Non-Photorealistic Rendering

Evaluating NPR

Tobias Isenberg

Overview – What Questions to Ask?

- how and why is NPR good anyway?
- is my application/approach accepted by users, does it serve the intended purpose?
- how and why does NPR imagery assist a certain goal (recognition, perception, …)?
- what do people think about NPR imagery?
- how does it compare to hand-drawing?

→ address these in three groups:

  - motivation for NPR
  - assisting a certain goal
  - comparison with hand-drawn examples

Evaluating NPR

A Motivation for Non-Photorealistic Rendering

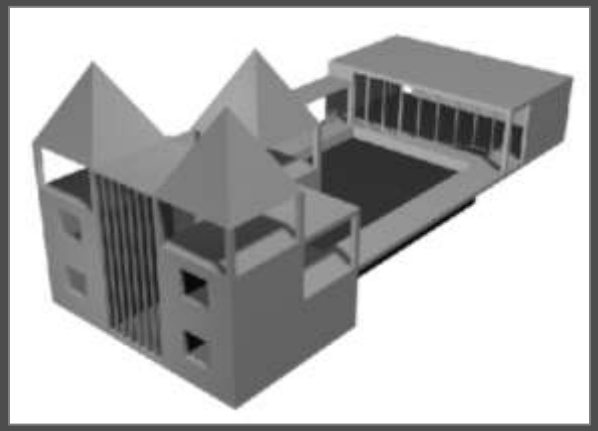
The Effect of NPR

- evaluation of the effect of NPR with 54 architects
  - to compare image usability w.r.t. communicative goals
  - three major groups of aspects:

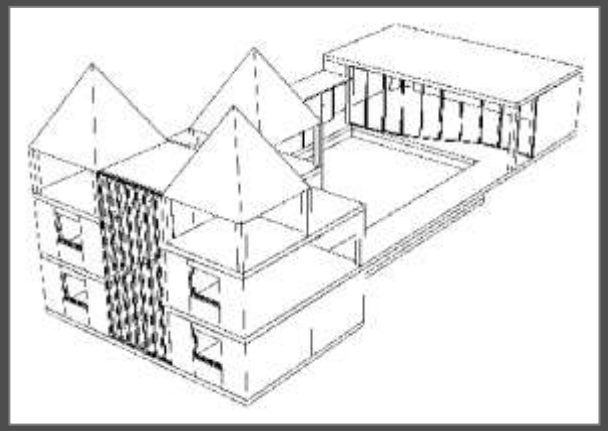
→ *cognitive* aspects: understandability, clarity, spatiality

→ *affective* aspects: emotions, interest, imaginativeness

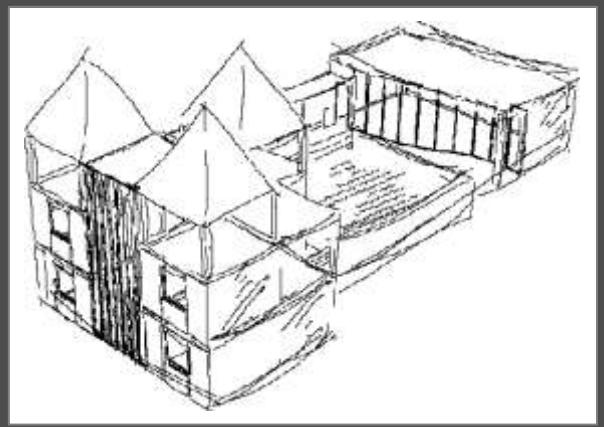
→ *motivational* aspects: invitation to participate in design



shaded image



CAD plot/line image



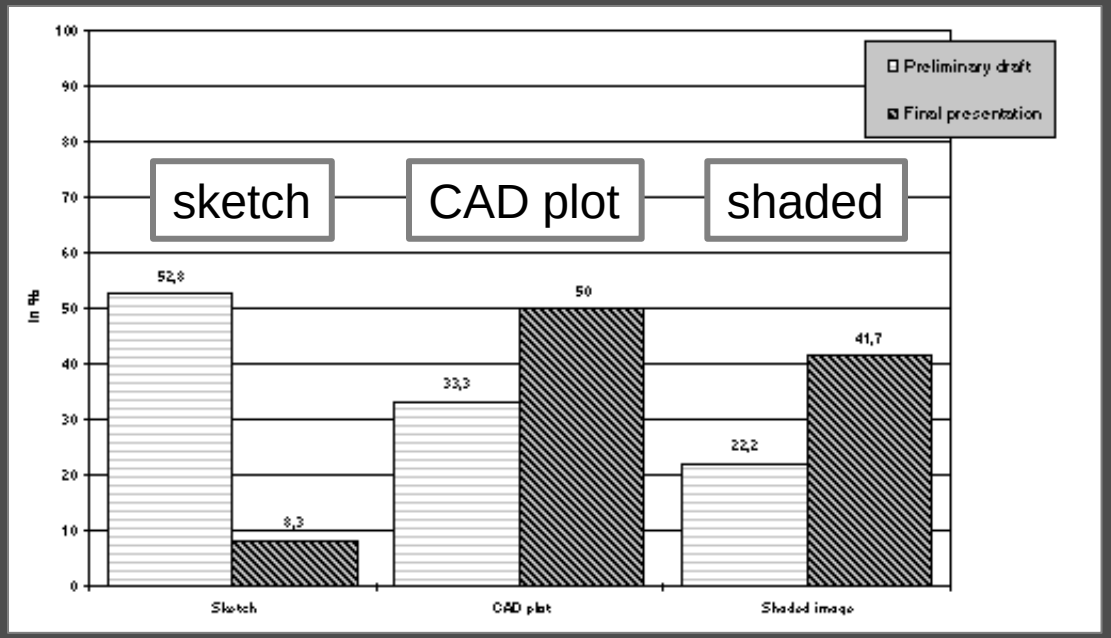
NPR sketch

The Effect of NPR

- three hypotheses:
  1. sketches are preferred for presenting early drafts
  2. sketches perform better for communicating affective and motivational aspects, exact images perform better for cognitive aspects
  3. sketches stimulate viewers more to participate in design
- all hypotheses confirmed
- let's look at H1 and H3 in detail

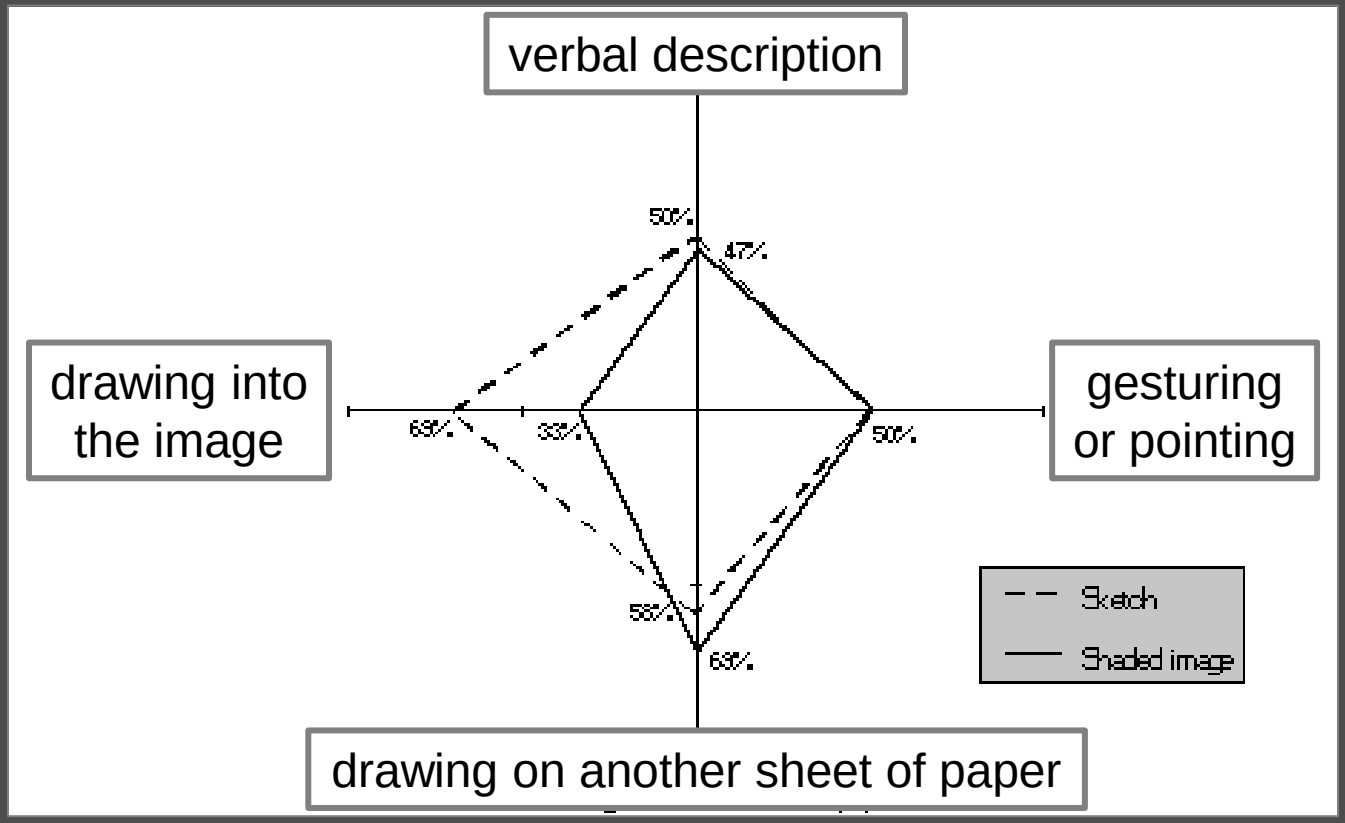
The Effect of NPR

- H1: image use in design process
  - sketches chosen significantly more often than line or shaded images for early drafts
  - sketches chosen significantly less often for presenting final results
  - sketches: show preliminary character, less focus on detail
  - plot/shaded: exactness, often desired for final evaluation



The Effect of NPR

- H3: stimulation to participate in the design



  - sketches encourage people to voice their opinions and to suggest changes, do not look as if cast in stone

A Psychology of NPR

- application of psychological theory to NPR
  - general psychology, e.g., figure-ground segregation

  - social psychology, e.g., social perception and judgment

A Psychology of NPR

- application of psychological theory to NPR
  - environmental psychology, e.g., participation and interaction in environments

- results
  - NPR can guide people's actions & behavior
  - NPR can affect people's social perceptions (danger, safety, strength, weakness, …)
- use of NPR for intent-driven illustration

Guiding People's Attention

- evaluation of where people look in photos and NPR
- use of eye tracking setup
  - to derive where people look on photos, this guides the image creation
  - to evaluate where people look on differently abstracted images

Guiding People's Attention

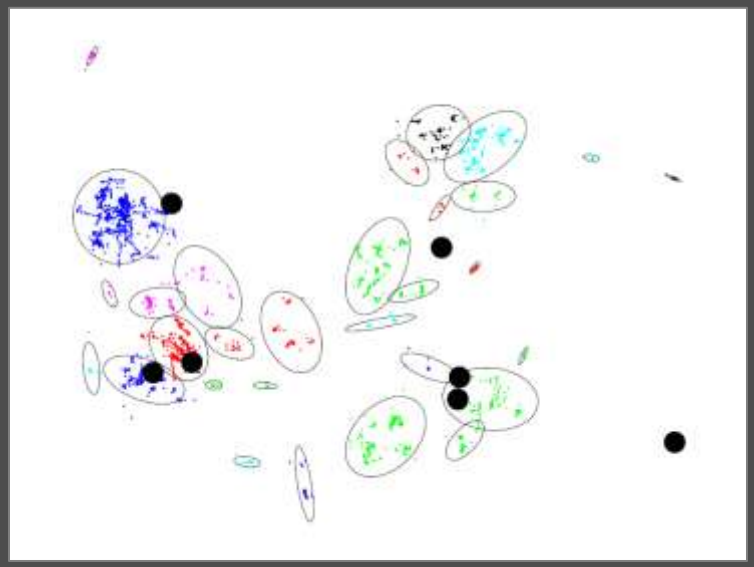
- five types of images
  - photography

  - two general abstraction levels: low and high

  - two selective abstraction levels: by salience or from eye tracking

Guiding People's Attention

- a number of results:
  - effect of local and selective detail in images on how people look at them: significantly fewer fixation clusters
  - also effect on distance of clusters to detail points: people actually look at used detail points



  - people look at less detail points for abstraction from eye tracking, compared to abstraction from salience
  - distance to detail points closer for eye tracking, compared to abstraction from salience

Evaluating NPR

Assisting a Certain Goal

Space Perception in VR Environments

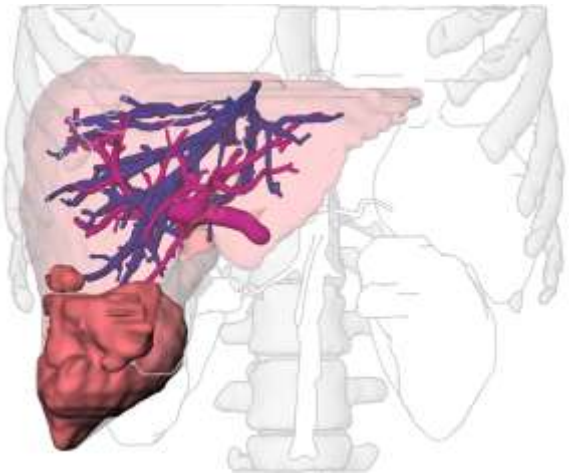
- HMD stereo environment
  - looking at space perception
  - task: directed walking
- study approach
  - see target at distance (2m, 3.5m, or 5m) in either real or NPR view
  - walk to targets without vision
- results
  - people overestimated distances by 34% in NPR condition
  - consistent with traditionally rendered environments

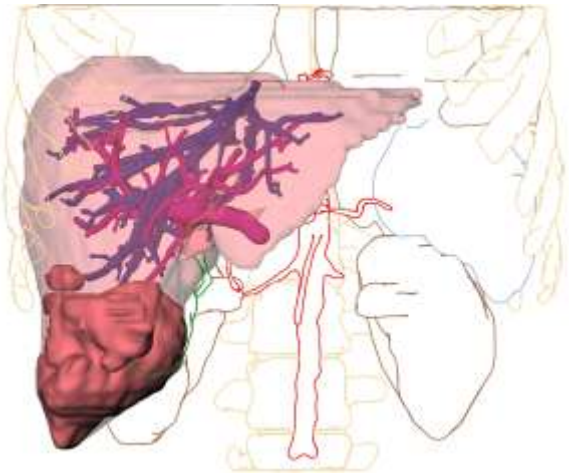
Face Recognition and Learning

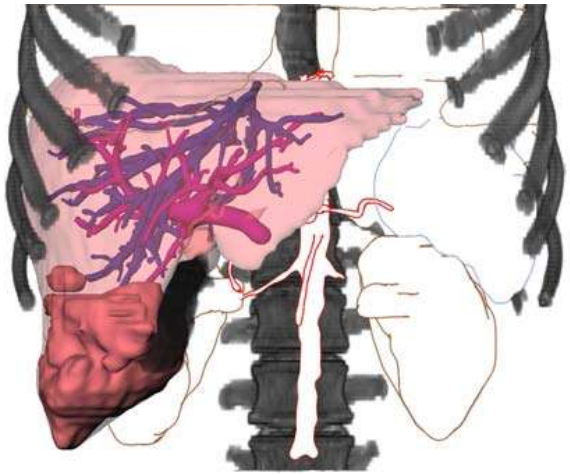
- comparing speed of face recognition and learning
  - for b/w photographs
  - for b/w illustrations
  - for b/w caricatures
- recognition time
  - use familiar faces
  - illustrations and caricatures as effective as photographs
- learning new faces
  - unfamiliar faces and associated names presented
  - sets shuffled, names to be named, repeated until correct
  - illustrations 2x faster, caricatures 1.5x faster

Application in Medical Illustration

- objects in focus, near the focus, and as context
- combinations of lines, shading, volume rendering
- comparison of different combinations of styles
  - specific application domain: experts in liver surgery
  - questionnaire-based evaluation, comparing 2 images per page: general impression, specific tasks/problems

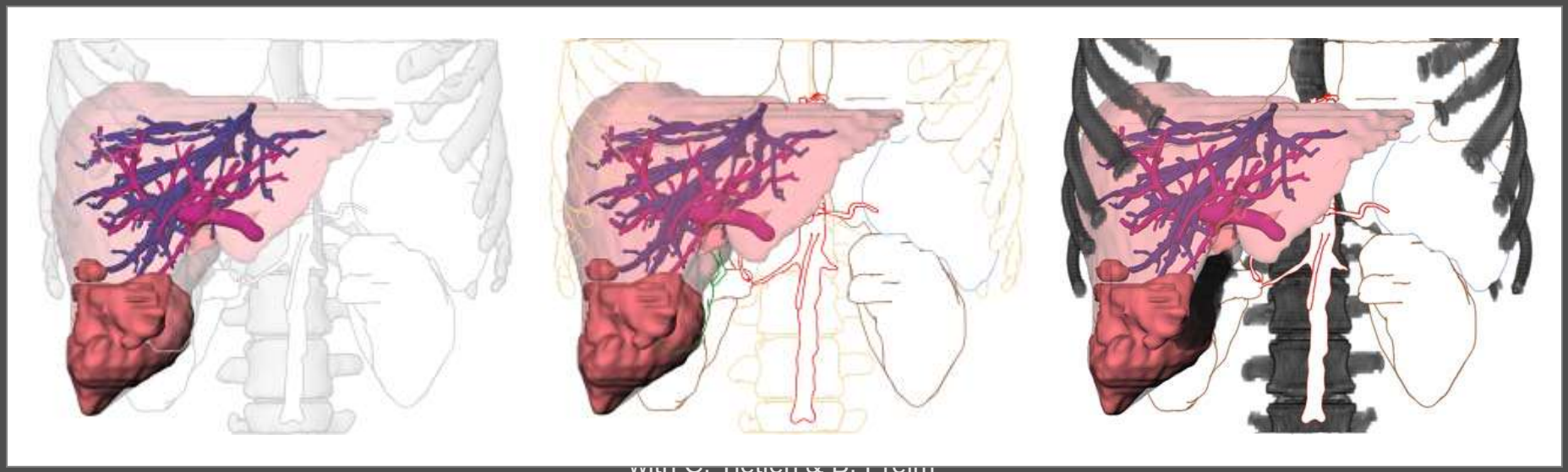






Application in Medical Illustration: Results

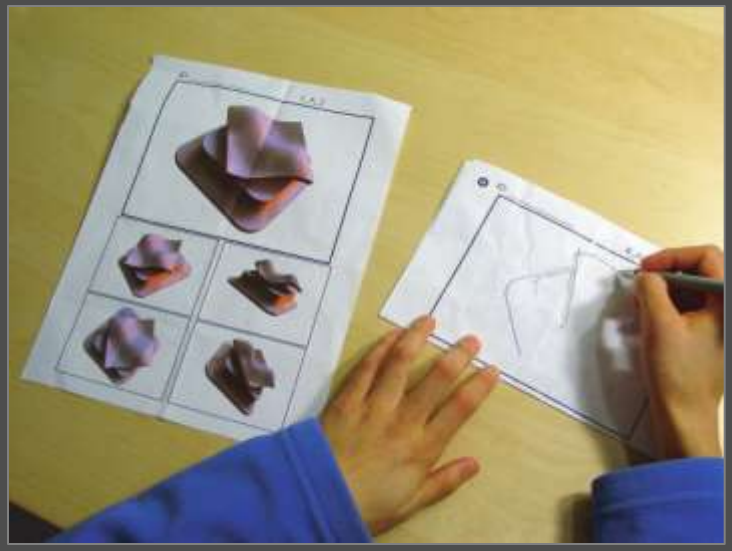
- less context information, but context is necessary
- silhouette representation of context appropriate
- lay people's opinions similar
  - only silhouettes not good, some shading important
  - colored silhouettes better, also slight shading good



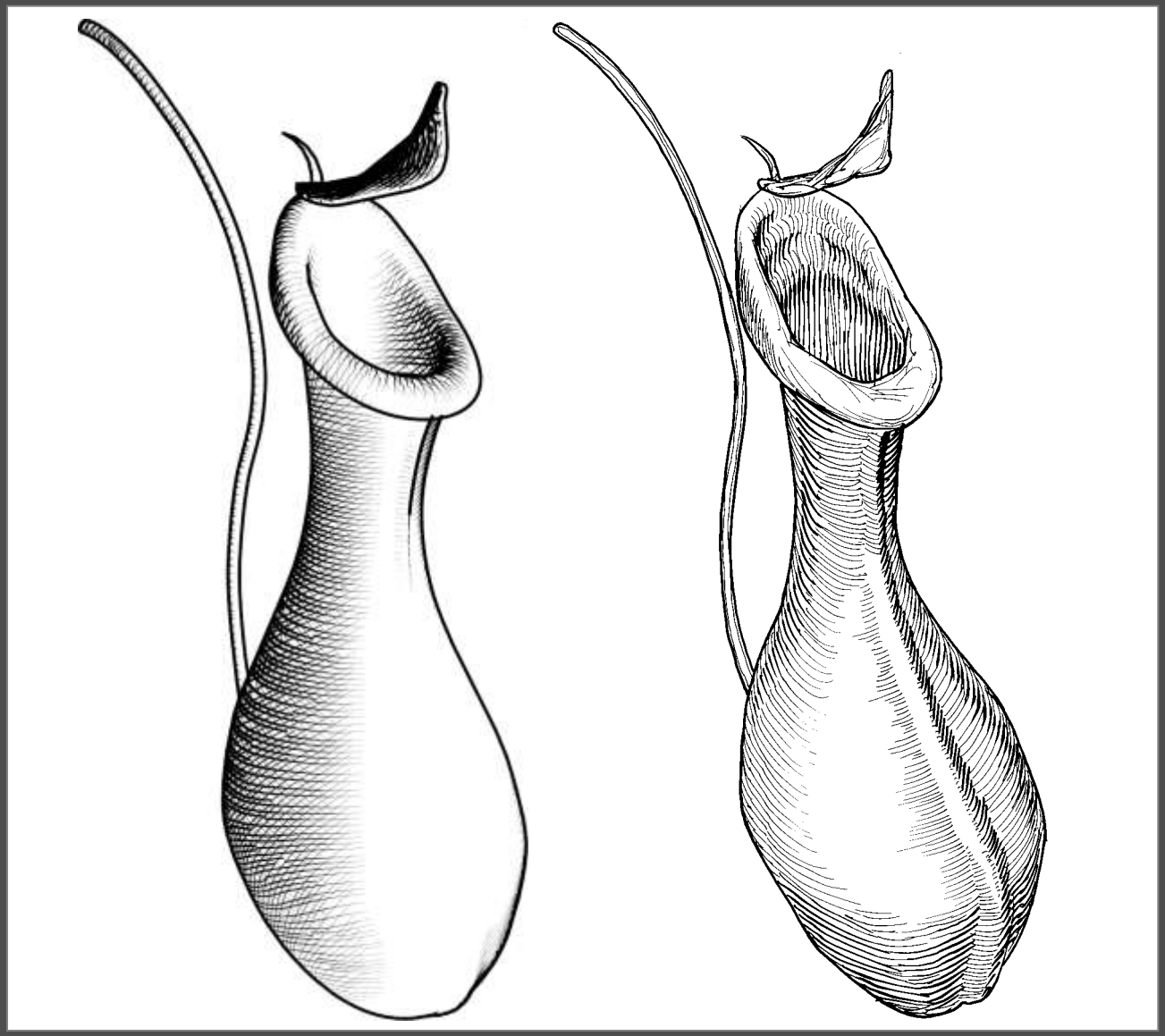
with C. Hetjen & B. Preim

Evaluating NPR

Comparisons with Hand-Drawn Examples



“High-Quality Hatching” …?



with P. Neumann, S. Carpendale, M. Sousa & J. Jorge

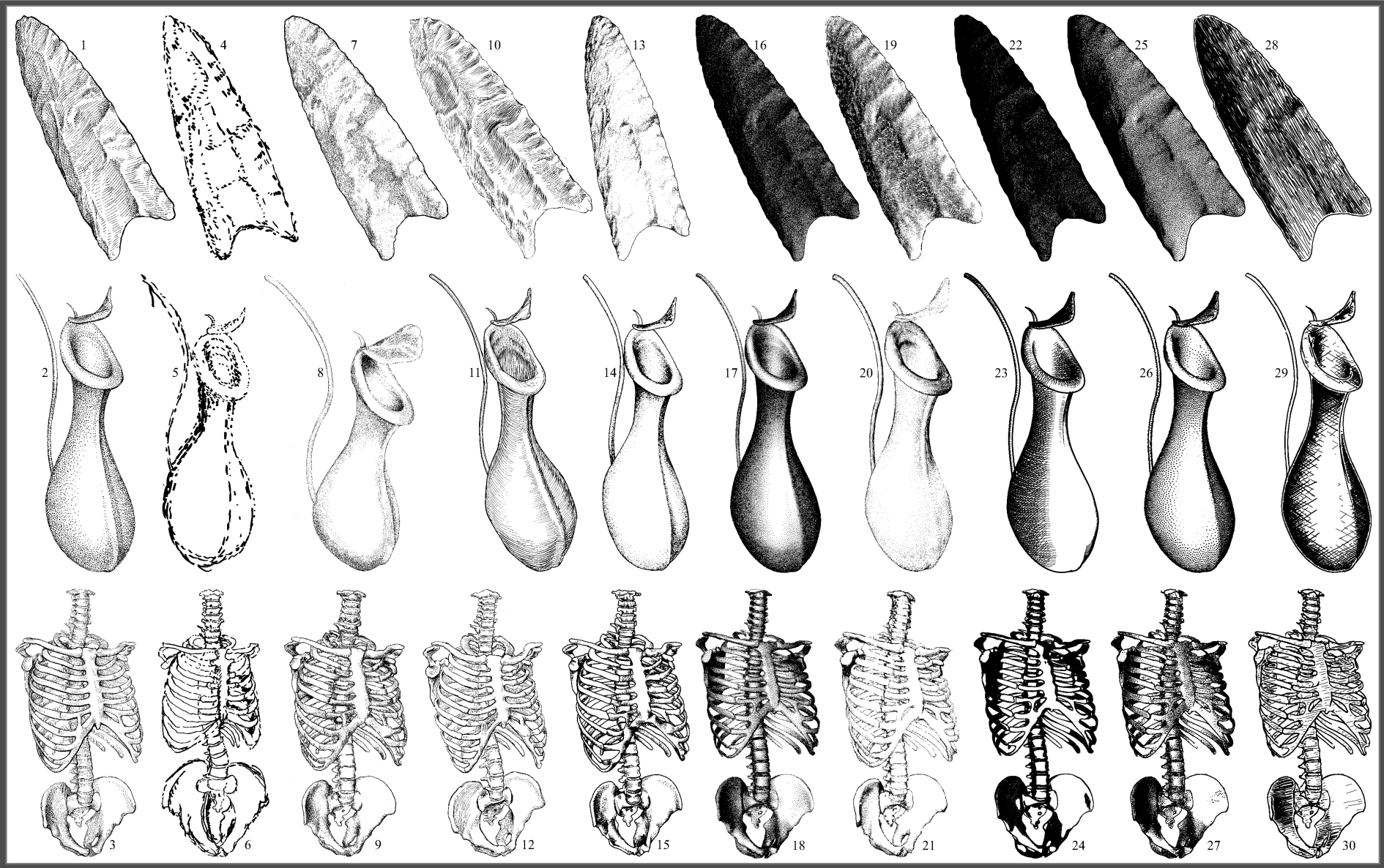
How to evaluate drawing techniques?

- ask people, ask an expert?
  - issue: how to ask the right questions? → avoid bias
  - techniques: qualitative, ethnographic techniques
- measure some quality?
  - issue: what is the right quality to measure?
  - technique: statistical approaches
- mixed approaches?
  - issue: how to validate current algorithmic approaches?
  - technique: directly compare drawings by people with those generated by an algorithm

Side Note: Ethnographic Studies

- qualitative evaluation technique
  - extraction of non-numeric criteria
  - e.g., opinions, feelings, concepts, common practices, etc.
  - major goal: not to bias/influence people
- bias already by wording of questions:
  - What do you like about this image/illustration?
  - Do you think this image/illustration is effective for you?
  - Why do you think this image/illustration is bad?
- question-based interviews will always bias people
- use techniques instead that do not ask questions but extract opinions/concepts otherwise

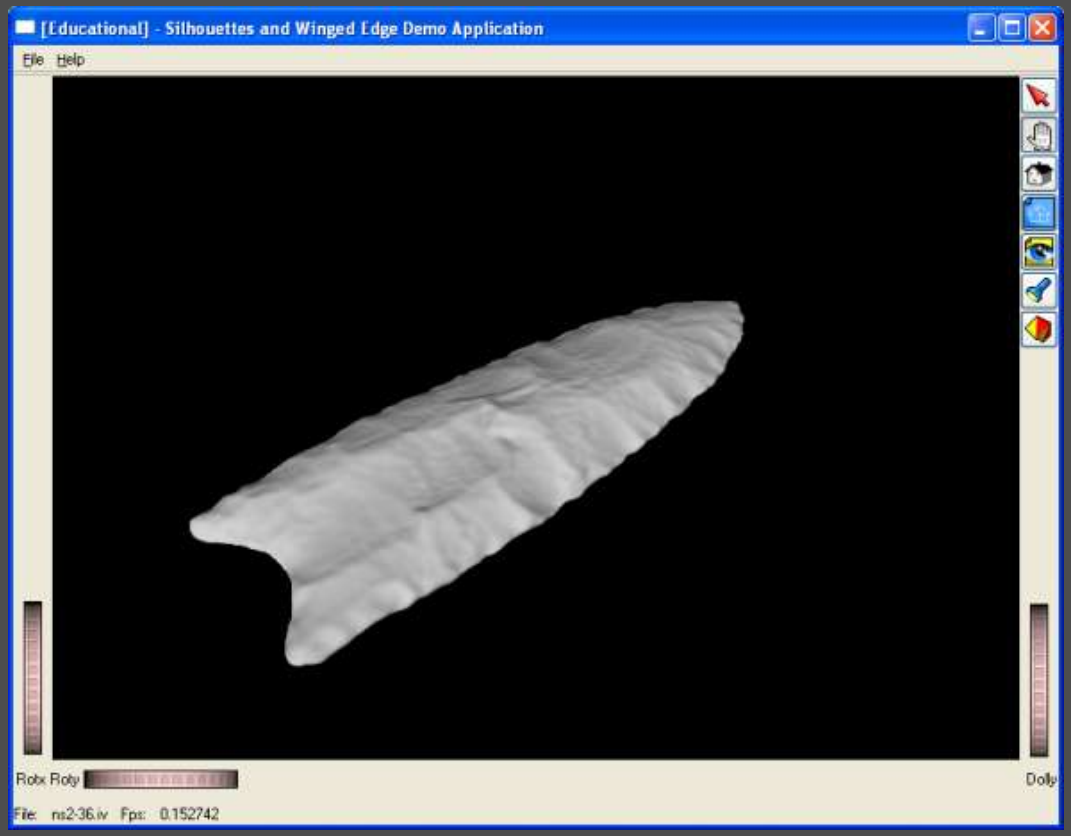
Ethnographic Evaluation of NPR

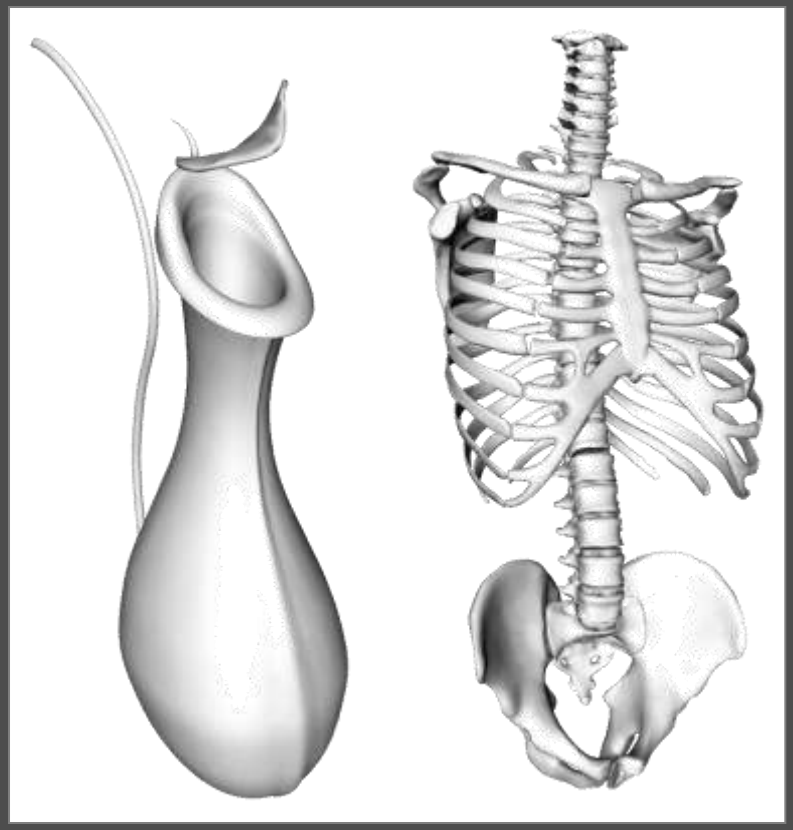


Ethnographic Evaluation of NPR

- scope of the evaluation: compare NPR pen-and-ink techniques with ones created by illustrators by hand
- 5 NPR techniques compared to 5 illustrators
  - hatching and stippling techniques
  - 3 different shapes: archaeology, anatomy, biology
  - same default view for each object
  - (5+5) × 3 = 30 high-resolution images
  - each image printed individually on Letter-sized paper
  - randomized order of images
- ethnographic combined with semi-structured interview technique

Ethnographic Evaluation of NPR





with P. Neumann, S. Carpendale, M. Sousa & J. Jorge

Ethnographic Evaluation of NPR

- pile-sorting study
  - get image stack
  - ask participant to sort
  - use own criteria (except object type or size)
  - use as many piles as necessary
- discussion afterward
  - what characterizes each pile, why are image in a pile?
  - also ask a number of questions:

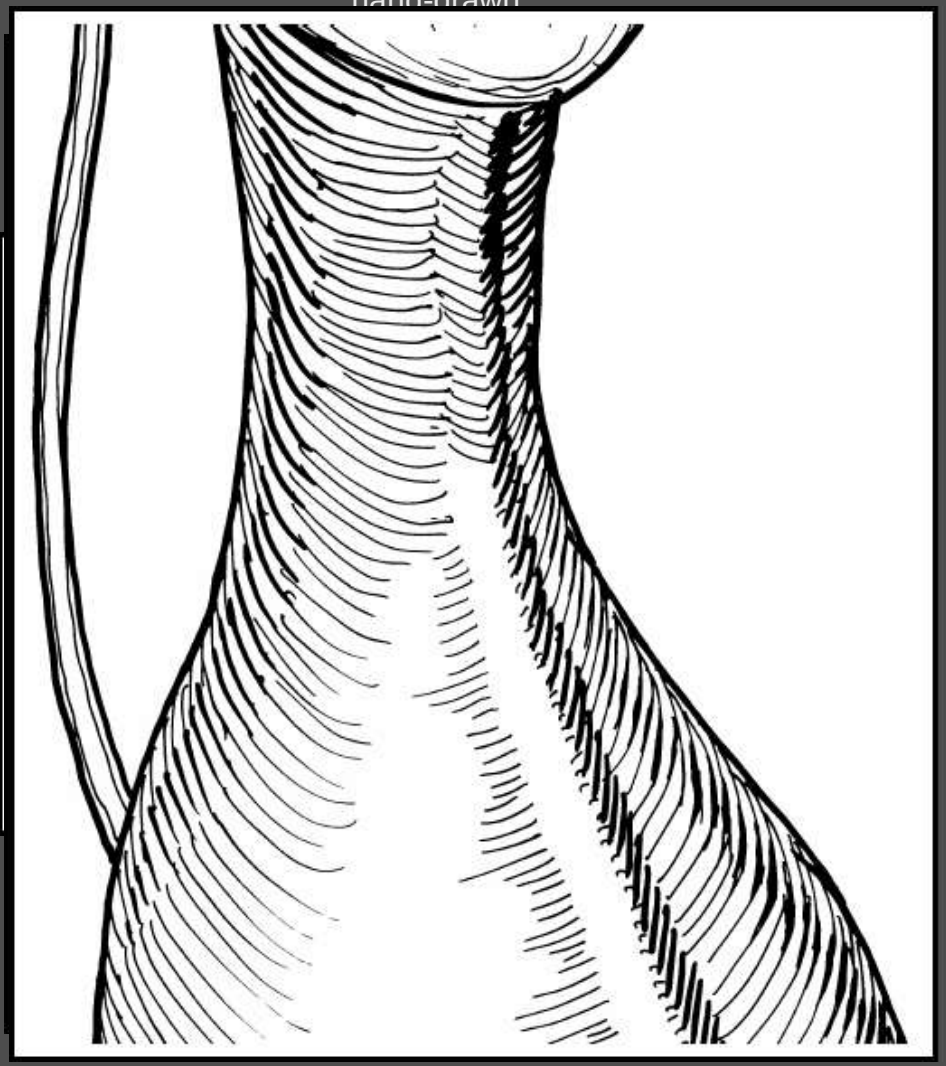
  → possible application domains? useful for illustrations?

  → look particularly hand-drawn or computer-generated?

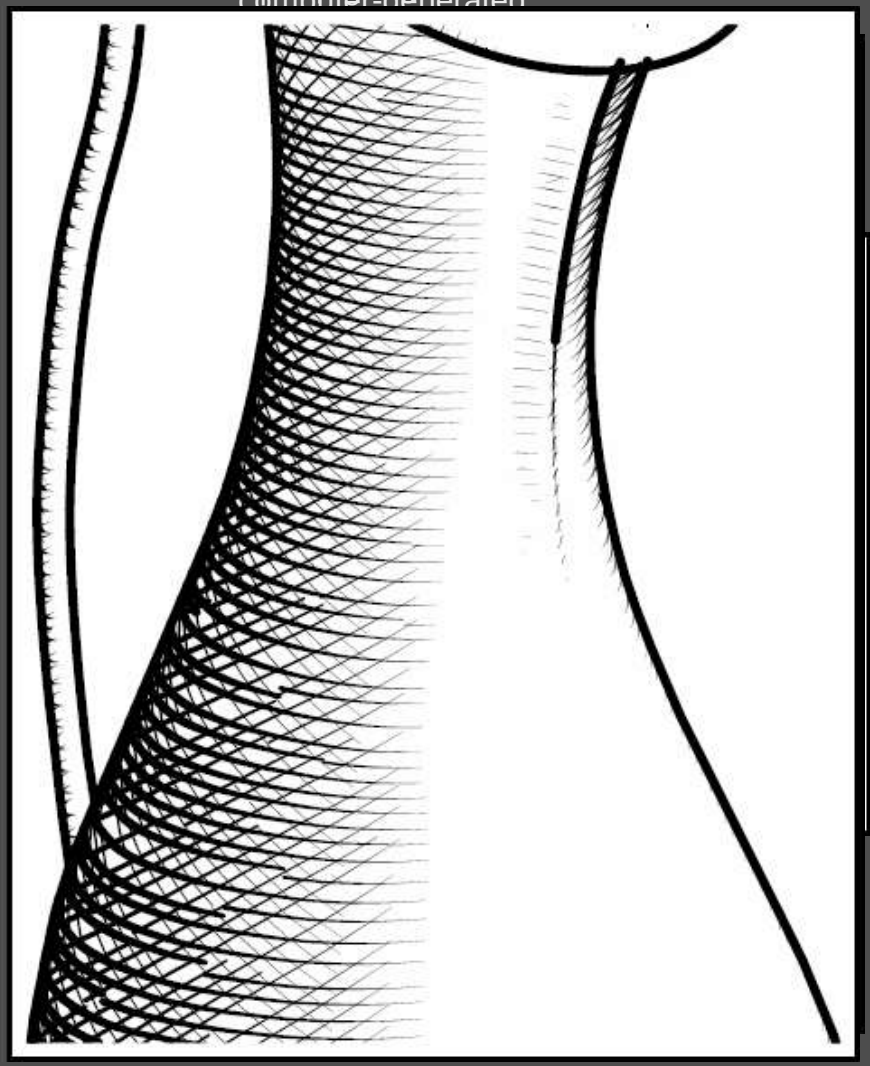
with P. Neumann, S. Carpendale, M. Sousa & J. Jorge

Ethnographic Evaluation of NPR: Results

hand-drawn:



computer-generated:



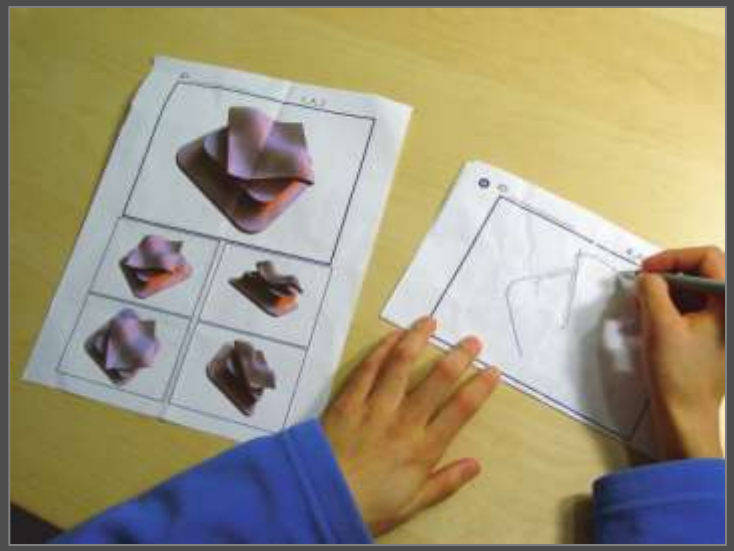
with P. Neumann, S. Carpendale, M. Sousa & J. Jorge

Ethnographic Evaluation of NPR: Results

- NPR Turing test not yet passed
- differences in a number of areas
  - amount of detail
  - complexity of shading for shape depiction
  - surface and material depiction
  - interpretation vs. exactness of shape
  - artifacts in mark placement
  - "character" of individual marks
- does not mean that one is better than the other
  - NPR images liked for their precision and "(photo-)realism"
  - hand-drawn images liked for their character and style

Where do people draw lines?

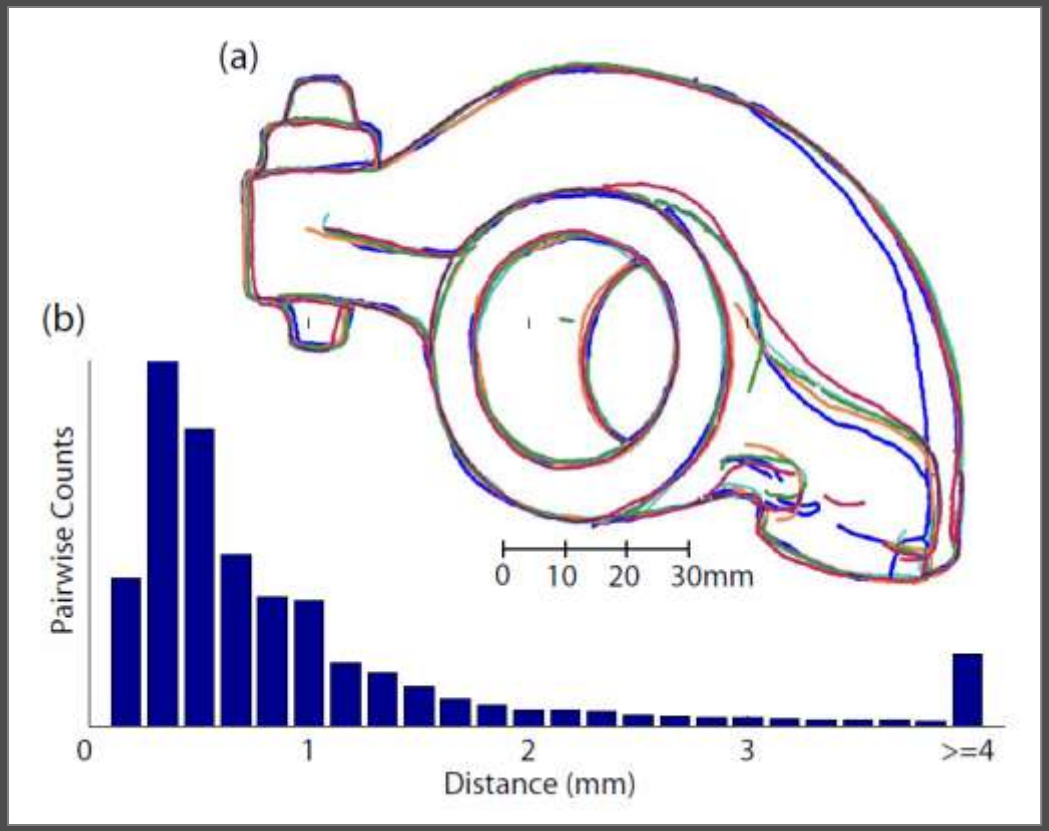
- goal: correlate people's line drawings with NPR
  - compare hand-drawings with current NPR line rendering concepts (silhouettes and feature lines)
  - derive algorithms that predict where artists would draw lines with certain probabilities



- approach: let people draw shapes from CG images
  - 2 steps: free drawing in frame and tracing a faint copy
  - traced images scanned and registered within frame
  - post-processing to obtain one pixel wide lines
  - 29 artists, each person drew 12 shapes

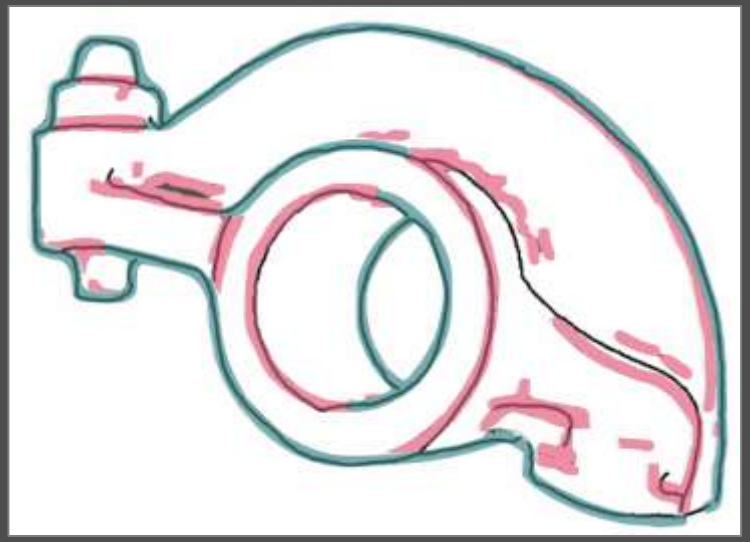
Where do people draw lines? Results

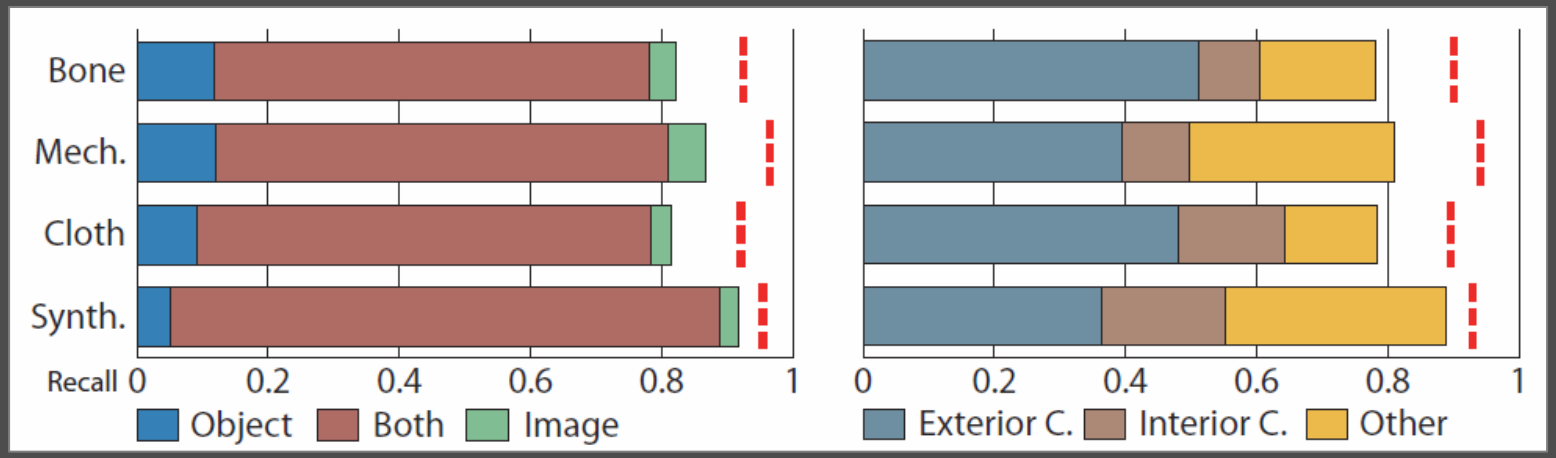
- images very similar to each other
  - 75% within 1mm for pair-wise comparisons
  - (a): five drawings overlaid in different colors
  - (b): pair-wise closest distance



Where do people draw lines? Results

- many hand-drawn lines are part of the CG line zoo
  - lines are near (1mm)
  - silhouettes/ occluding contours
  - suggestive contours
  - apparent ridges
  - image edges





Where do people draw lines? Results

- ca. 75% of hand-drawn lines are within 1mm of other hand-drawn lines
- overlaps mainly at silhouette/occluding contour (57% of all lines drawn)
- 80–90% of hand-drawn lines can confidently be explained with the CG line zoo
- remainder based on other local criteria or on more global criteria

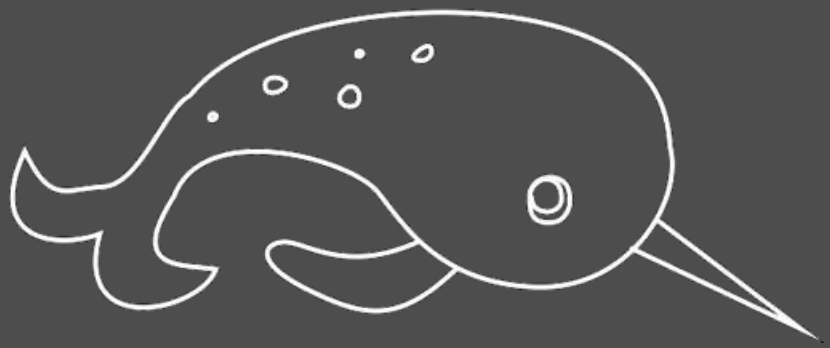
Evaluating Computer-Generated Pixel Art

- pixel art: inspired by early computer graphics

- now an art form in itself

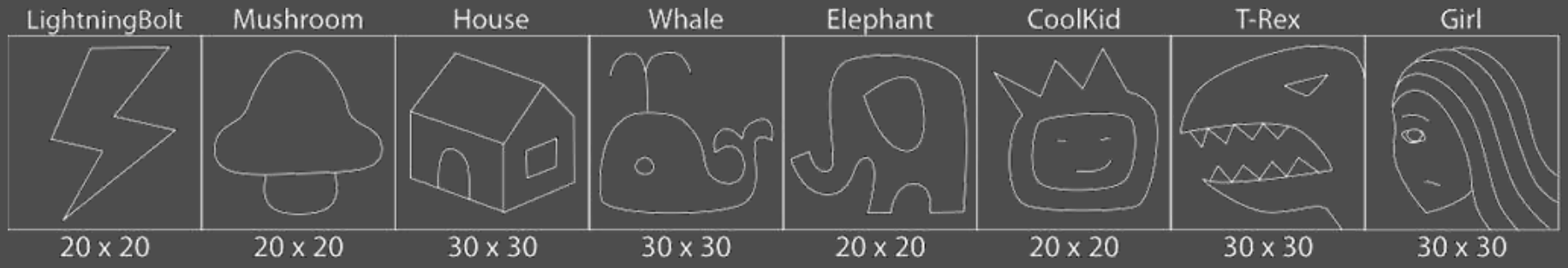
Evaluating Computer-Generated Pixel Art

- replication of pixel art aspects with NPR techniques
- based on principles used by pixel artists



- how does it compare to
  - other computer-generated pixelations (Photoshop etc.)?
  - human-created pixelations?
  - artist-created pixelations?
- crowd-sourced comparison …

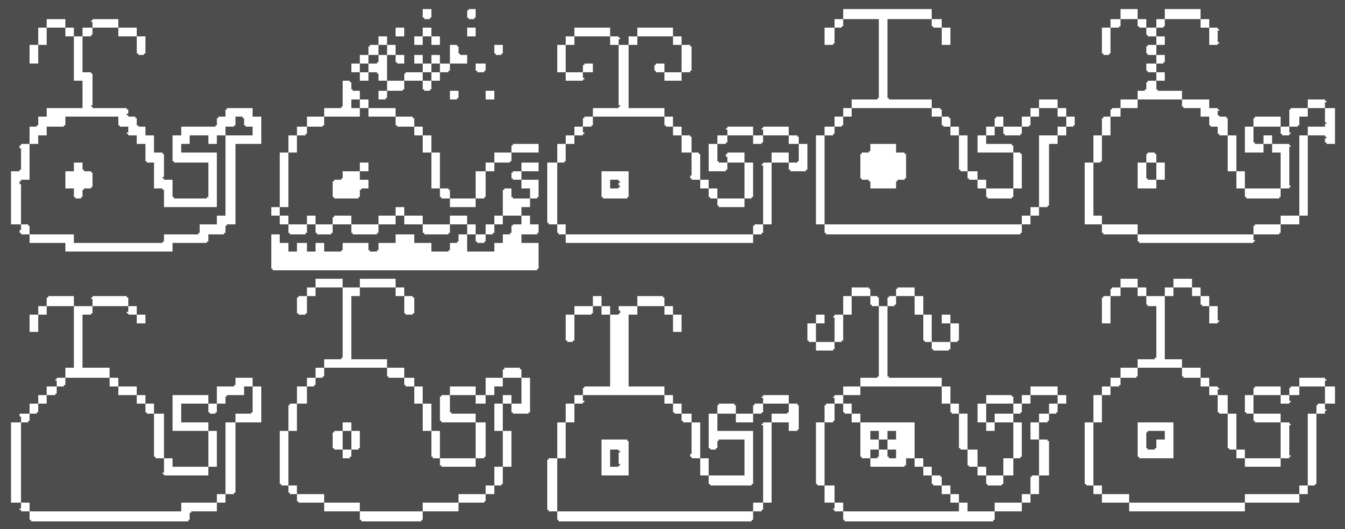
Evaluating Computer-Generated Pixel Art



- NPR (pixelator), Illustrator, Photoshop:

Evaluating Computer-Generated Pixel Art

- 148 hand-drawn sets (crowd-sourced)



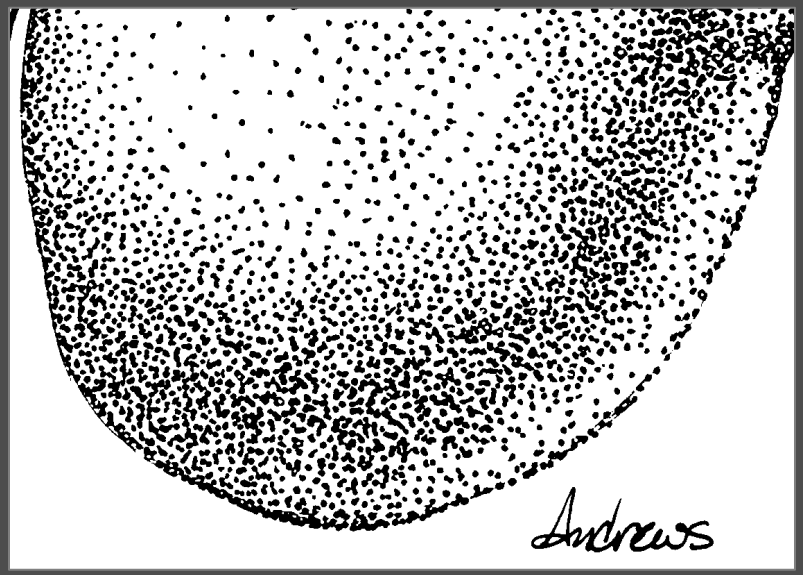
- averages of the human-drawn examples:

Evaluating Computer-Generated Pixel Art

- crowd-sourced rating phase: 200 participants
  - pair-wise comparisons, selected from CG or HD groups
  - "Choose the one that looks better"
  - "Choose the one that looks more similar to the original"
- results:
  - Pixelator outperforms Photoshop & Illustrator
  - Pixelator outperforms humans overall (not individually)
  - images by pixel artists did not outperform Pixelator
    - pixel artists deviated from example
    - results reflect the questions that were asked
    - pixel artists not rated highly on aesthetics; potentially because some participants participated in both parts of the study

Statistical Evaluation of Stippling

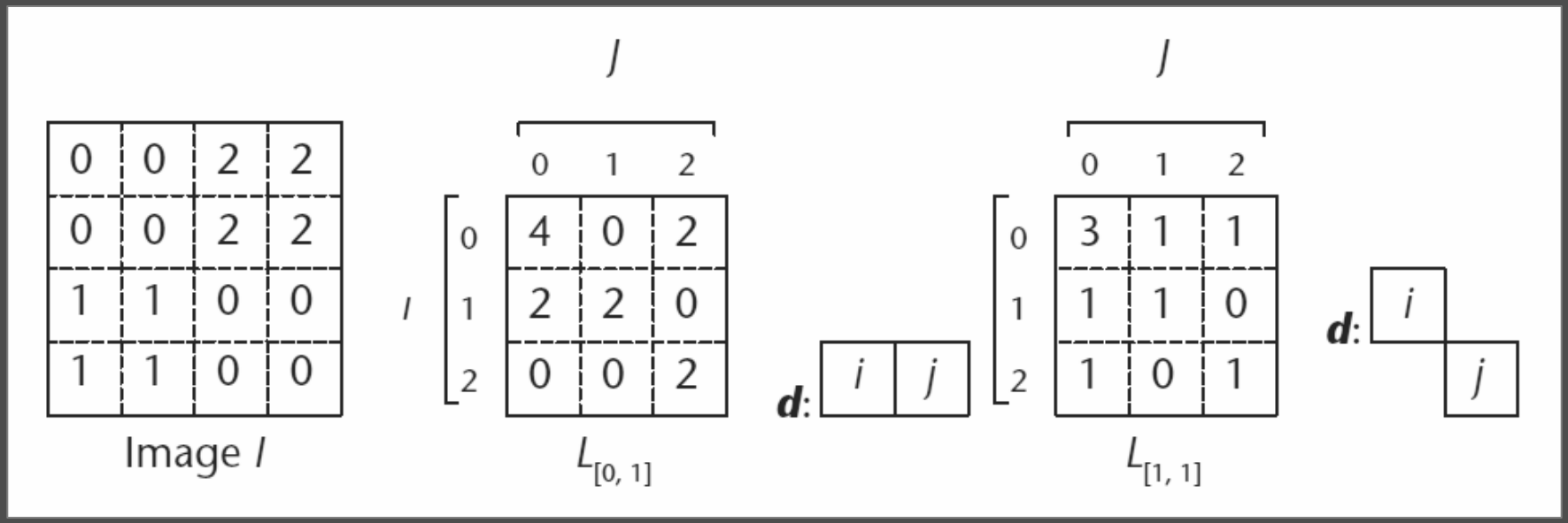
- what characterizes a hand-drawing style?
- stippling: distribution of stipple points
  - can be analyzed with respect to each other
  - statistical metrics to analyze properties of distribution



- goal: compare hand-drawn stippling to CG images

Statistical Evaluation of Stippling

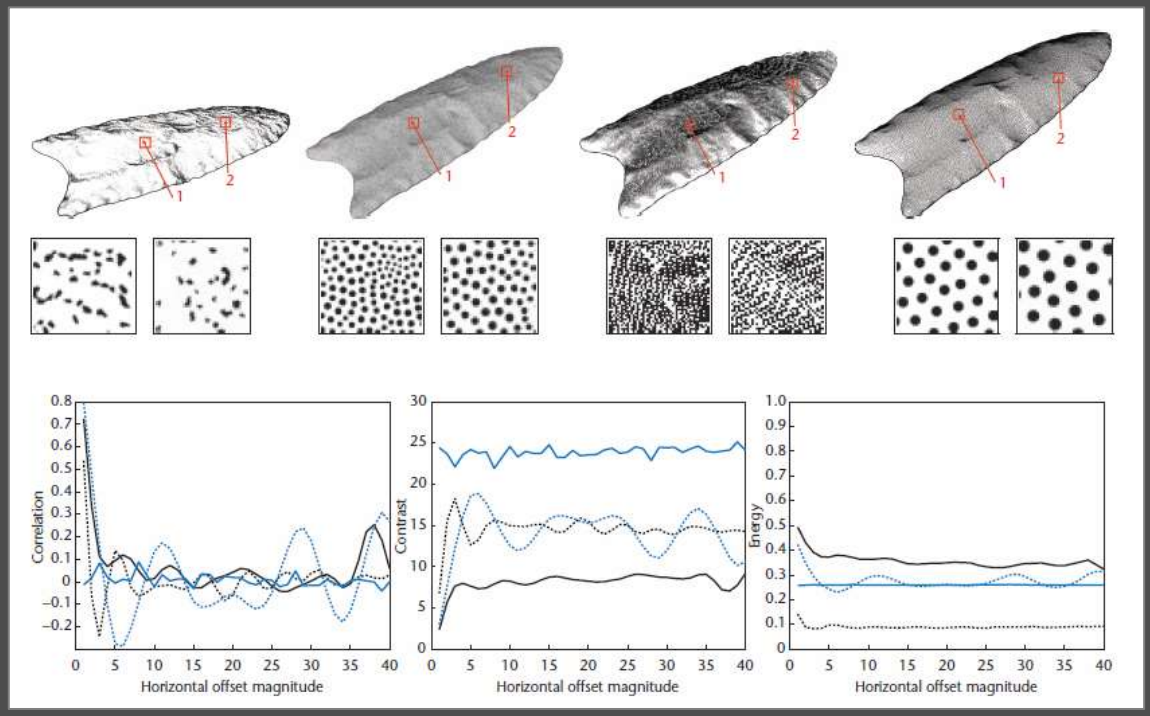
- based on gray-level co-occurrence matrix (GLCM)
  - 2D array recording the number of co-occurrences of gray level values in given spatial relationship
  - based on given offset vector, example:



  - probability that a given gray value occurs in certain spatial relationship with respect to other gray value

Statistical Evaluation of Stippling

- CG images:
  - higher correlation of stipple placement to distance from other stipples in certain distances



- other results:
  - artifacts of CG stippling can be found in statistics
  - hand-drawn stippling has similarities to natural textures

Evaluating NPR

Summary

Evaluating NPR – Summary

- new insight on where NPR techniques are applicable
- new insight on what people think about NPR images
- new insight on usefulness of NPR for specific domains and applications
- different techniques
  - qualitative and quantitative study techniques
  - experiments often w.r.t. given goal/purpose/domain
- (potential) ultimate goal:
  - algorithms to measure quality of produced images
  - algorithms to produce better images for a given purpose