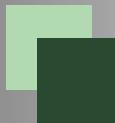


Image Phenomics:

The Development of an Image
Grammar for High-Throughput
Phenotyping Using Biological Images

Dirk Colbry
Institute for Cyber-Enabled Research

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Research Team

- **Dirk Colbry**
 - Institute for Cyber Enabled Discovery
- **Fred Dyer**
 - Zoology
- **Ian Dworkin**
 - Zoology
- **Yang Wang**
 - Mathematics
- **Lifeng Wang**
 - Statistics & Probability

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■
■

Phenomics

Area of biology concerned with the measurement of phenomes — the physical and biochemical traits of organisms — as they change in response to genetic mutation and environmental influences.

Houle, D.; Govindaraju, D.R.; Omholt, S. (2010), "Phenomics: the next challenge", *Nature Reviews Genetics* 11 (12): 855–66



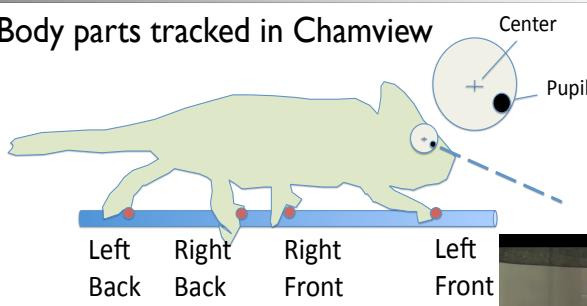


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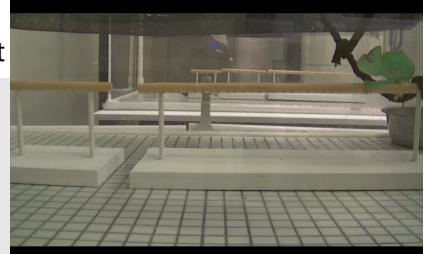
Animal Behavior

Dr. Fred Dyer

Body parts tracked in Chamview



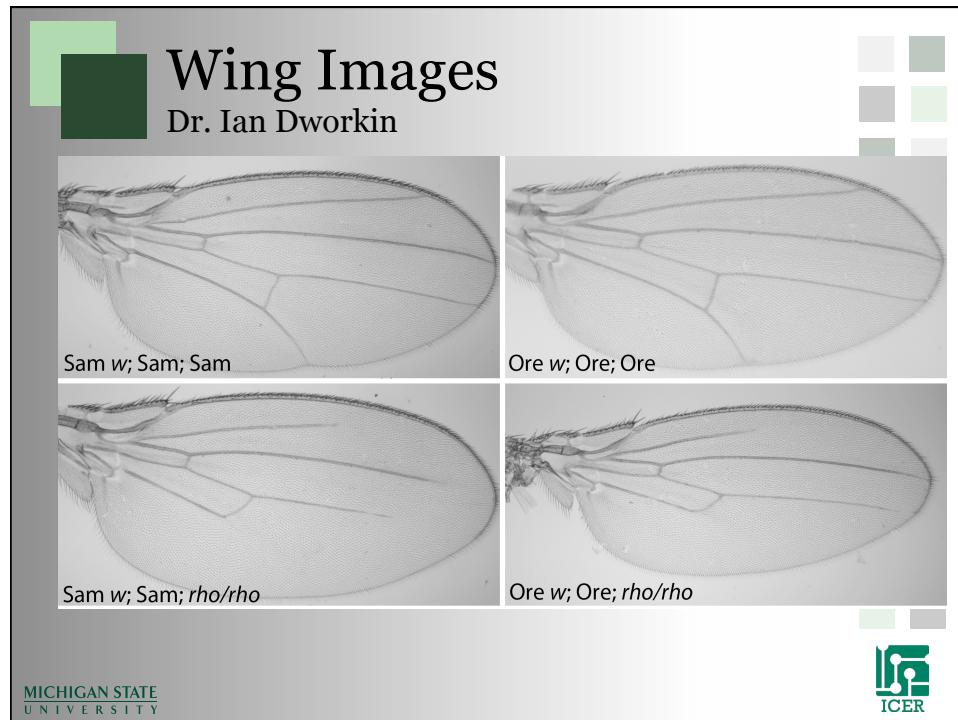
The diagram shows a light green silhouette of a cat in a walking pose. Red dots mark tracking points: 'Left Back' on the left hind limb, 'Right Back' on the right hind limb, 'Right Front' on the right forelimb, 'Left Front' on the left forelimb, 'Center' on the head, and 'Pupil' on the eye. A dashed blue line connects the 'Left Back', 'Right Back', 'Right Front', and 'Left Front' points.



A small video frame showing a cat in a behavioral experiment setup. The cat is on a grid floor, facing a glass partition with some foliage visible behind it.







Wing Images
Dr. Ian Dworkin

Sam w; Sam; Sam Ore w; Ore; Ore

Sam w; Sam; rho/rho Ore w; Ore; rho/rho

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Visual Science

- Long history in Biology
- Traditionally done by hand

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Photography

- Changing science
 - Scientists are able to record video without knowing what they will see
 - Cameras may see something the scientists missed
 - Different scientists can view the same data with different scientific questions in mind

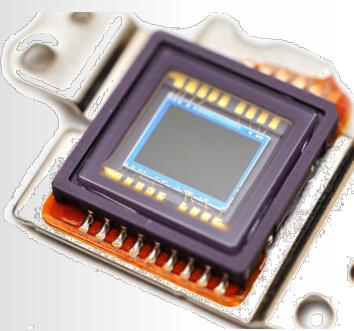


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Cameras Everywhere

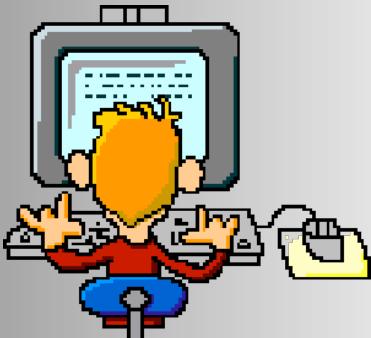
- Transforming how scientists gather data
- Very affordable
- Data is becoming very cheap to gather, so there is a lot more of it
- Still need people to analyze the data
 - time consuming and costly



Charge-Coupled Device (CCD)

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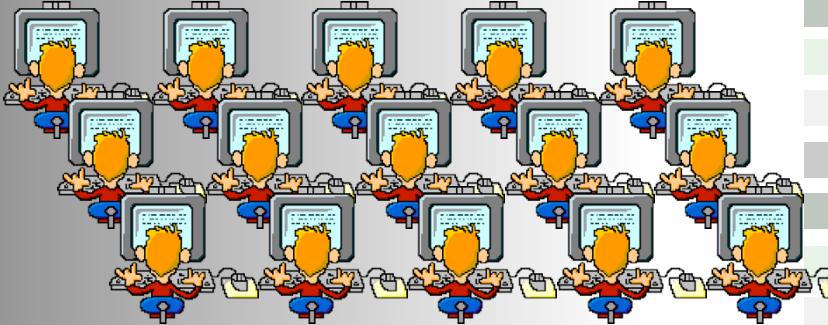


How are digital images analyzed?

Graduate students are cheap...
Undergraduates are even cheaper!

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A cartoon illustration of a graduate student with orange hair, wearing a red shirt and blue pants, sitting at a desk and working on a computer. The slide features decorative color swatches in the top left and top right corners.

Also, easy to run in parallel

Does this solution truly scale?

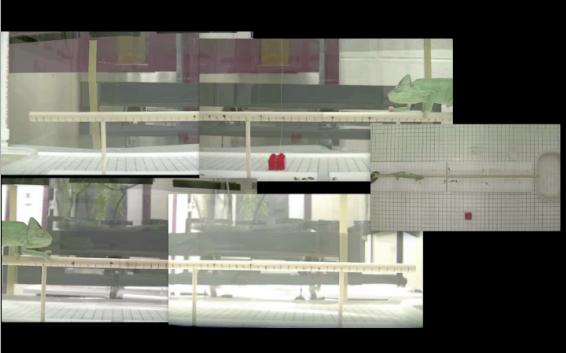
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A cartoon illustration showing a grid of graduate students, each working at their own computer. The slide features decorative color swatches in the top left and top right corners.

Problems with Video/Image Analysis

- Data is growing at a fast rate:
 - 11 years of YouTube video are uploaded every day (http://www.youtube.com/t/press_statistics)
- Even Small experiments can use many cameras



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Goal: Automate Image Analysis

- Let computers do the work for you
- Automatically identify information in images
- Return that information as data to the scientist
 - Pattern Recognition
 - Machine Vision
 - Image Processing

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Existing automated approaches

Task Specific	Overly General
<ul style="list-style-type: none"> • Program solves a specific problem for a specific type of input • Domain specific assumptions make it easy to automate image analysis <p>Ex. Tire Imaging tool, wingmachine</p>	<ul style="list-style-type: none"> • Tools make it easy to do global manipulation of images • Difficult to do anything specific to a problem <p>Ex. Photoshop, ImageJ</p>



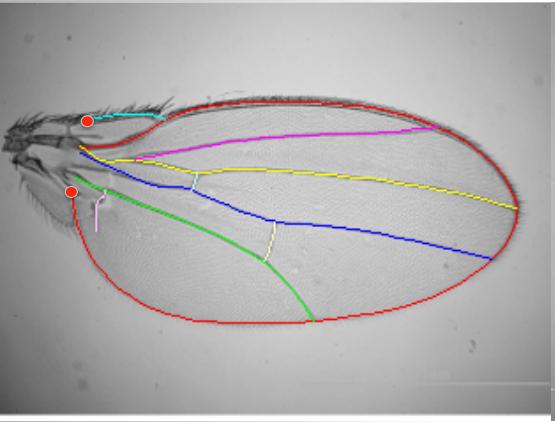




- Free, Open source
- Over 1,700 users
- More than 500 Plugins listed on their website
- Many, many features





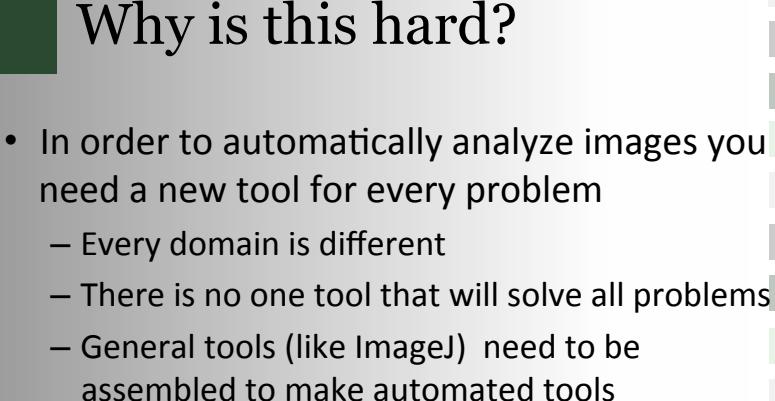


Wingmachine

Wingmachine software developed by the Houle lab, FSU
Houle *et al.* 2003 BMC Evo. Biol. 3:25

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- In order to automatically analyze images you need a new tool for every problem
 - Every domain is different
 - There is no one tool that will solve all problems
 - General tools (like ImageJ) need to be assembled to make automated tools

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Our Goal

- Focus on the workflow of making tools, not on the individual tools themselves
- Make it easier to make new tools
- How?



Idea: Make an Image Grammar

- Can we make a language that helps us build tools?
- What would this image grammar look like?
- How would it work?
- Would such a grammar make exploratory science easier?



Syntax of images

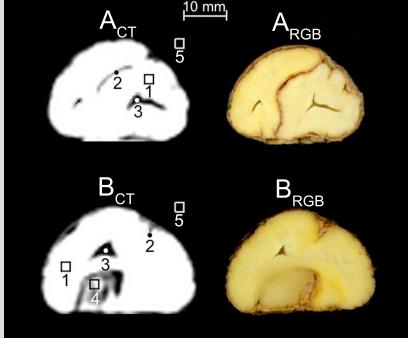
- How images are made and used
 - Pixels
 - Relationships between pixels
 - Temporal
 - Spatial
 - Etc.
- General algorithms that are available in packages like ImageJ
 - Image encasement
 - Cropping
 - Segmenting
 - Etc.

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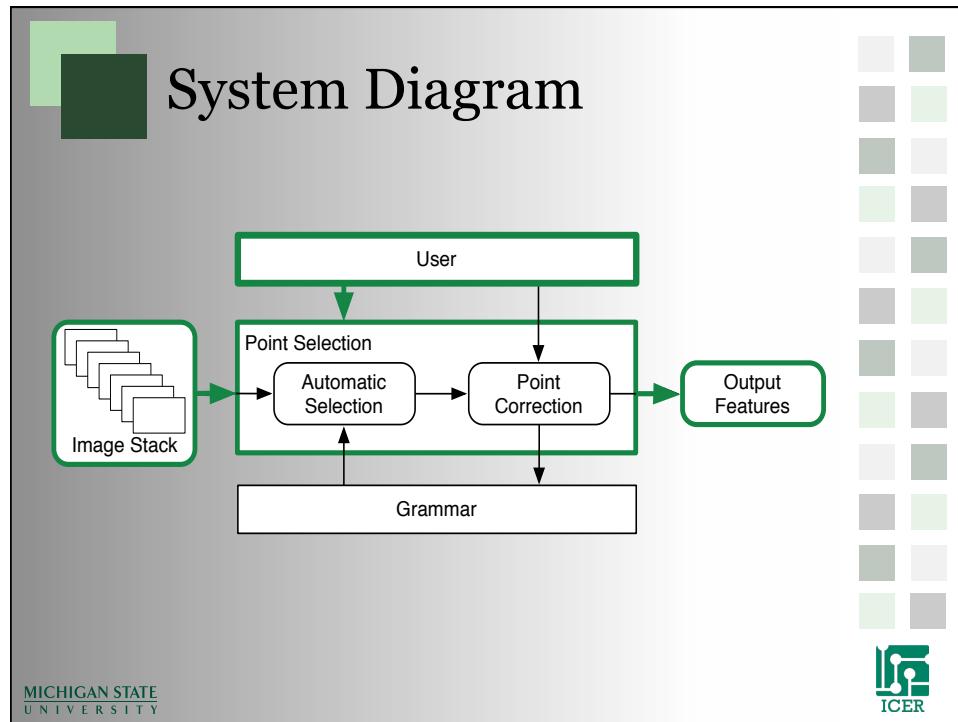
Semantics

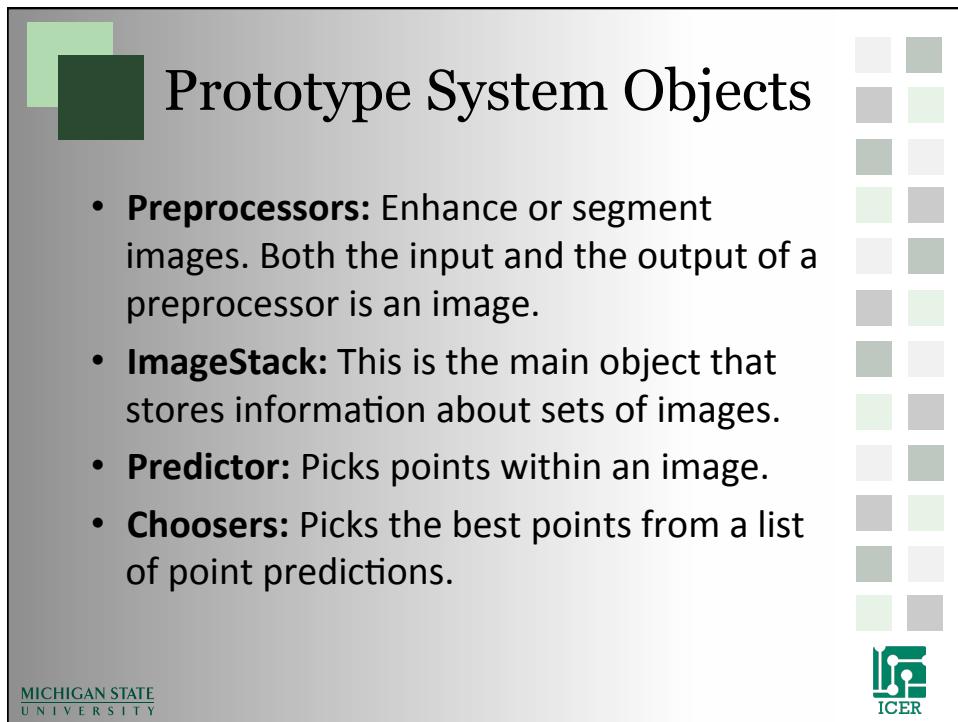
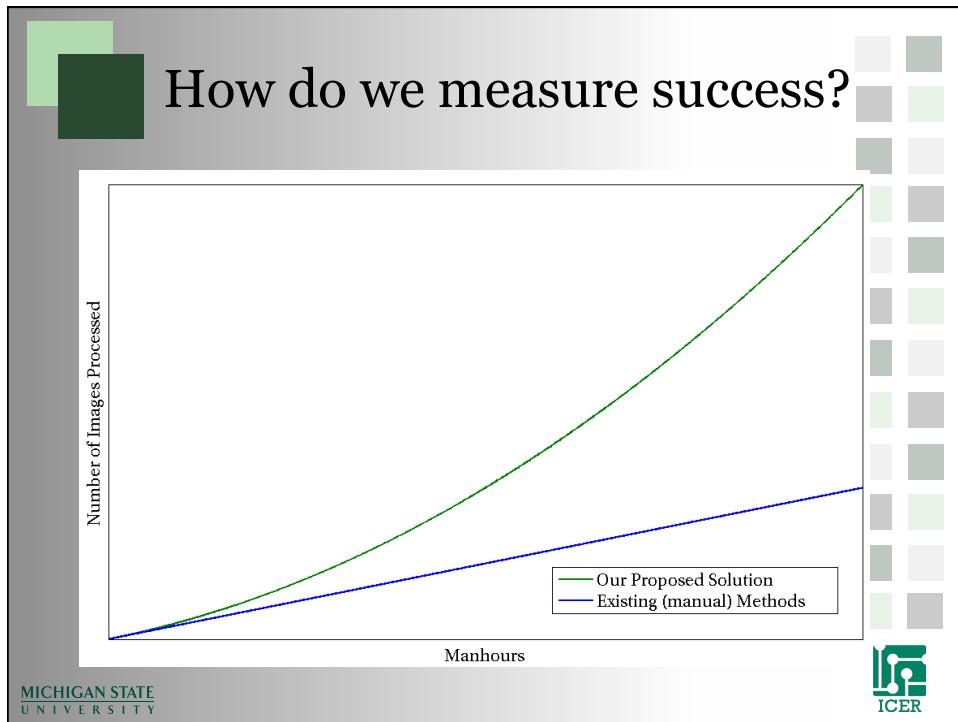
- What is it we are measuring and looking for?
 - Wings
 - Brains
 - Chameleons
 - Arm
 - Leg
 - Etc.



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Example

- Preliminary Point Pickers:
 - Kinetic
 - Template Matching
 - SIFT Features

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Point tracking on Chameleons

Patrick Korth, CSE University of Michigan

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Preliminary SIFT Results

Error from Object Center vs Frame

The graph plots Error (pixels) on the y-axis (0 to 70) against Video Frame on the x-axis (0 to 140). Two series are shown: Static (green line) and Learning (blue line). The Learning method generally shows lower error than the Static method across most frames.

Video Frame	Static Error (pixels)	Learning Error (pixels)
0	0	0
20	45	10
40	10	10
60	10	10
80	50	10
100	10	5
120	10	5
140	10	5

Patrick Korth, CSE University of Michigan

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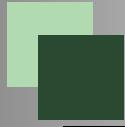
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Future Challenges

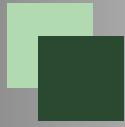
- More pickers
- More Projects
- More than just points
- Automated search though the grammar space
- Automated tweaking of algorithm parameters
- Bigger datasets (Run on the HPCC)
- Intelligent feedback to the researchers

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Questions?



Research Workflow



- What is research workflow?
 - Study of how do researcher gather and use images
 - Understanding of what programs are used
- How do we build a program that understands research workflows?
 - Do lots of different example problems
 - Find commonalities between the examples
 - Generalize as much as possible



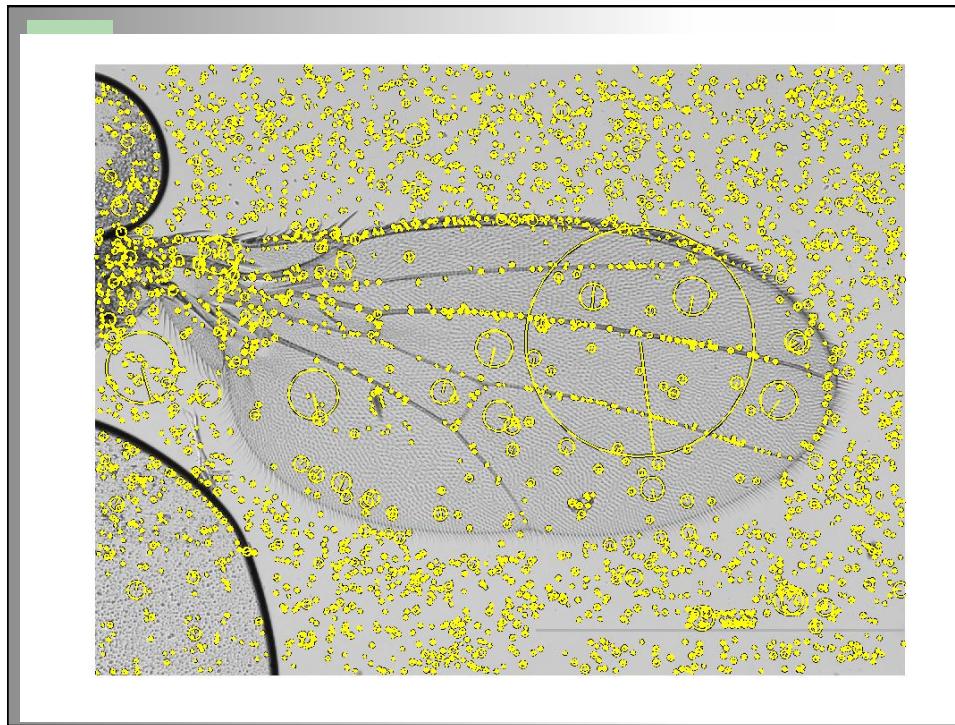


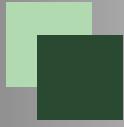
SIFT Features

- Rotation and scale invariant salient features
- Used in image registration
- Could also be used to identify interesting points in the image (in theory)



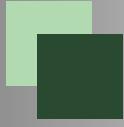




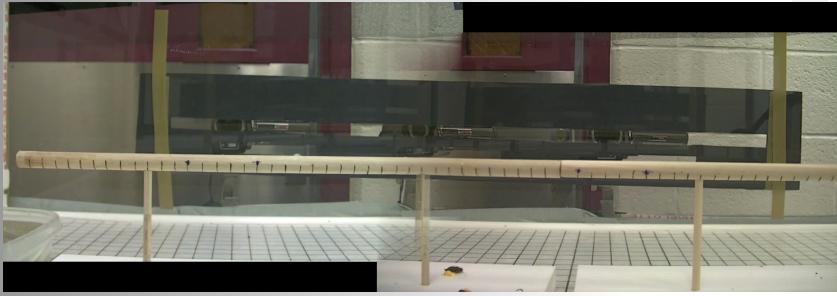


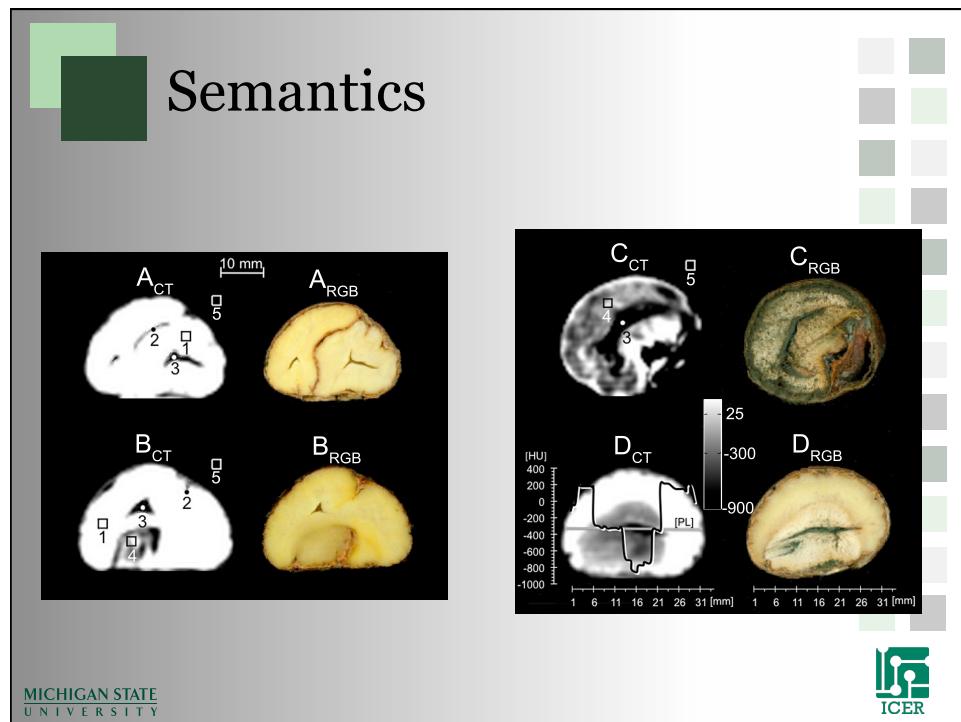
SWIFT Features

- Scale and rotation invariant salient points
- Are these syntax or semantics?
 - Sort of both



Example: Movie Stitching





Surface Curvatures

METHYLMERCURY (MeHg) DISRUPTS FLUO4 FLUORESCENCE IN CEREBELLAR SLICES FROM GABA_A RECEPTOR $\alpha 6^{(-/-)}$ MICE.

Aaron B. Bradford^{1,2} and William D. Atchison^{2,3}

¹Dept. of Biochemistry/Molecular Biology, ²Center for Integrative Toxicology, and
³Dept. of Pharmacology/Toxicology
Michigan State University, East Lansing, MI 48824

3D Feature Fusion

David Zhu

2.5D Surface Map

3D fMRI Volume

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<http://skyview.gsfc.nasa.gov/>

- Do you really need a telescope to ask your research question?
- Query data saved from other experiments to save money and time
- Enables researchers to ask larger questions

SkyView
The Internet's Virtual Telescope

NASA

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Massively Parallel Pattern analysis

ZOONIVERSE REAL SCIENCE ONLINE

666,598 people taking part worldwide

<https://www.zooniverse.org/>

Climate
Model Earth's using wartime
Help scientists make worldwide weather observations made by Navy ships.
oldWeather

Nature
Hear Whales communicate
You can help researchers understand what whales are saying.

Humanities
Study the lives of ancient Greeks
The data gathered from Lives helps scholars learn about Oxyrhynchus.

Space
How do galaxies form?
NASA's Hubble Space Telescope archive provides hundreds of thousands of galaxy images.

GALAXY ZOO

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Leveraging “Citizen Scientists”

ZOONIVERSE

GALAXY ZOO

MOON ZOO

Crater Survey

Play About Community
Craters Boulder Walls Explore Moon Forum
Boulder Walls Glossary Blog
My Moon Zoo Tutorials Moonrometer
Live FAQ Log Out

Examples

HIDE ALL CURRENT SUBMIT

Illumination Crater Mound

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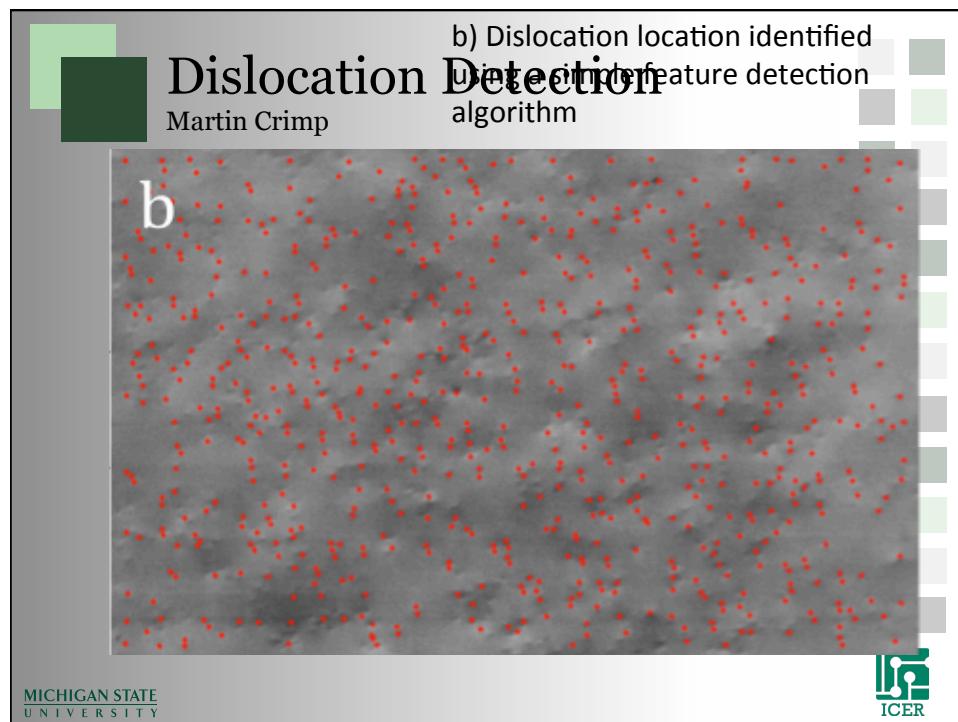
reCAPTCHA™ Digitizing books one word at a time

- Idea invented by Luis von Ahn, Ph.D. Carnegie Mellon
- Crowdsourcing – Distributing tasks to large numbers of people
- Winner of the MacArthur Award
- Security pass-phrase

Known "secret" password Unknown word from a book

online **Engineer**

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Dislocation Detection
Martin Crimp

b) Dislocation location identified using joint feature detection algorithm

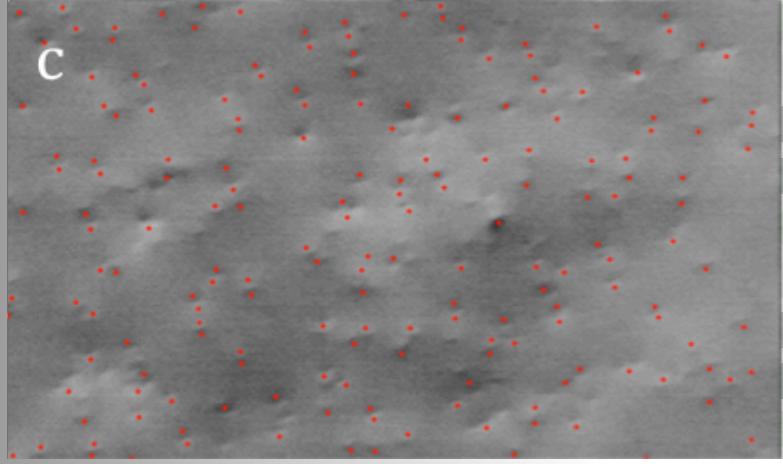
b

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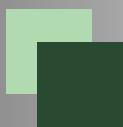
 **Dislocation Detection**

Martin Crimp

Higher magnification image showing some errors in dislocation identification.





 **Tire Tread Recognition**