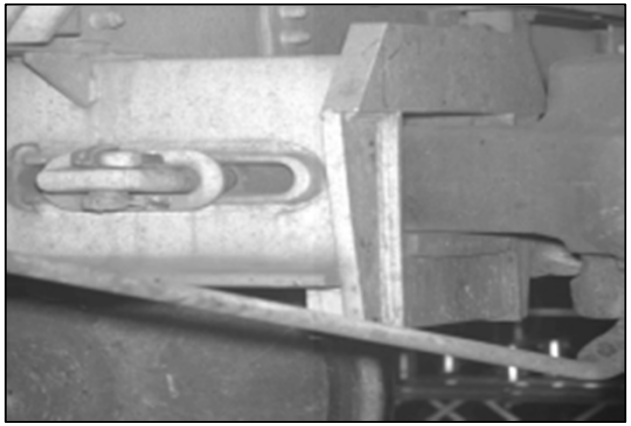
Line Scan Examples

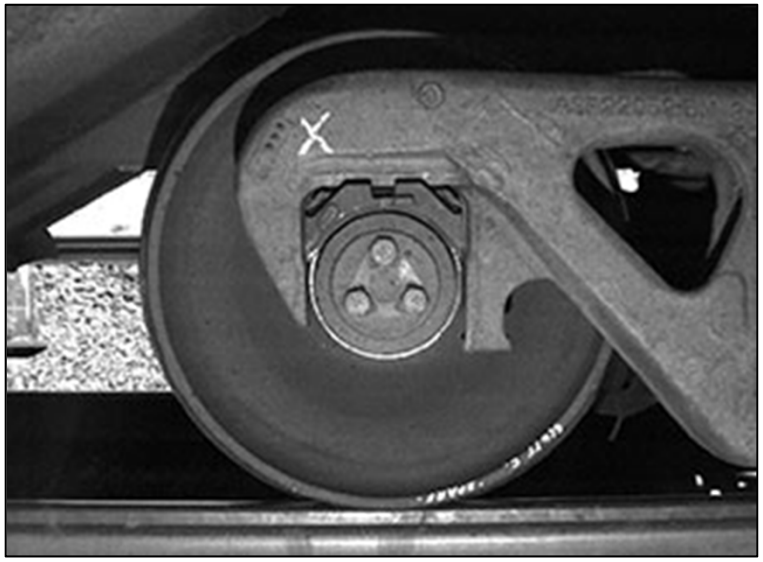


Line Scan Examples



Area Scan Examples



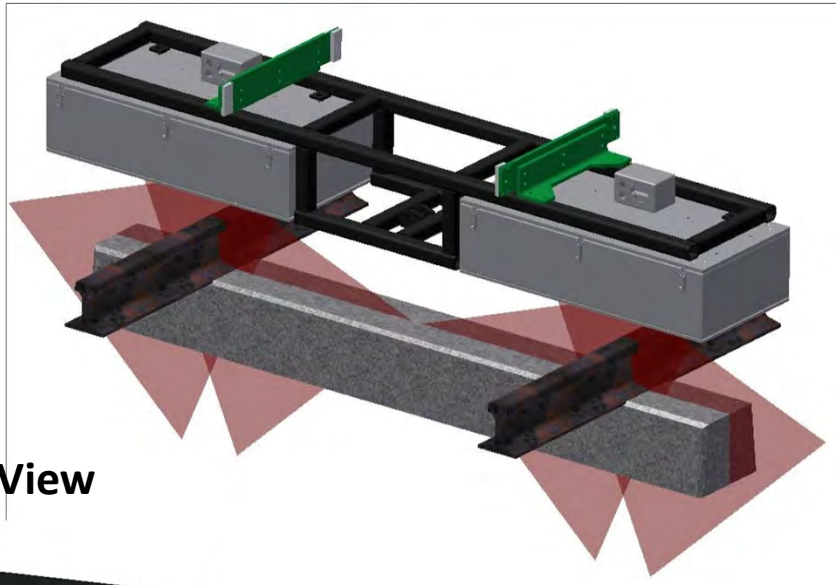


Line Scan Camera

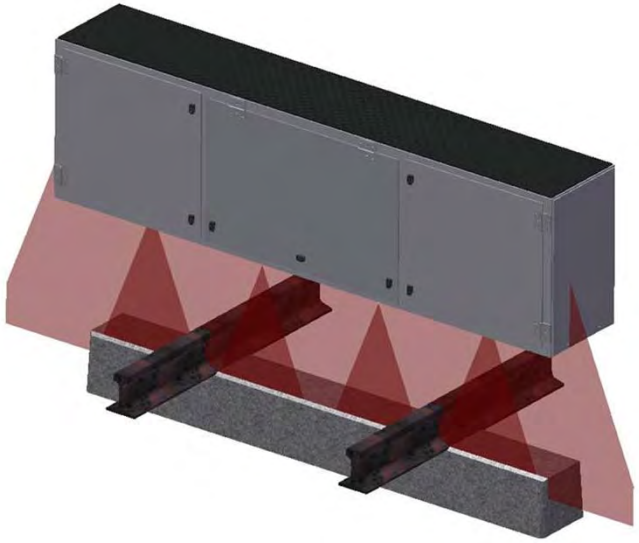
Tachometer

Line Scan Camera

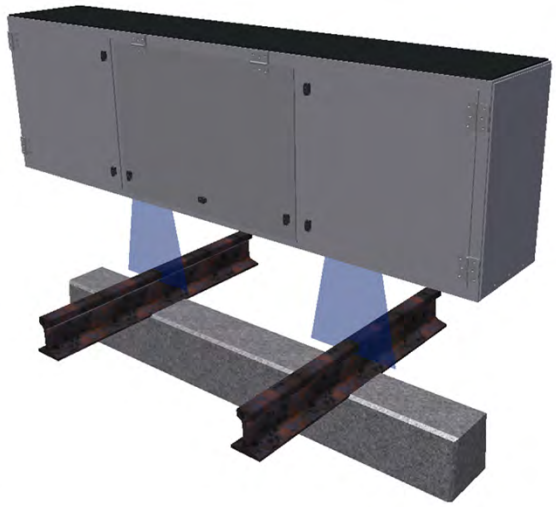
Joint Bar View



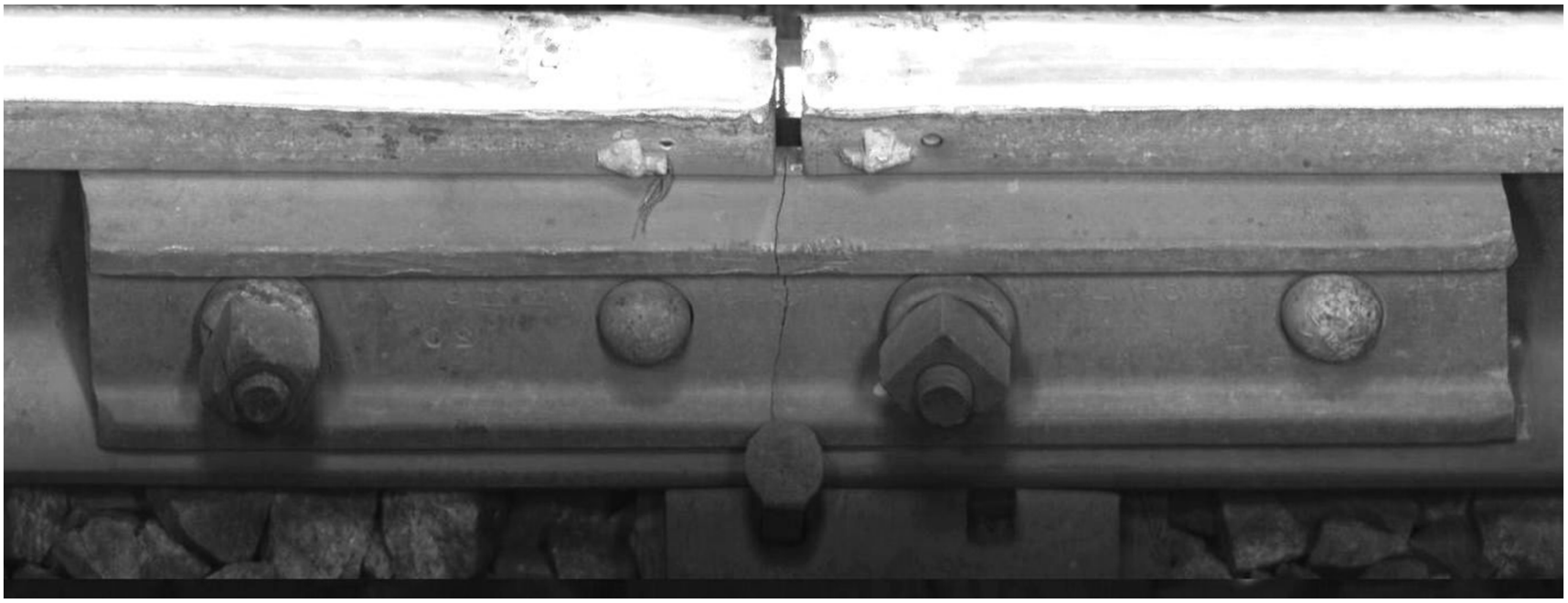
Track Bed View



Rail Surface View

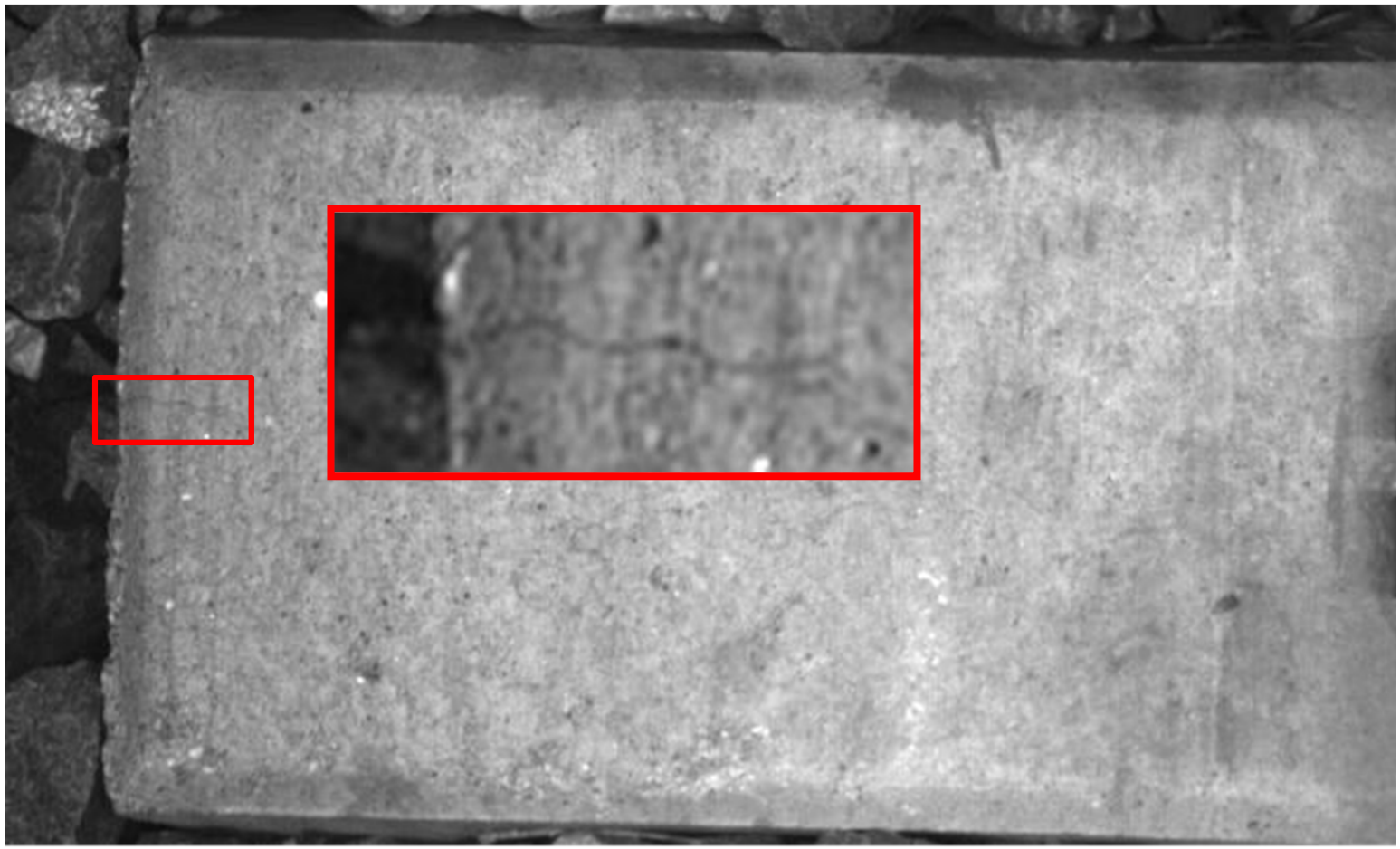


Line Scan Examples

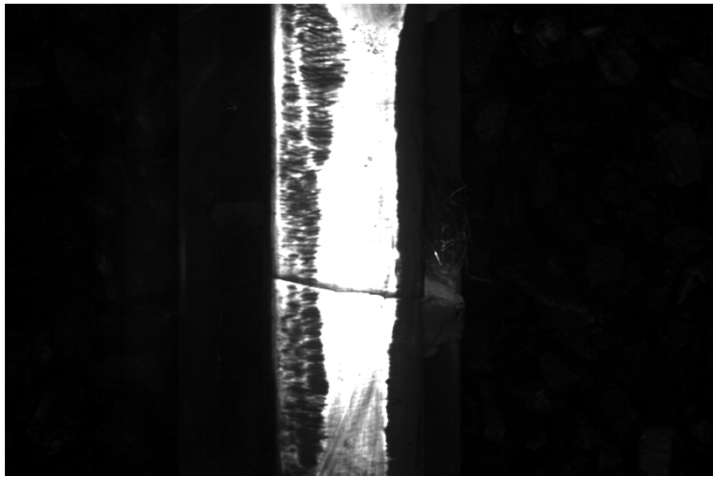


Line Scan Examples

Line Scan Examples



Line Scan Examples



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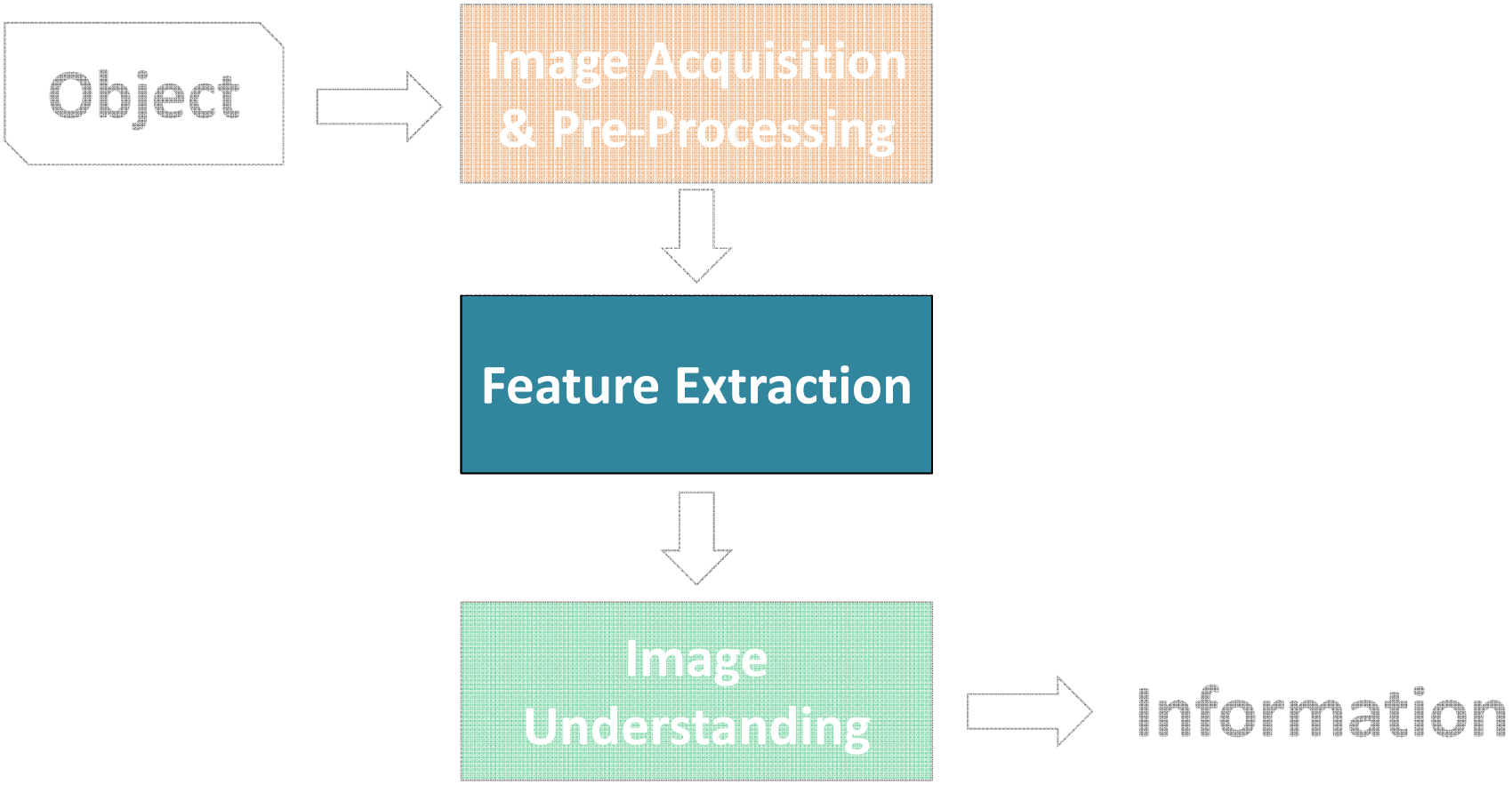
Object
Image Acquisition & Pre-Processing
Feature Extraction
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Information

Overview

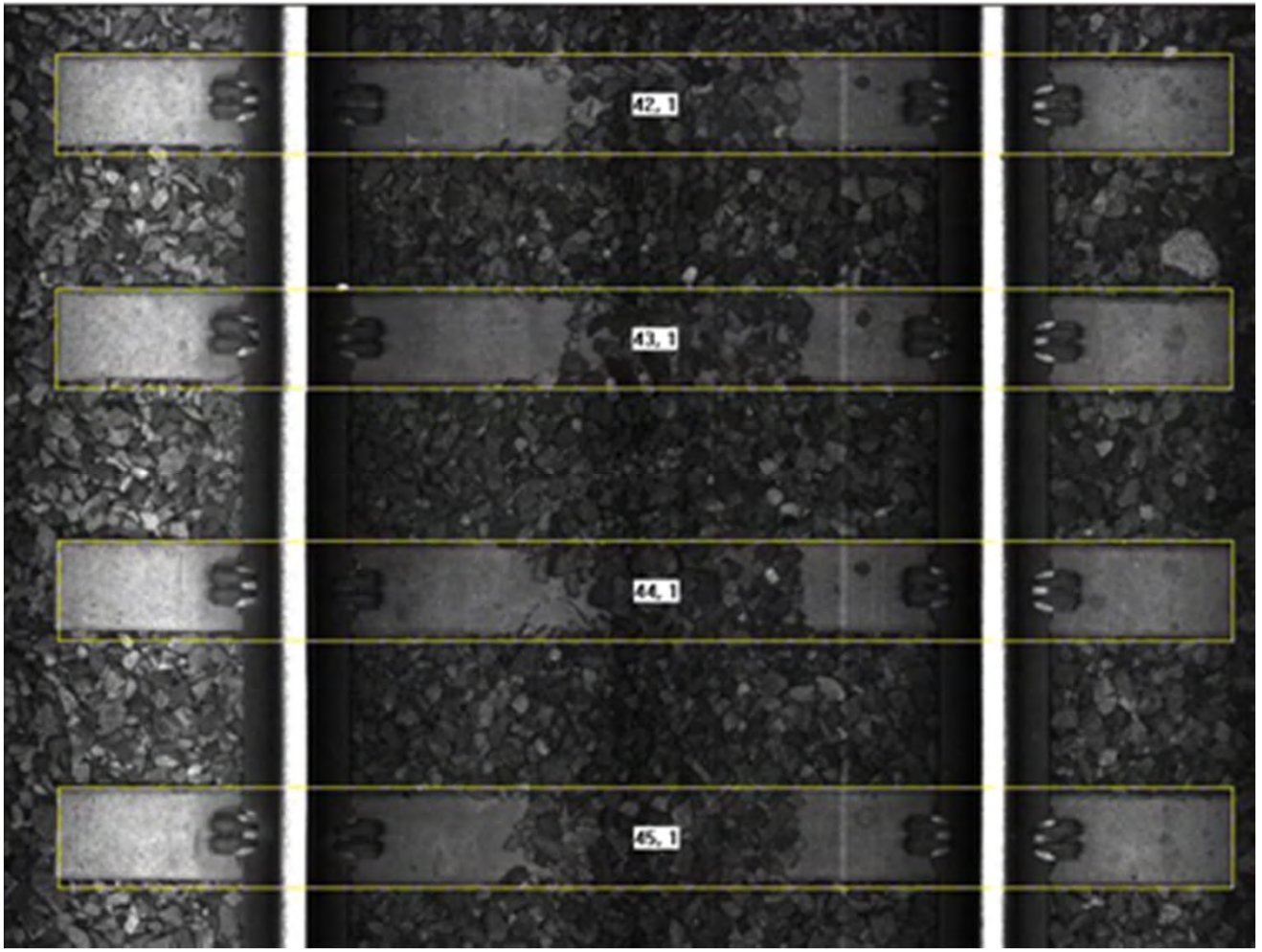
Features are automatically identified in the images.

Features are used in the final step, “Image Understanding”.

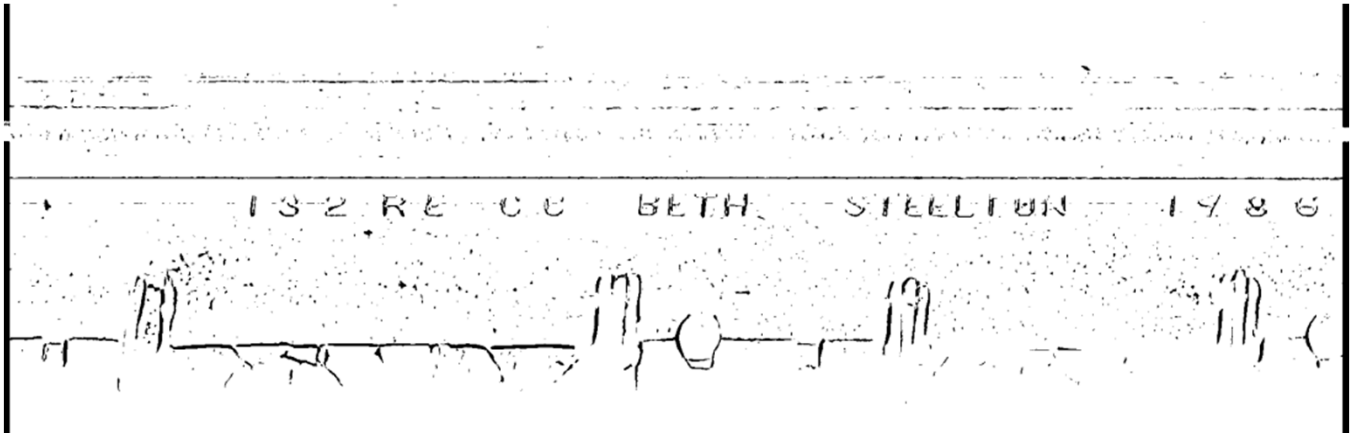
Common Feature Extraction Methods:

- Edge Detection
- Corner Detection
- Blob Detection
- Assistance from Laser Projection

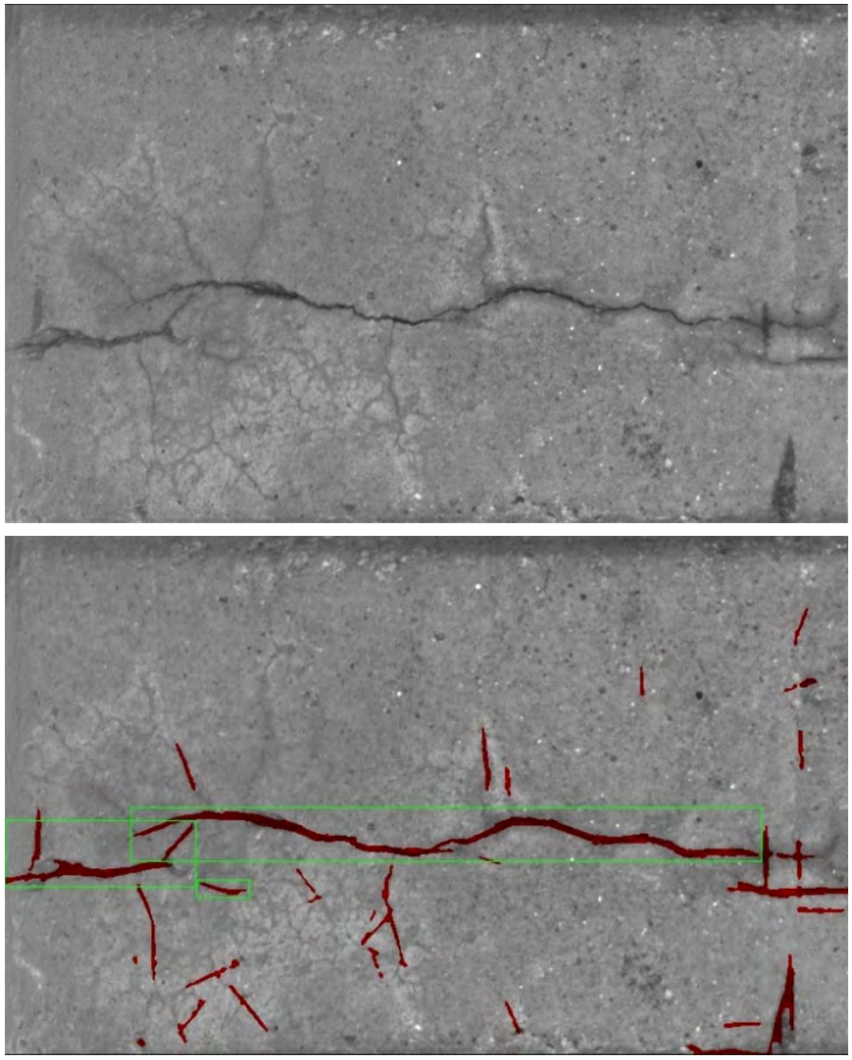
Examples



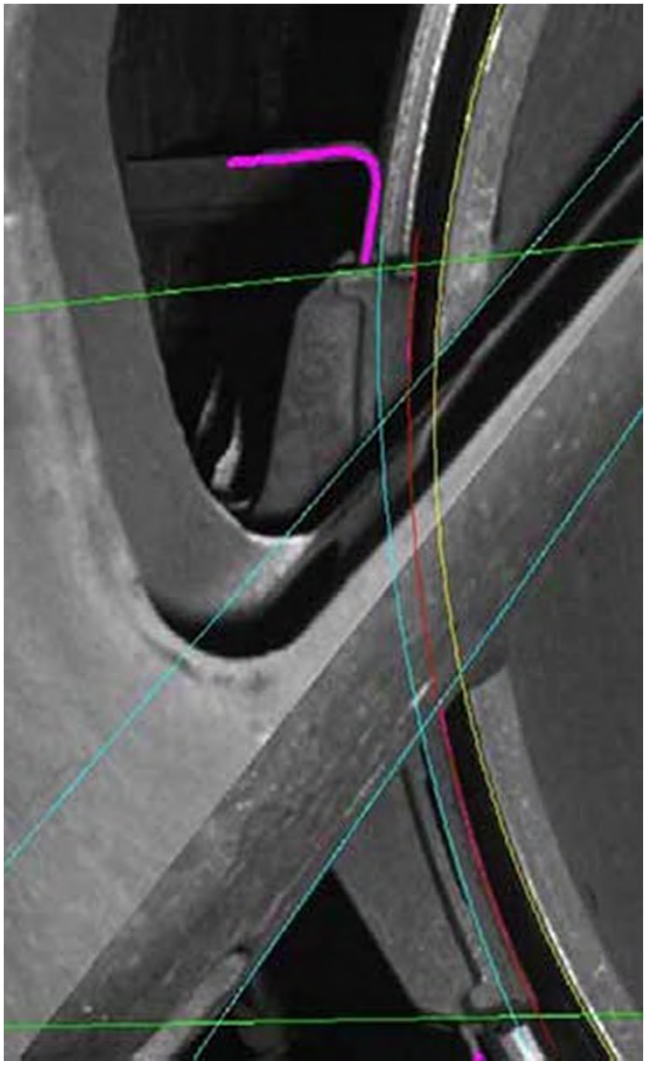
Examples



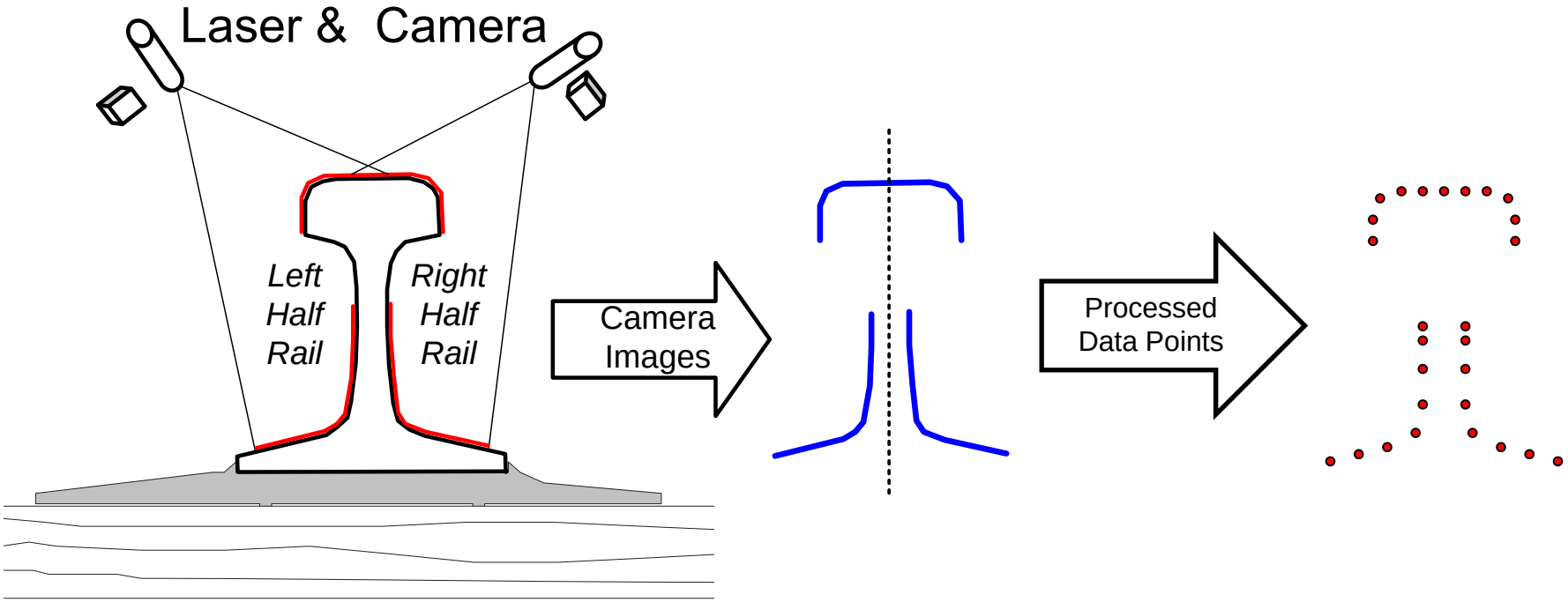
Examples



Examples



Laser Projection

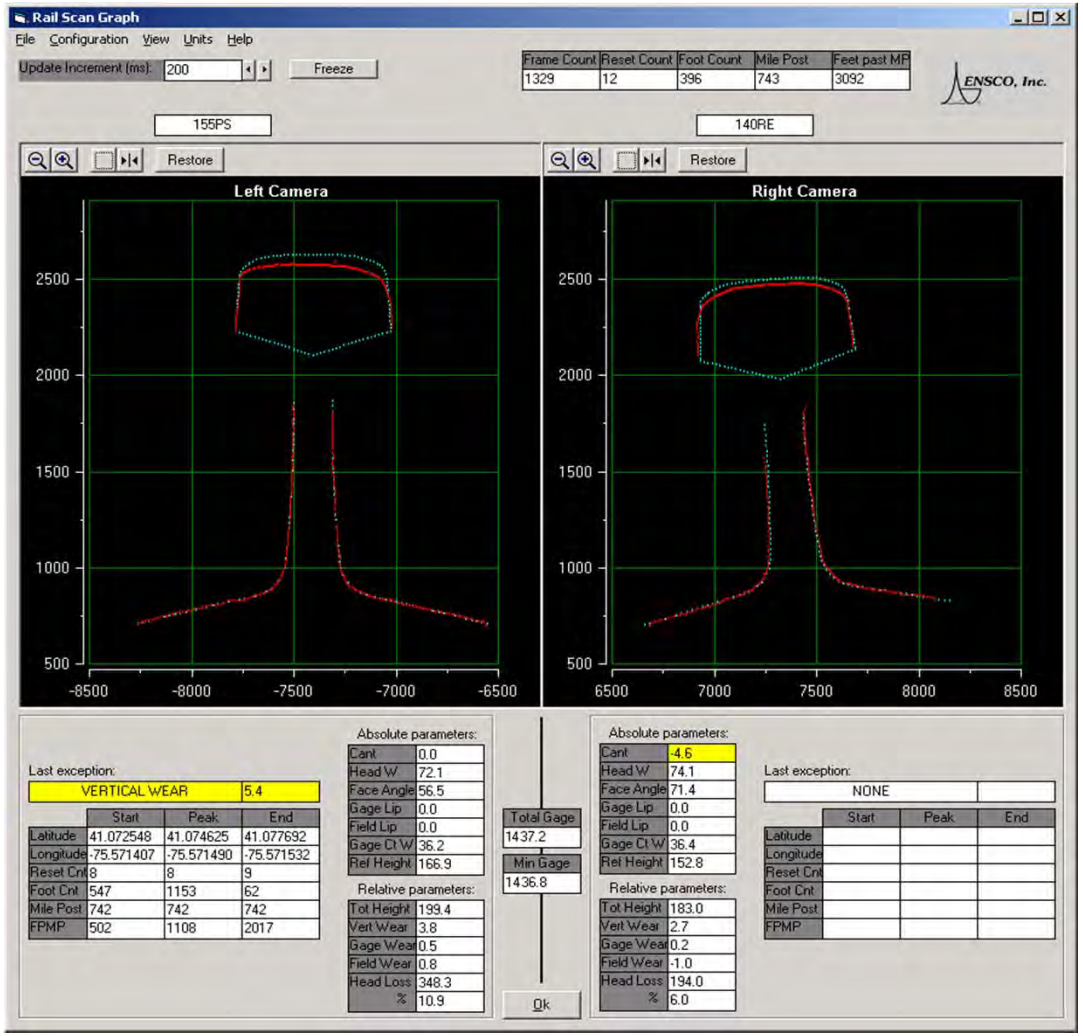


Ref 1

Laser Projection

Area Scan Image of
Line Laser on Rail

Laser Projection



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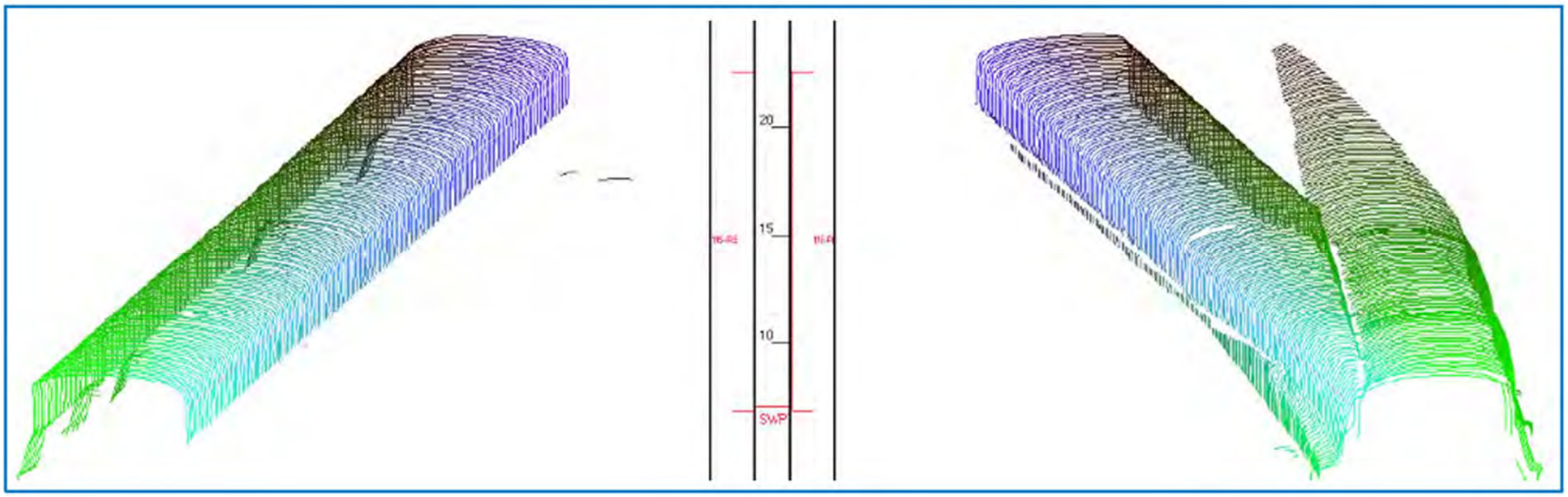

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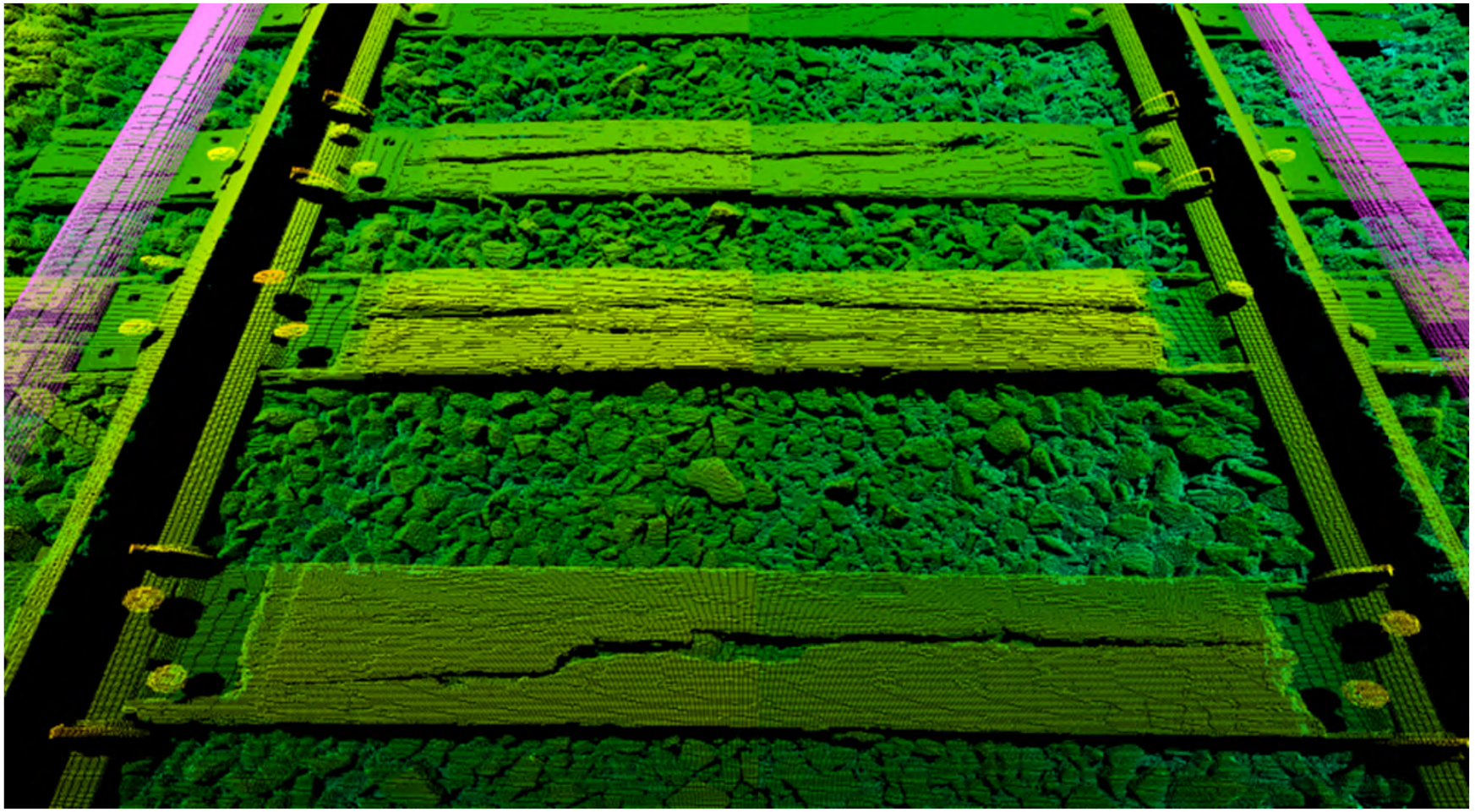
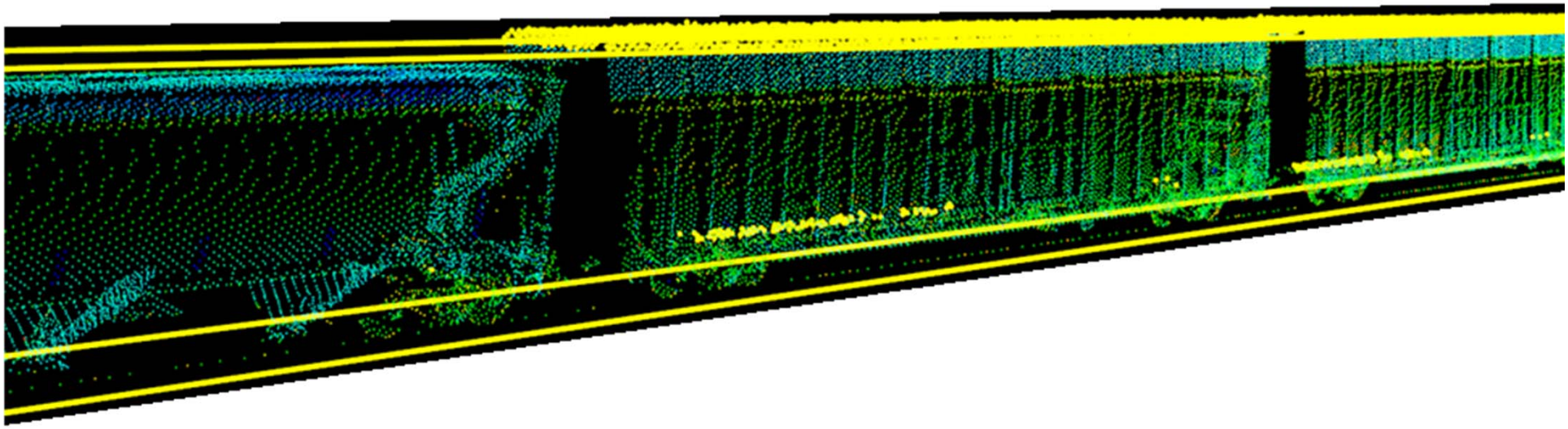
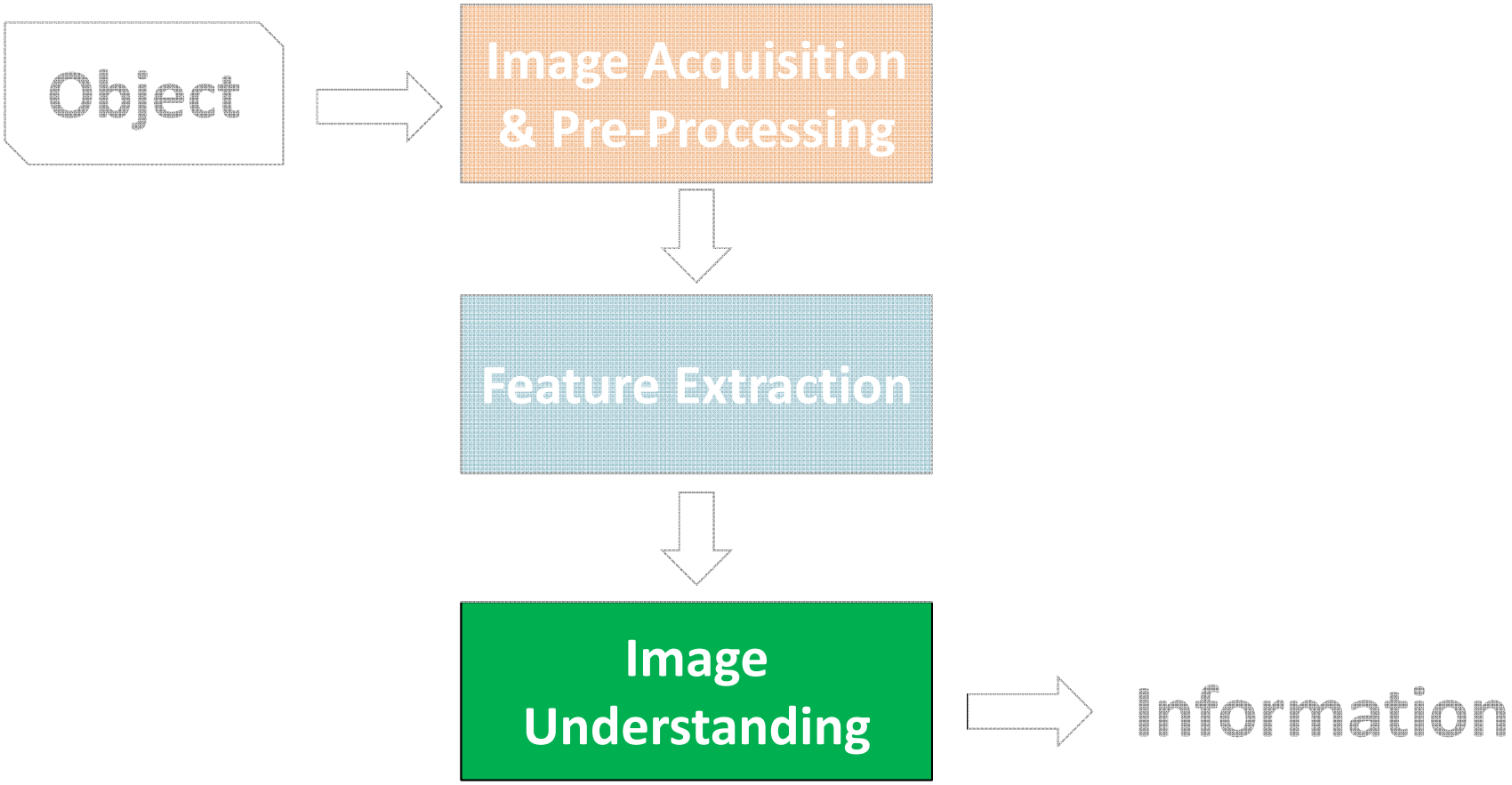


Laser Projection




Object
Image Acquisition & Pre-Processing
Feature Extraction
Image Understanding
Information

Overview

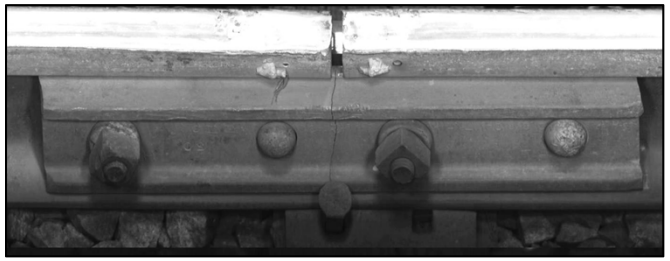
Transform data to information

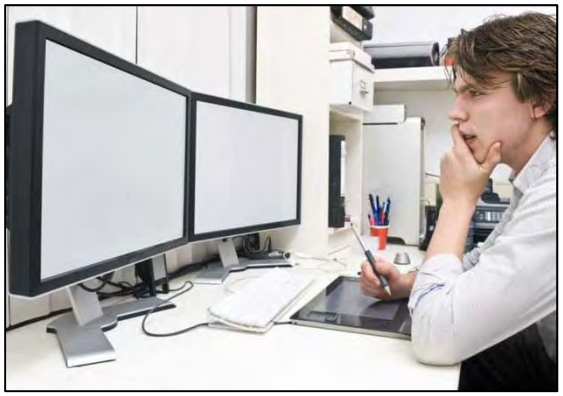
Identify exceptions

Identify characteristics

Eliminate false-positives

Overview



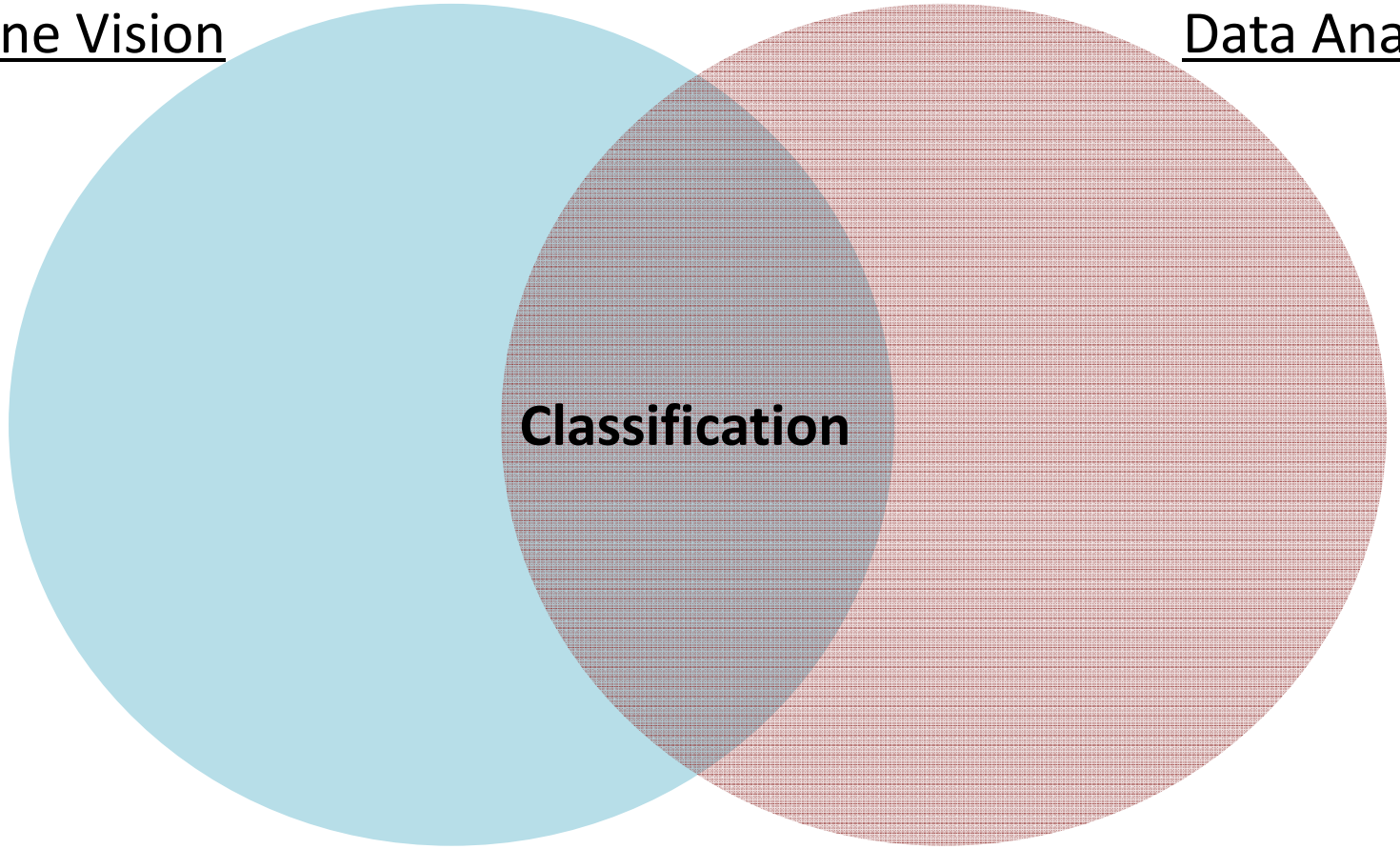


Manual Human Review

<u>Hybrid Approach:</u>
Manual Review
Assisted by
Automation

Fully Automated

Overview



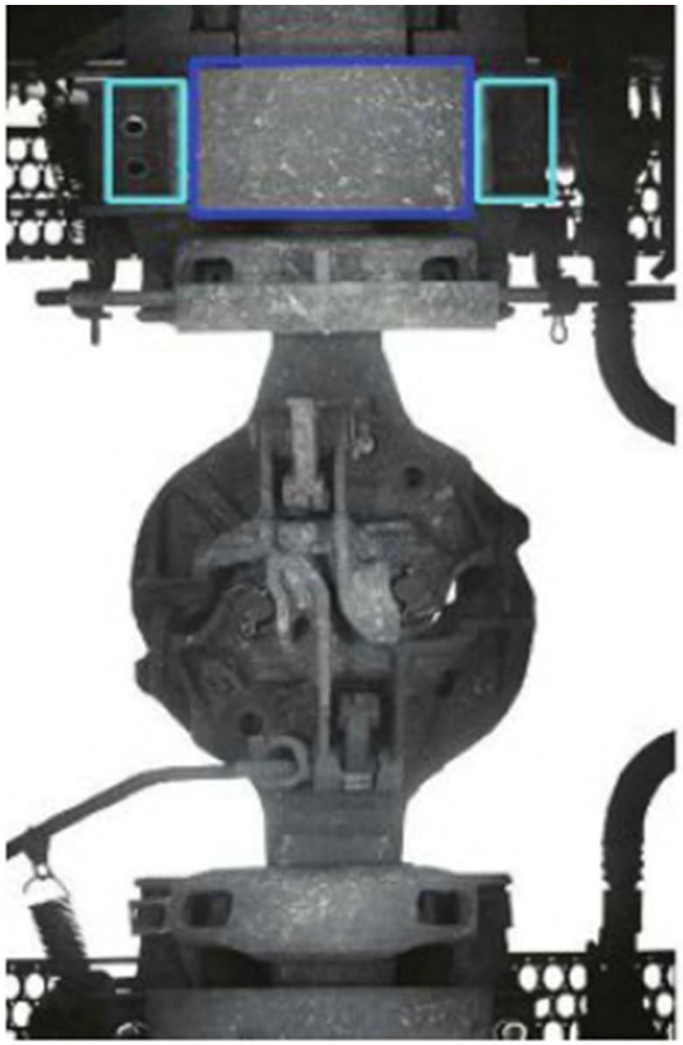
Example: Template Matching

Use reference template

Identify things that have changed

Identify components based on contour

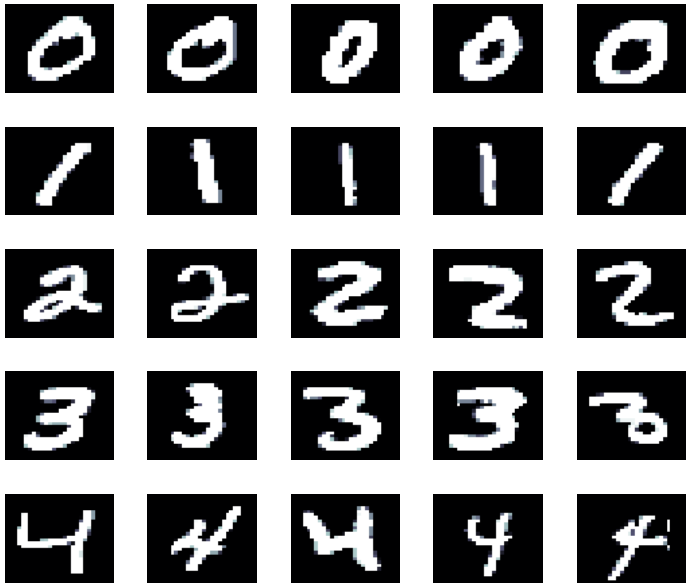
Can often account for image size or image orientation changes



Example: Training Data

Naïve Bayes Classifier

Example Training Set of handwriting
Numbers from 0 to 4



Each sample is labeled Y_i = {0,1,2,3,4} (classes)

Create "variables" based on the image pixels.

Calculate prior and posterior probabilities.

For a new sample, calculate the posterior probabilities for each class, then choose class with highest probability.

Example: Training Data

Principal Components Analysis

Original handwriting samples
each image has 16x16 pixels

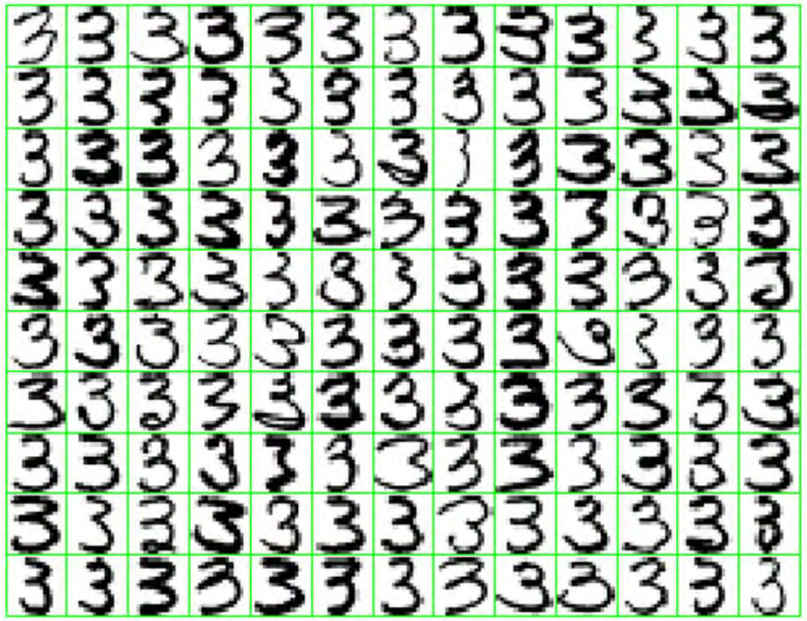


FIGURE 14.22. *A sample of 130 handwritten 3's shows a variety of writing styles.*

First two principal components
Images reconstructed at 25 vertices

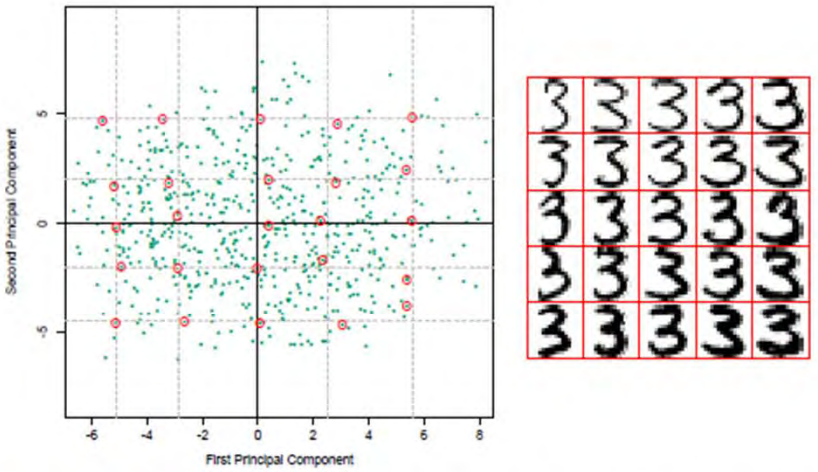
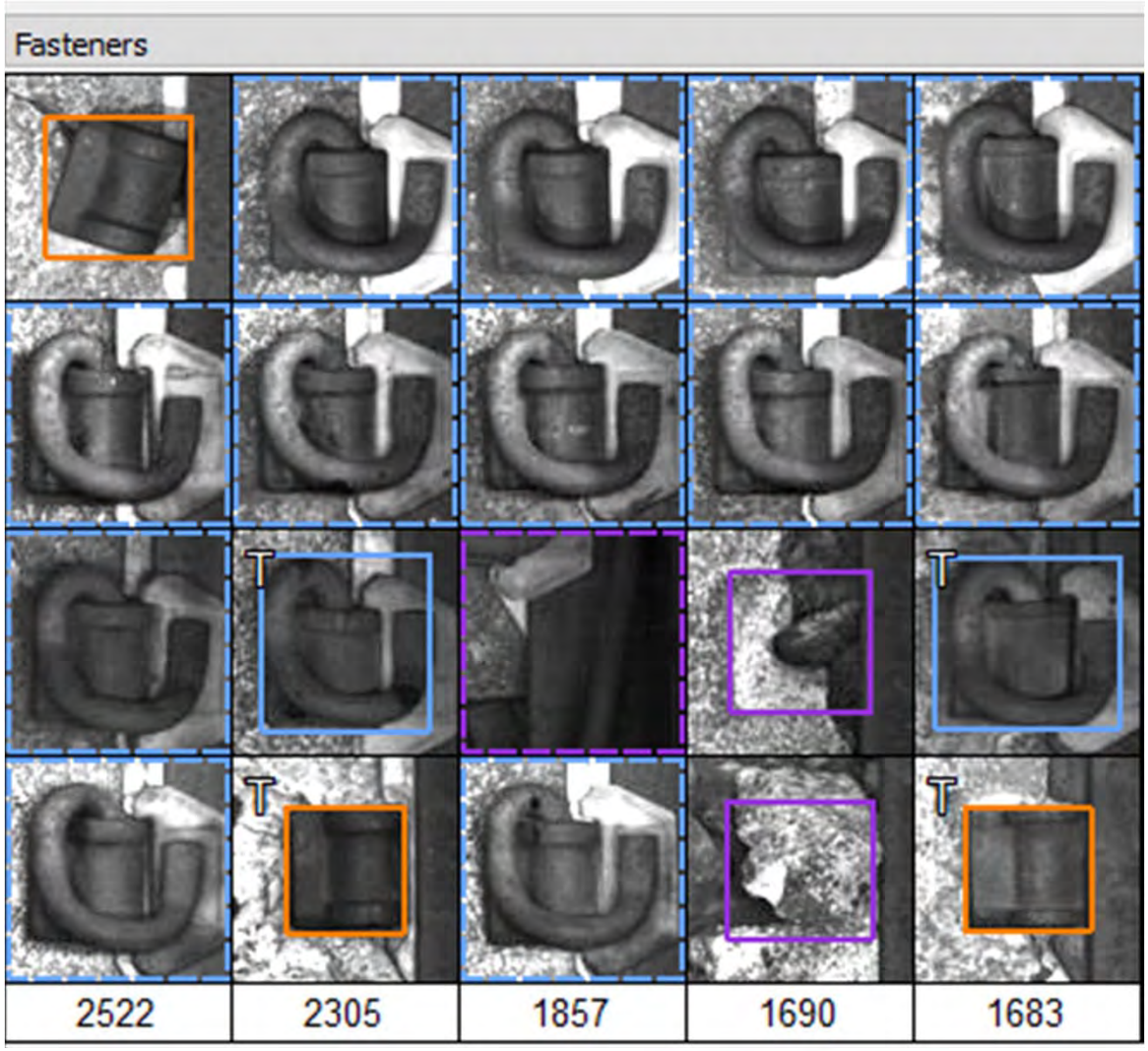


FIGURE 14.23. *(Left panel:) the first two principal components of the handwritten threes. The circled points are the closest projected images to the vertices of a grid, defined by the marginal quantiles of the principal components. (Right panel:) The images corresponding to the circled points. These show the nature of the first two principal components.*

Ref: pp. 537-538 of The Elements of Statistical Learning, Data Mining, Inference, and Prediction, Second Edition, by Trevor Hastie, Robert Tibshirani, and Jerome Friedman.

Example: Training Data



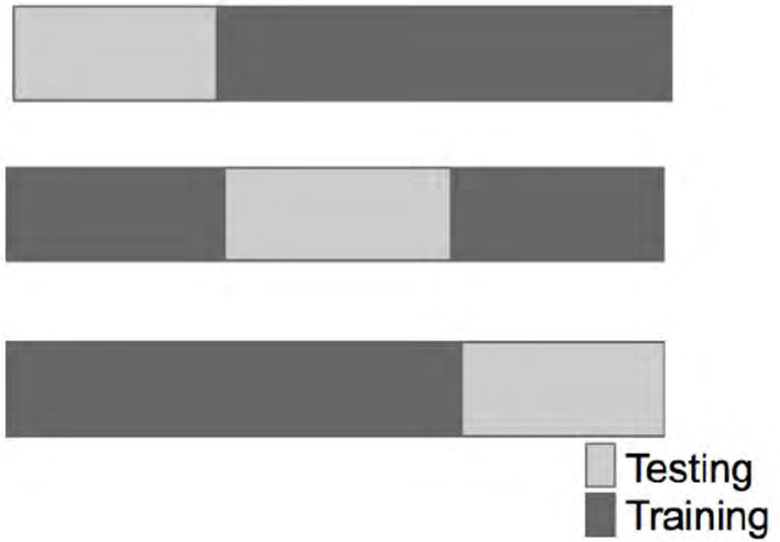
Example: Training Data

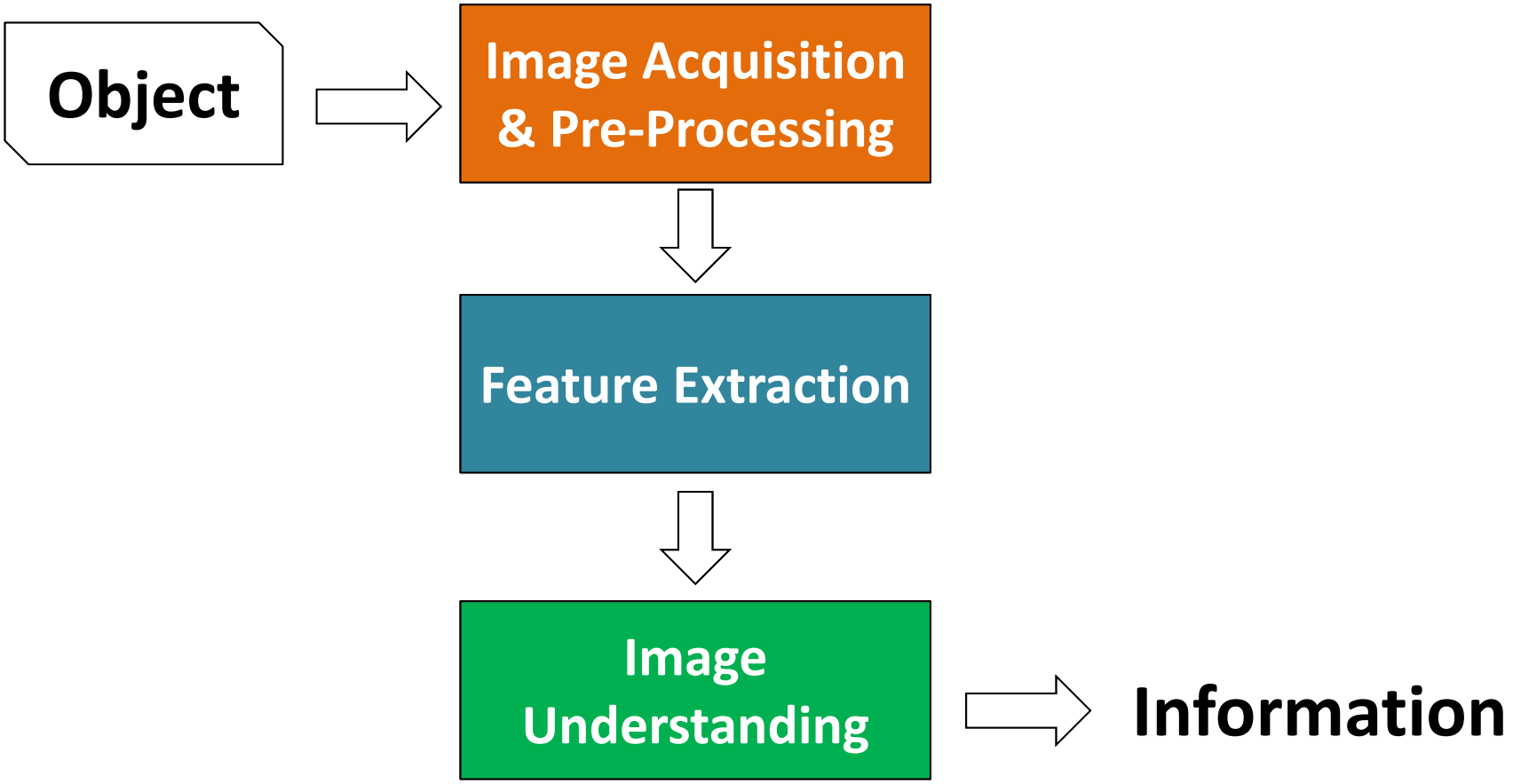
Use cross-validation when using training data.

Allows you to calculate the performance of one or more algorithms.

Many different resampling techniques are used to assess error/performance.

K-fold Sampling

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What is the future of railway machine vision?

Supporting Manned Patrols

Unmanned Aerial Systems (UAS)

Special Thanks!

ENSCO's Machine Vision Group

Thanks to the following companies for use of their photographs within this presentation:

- Union Pacific
- Beena Vision
- KLD Labs
- FRA Office of Research, Development, & Technology
- GREX
- Harsco
- TTCI
- University of Maryland
- UIUC

Questions?