Quantitative Characterization of Cellular Irregularities in Extruded Polystyrene Foam Using Digital Image Processing and Analysis

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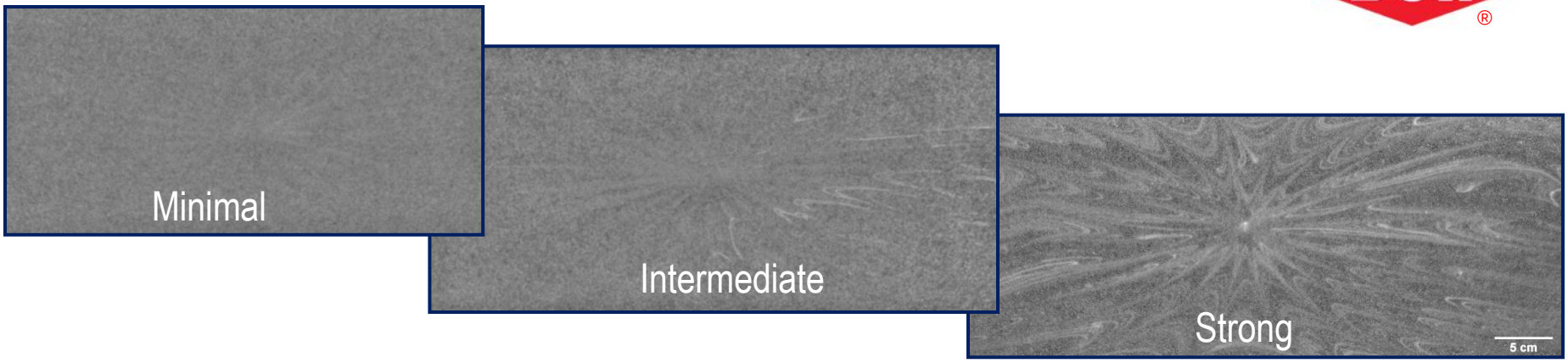
Motivation and Background

Image Analysis

Correlation of Human Rating with Image Analysis

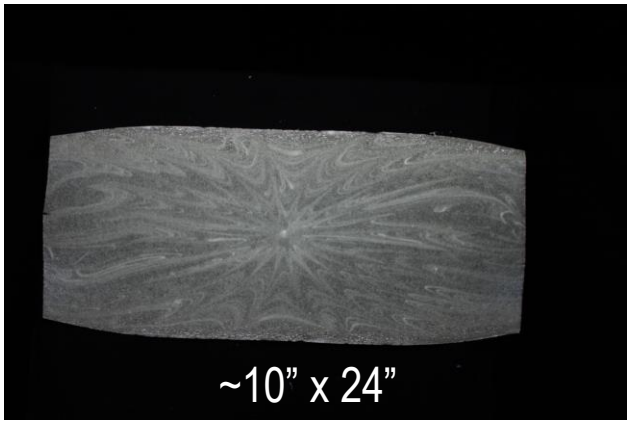
Conclusions and Path Forward

Motivation and Background



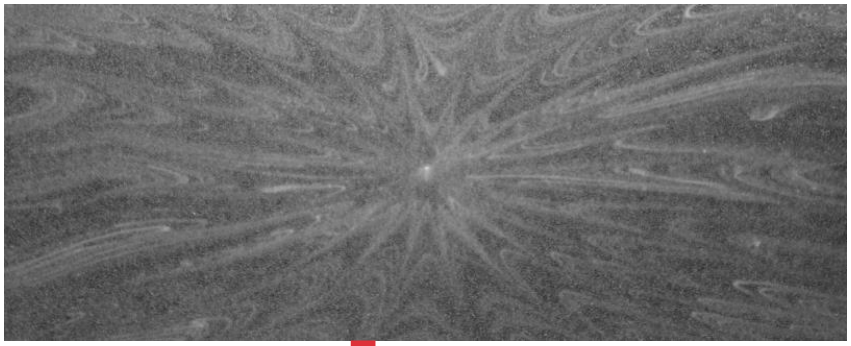
- Flow - induced cell size irregularities in extruded foam structure → **foam pattern**
  - Overall pattern strength
    - » Magnitude of difference between “small” and “large” cells
    - » Sharpness of boundaries between small-cell and large-cell domains
    - » Cell size consistency within domains
  - Overall pattern shape due to extent of correlated sizes
- ***Historic human panel rating is inconsistent.***
- ***Ubiquitous foam patterns + difficulty to quantify → need for robust analytical method***

Image Analysis - Method

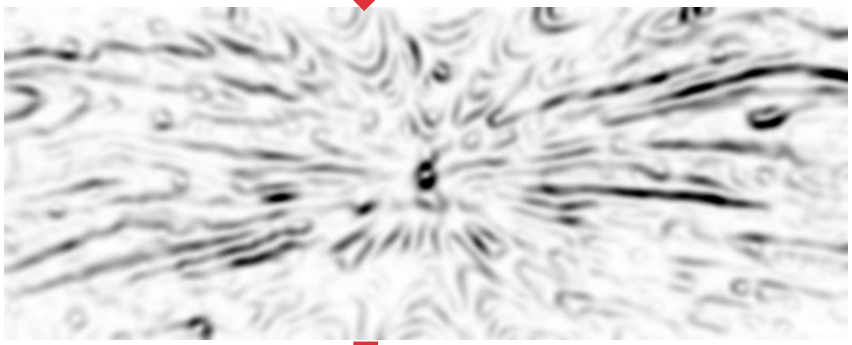


Crop
Straighten
Center

Grayscale
Background
correct

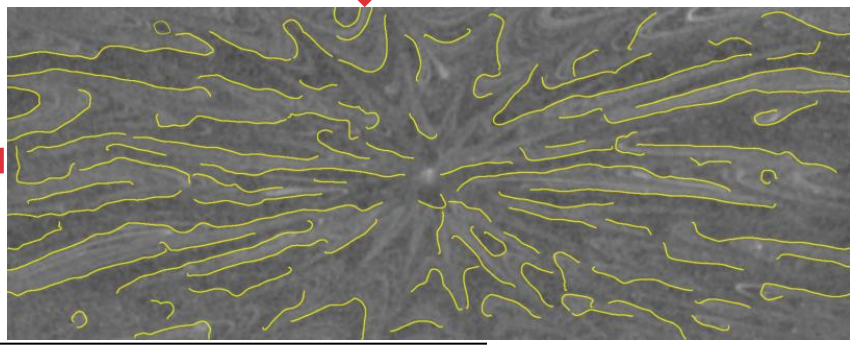


Variance Filter



Find Ridges (Variance example)

- Ridge isolation: *Remove Outliers…* “bright” and “dark”
- *Find Ridges* (Variance, Brightest, Darkest)
- Pattern–based feature acceptance/rejection
- Quantitative pattern assessment
  - Line and Chevron count
  - Summed line length
  - Contrast-weighted line length (Ridge Factor)



Add All
Ridges

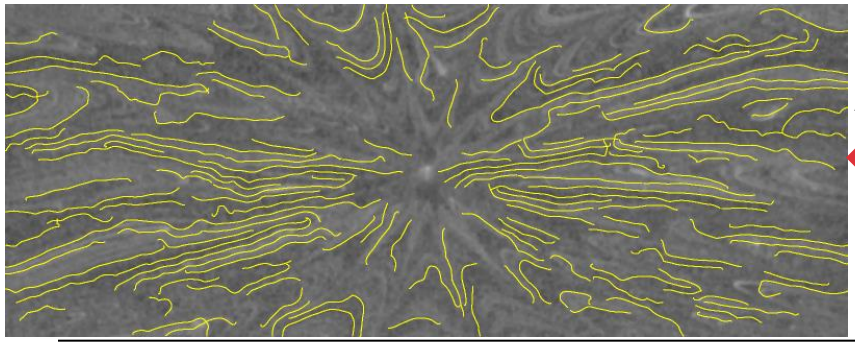
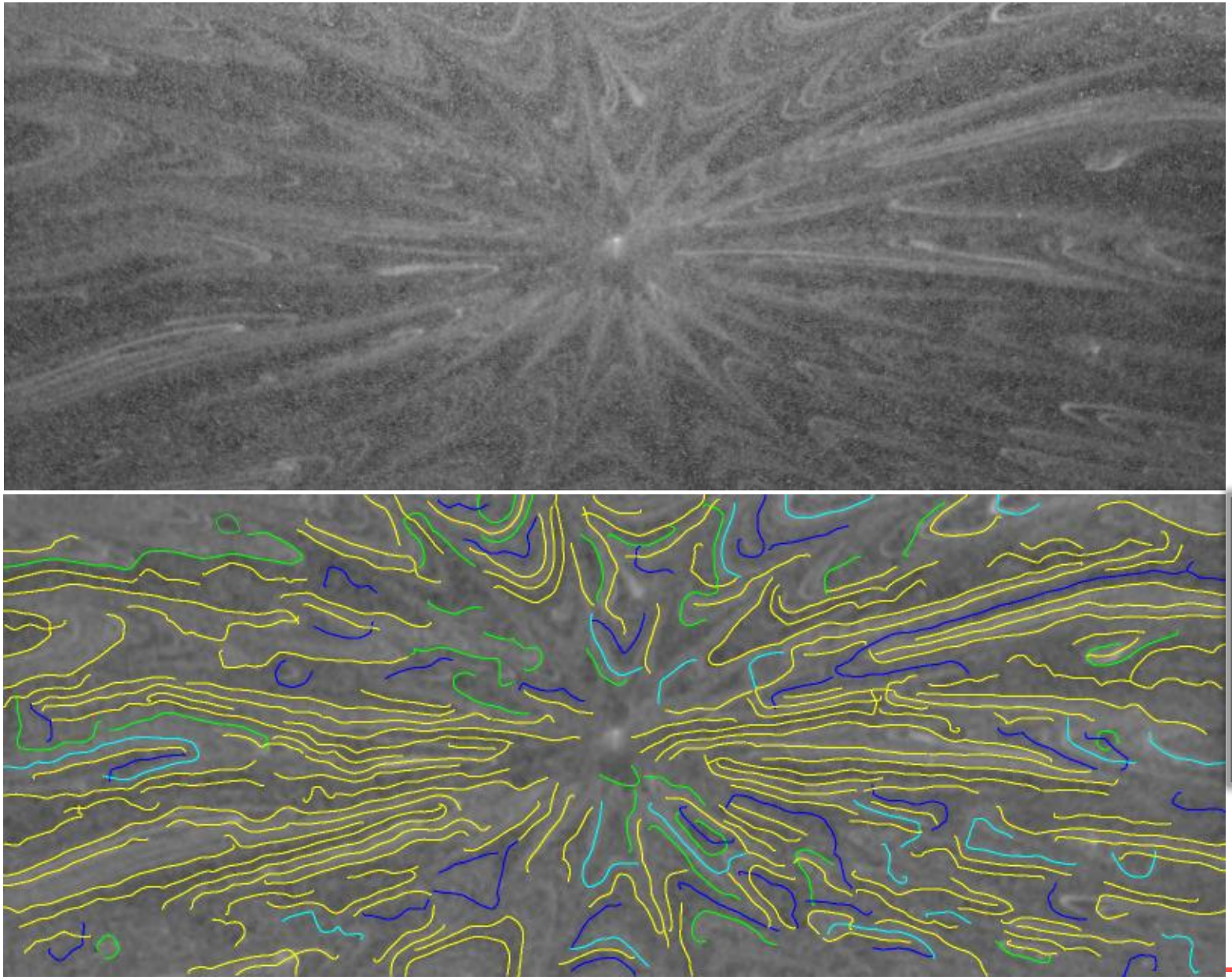
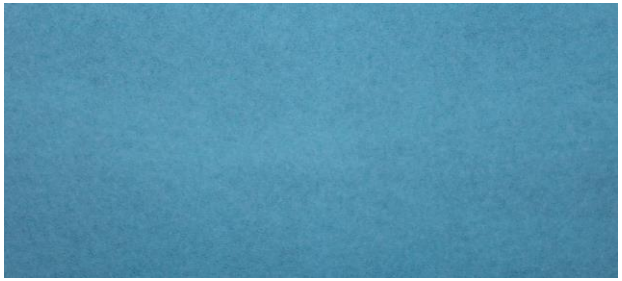


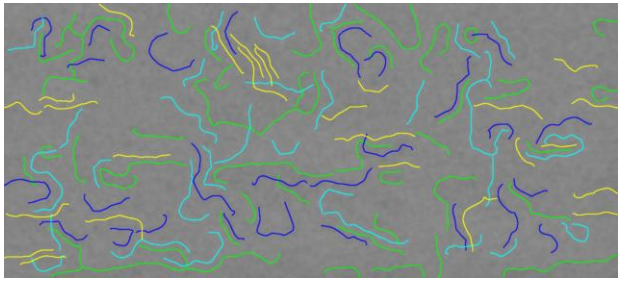
Image Analysis – Detail of Keep/Reject Results



KEEPERS
Green/Variance
Cyan/Bright
Blue/Dark

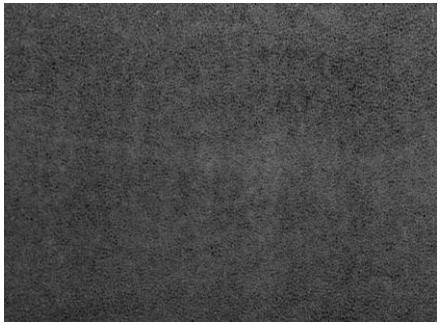
Image Analysis – Several Examples

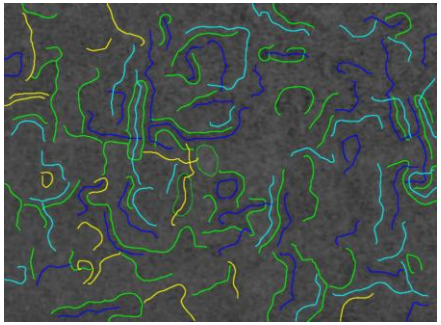




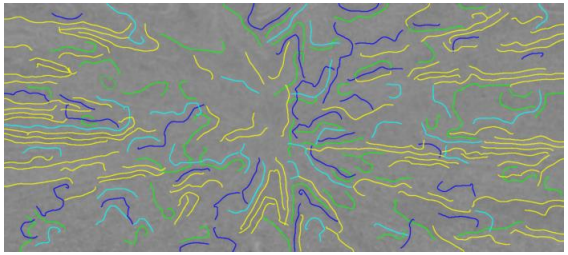
Line:	27
Chev:	8
Sum:	4,257
Ridge:	9,636

KEEPERS
Green/Variance
Cyan/Bright
Blue/Dark

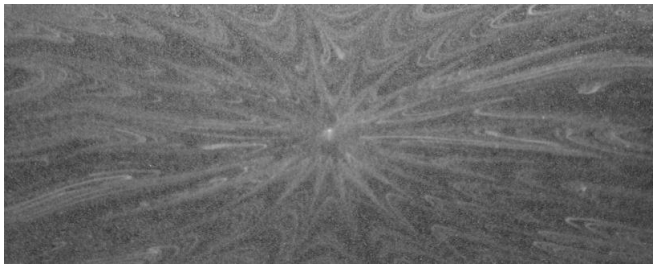


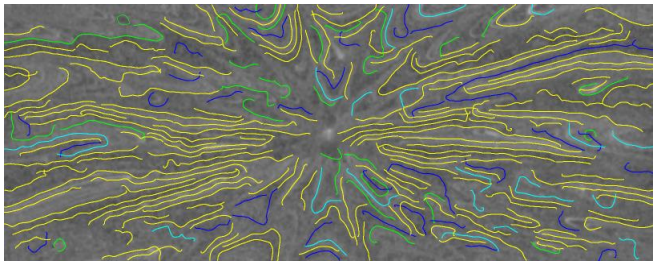


Line:	10
Chev:	15
Sum:	2,969
Ridge:	13,933



Line:	87
Chev:	15
Sum:	17,179
Ridge:	56,155





Line:	116
Chev:	29
Sum:	30,642
Ridge:	272,144

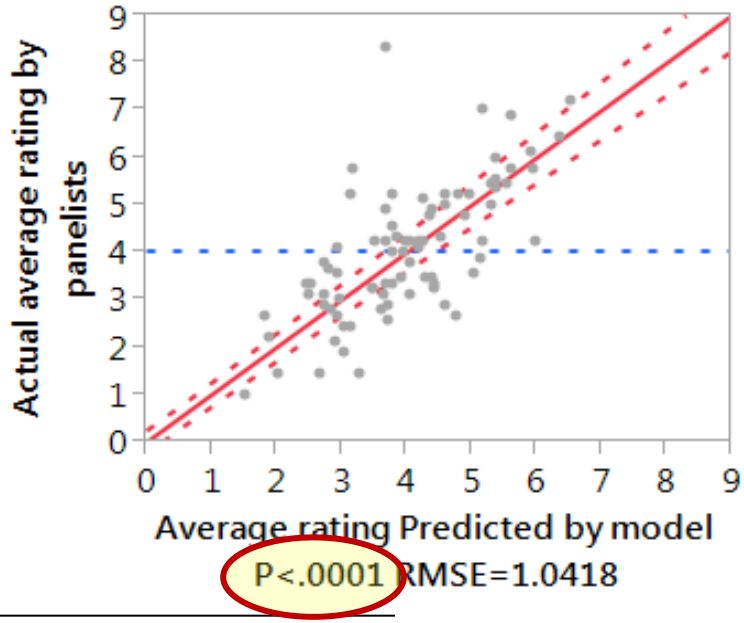
Correlation of Human Rating with Image Analysis

- Criteria (broad descriptions)
  - Panelists ranked same images as image analysis algorithm
  - Lowest rating (1) = least pattern features (lines, chevrons)
  - Highest rating (10) = most pattern features
- Averaged survey data compared to image analysis measures
- Reasonable statistical correlation between human perception and image analysis data → ***model is useful!***

Survey data (9 panelists)

\+ Image analysis data (83 samples)

= Correlation model (JMP)



Key ImageJ functions, plugins, etc.

- ***Remove Outliers…*** (built-in)
  - Bring locally-bright (dark) pixels in line with bulk in region
  - Consolidate ridge (valley)
- ***Variance…*** (built-in) to find "slopes" between ridges and valleys.
- ***Find_Ridges*** (plugin by Bob Dougherty, OptiNav, Inc., http://www.optinav.com/imagej.html)
  - Isolate gray-level ridges
  - Applied to "bright", "dark" and variance images
- ***BinaryConnectivity*** to isolate nodes/trunks/branches in skeleton (from Gabriel Landini's Morphology Package: http://www.mecourse.com/landinig/software/software.html)
- **ROI Manager** (built-in) to manage feature boundaries

Classifying Feature Outlines

- *Get XY coordinates of isolated-line skeletons (no nodes)*
- *Find and assign ends, then eliminate the "other half" of the outline*
- *"Line" vs "Chevron" from net curvature*
- *Pointing direction (must point to center of pattern)*
  - Lines (slope/intercept passes through center)
  - Chevron (use triangle to assess pointing direction)
    - » Base = two ends
    - » Vertex = point along curve at maximum distance from base
    - » "Orientation" is line from mid-point of base to vertex

Conclusions and Path Forward

- ***Current image analysis method generates reasonable agreement with panel results***
- Opportunities:
  - Auto-center analysis region (special case for radial pattern)
  - Better filtering for “crossing” ridges
  - Adaptive recognition of chevrons

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End Of Talk