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Design of a Rotational Speed Measurement System using Machine Vision for Quality Testing

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Introduction

Outline

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- Project Objectives
- Design Alternatives
- Design Process
  - Image Acquisition
  - Algorithm
  - Improved Algorithm
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- Recommendations
- Conclusion

Problem Statement

- Local industrial plant (ACs)
- Quality Control Problem:
  - Testing fan speed
  - No contact with process
- Existing System:
  - ACs on conveyor belt: 0.5 ft/s
  - Fan: 4 blades, Black, Metal

Project Objectives

1. Design of a non-contact automatic rotational speed measurement system
2. Engineering analysis and evaluation of the system
3. Development of a software package
4. Explore new applications of image processing

Design Alternatives (pros & cons)

- Electromagnetic Tachometer
- Optical Tachometer
- Machine Vision:
  - No contact
  - No interference: mark
  - Innovative
  - Intergrability with inspection

Design Process

Image Acquisition

- Selection Criteria:

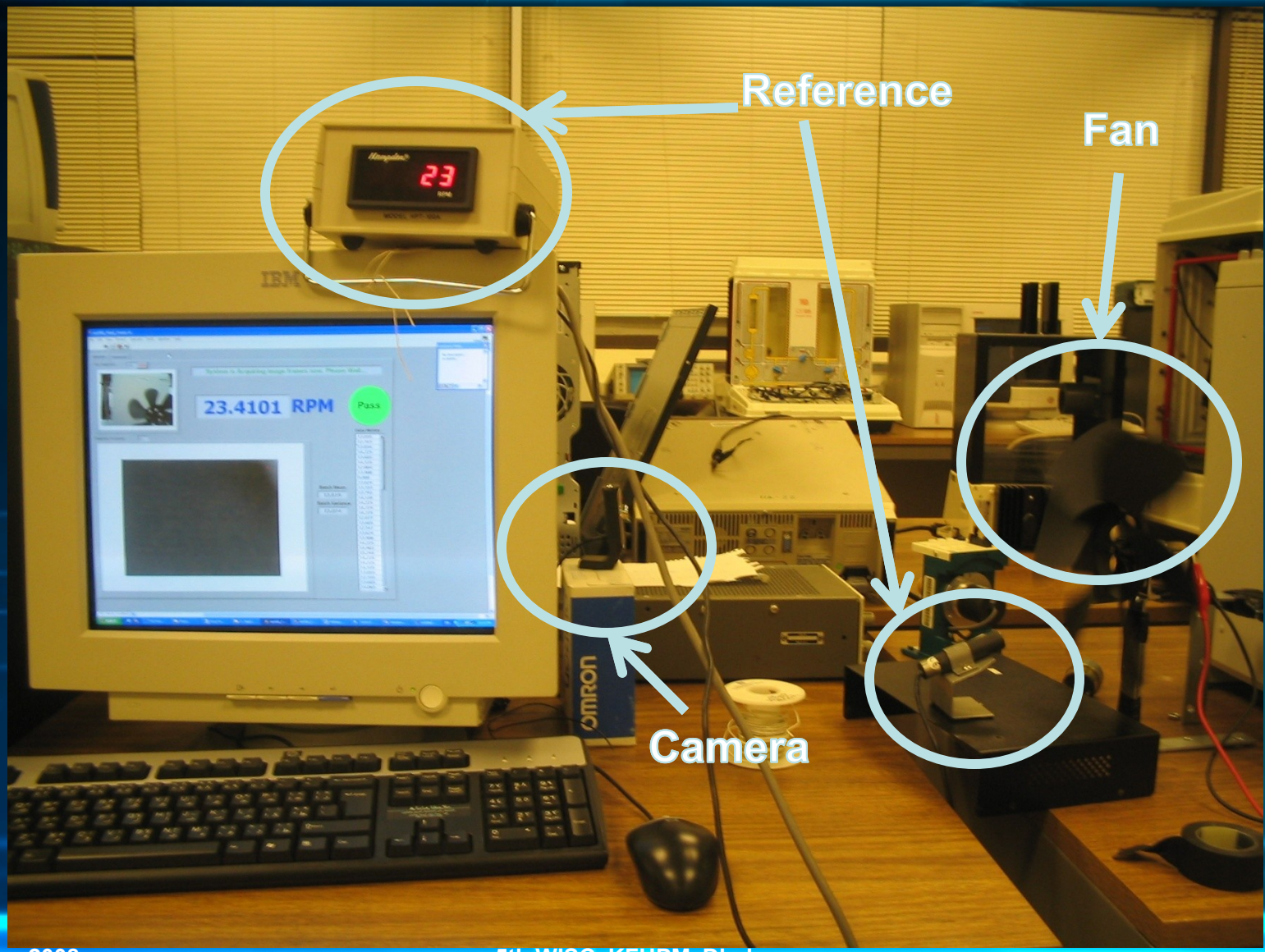
  selection depends on frame rate which depends on algorithm used

1. Frame Rate
2. Resolution: quality, processing
3. Communication Speed: FireWire, USB

Project's Experiment

- For the **prototype**:
  - Genius® Slim 320
  - USB 2.0 WebCam
  - 30 fps
    - Average frame rate measured in the lab = 20 fps
    - blur after 60 RPM
- 12V DC motor was used to provide speeds of 0-200 RPM
- Software used is **LabVIEW 8.0**

Project Apparatus



Camera Output, example

Algorithm

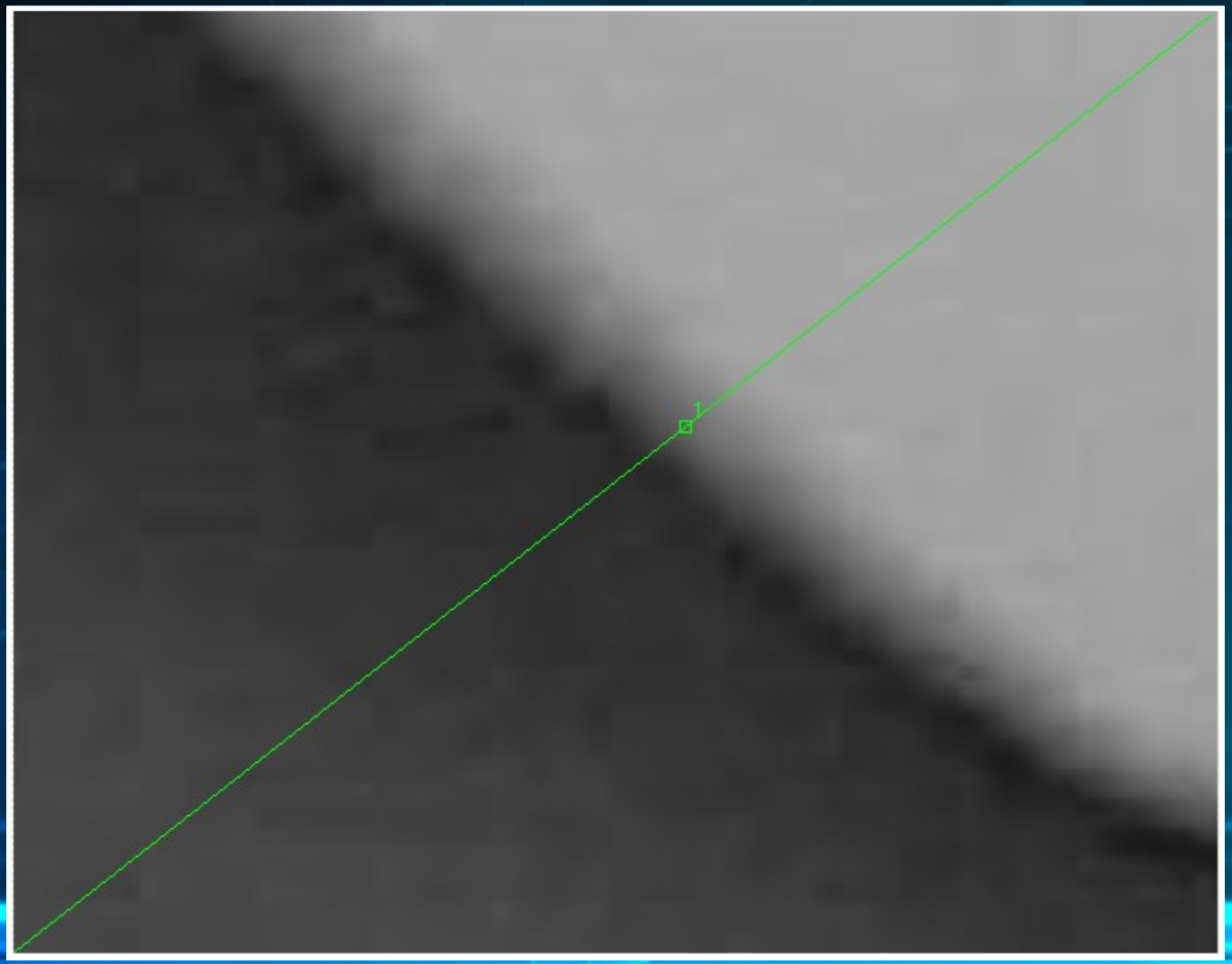
- Major Concept: Count ***blade crossings*** in unit time
- Blade crossings are identified by the technique of **Edge Detection**
- Acquire preset number of consecutive frames stored temporarily with their time stamps.
- Image processing is executed on each frame per iteration.
- In each iteration, ***Zooming*** is done on an appropriate area of specific coordinates

Algorithm: Zooming Characteristics

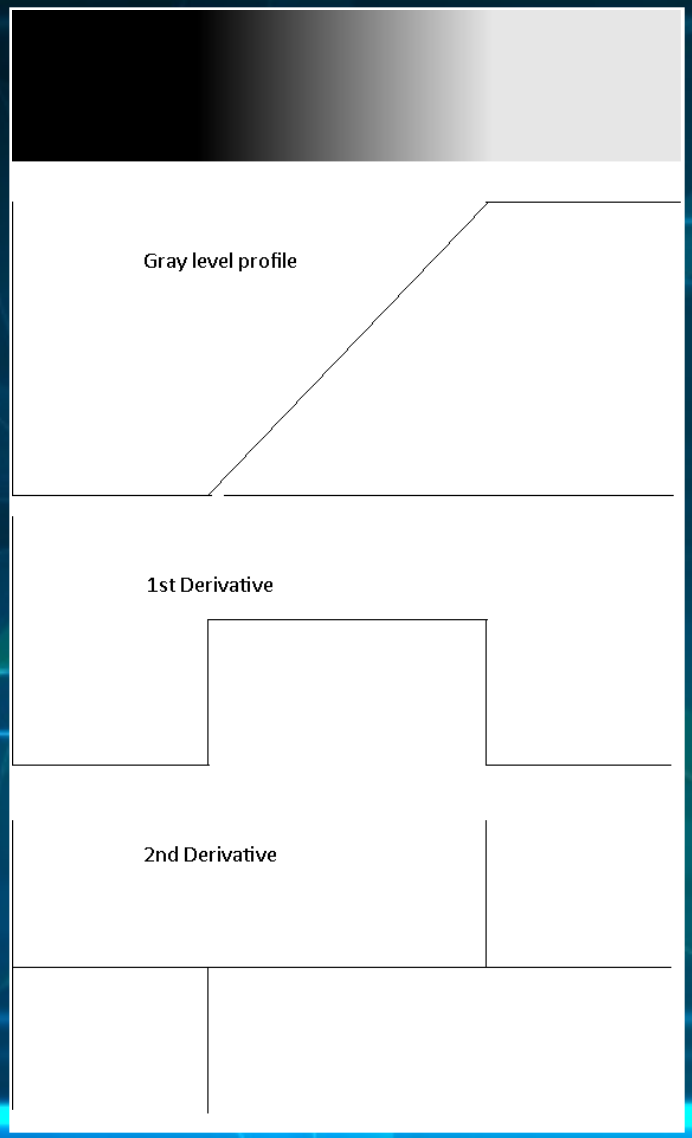
- Importance:
  - Zoom area designed not to contain two sides of one blade in any frame.
  - Avoid Ambiguity.
  - Reduce Processing and Computation, less pixels

Edge Detection

- Edges are detected along a line.



Algorithm: Edge Detection



Extracting Edge Information

- After edge detection, the following information is at hand:
  1. Number of edges along the line
  2. Pixel Coordinates of each edge
  3. Edge Polarity (-1,1)

- Given the zoomed area, only three cases are logically possible to appear:
  1. Only an upper edge of a blade
  2. Only a lower edge
  3. Two adjacent edges of consecutive blades

  (Two edges of same blade never appears due to zoomed area)

Algorithm: Steps

A. The blade ***counter*** starts only when the upper edge of a blade is detected.

B. Afterwards, the blade counter will not increment until a frame containing more than one edge (i.e. adjacent sides of consecutive blades) is detected.

Summary: Counter is incremented when new blade comes.

C. The algorithm proceeds to the next level after *m* blades have been counted. Counter stops after *m* blades.

Speed Calculation

- We're interested in the two time-stamps of the frames corresponding to the **starting** and **ending** of the blade counter.

$$RPM = \frac{60 \cdot m}{N \cdot \Delta t}$$

Where N is number of fan blades (parameter), here =6

m is the number of blades passed (parameter), by developer

Δt is the time difference, **time-stamps difference**

Algorithm Deficiency

Improved Algorithm

- Latching Coordinates
  - When the blade counter starts, the **coordinates** of the corresponding edge pixel are latched (stored).
  - Every Subsequent blade edge detected has its coordinates compared with the latched ones.
  - Counter terminates when the difference in the comparison falls below a predefined threshold.

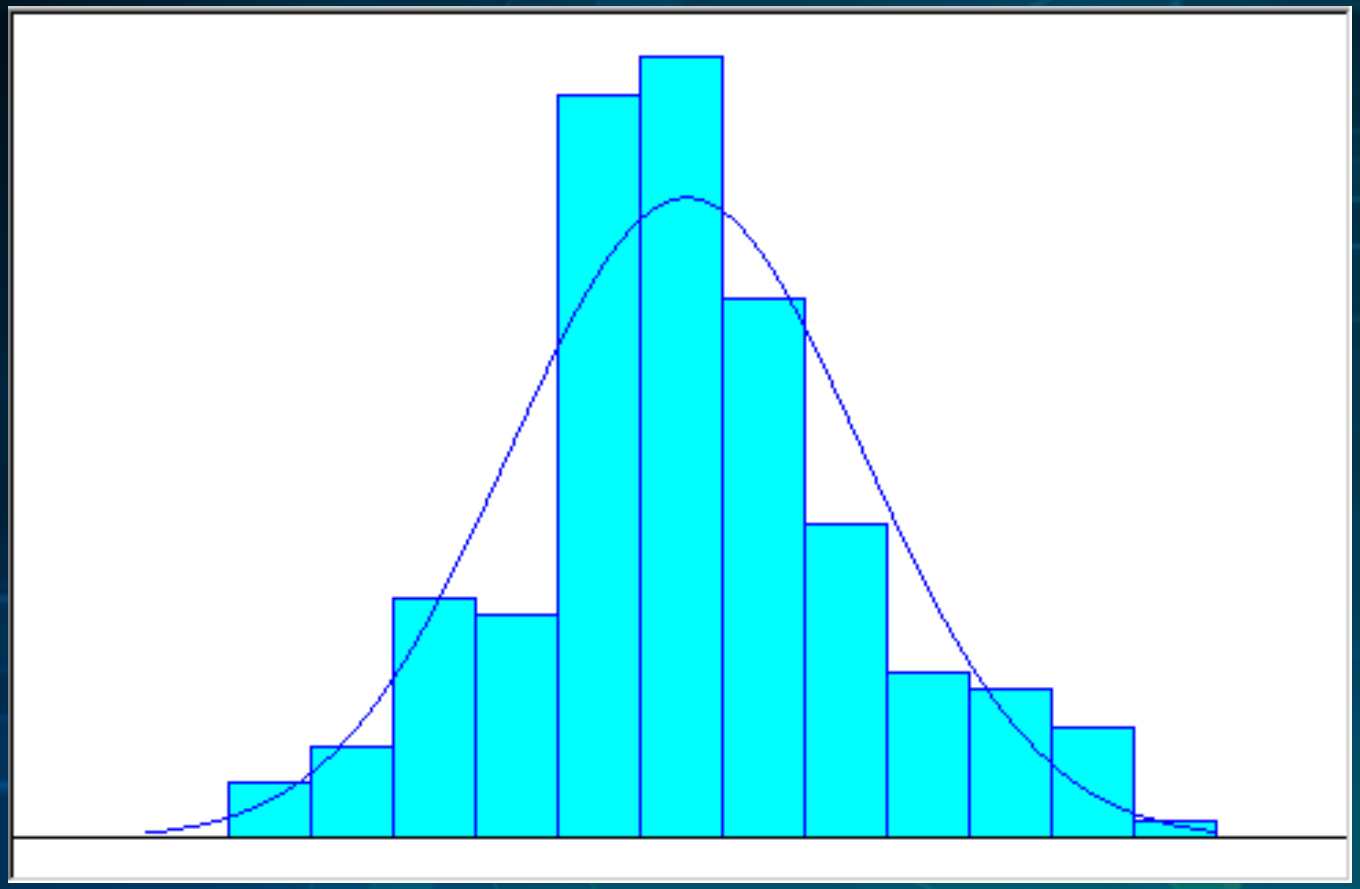
Speed Calculation

- Hence a tradeoff exists between accuracy and average number of frames processed.

$$RPM = \frac{60 \cdot m}{N \cdot \Delta t}$$

Where *m*, the number of blades passed, is a **variable output**, not a fixed parameter as in the simple algorithm.

Statistical Analysis



* Dealing with outliers

10 rpm, 1st program

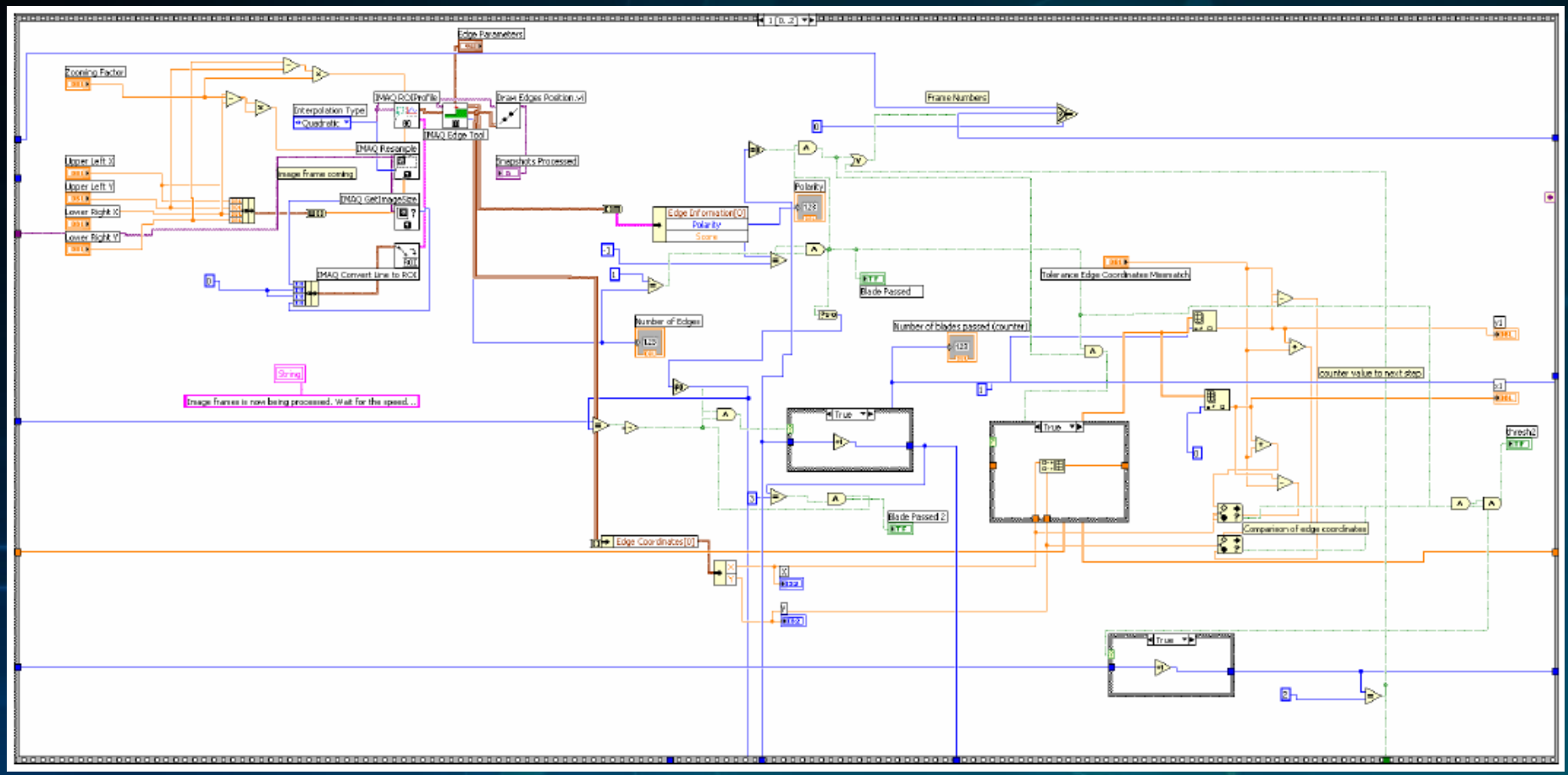
Statistical Analysis

- Data Collection: 10,20,… ,40 for each program.
  - Each experiment collected 100 trials

(Mean, Var)	10 Rpm	20 Rpm	30 Rpm	40 Rpm
Method 1	(10.1, 0.647)	(20.8, 1.52)	(30.2, 2.31)	(40.5, 3.69)
Method 2	(10.2, 0.714)	(21, 2.29)	(29.8, 2.27)	(40.9, 2.5)

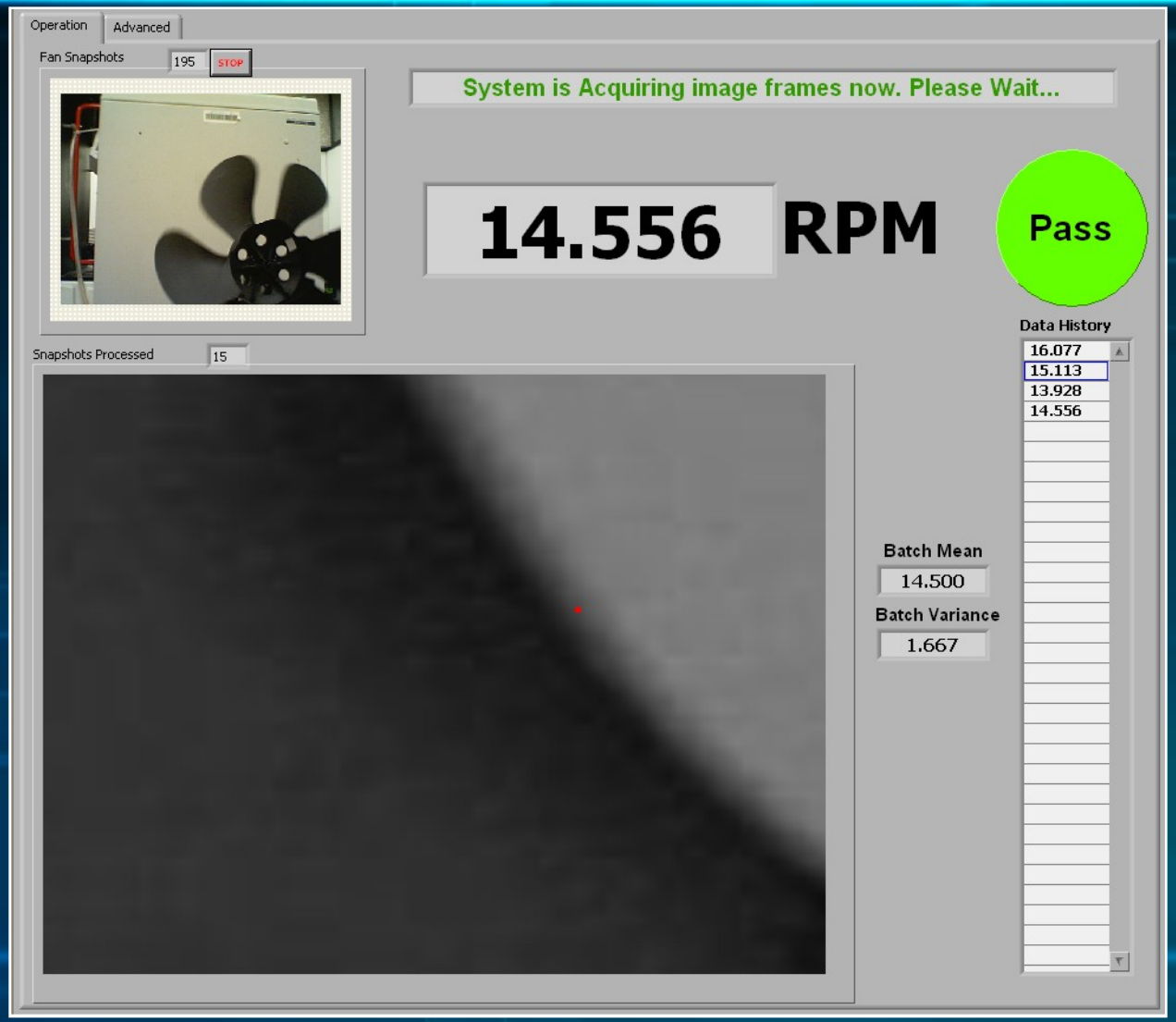
  - No Bias in Mean.
  - Variance increases as speed increases due to low frame rate quality.

LabVIEW program, *partial*



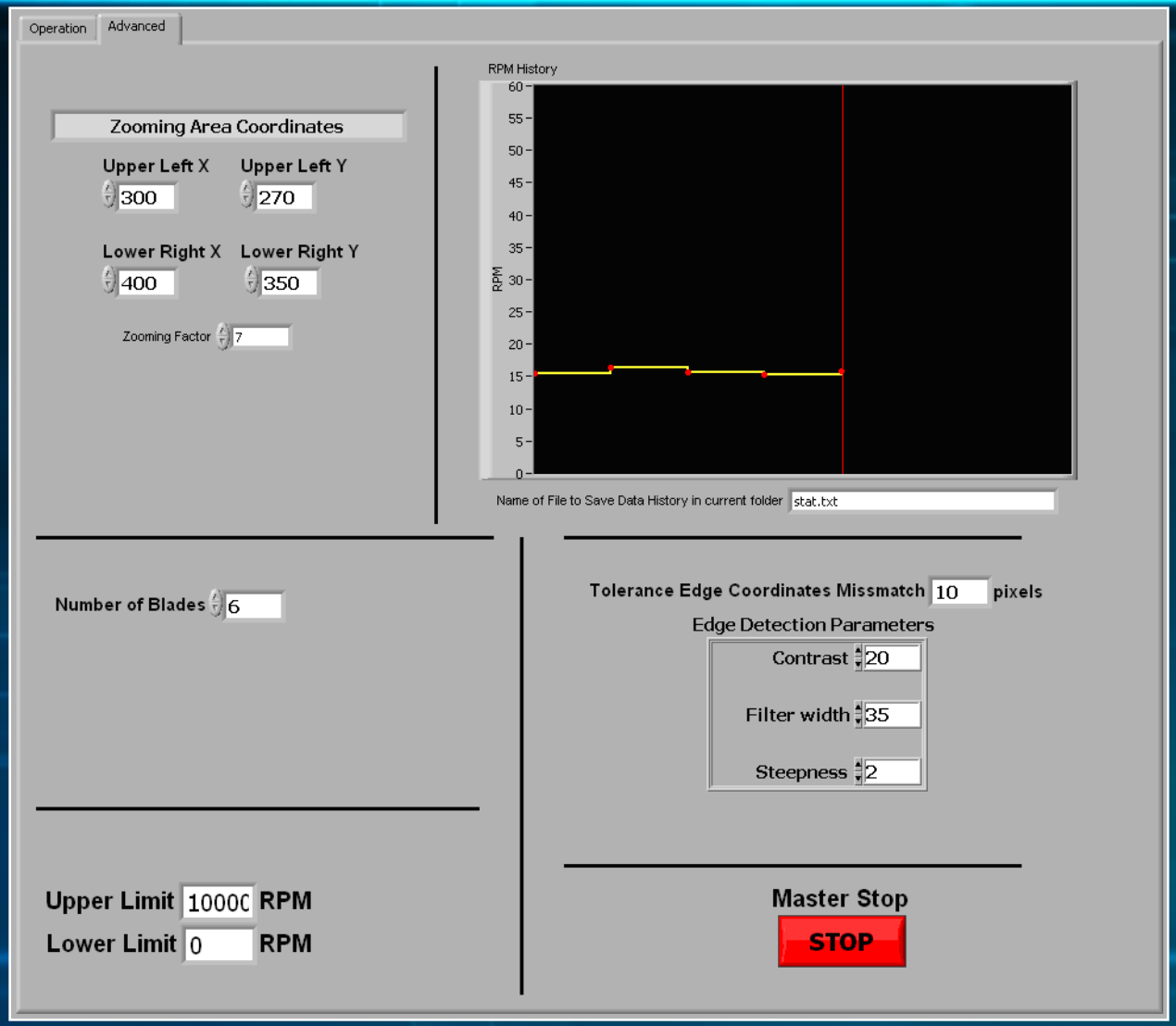
User Interface

Operation



User Interface

Advanced



Recommendations

- System Integration: Adding automatic inspection.
- Linking process to plant network.
- More sophisticated Algorithms

THANK YOU

Questions R Welcomed