CSCI 4550/6550 Interactive Visualization

https://www.cs.rpi.edu/~cutler/classes/visualization/S24/

Lecture 19: Large Scale & In Situ Visualization

Today

- Definition of In Situ (for Computer Science)
- SpatioTemporal Definition & Examples
- Readings for Today
  - “An Image-based Approach to Extreme Scale In Situ Visualization and Analysis”
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- "in situ" definition:
  "in its original place", "on site", "in position", "locally", "in place"
- In computer science:
  - An in situ operation is one that occurs without interrupting the normal state of a system
  - Without taking the system down, while still running, without rebooting
  - In place algorithm (no extra memory)
  - User Interface (UI): without going to another window
  - For Big Data: Doing computation where the data is located

From http://en.wikipedia.org/wiki/In_situ

"Semotus Visum: A Flexible Remote Visualization Framework", Luke & Hansen, IEEE Visualization 2002

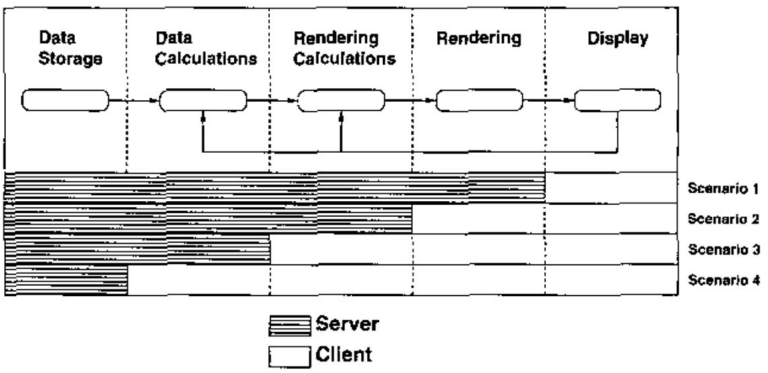


Figure 1: Dataflow in scientific visualization applications. In scenario 1, images are streamed from server to client. In scenario 2, part of the rendering calculations are done on the server. Scenario 3 allows the client to do all rendering calculations. Scenario 4 uses the server for data storage only; all calculations are done on the client.

"A Review of Image-based Rendering Techniques"
Shum & Kang,
Visual Communication & Image Processing
2000

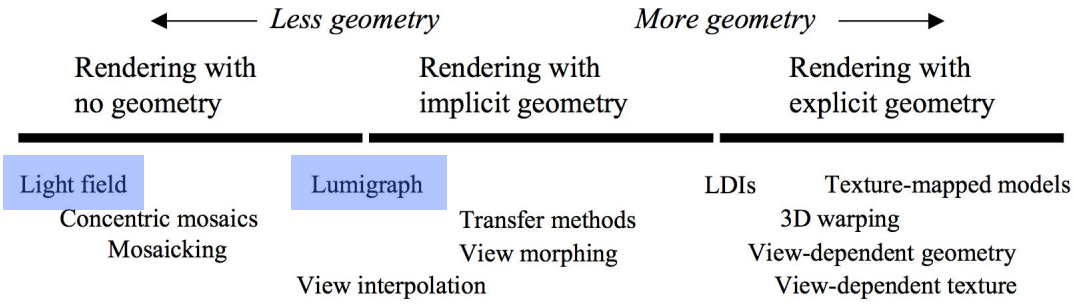
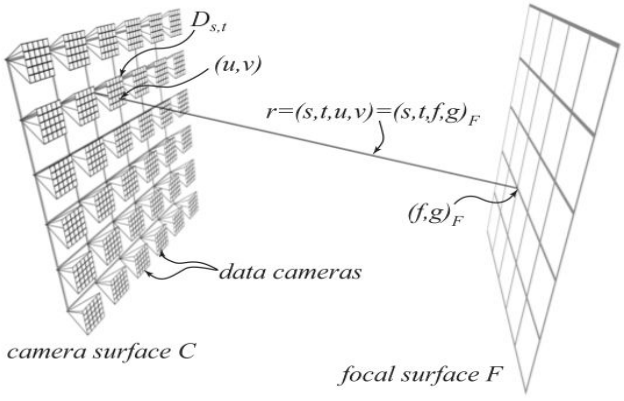
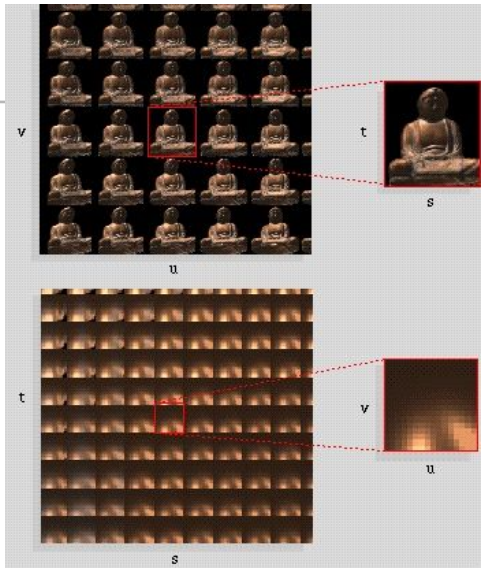


Figure 1: Categories used in this paper, with representative members.

Light Fields



Plenoptic Modeling: An Image-Based Rendering System,
McMillan & Bishop, SIGGRAPH 1995
Dynamically reparameterized light fields,
Isaksen, McMillan, & Gortler, SIGGRAPH 2000



Light Field Rendering,
Levoy & Hanrahan,
SIGGRAPH 1996

Unstructured Lumigraph Rendering
Buehler et al. SIGGRAPH 2001

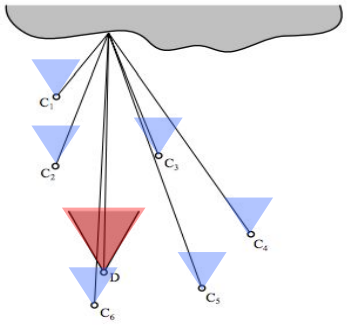


Figure 1: When available, approximate geometric information should be used to determine which source rays correspond well to a desired ray.

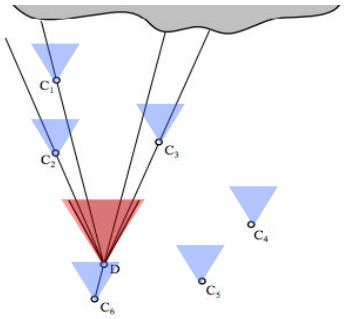


Figure 2: When a desired ray passes through a source camera center, that source camera should be emphasized most in the reconstruction.

Unstructured Lumigraph Rendering
Buehler et al. SIGGRAPH 2001

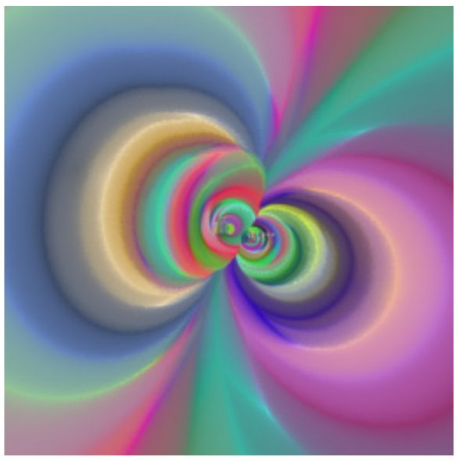


Figure 7: A visualized color blending field. Camera weights are computed at each pixel. This example is from the "hallway" dataset

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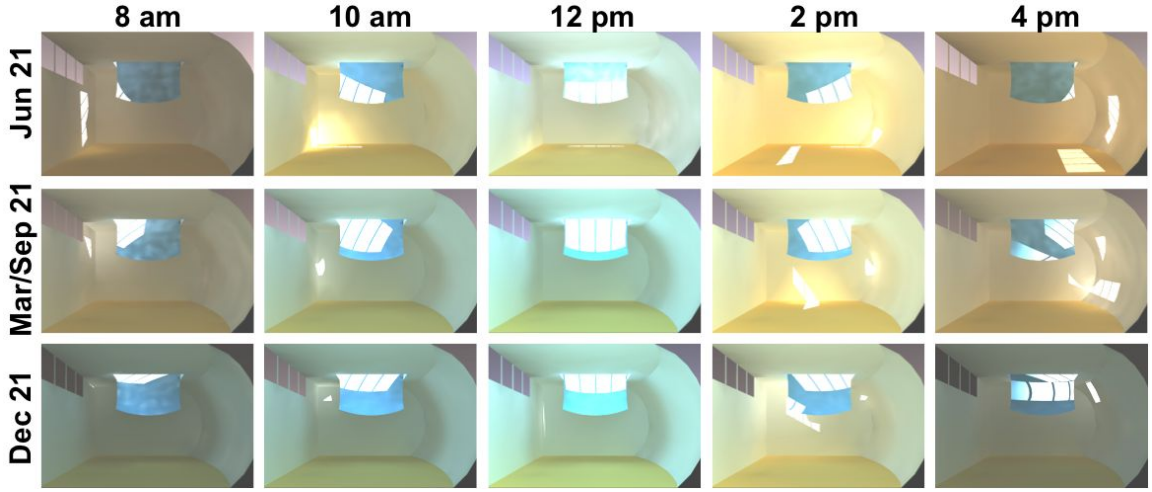
Spatiotemporal (Databases)

- Both space and time information. Examples:
  - Tracking of moving objects – a single position at a given time
  - A database of wireless communication networks – existing only for a short timespan within a geographic region
  - Tracking members of a species in a region – members of the species are born or die out
  - Historical tracking of plate tectonic activity
- Not just an extension of spatial data. Specifically includes:
  - geometry changing over time and/or
  - location of objects moving over invariant geometry (moving objects databases or real-time locating systems)

From: http://en.wikipedia.org/wiki/Spatiotemporal_database

Architectural Daylighting Design: The use of windows and reflective surfaces to allow natural light from the sun and sky to provide effective and interesting internal illumination.

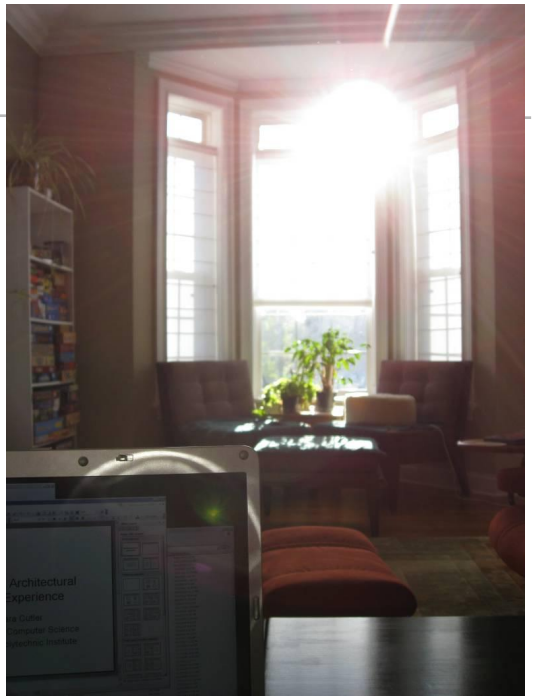


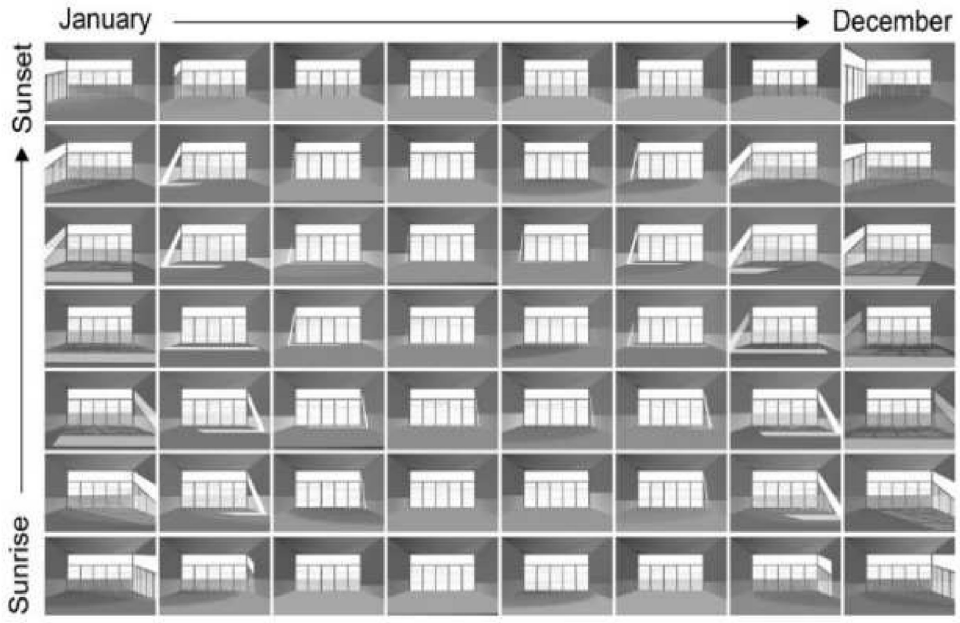
Residential design proposal by Mark Cabrinha

Daylighting Challenges

Daily & Seasonal variations

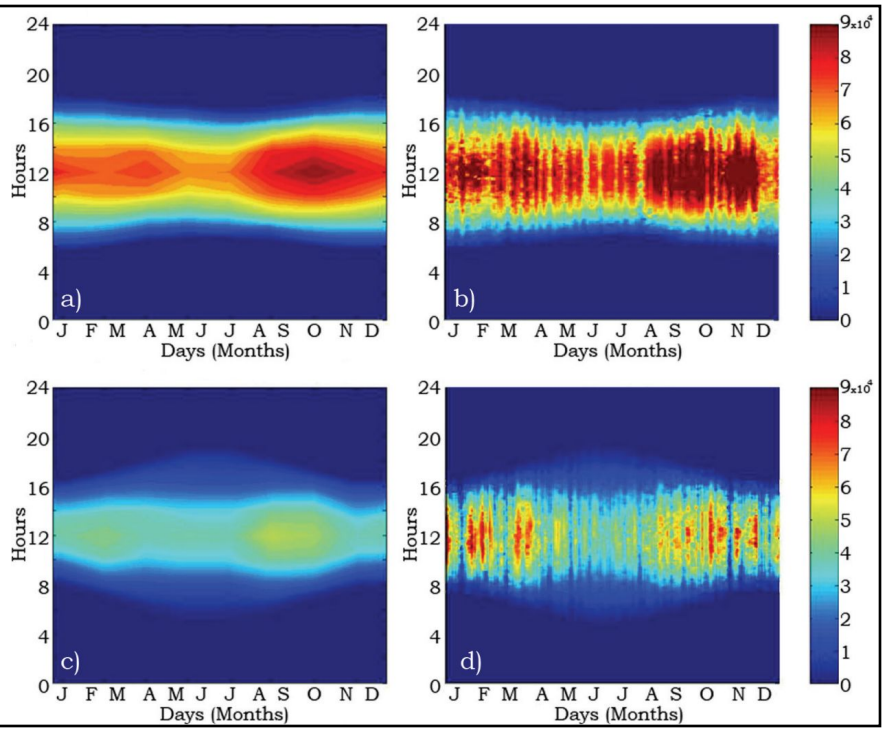
Discomfort/Disability Glare:
too much contrast reduces visibility





"Measuring the Dynamics of Contrast & Daylight Variability in Architecture: A Proof of Concept Methodology" Rockcastle & Andersen

"Graphical Representation of Climate-Based Daylight Performance to Support Architectural Design" Kleindienst, Bodart, & Andersen



Motivation

- Detect direct illumination on sensitive objects (artwork, chalkboard, tv, etc.)
- Detect under-illumination (when/where artificial light is needed)

What is correct sampling frequency?

- Daylighting experts hypothesized that 56 moments is sufficient (8 days of the year & 7 times of the day)

Visualization

- Requirements: Show minimum & maximum & average lighting For each each day/timespan (~45 days & ~ 2 hours)

How?

- Animation: full year, or range of hours for usage, multiple windows for day, animation of a day, play it on a loop, bin into common 'image features', sliders for 3 axes (day/time/weather)

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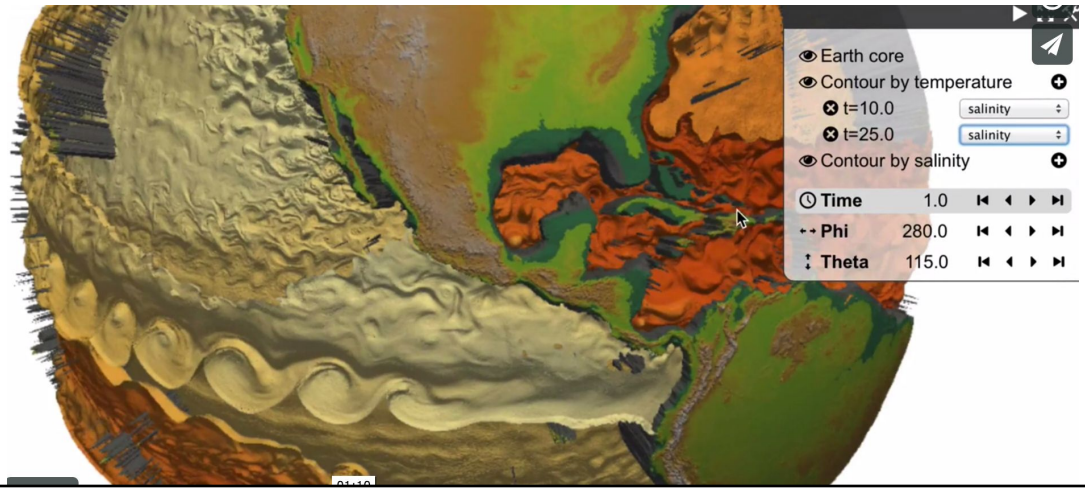
Reading for Today

- "An Image-based Approach to Extreme Scale In Situ Visualization and Analysis", Ahrens, Patchett, Jourdain, Rogers, O'Leary, & Petersen, Supercomputing 2014



- Motivation: power & I/O constraints
- Without in situ: write huge files to disk (size: ?), then later input those files for interactive exploratory visualization & analysis
  - However, storage bandwidth is significantly falling behind processing power & data generation
- Instead: compute & save many images to disk
  (size: 1 image 10^6, set of images 24 TB=10^{13}),
  then later explore & analyze by viewing those images interactively
  - Preserve important elements from simulations
  - Significantly reduce data needed
  - Be flexible for post-processing interactive exploration
  - Perform predefined (by expert scientist) set of analyses & predefined data bounds of interest
  - (Rarely) make automated decisions about what visualization & analyses to perform

Requirements/Features

- Animation & Selection of objects
- Control over Camera & Time
  - Temporal exploration encouraged
- Responsive, Interactive System (constant time retrieval & assembly/compositing of images)
  - Computationally intensive analyses (precomputed) encouraged
- Enables Metadata Searching
  - Image-based visual queries
  - prioritize exploration of matching results
- Provides interface for scientists to make decisions for the production of this in situ visualization

- When designing in situ visualization (preprocess) use Paraview
  - provides cost estimate (# of images, total size of image dataset, time to produce)
- No penalty/disincentive/bias against exploring “expensive” visualizations, because they have already been computed and saved as images
- Query image database for all images that match XXX, then sort by YYY
  - Where is the largest visible mass of low salinity in the northern hemisphere?
  - What is the “best view”?

- Compositing allows user to reason about simulation results from visualization space, not just image space rendering & sampling
- Interactive tool for displaying & compositing items from the image database with interface very similar to Paraview – simulates experience of exploring simulation data
  - Interactive, at least 12 fps (surprisingly slow? What's the bottleneck? Could some quality be sacrificed for speed?)
- Data saved per image for compositing (2X normal image)
  - color (rgb) + depth (z-buffer)
  - sprite layers
  - For opaque layers: save simulation data (geometry?) which allows recoloring/relighting
  - Image provenance (how image was created, parameters, etc.)
  - Images can be compressed into video format

- Well-written, good illustrations
- Good motivation & good explanation of features… but lacked detail on how things worked
- Impressive use of real-world datasets
- Niche but critical audience for this tool
- How powerful are their camera settings? Can you rotate about an arbitrary point or limited to the initially chosen rotation center?
- What hardware is needed to run the simulation? *A supercomputer.*
- What hardware is needed to analyze/visualize the resulting data? *A fancy desktop or a supercomputer*
- What hardware is needed to display/composite the pre-generated visualization images? *A fancy desktop*
- Image based (feature based) search of simulation results is inspiring for my final project
- MPAS: Model for Predication Across Scales
- 24 TB, 2^{15} is "reasonable". Impressive. Ridiculous.
- Each image 1 MB. Will increasing the image size help scientists better explore the data? Or is this the limit of the simulation resolution?

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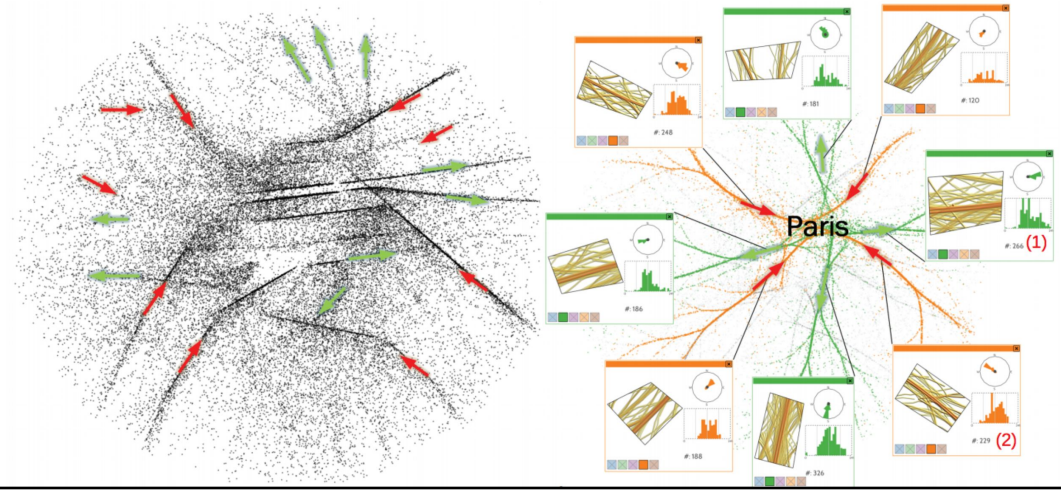
Reading for Today

- “Visualization, Selection, and Analysis of Traffic Flows”, Scheepens, Hurter, van de Wetering, van Wijk, IEEE InfoVis 2015



- Analyzing trajectories is important & special
  - If you only look at current position, you're missing stuff
  - You can extrapolate if you have position & velocity
  - This paper is not about objects with un-predictable, non rule based movement (airplanes not animals or football players)
- Point data manually or automatically clustered into Voronoi cells.
- Discover/search/identify traffic flows
- Summarize/aggregate/annotate dynamics of a flow
- Explore/compare flows to each other
- Produce a visualization

- Tried particles that move with actual or synthetic or constant speeds.
  - Does it allow separation into different flows (higher altitude = closer to camera = faster)
- Our other papers this term: User Study of Novices vs this paper: Expert Feedback (2 controllers w/ 10 years experience at busy French airports!)
  - Validate what they knew to be true
  - Looked for and tried to understand outliers
- Experts thought that tool was useful for:
  - Education/training of new controllers
  - Studying air space "tangle"
  - Complement to existing tools
  - Communication, study statistics, forecast

- Applies to self-driving cars
- Experts are great! But are experts biased to like tools similar to ones they already have?
- Brushing
- Real velocity is distracting… what?
- Use this visualization style to study packet routing protocols?
- Where is the video? I am apparently unable to use Google to find the video.

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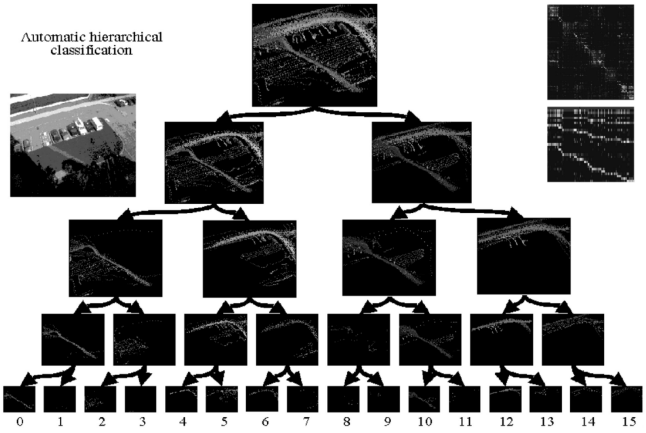
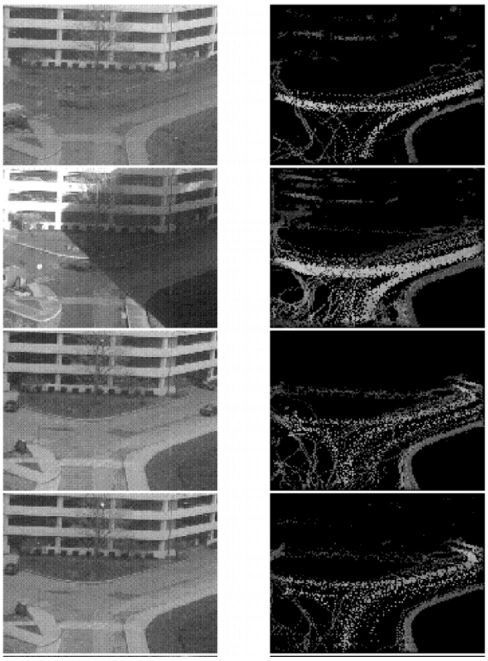
Reading for Today

- "Learning Patterns of Activity Using Real-Time Tracking", Stauffer & Grimson, IEEE PAMI 2000





- Goals:
  - detect typical activity patterns at given time of day
  - detect unusual activities
  - detect unusual interactions between objects
  - not require complicated installation/calibration
  - online - live data for security
- Prior work / Challenges
  - background subtraction against a single image fails over time, error accumulates, ghosting
  - lighting changes
  - slowly moving trees
- Techniques
  - mixture of Gaussian distributions
  - Kalman filter
  - expectation maximization
  - connected components
  - vector quantization (faster than k-means)

- Results
  - variety of weather
  - cars, birds, mice, fish, people,
  - branches, water, specularity, slowly moving objects, noise
  - classify patterns of movement
- Notes from Submitty
  - learned similar techniques in machine learning and computer vision coursework
  - not really visualization related, not clear the connection to this course
- Discussion
  - is this ethical? it could detect serious crime
  - no one mentioned the challenge of the figures being in B&W (but captions referred to color)

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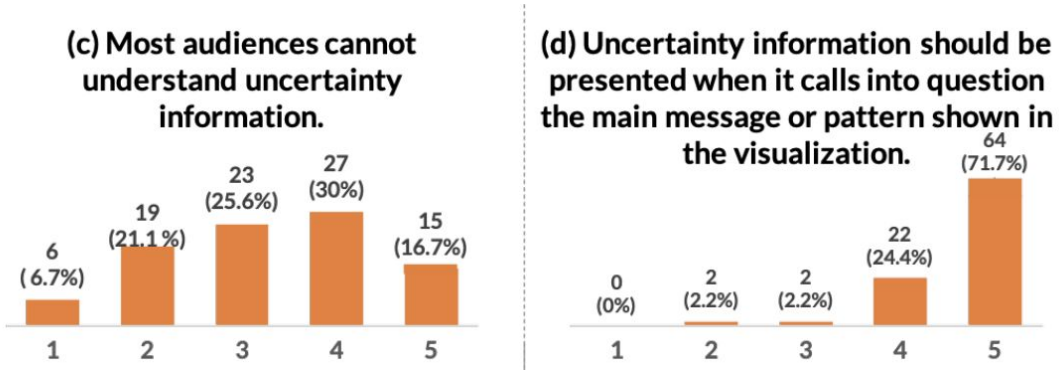
Reading for Tuesday *pick one*

- "Why Authors Don't Visualize Uncertainty", Hullman, IEEE VIS 2019



Reading for Tuesday *pick one*

- "Beyond Generating Code: Evaluating GPT on a Data Visualization Course", Chen, Zhang, Wang, Troidl, Warchol, Beyer, Gehlenborg, & Pfister, IEEE EduVis 2023

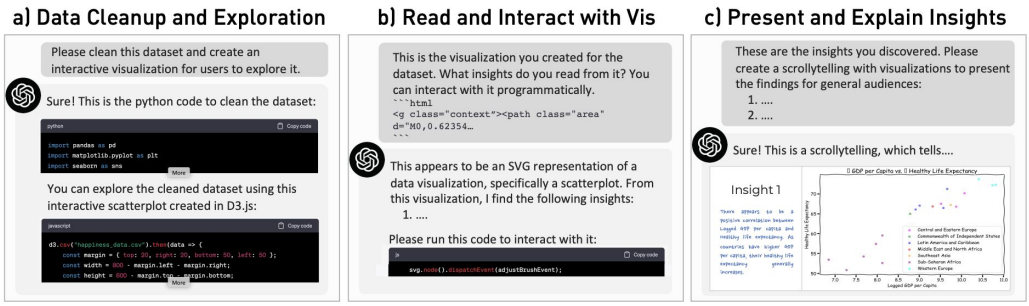


Figure 1: Our experiments show that GPT can a) clean and explore CSV datasets, b) read visualizations in SVG format, interact with visualizations through dispatching Javascript events, and c) create explanatory visualizations to present data insights.

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