

Exceptional service in the national interest



Challenges in Eye Tracking Data Analysis: From the Laboratory to the Wild World of Information

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Topical Outline

- **Visual Cognition at Sandia National Laboratories**
- **From Visual Inspection to Information Foraging**
- **Linguistic Inspiration: Behavioral Events as Texts**
- **A Concluding Thought**

Topical Outline

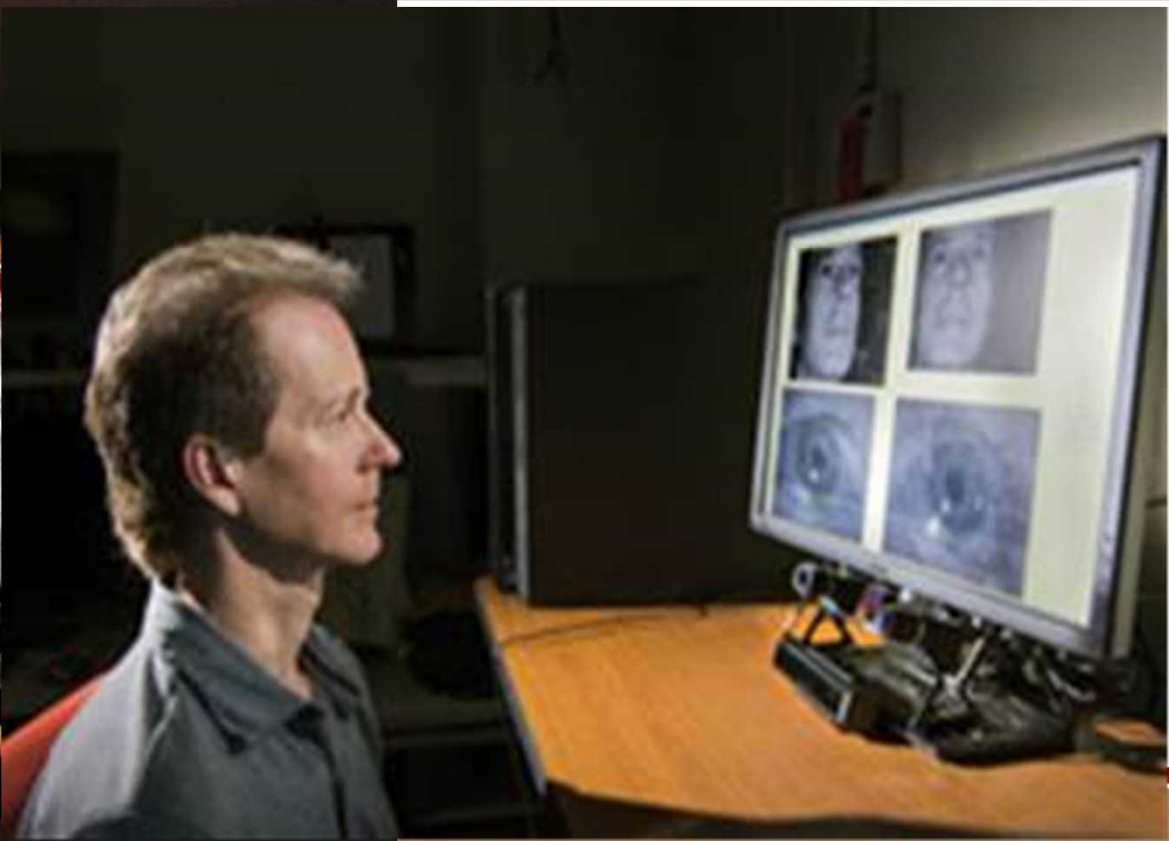
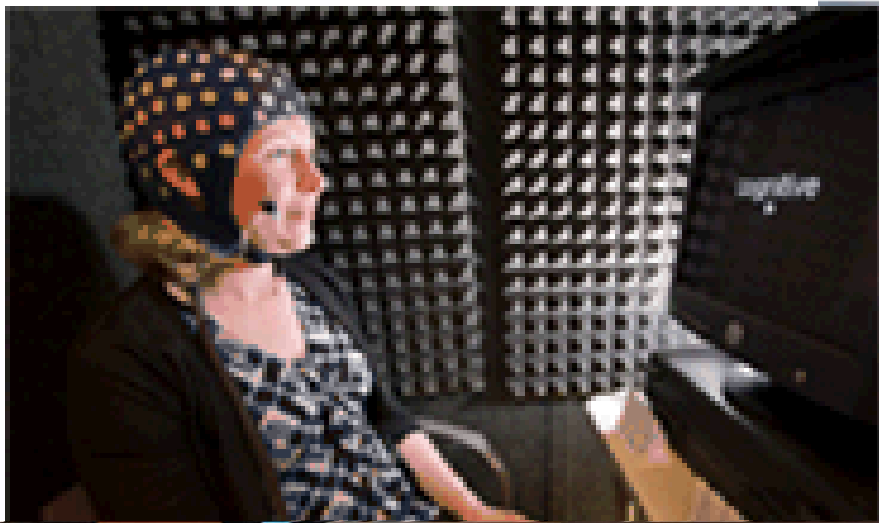
- **Visual Cognition at Sandia National Laboratories**
- From Visual Inspection to Information Foraging
- Linguistic Inspiration: Behavioral Events as Text
- A Concluding Thought





Interdisciplinary Applied R&D Team

- Kerstan Cole, Human Factors
- Kristina Czuchlewski, Remote Sensing
- Kristin Divis, Cognitive psychology
- Michael Haass, Signal processing/physics
- Laura Matzen, Cognitive Neuroscience
- Laura McNamara, Organizational Anthropology
- J. Daniel Morrow, Computer science/analytics
- Susan Stevens-Adams, Cognitive Psychology
- David Stracuzzi, Computer science/mathematics



Visual workflows in diverse domains

How do top down and bottom up cues guide visual search?
 What are the characteristics of domain-specific expertise in visual search?
 How does domain expertise change domain-general cognition?

Image Analysis
EO, SAR, others



Base images
and change
products to
enhance feature
salience

Security screeners
X-Ray image products



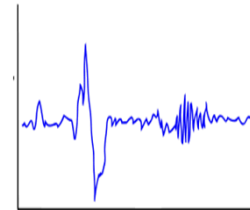
Enhance feature
salience for
visual detection

Novices



Natural
scenes

Engineer Analysts
Waveforms



Visualizations
of raw signal
data

Cyber
Log Files

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Topical Outline

- Visual Cognition at Sandia National Laboratories
- **From Visual Inspection to Information Foraging**
- Linguistic Inspiration: Behavioral Events as Texts
- A Concluding Thought

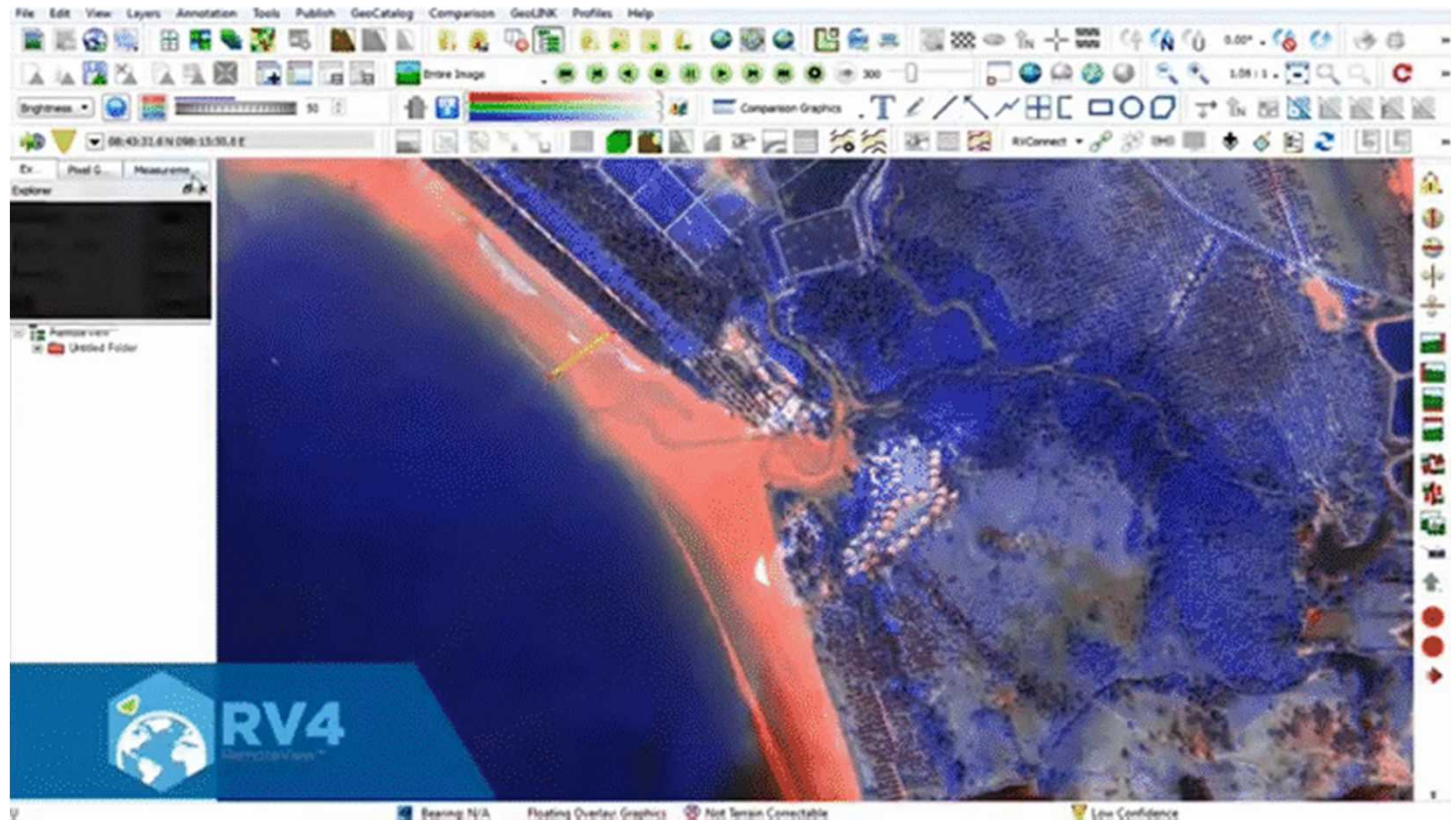
Imagery Analysis as Visual Inspection

Models of Visual Inspection

- **Select** object to inspect
- **Search** object for anomalies
- **Classify** detected anomalies
 - What does this anomaly mean?
 - Does it merit concern?
- **Act** on anomaly
 - Do we invest resources in addressing the detected anomaly?



...Until the Age of Softcopy.



It's really visual inspection with foraging.



Hunting information in the wild

- Human informavores rely on learned semantic cues to navigate massive information spaces
- Valuable information isn't distributed regularly or evenly – instead, it's patchy
- We look for *proximal semantic cues*, or 'scents,' to navigate to patches of interest
- An effective foraging strategy should *maximize the value of information gained* in relation to *effort finding the information*
 - Time spent *between patches* vs. time spent *within patches*

SNIF-ACT: A Cognitive Model of User Navigation on the World Wide Web

Wai-Tat Fu

University of Illinois at Urbana-Champaign

Peter Pirolli

Palo Alto Research Center

Gaze behaviors:

What the individual is looking at, for how long, and in what order



Manual operator actions

Mouse clicks, key presses, menu-based commands

Cognitive Workload Measures:

Dual-task data, pupil-based measurements; possibly head position, facial expressions?

Geospatial imagery interaction:

Movement across images, changes in image resolution, geospatial coordinates, time on screen, movement among available views, etc.

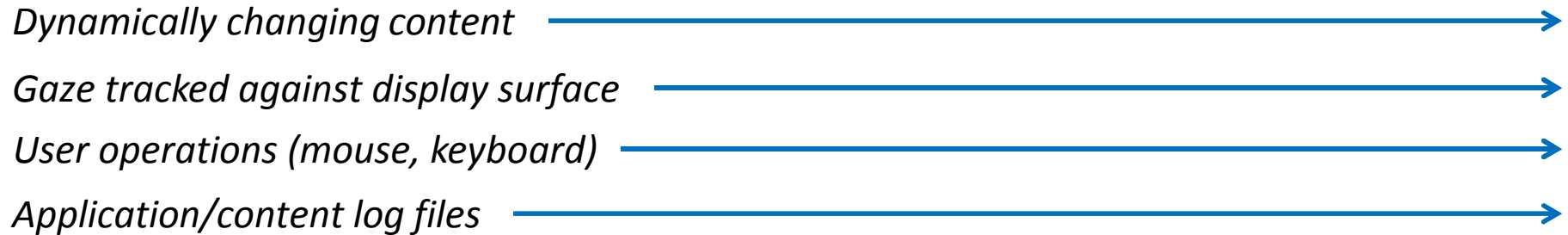
Software application/tool usage:

Opening, closing, moving among different functions within software and/or across different software applications; cutting and pasting data, creating products, etc.

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Elements of a Gaze-Informed Foraging Model



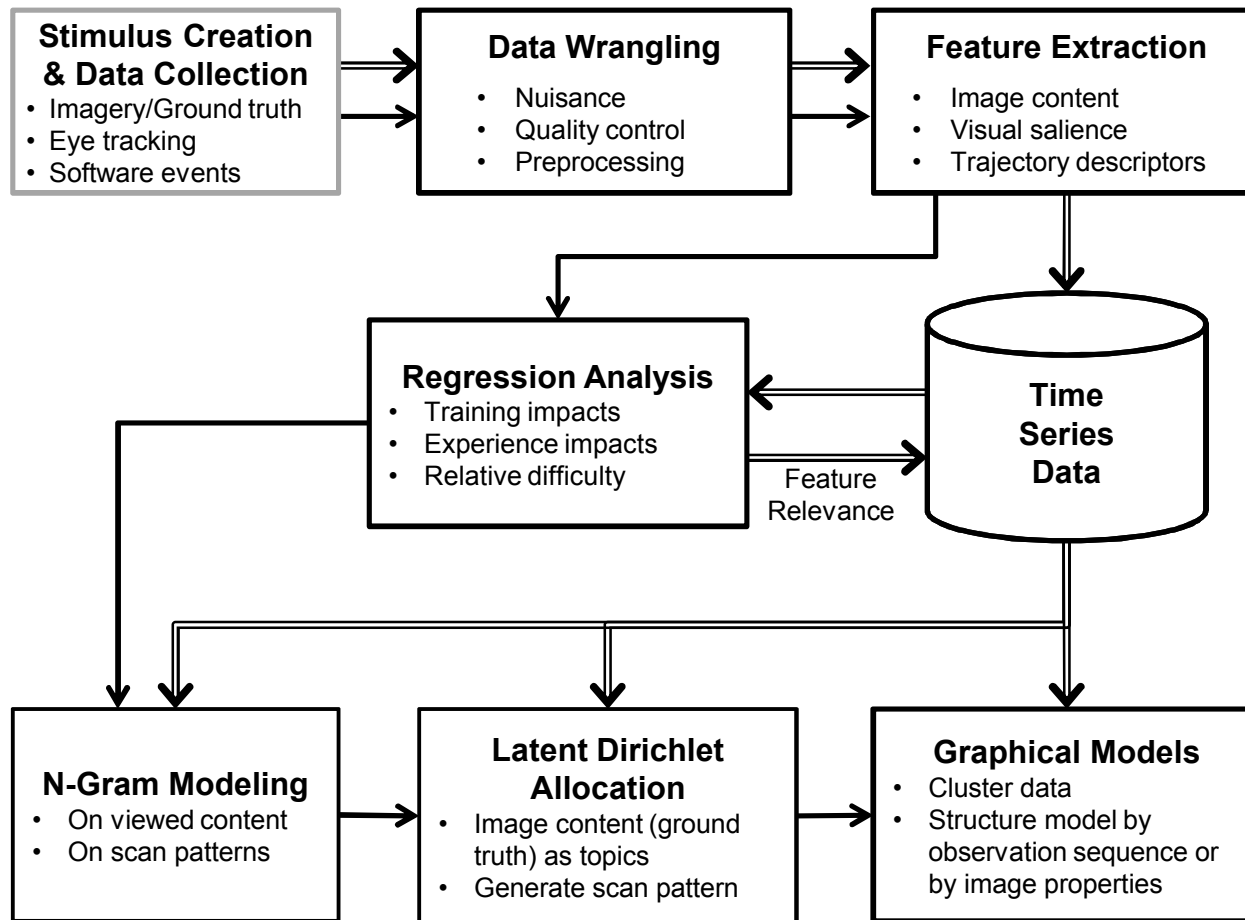
VECTOR OF EVENTS

integrated into a single timeline with minimal latency (~100-500 milliseconds).



Developing models of visual cognitive strategies with geospatial temporal datasets will require integrated analysis of user operations, application logs, gaze patterns, and displayed content. Relevant events must be defined, identified, and synchronized with minimal temporal latency before we can develop the models needed to understand what makes a visual analytic system “effective” in supporting accurate signature search and characterization, particularly when data are noisy and/or ambiguous.

When a cognitive/AI scientist meets eye tracking data...



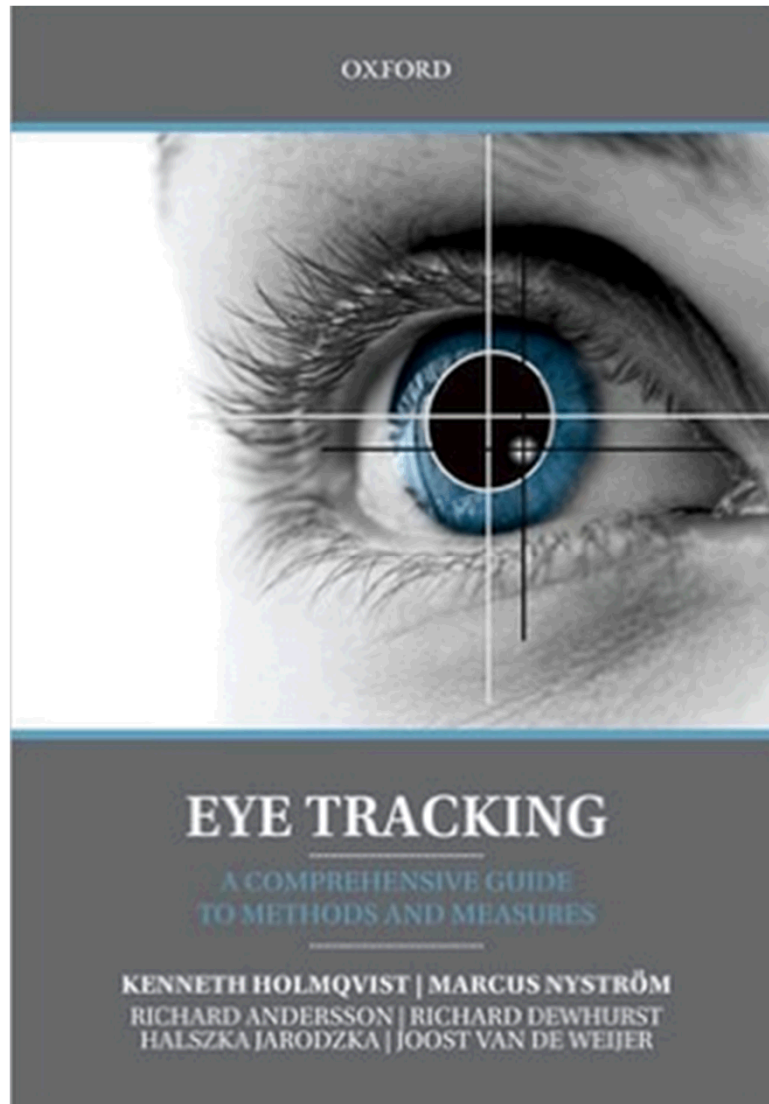
... This is the kind of thing you can expect. 😊

Human Foraging Behaviors as *Texts*

- How do we tease out structure from the sequences of events descriptive of user actions? Computational linguistics deals with a lot of the same problems.
- **N-Grams:** Probabilistic prediction of next item in a sequence of items, based on analysis of sequential patterns in previous $n - 1$ observations
 - Rooted in Shannon's theory of information
 - Imagine putting a small window over a set of characters (a word or 'gram') so that only n -words are visible at one time.
 - Given observed events, what observation is most likely to occur next?
- Tease out local patterns within longer sequences of observations to examine structural regularities in data
 - Given a pattern of panning, zooming, and gaze behaviors, what's the probability that Imogene the Imagery Analyst will open a new image window?
- Enable comparison/contrast of imagery analytic strategies within and across analyst communities

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- **A Concluding Thought**



Eye-tracking data have a structure that lends itself to many different types of data analysis...

Analyzing eye-movement data is always a matter of reducing the amount of information in the data.

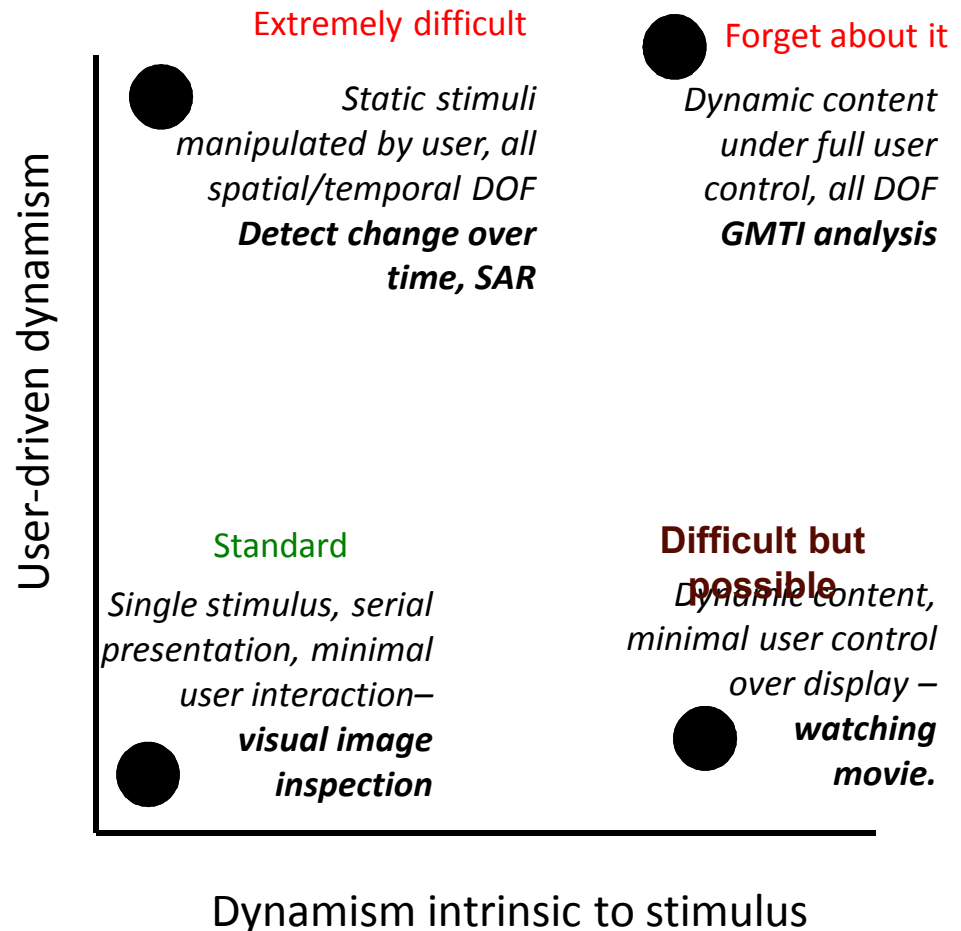
-Holmqvist, Nustrom, Andersson, dewhurst, Jarodzka and van de Weijer 2011: 465

AUX SLIDES

The Problem

- Gaze tracking is a potentially powerful source of behavioral data for perception and cognition in complex information search, acquisition, and problem-solving
- We'd love to incorporate gaze tracking into studies of visual cognition as people interact with large, heterogeneous datasets.
 - User interaction drives change of stimulus content
 - Stimuli may be intrinsically dynamic – moving targets, for example
- However, gaze/eye tracking algorithms, software don't cope well with dynamism
 - Manageable when the stimulus is dynamic
 - The more the user is controlling what's displayed, the harder it gets
 - Even harder for capturing emergent search/problem solving behaviors – can't predefine "targets" nor contingent visual events

Gaze tracking technology originated in laboratories, where stimuli and tasks are highly structured and controlled. Infrastructure for naturalistic studies of user-driven behaviors doesn't exist – yet.



What features capture Charlie's attention as he inspects a baseball diamond?

*Gaze sampling can vary from a few
tens to ~1000 Hz,
depending on system*



Charlie Brown, Imagery Analyst
Transnational Baseball Diamond Team

Eye tracker

Display

Displayed Content



Content “slices” sampled @ 10 Hz throughout user session.

If content doesn't change, mapping gaze-to-display-to-content is straightforward.

But what if Charlie is looking for the perfect pitcher's mound?



Charlie pulls up a few baseball diamonds, flickers across them to compare features. He briefly examines a close-up shot of home plate. He focuses tightly on one pitcher's mound, then another, and moves among these and home plate to compare ground characteristics.

Eye tracker

Display

Displayed Content



When we can't predict what images Charlie will use, nor how he will interact with them, gaze tracking is very difficult – it usually requires laborious hand-coding.

Charlie has videos of teams playing at different fields.



Charlie watches a recorded game from one of the fields. He stops the video, rewinds to examine the pitcher's stance, stops, zooms in on the mound, toggles back and forth. He then starts a video from another game at a different field, toggling back and forth between the videos, rewinding and zooming and panning.

Eye tracker

Display

Displayed Content



When content is dynamic, and when we can't predict which features will capture Charlie's attention, mapping gaze-to-display-to-content is *extremely* challenging.