

# Non-Destructive Rapid Method for Blend Grade Verification using VNIR Hyperspectral Imaging and Advanced Data Processing Algorithms

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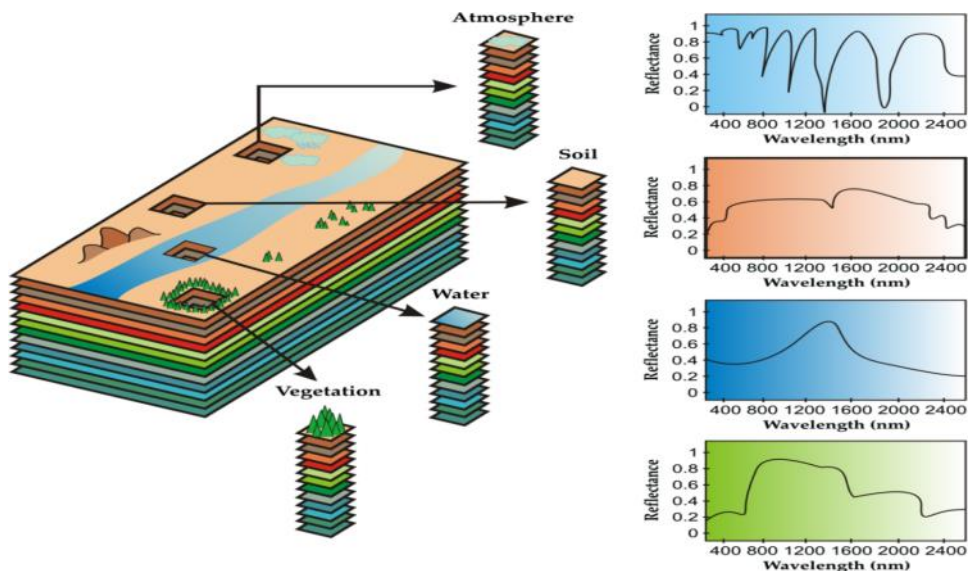
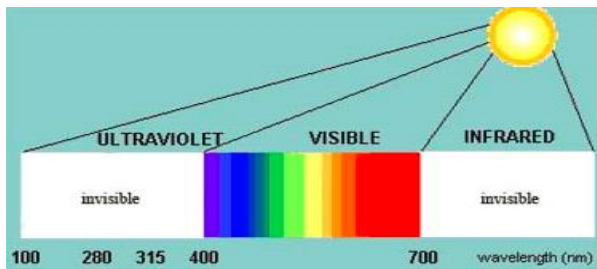


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# What is Hyperspectral Imaging?

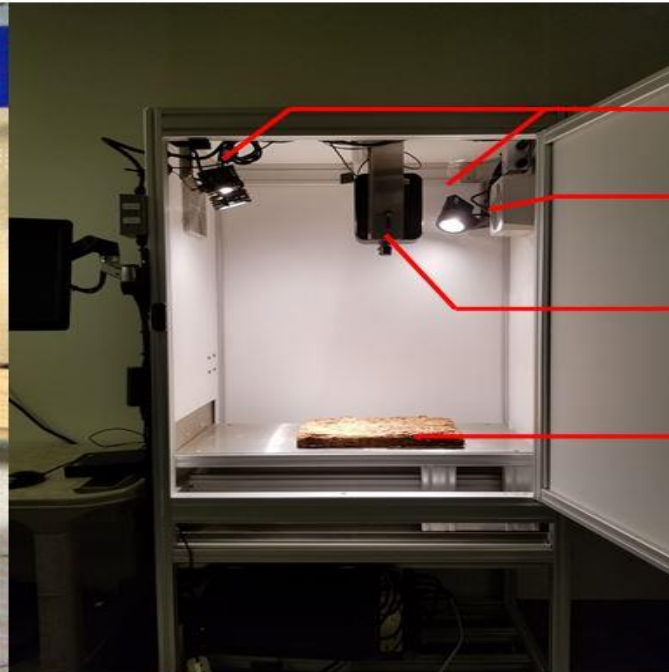
- Combination of spectroscopy and imaging
- Measures spectra for each sample point represented by a pixel
- Identifies materials



# Project Impact and Benefits

- Maintains consistency of leaf grades in a cost effective manner
- Reduces human subjectivity
- Supplements SME's time and skill
- User-friendly and real time with minimal training
- Streamlines blend grade verification process
- Supports tobacco purchases
  - Grade verification
  - Appropriate purchase price

# Stemmy AutoGrader Apparatus



Tungsten-Halogen Lamps

Cooling fan

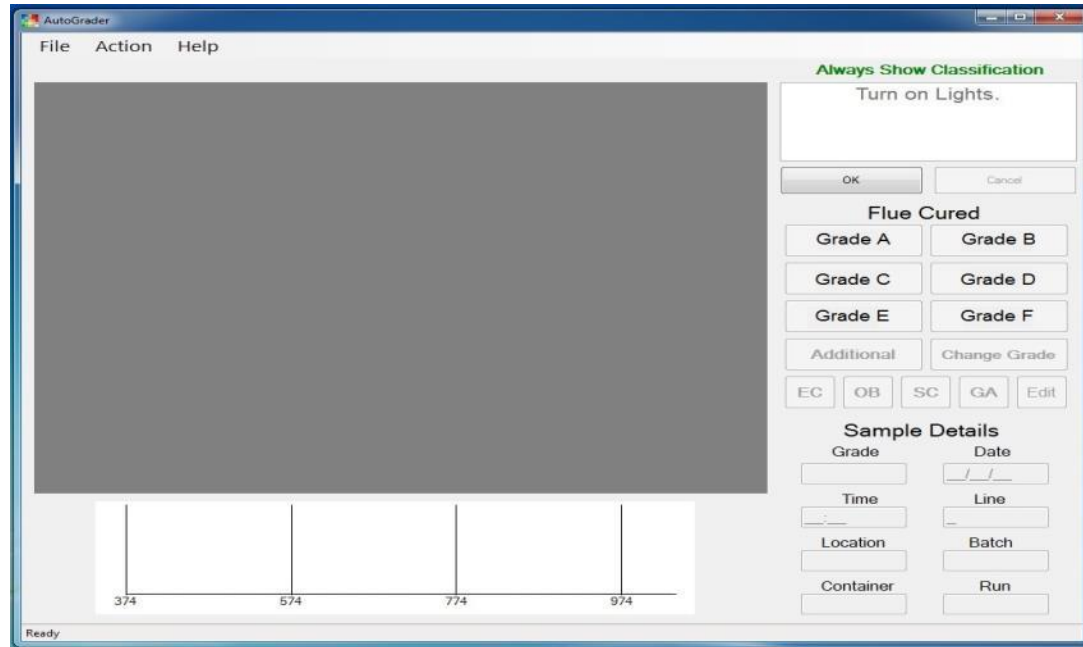
Hyperspectral Imager

Tobacco Sample

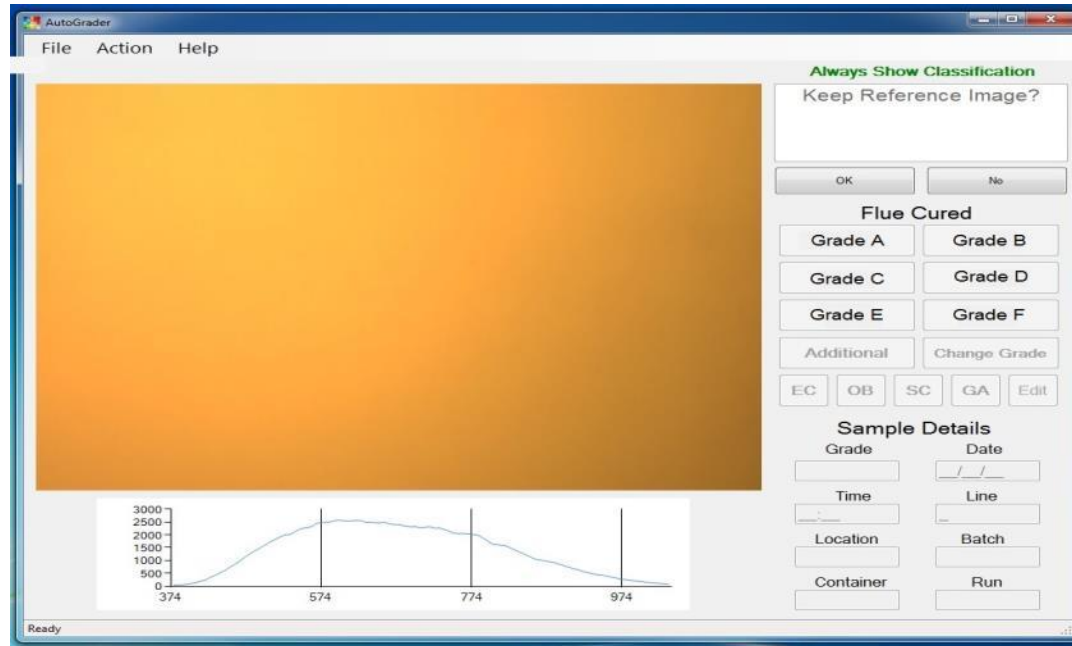
Cost per unit of ~\$60k



# AutoGrader Program Workflow Example



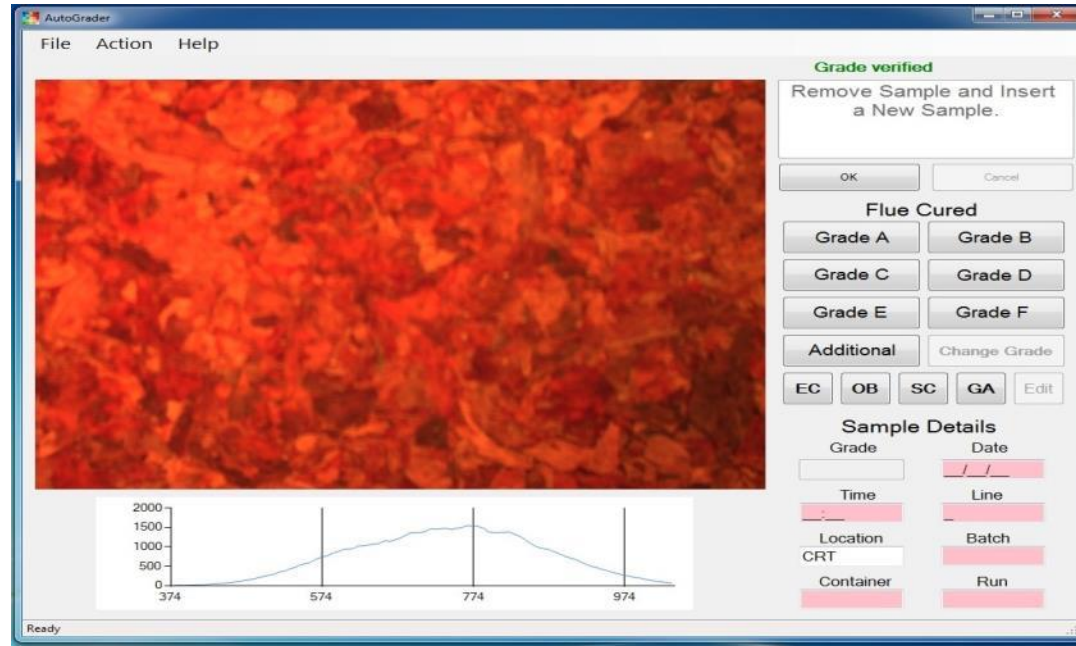
# AutoGrader Program Workflow Example



# AutoGrader Program Workflow Example

The screenshot displays the AutoGrader software interface. The main window contains a large image of a red, textured sample. Below the image is a histogram with a y-axis ranging from 0 to 3000 and an x-axis with markers at 374, 574, 774, and 974. The control panel on the right includes a menu (File, Action, Help), a checkbox for 'Always Show Classification', a 'Keep Second ImageCube?' dialog with 'OK' and 'No' buttons, a 'Flue Cured' section with buttons for Grade A through F (Grade E is highlighted), an 'Additional' section with 'Change Grade' and 'EC', 'OB', 'SC', 'GA', and 'Edit' buttons, and a 'Sample Details' section with input fields for Grade (20), Date (06/24/16), Time (11:15), Location, CRT (0), Container (0), Line, Batch, and Run (0). The status bar at the bottom left shows 'Ready'.

# AutoGrader Program Workflow Example





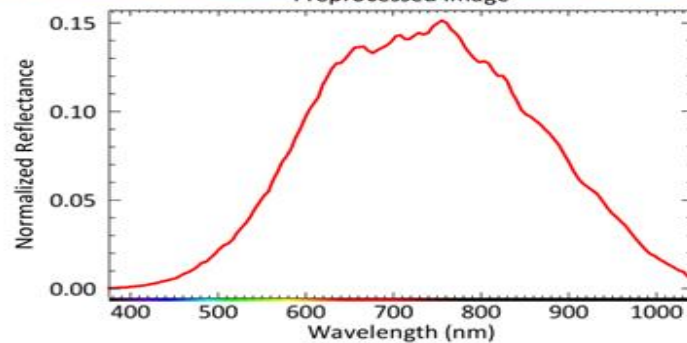
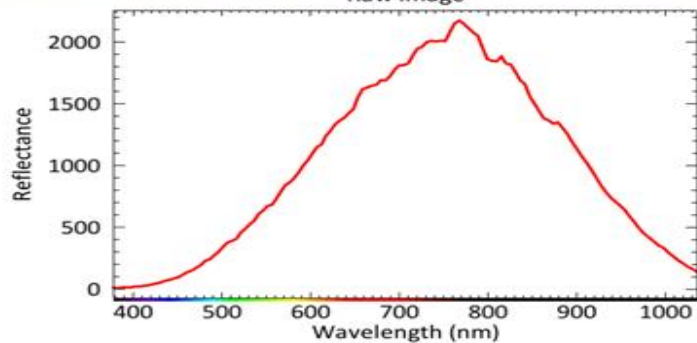
# Preprocessing



Raw Image



Preprocessed Image

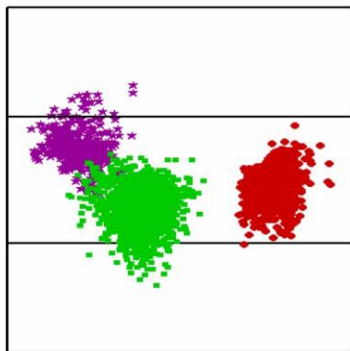





# Classification

- Use Mahalanobis Distance to measure differences between control and test
- If sample is within 3 standard deviations of the labeled class centroid then it is **acceptable**
- If sample is outside of 3 standard deviations of the labeled class centroid then the class distance ratio is calculated:
  - If the class distance ratio is less than 70% then **inspect** the sample
  - If the class distance ratio is greater than 70% then it is **acceptable**

# Proving Success in Tobacco

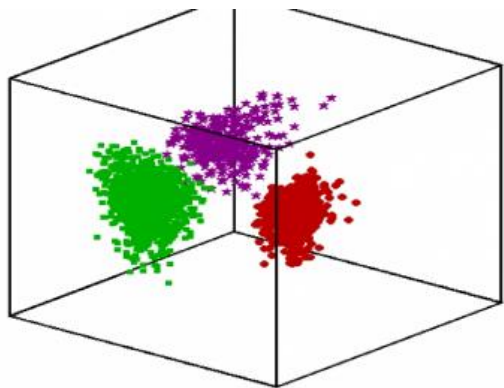
## Major Groups



-  **US Burley**
-  **US Flue Cured**
-  **Oriental**

# Proving Success in Tobacco

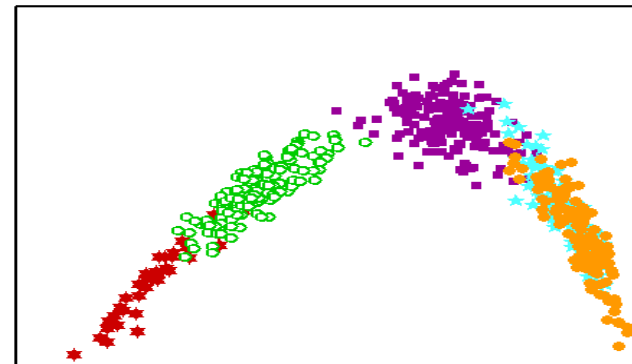
## Major Groups



- US Burley
- US Flue Cured
- ★ Oriental



Tobacco plant



- Tips
- ★ Red Leaves
- Leaves
- Cutters
- ★ Lugs



# Hyperspectral Imaging Accuracy Success\*

## Flue-Cured Tobacco

### East Carolina Belt Machine Classification

Labeled Grade

Lugs	98	2			
Cutters		77	3		
Leaves			34		
Red Leaves				153	20
Tips					73
	Lugs	Cutters	Leaves	Red Leaves	Tips

### Old Belt Machine Classification

Labeled Grade

Lugs	37				
Cutters		33			
Leaves			14		
Red Leaves				71	
Tips					26
	Lugs	Cutters	Leaves	Red Leaves	Tips

**Relative Classification Accuracy = 95%**   **Relative Classification Accuracy = 100%**

**Classification Accuracy = 100%** Hyperspectral System Grading vs. ALCS Grader



# Hyperspectral Imaging Accuracy Success\*

## Burley Tobacco

### Machine Classification

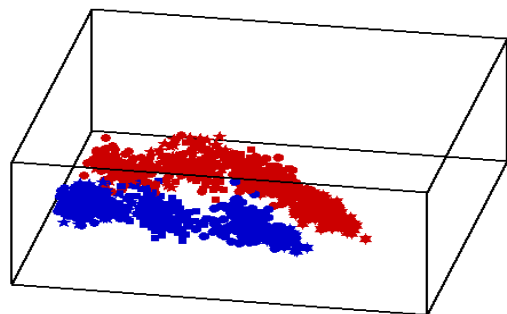
Labeled Grade

Lugs	78	28			
Cutters	1	280	3		
Leaves			424	8	
Red Leaves				48	50
Tips				10	97
	Lugs	Cutters	Leaves	Red Leaves	Tips

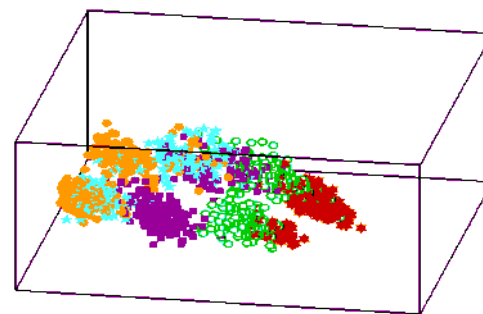
**Relative Classification Accuracy = 90%**

**Classification Accuracy = 100%**

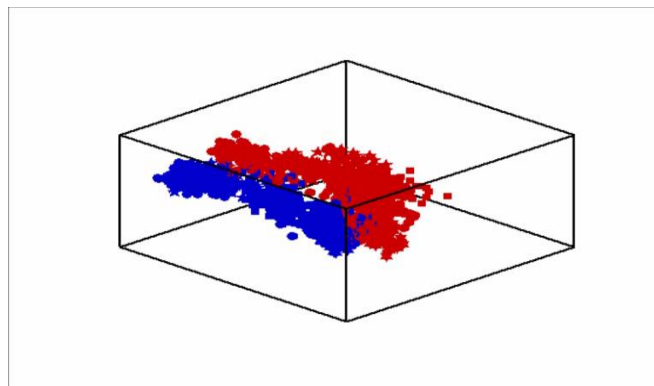
# Burley Annual Variation



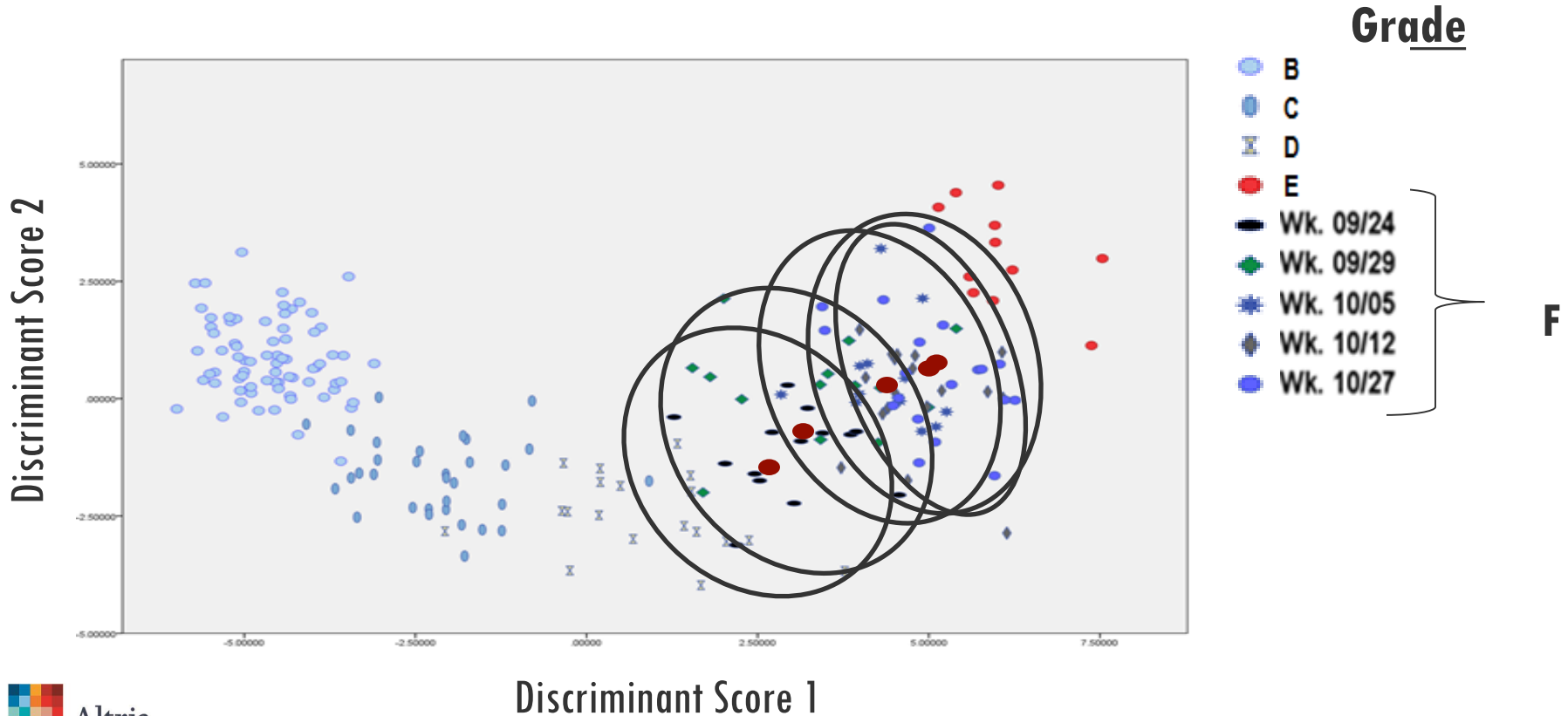
● 2011 Sample  
● 2012 Sample



★ Lugs  
○ Cutters  
■ Leaves  
★ Red Leaves  
○ Tips



# 2015 Flue Cured Variation





# Implementation Challenges

- Factory personnel
  - Blown light bulbs
  - Lens out of focus
  - Required a more user friendly, robust system and protocol
- Flexibility for new grades
  - New grades can be added to database
- Calibration features
  - Master-sample feature

# Conclusion

- A VNIR hyperspectral imaging system can be used for tobacco grading
- The system can successfully differentiate between the three major groups of tobacco – Burley, Flue-Cured and Oriental
- The system can differentiate between tobacco leaf stalk positions
- The relative classification accuracy ~ 93%

# Reducing risk. Expanding choice.

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