

Interactive NPAR: What type of tools should we create?

Tobias Isenberg



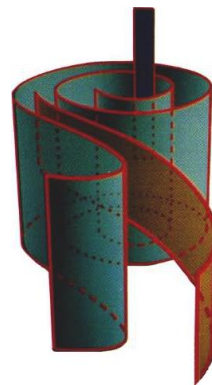
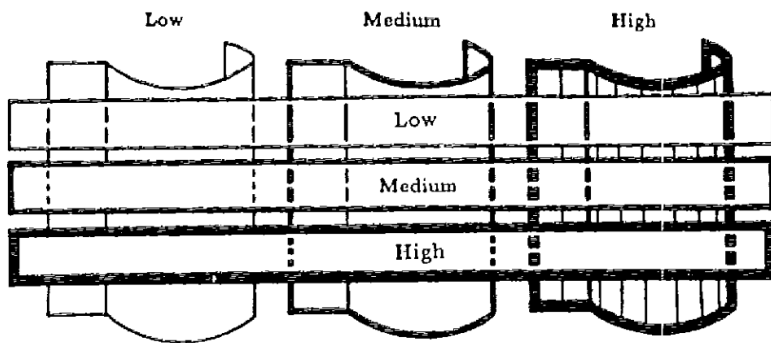
In NPAR, we've come a long way ...



[Saito and Takahashi, 1990]



[Haeberli, 1990]

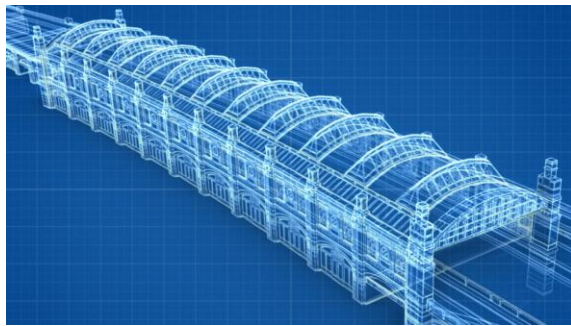


[Dooley and Cohen, 1990]

In NPAR, we've come a long way ...



[Zhao & Zhu, 2010]



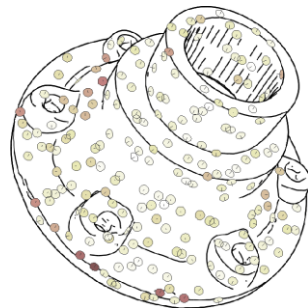
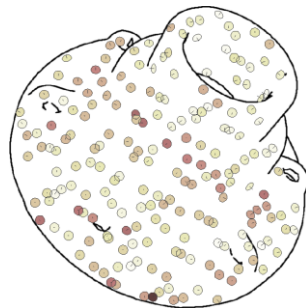
[Semmo & Döllner, 2014]



[Bousseau et al., 2007]



[Bénard et al., 2013]



[Cole et al., 2009]

Largely a focus on rendering/animation



[nVidia]

What about the interaction with the tools?



[Nijboer et al., 2010]

Salesin's 7 Grand Challenges [2002]

Non-Photorealistic
Animation & Rendering:

7 Grand Challenges

David Salesin

June 2002

Salesin's 7 Grand Challenges [2002]

Challenge 4: *Interactivity*

Salesin's 7 Grand Challenges [2002]

*“All you need is a strong Art Director and
willing TDs. . . .”*

— Tom Porter, PIXAR

Salesin's 7 Grand Challenges [2002]

Challenge:

How do you build tools for “right-brained” thinking?

Or:

How do you lose the TDs?

Salesin's 7 Grand Challenges [2002]

Common elements for a good system:

- Should let artists and computers each do what they are good at
- Needs to be simple yet flexible
- Should support full design cycle:
Create / Evaluate / Rework

Gooch et al. [2010] revisit Salesin's challenges

- interaction not only for people trained in the arts
- Heinlein's model of field maturation (imitation, optimization, acceptance)
- interaction still difficult, need to focus on interaction with our algorithms

Viewing Progress in Non-photorealistic Rendering through Heinlein's Lens

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Abstract

The field of non-photorealistic rendering is reaching a mature state. In its infancy, researchers explored the mimicry of methods and tools used by traditional artists to generate works of art, through techniques like watercolor or oil painting simulations. As the field has moved past mimicry, ideas from artists and artistic techniques have been adapted and altered for performance in the media of computer graphics, creating algorithmic aesthetics such as generative art or the automatic composition of objects in a scene, as well as abstraction in rendering and geometry. With these two initial stages of non-photorealistic rendering well established, the field must find new territory to cover. In this paper, we provide a high level overview of the past and current state of non-photorealistic rendering and call to arms the community to create the areas of research that make computation of non-photorealistic rendering generate never before realized results.

CR Categories: L3.m [Computer Graphics]: Miscellaneous—Non-Photorealistic Rendering

Keywords: non-photorealistic rendering, grand challenges, metaphor

1 Introduction

There has been much discussion revolving around the current and future state of the non-photorealistic rendering (NPR) field. We survey the recent research that has been conducted in the NPR domain and discuss implications for the future. In particular, we postulate on where we see NPR research in terms of the technology maturation model put forward by Robert A. Heinlein [1985]. Heinlein is credited with having anticipated many technological advances, and some say that his writing, while sometimes controversial, has been influential in provoking thought and discussion about the role and evolution of technology [Ditnerman 2007]. Heinlein's model suggests that new technologies evolve over time through three stages of maturation:

1. Imitation: the new technology emulates previous work.
2. Optimization: the performance of the technology is improved.
3. Acceptance: the technology is no longer perceived as "new".

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While we do not agree with all of Heinlein's opinions, we find that his maturation model is an interesting lens through which to examine the state of NPR, and can serve as a useful starting point to provoke discussion on what directions should be taken into the future. We believe that NPR is currently at the second stage of the maturation model, and we outline the path we believe should be taken in order to advance the field into the third stage of maturation.

Rapid advances in computer graphics technology allow computer screens to be filled with complex visual information at near real time rates [HPG 2009]. Simulations and visualizations that once required supercomputers are now commonly run on desktop workstations or PC clusters. While Moore's law has correctly anticipated faster processors, larger disk drives and higher memory capacity, these advances have done little to help people understand the meaning of their data. The lack of understanding stems from the fact that machines process data in numerical form, while humans more easily comprehend visual data. We rely on graphs and charts that visually emphasize key features and relationships in the data to attain insight.

In the computer graphics and visualization communities, *rendering* is the process by which data is converted into an image. Photorealistic rendering denotes images based on physical simulations. The goal of photorealistic rendering is to create images indistinguishable from photographs of equivalent real world scenes. In contrast, the area of NPR is concerned with images that are guided by artistic processes. An underlying assumption in NPR is that artistic techniques developed by human artists have intrinsic merit based on the evolutionary nature of art. NPR techniques, such as illustration, are driven by aesthetic and communication constraints rather than physical simulations. *Visualization* is the process of using computer graphics to transform numerical data into meaningful imagery, enabling users to observe information [Vagel et al. 1991; Upon et al. 1989; Drebin et al. 1988; Senay and Ignatius 1994]. The art of non-photorealistic visualization lies in choosing visual representations of the data that maximize human understanding [Grinstein and Thurasingham 1996]. The resulting display allows a viewer to detect, analyze and discover features in numerical data which may not have been recognized otherwise.

NPR images convey information more effectively by omitting extraneous detail, focusing attention on relevant features, and clarifying, simplifying, and disambiguating shape. In fact, a distinguishing feature of NPR is the concept of controlling detail in an image to enhance communication. The control of image detail is often combined with stylization to evoke the perception of complexity in an image without explicit representation, as shown in the drawings in the right two images of Figure 1. NPR images also provide a more natural vehicle for conveying information at a range of detail levels. Additional advantages of artistic imagery include:

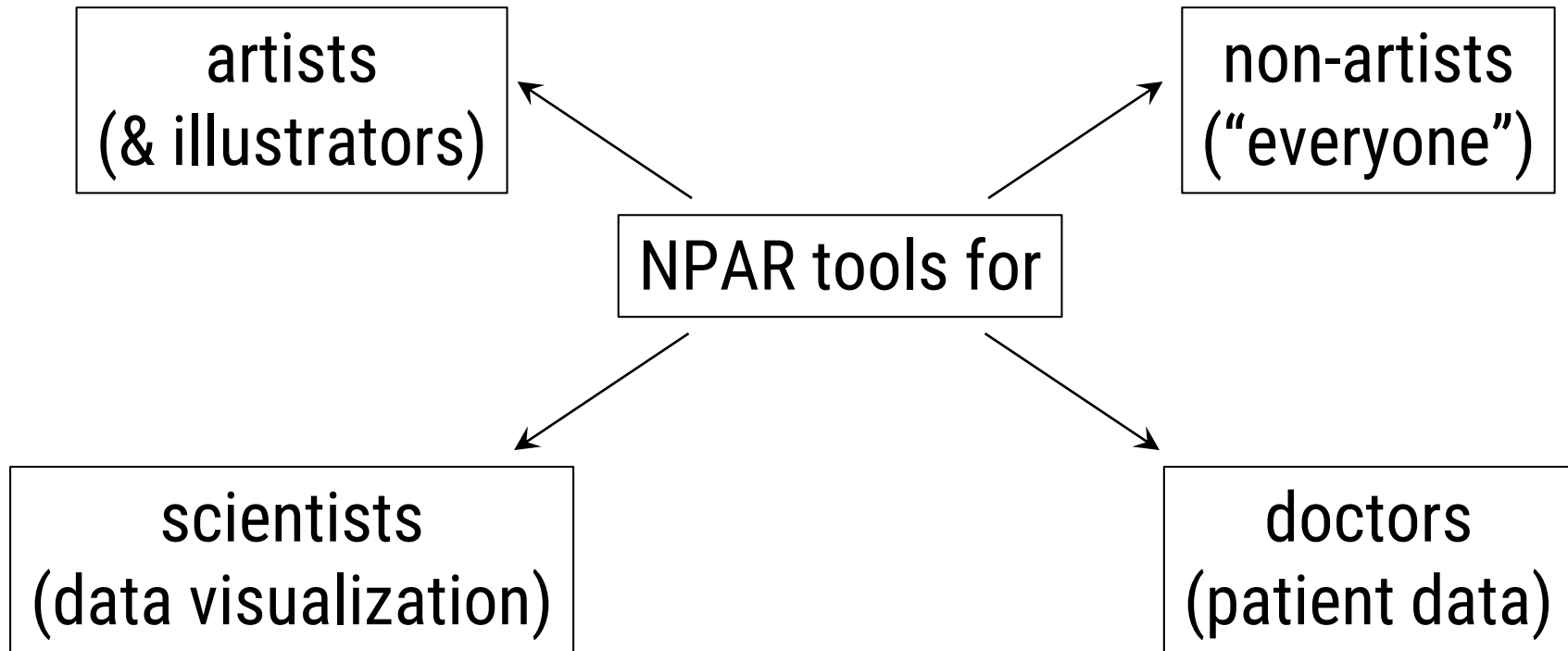
- Communication of uncertainty – Photorealistic computer graphics imply an exactness and perfection that may overstate the fidelity of a simulation or scan.
- Communication of abstract ideas – Simple line drawings, like the force diagrams used in physics textbooks, can communicate abstract ideas in ways that a photograph cannot.

Lum & Ma [2002]: Expressive Visualization

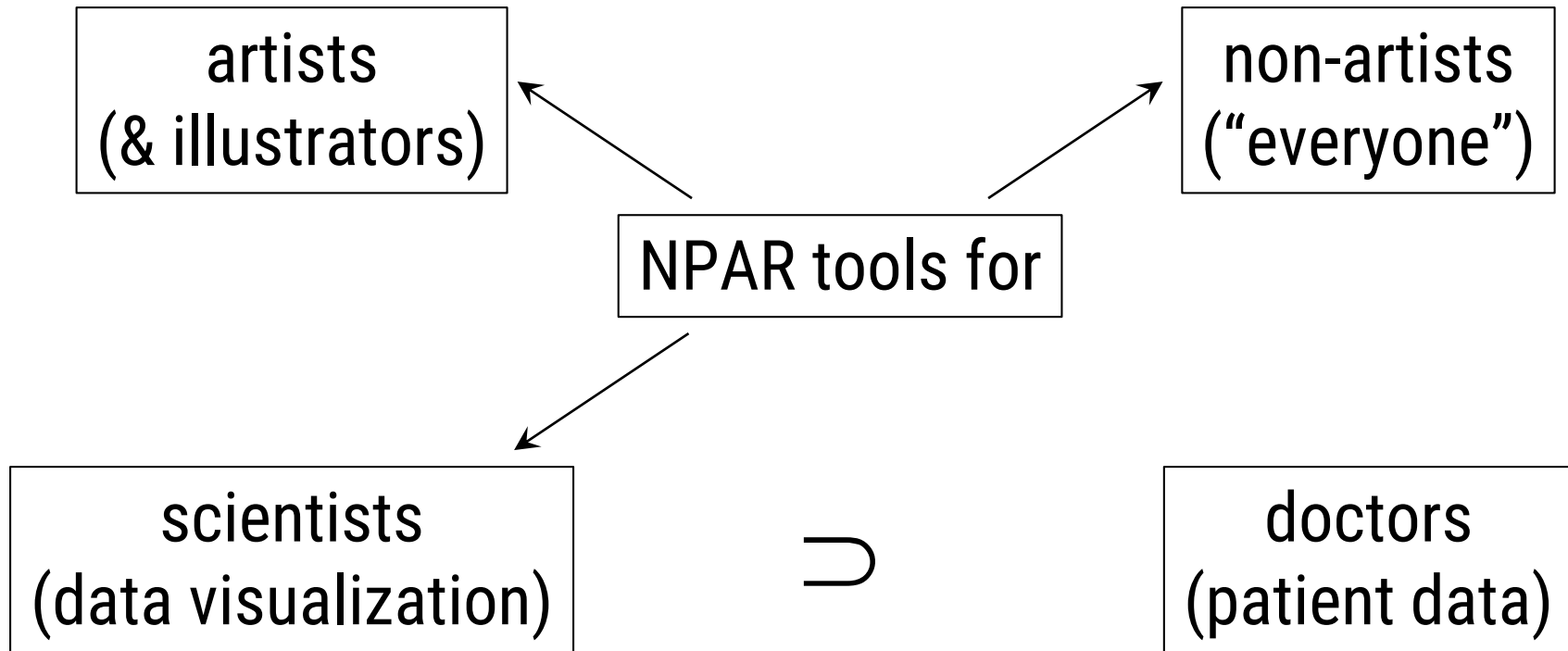
- scientists are not expert illustrators
- illustrative visualization provides tools, but “interactivity is the key”
- interactivity as high fps
- applies at interaction design as well



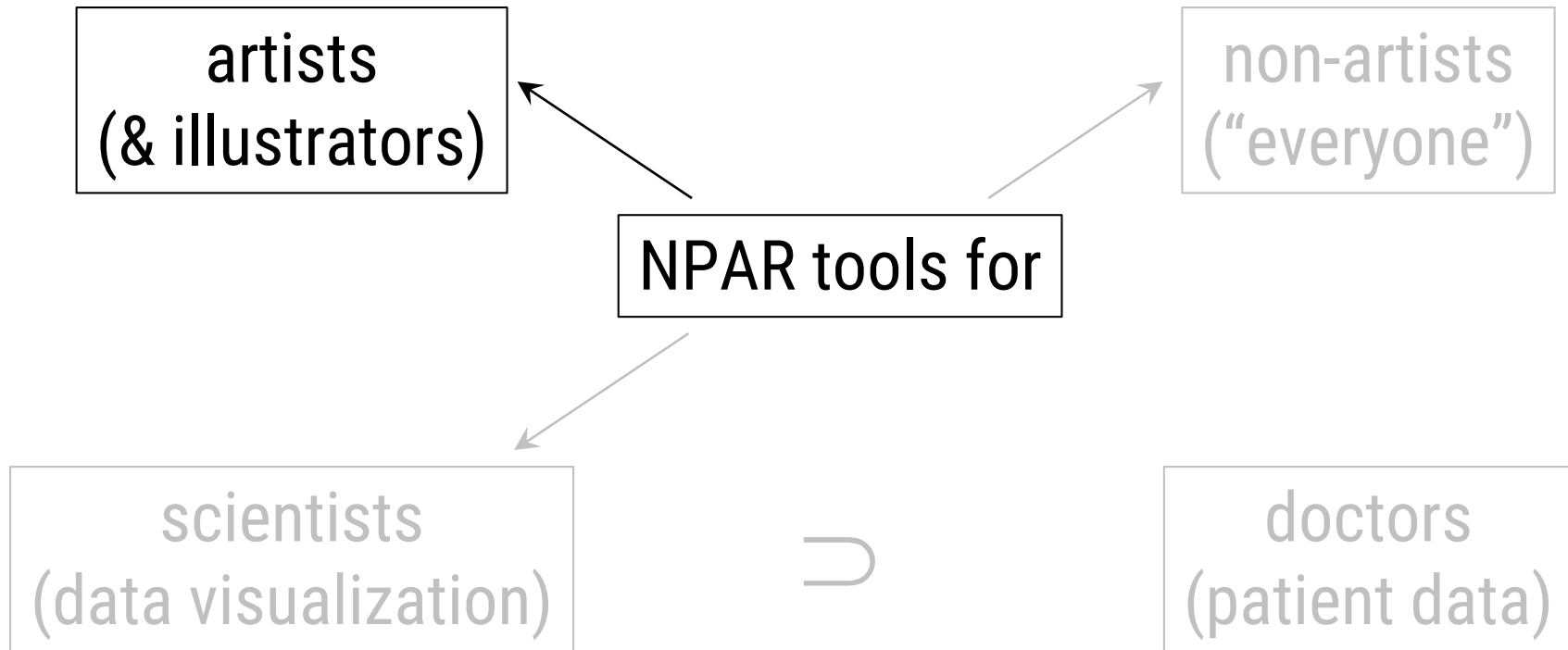
Goals & Application Domains of NPAR



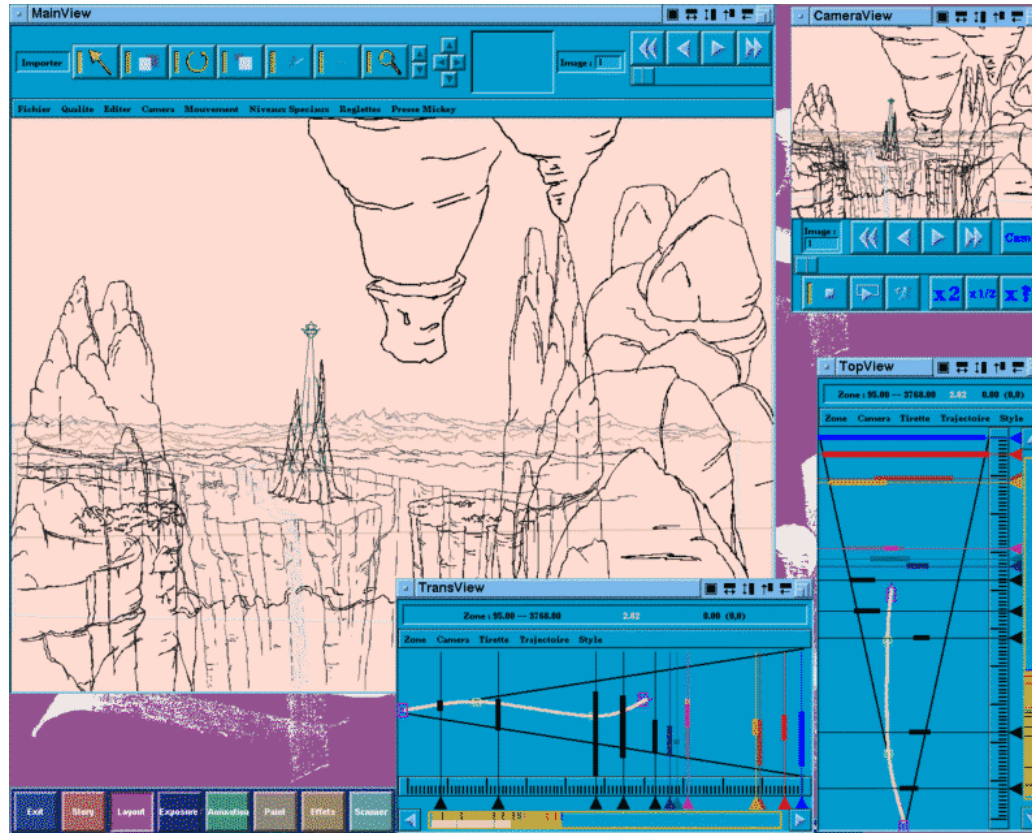
Goals & Application Domains of NPAR



Goals & Application Domains of NPAR

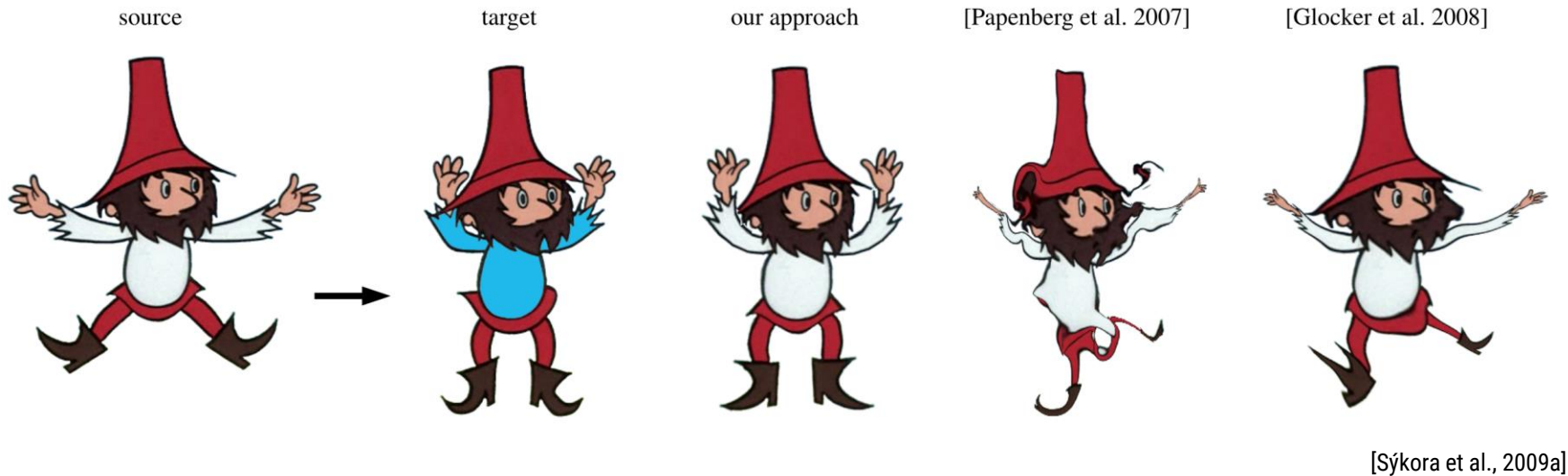


NPAR for Artists: In-Betweening

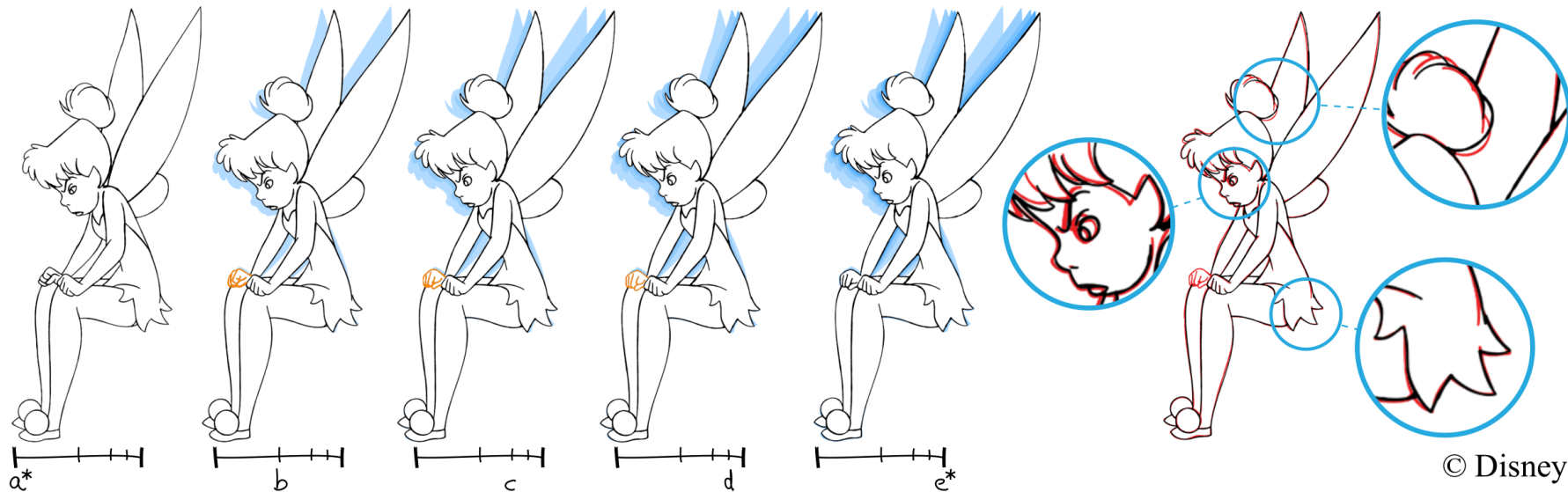


TicTacToon
[Fekete et al., 1995]

NPAR for Artists: In-Betweening

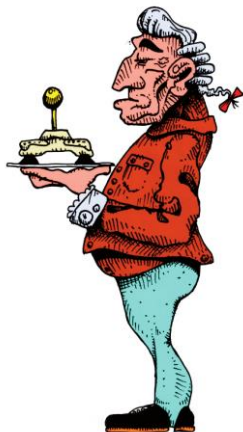
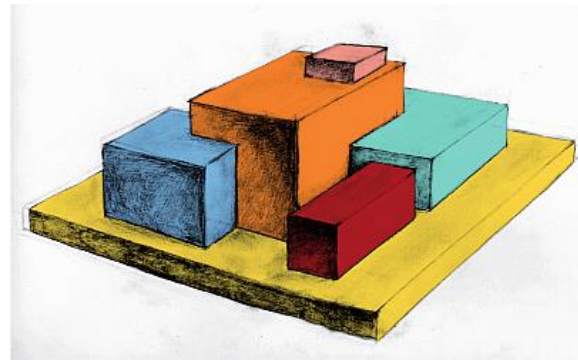
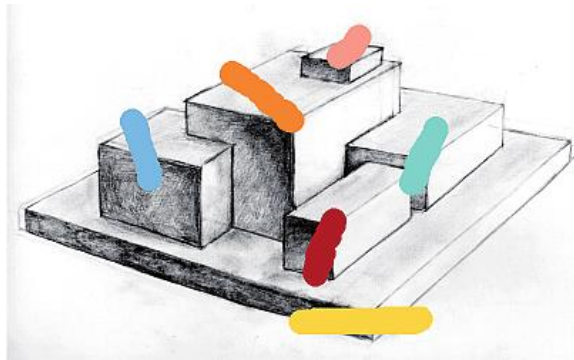
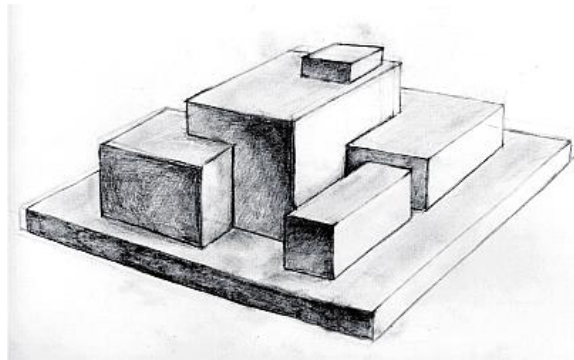


NPAR for Artists: In-Betweening



[Whited et al., 2010]

NPAR for Artists: Interactive Cartoon Colorization



[Sýkora et al., 2009b]

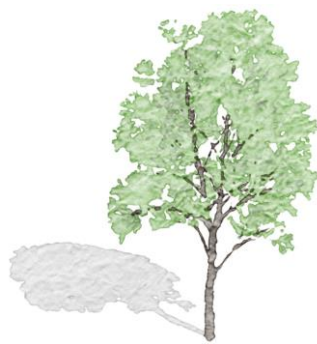
NPAR for Art.: (Photo-)Realistic ^[sic!] Media Simulation



[Curtis et al., 1997]



[Bousseau et al., 2006]



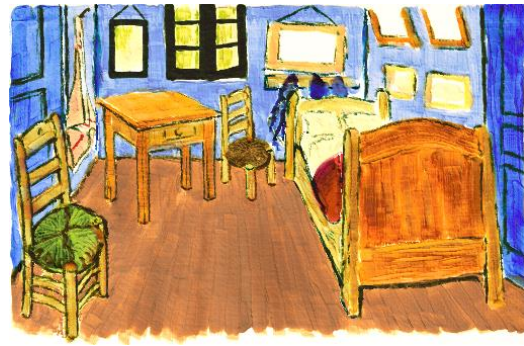
[Luft & Deussen, 2006]



[DiVerdi et al., 2013]



DAB [Baxter et al., 2001]



IMPasto [Baxter et al., 2004]

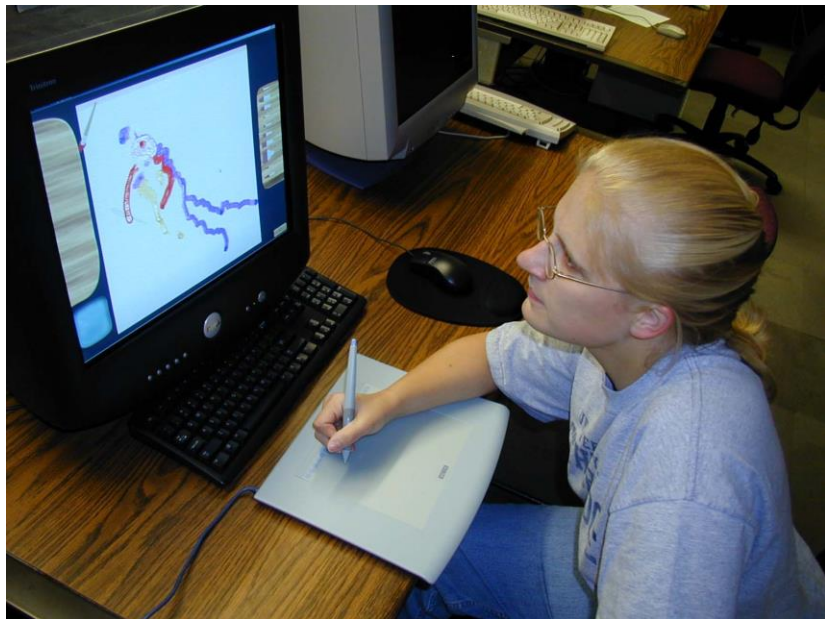
NPAR for Artists: Interactive Environments



[Disney's Deep Canvas]

NPAR for Artists: Control Needed at Multiple Levels

NPAR: low-level, tedious tasks; artist: higher-level decisions
Salesin: “let artists and computers each do what they are good at”



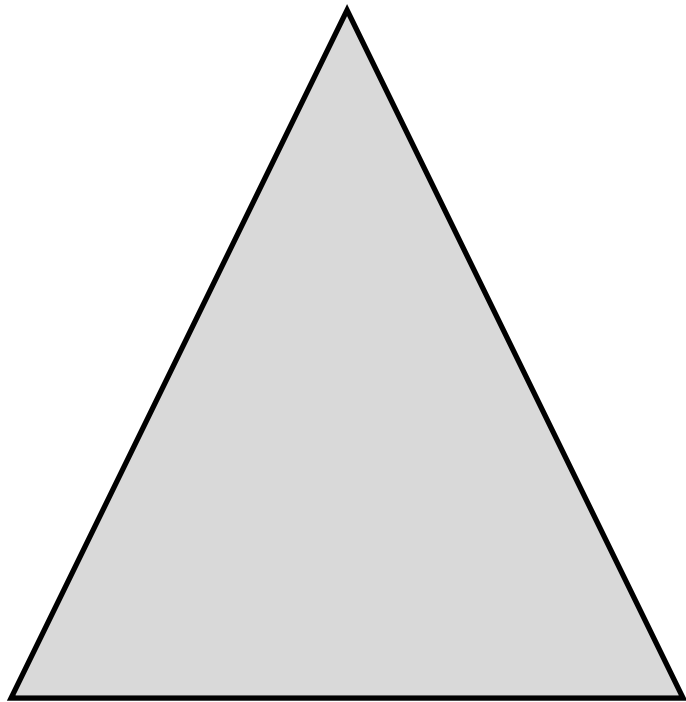
IMPasTo [Baxter et al., 2004]



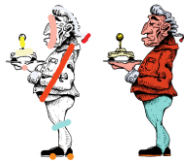
IntuPaint [Vandoren et al., 2008]

Low-level vs. High-level Tasks and Control

workload/control over result



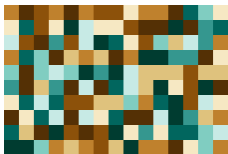
[Semmo et al., 2015/16]



[Sykora et al., 2009b]

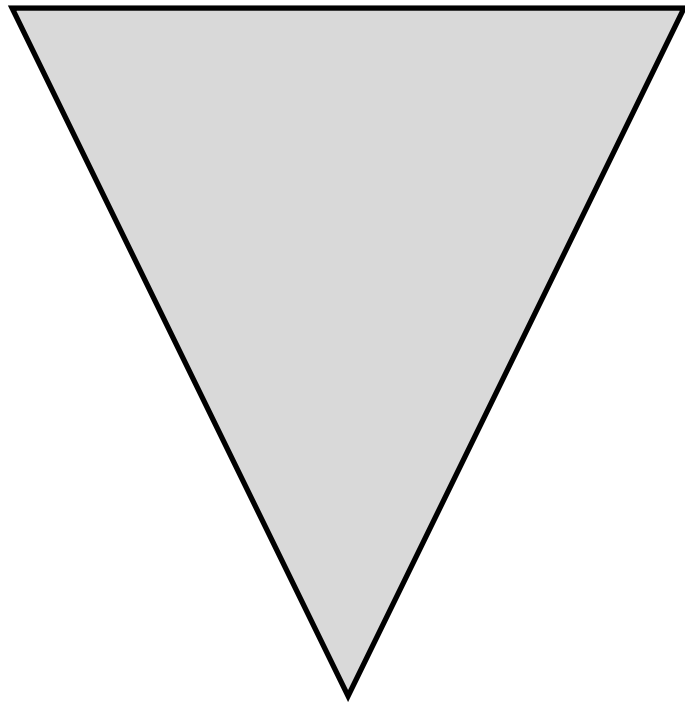


[Curtis et al., 1997]



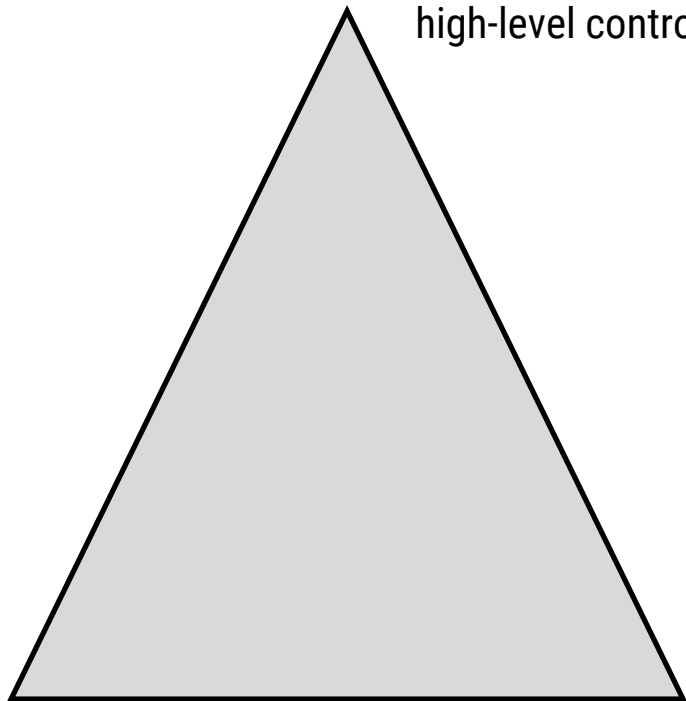
[<http://two-n.com/pi/>]

influence of input

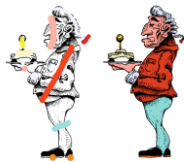


Low-level vs. High-level Tasks and Control

workload/control over result
high-level control



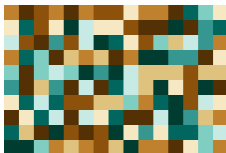
[Semmo et al., 2015/16]



[Sykora et al., 2009b]

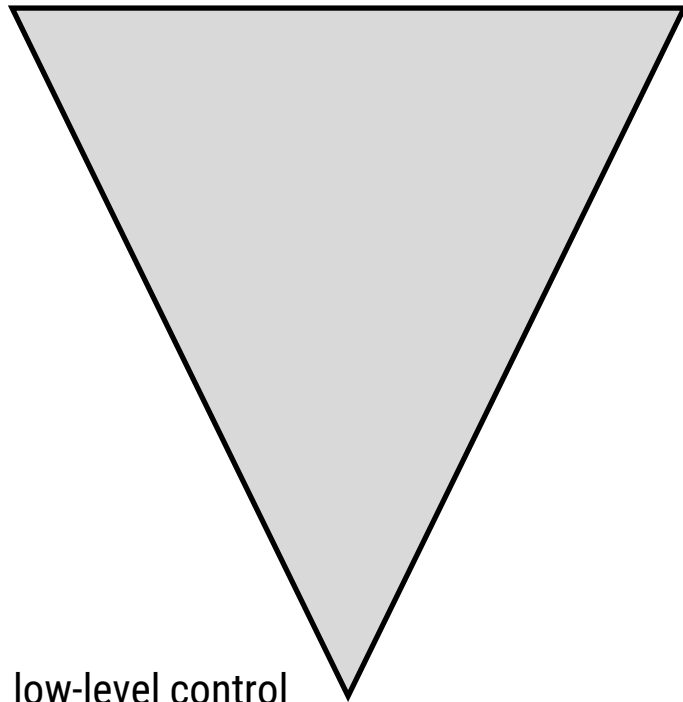


[Curtis et al., 1997]



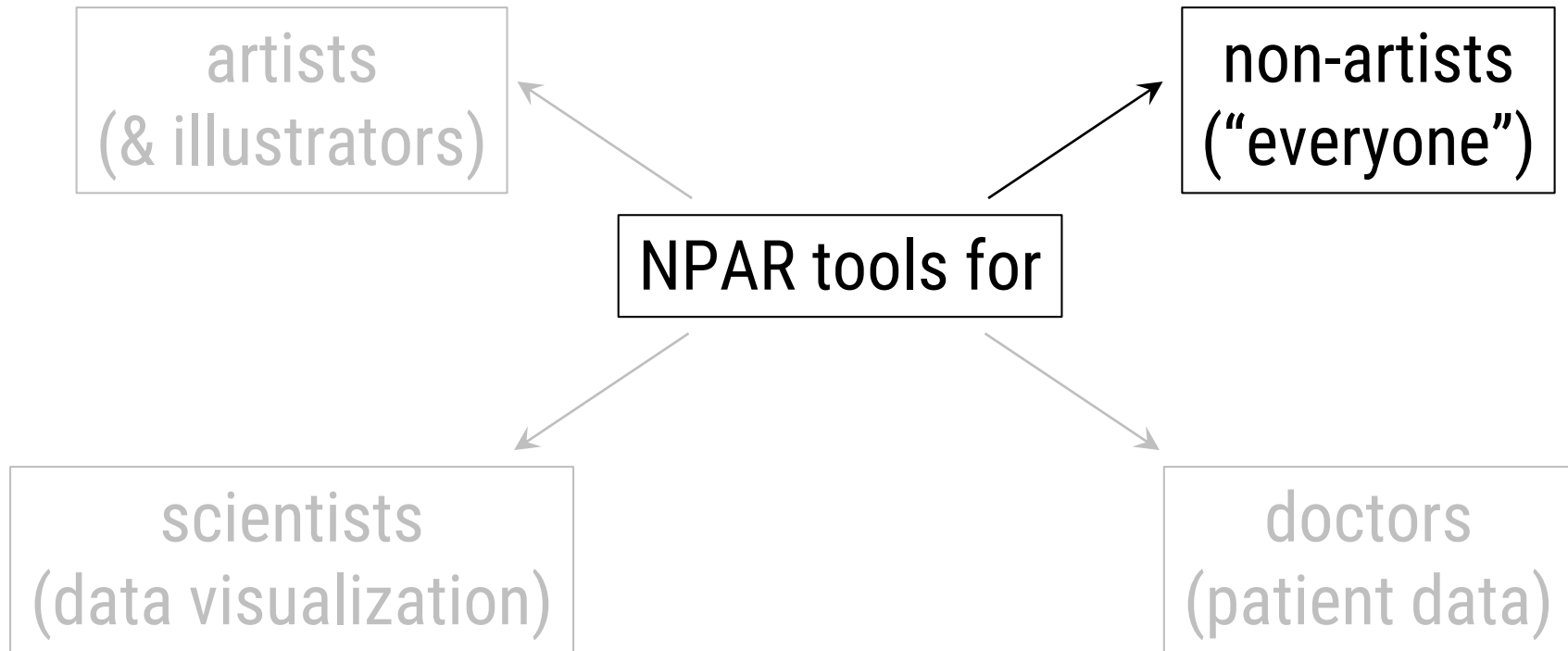
[<http://two-n.com/pi/>]

influence of input

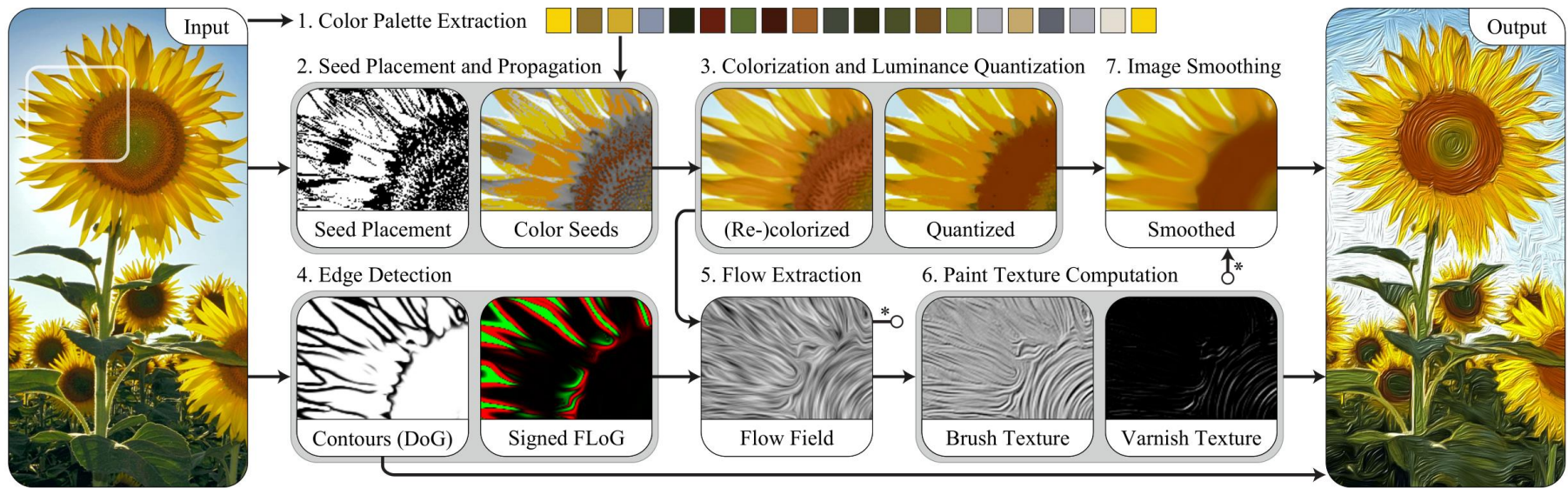


low-level control

Goals & Application Domains of NPAR

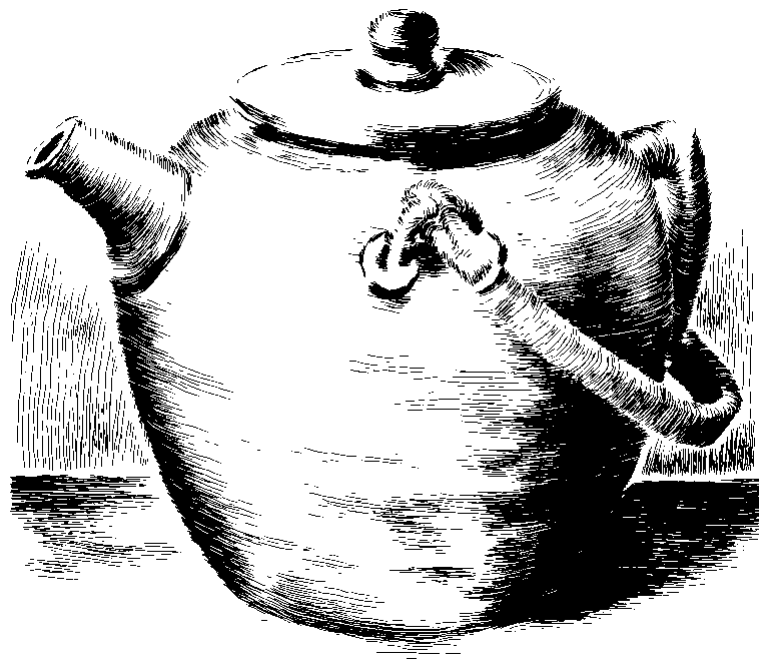
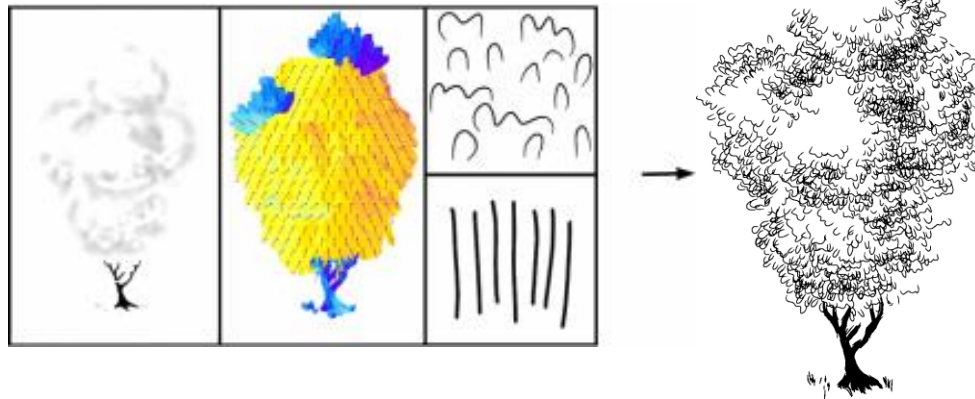
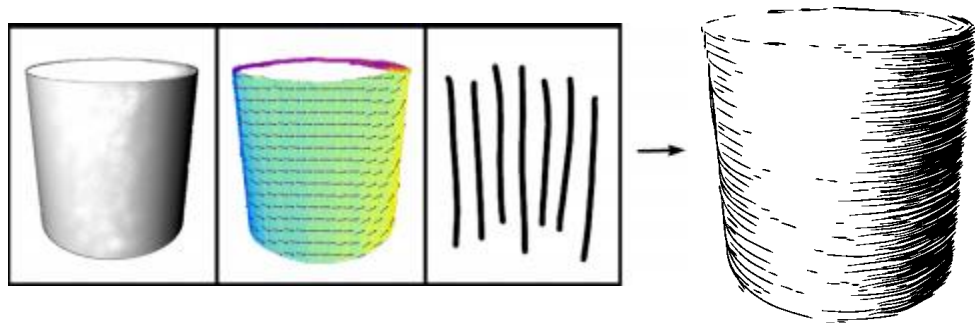


NPAR Tools for Non-Artists: Higher-Level Control



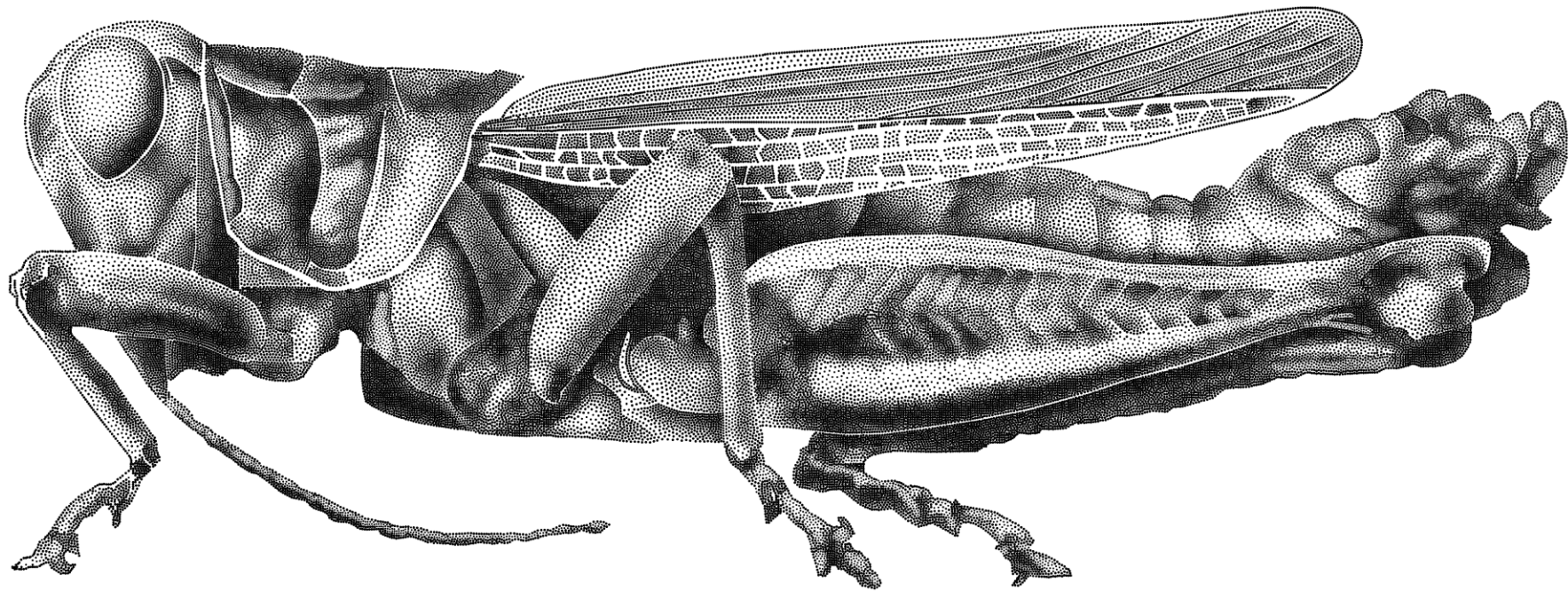
[Semmo et al., 2015/16]

NPAR Tools for Non-Artists: Filters (w/ Interaction)



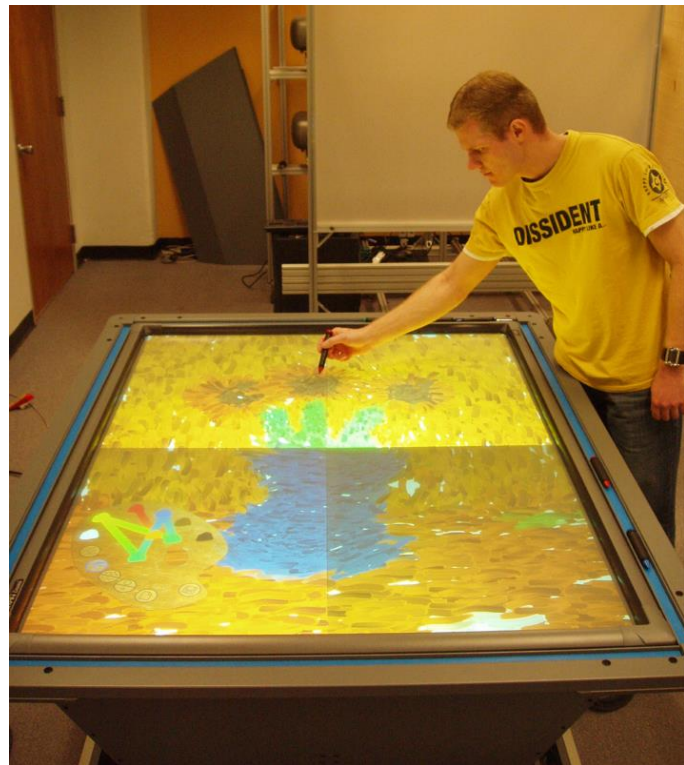
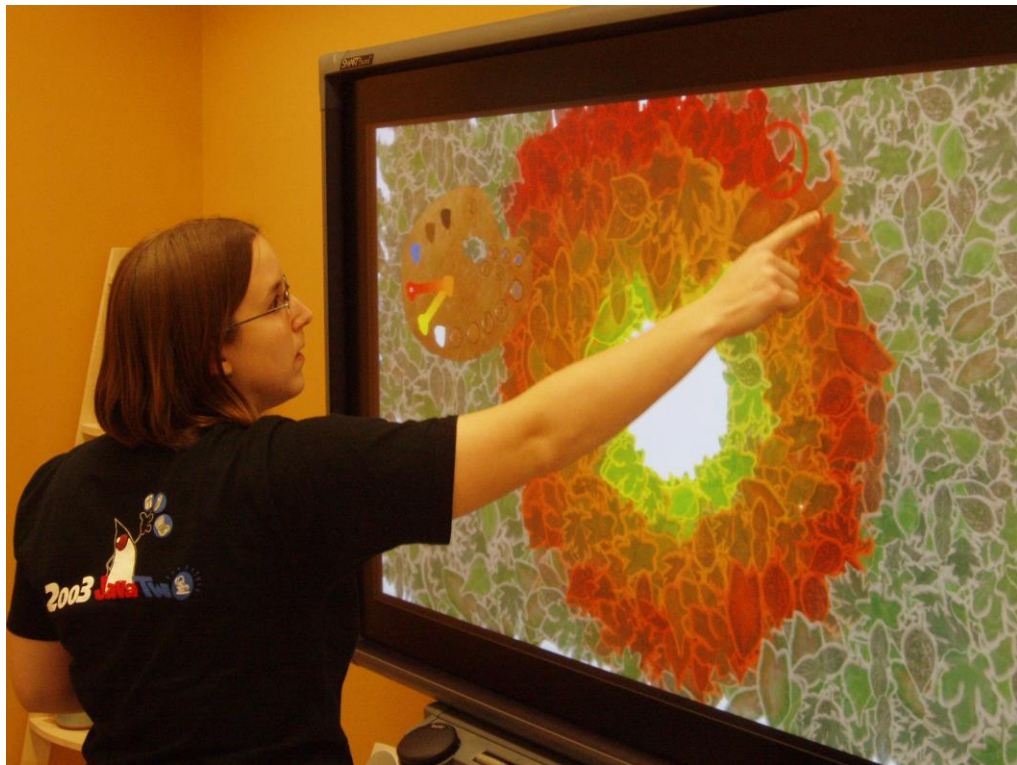
[Salisbury et al., 1997]

NPAR Tools for Non-Artists: Filters (w/ Interaction)



[Deussen et al., 2000]

NPAR Tools for Non-Artists: Filters (w/ Interaction)



[Schwarz et al., 2007]

NPAR Tools for Non-Artists: Filters for Video



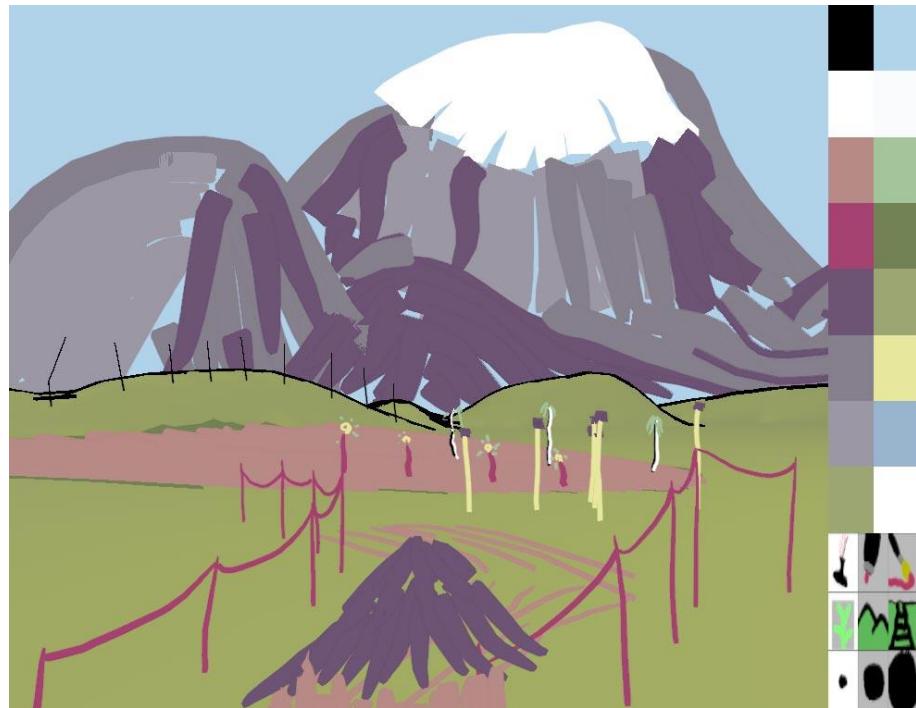
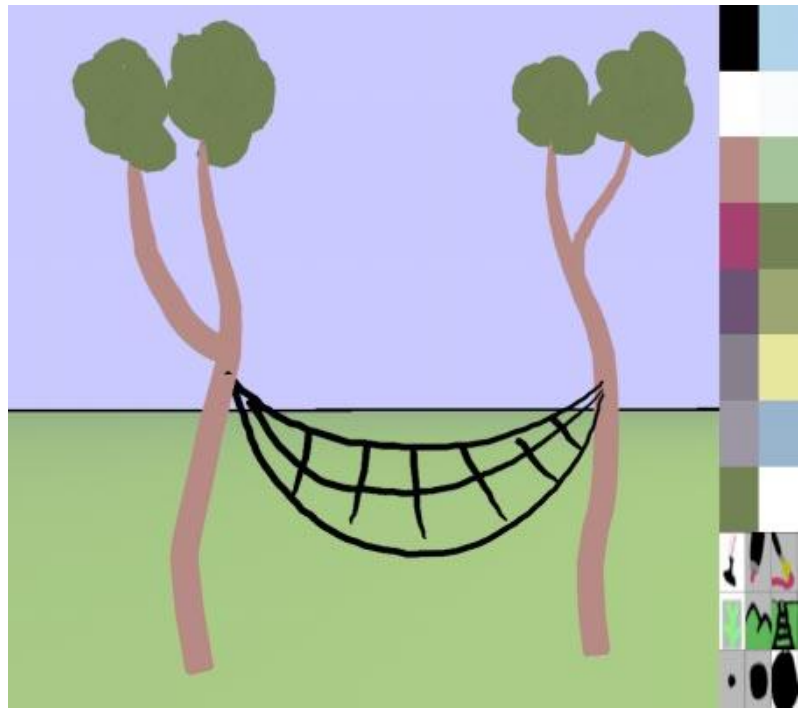
[Wang et al., 2004]

NPAR Tools for Non-Artists: Filters for Video



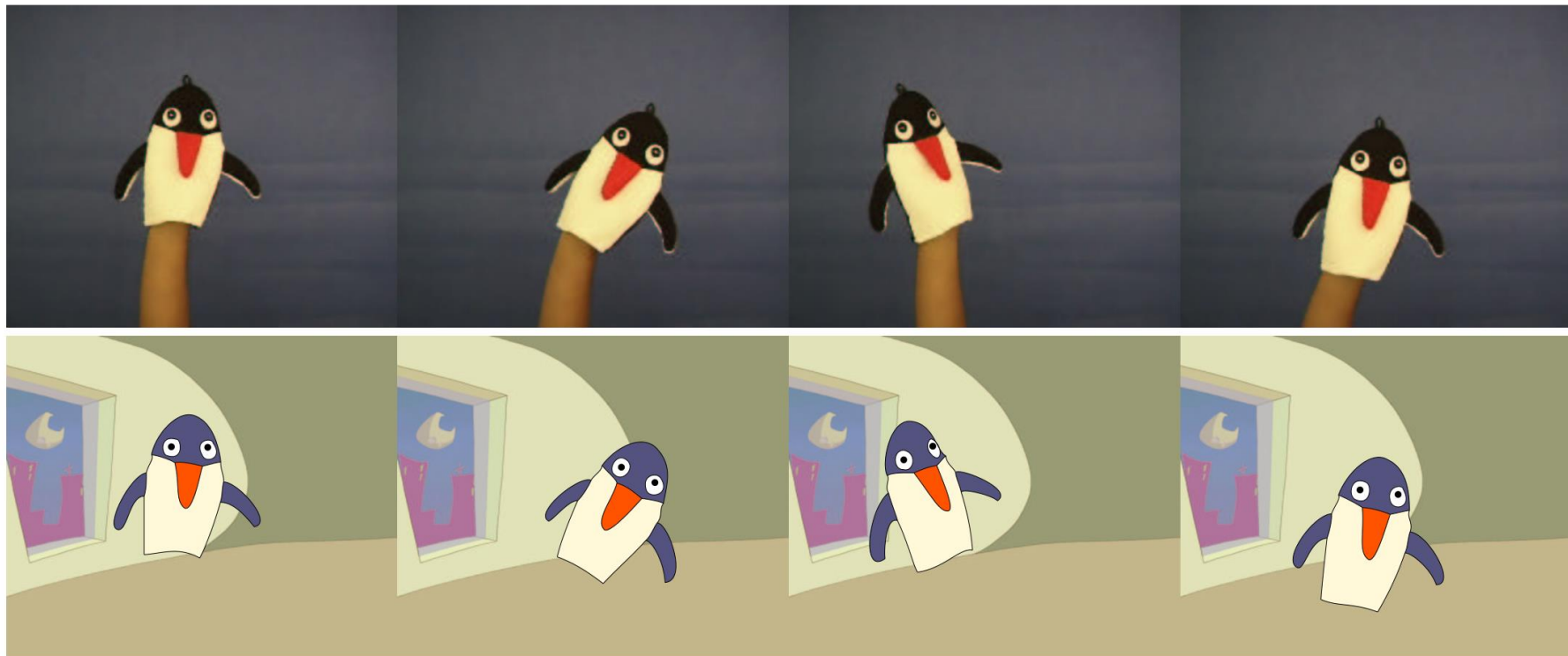
[Winnemöller et al., 2006]

NPAR Tools f. Non-Artists: Simple Drawing/Painting



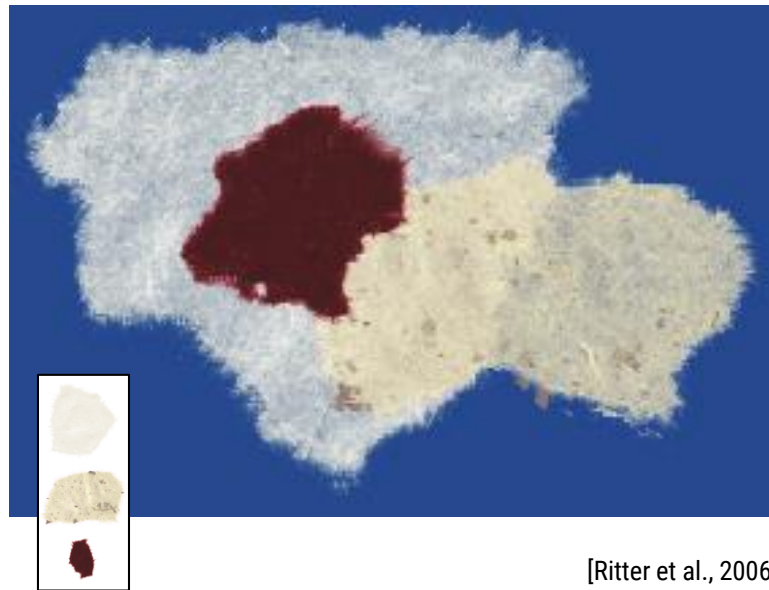
Harold [Cohen et al., 2000]

NPAR Tools f. Non-Artists: Simple Drawing/Painting



SnakeToonz [Agarwala, 2002]

NPAR Tools f. Non-Artists: Simple Drawing/Painting



[Ritter et al., 2006]

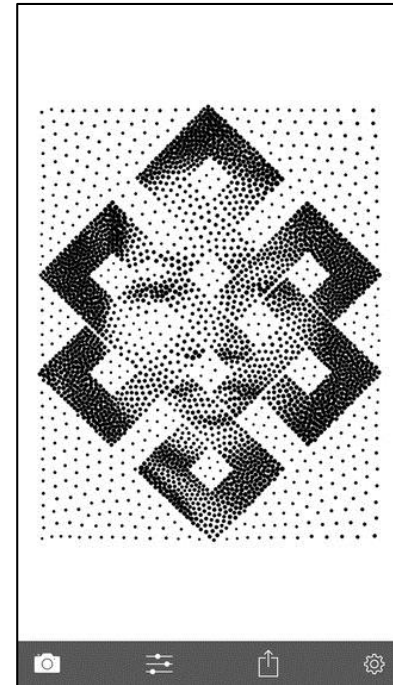
NPAR Tools for Non-Artists: Mobile Apps



[PaintCan by Winnemöller et al.]

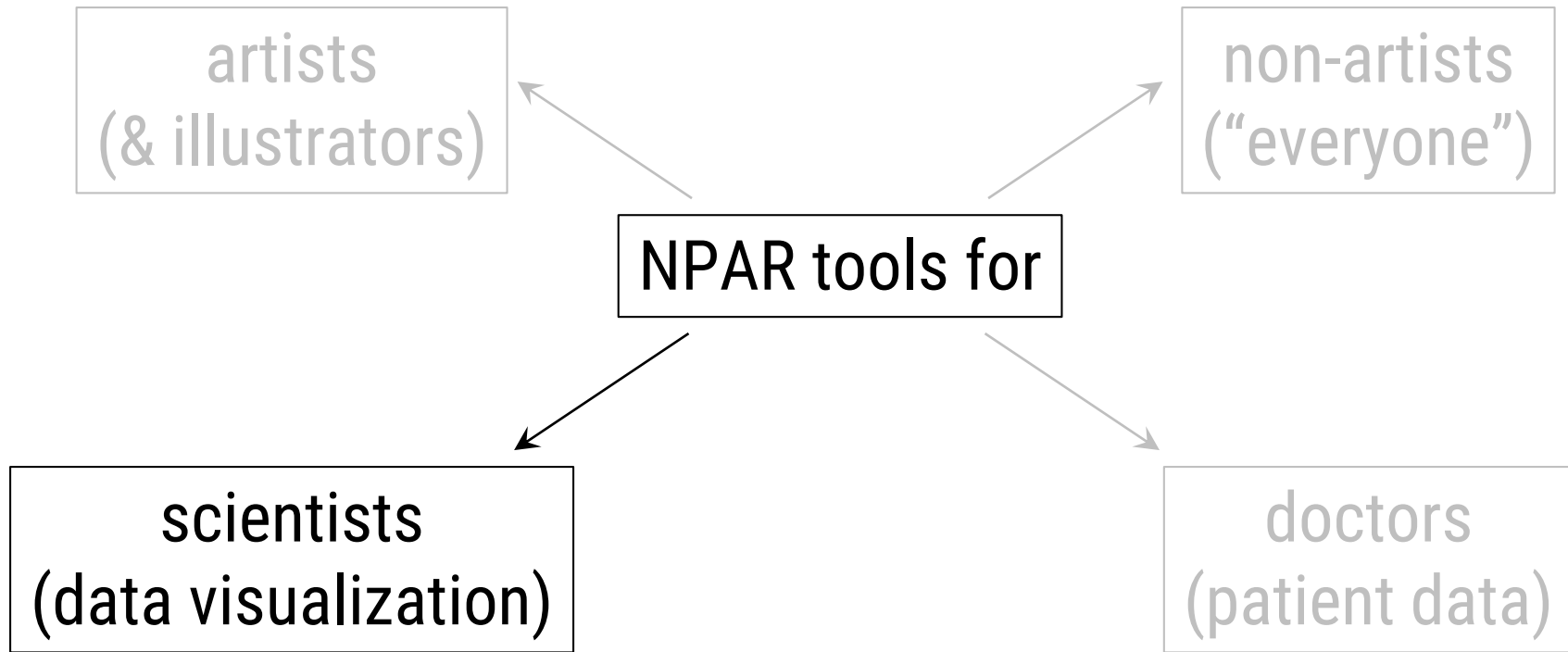


[PencilFX by Gooch et al.]



SnapDot based on [Secord 2002]

Goals & Application Domains of NPAR



Expressive/Illustrative Visualization

VIS FILES

Interactivity is the Key to Expressive Visualization

I have long believed in the importance of interactivity for effective visualization. Kwan-Liu Ma and his colleagues have been doing very interesting work developing new kinds of interactive visualization techniques, so I asked them to contribute this VisFiles column about their work.

— Bill Hibbard

Eric B. Lum and Kwan-Liu Ma
University of California, Davis

Scientific visualization is widely used for gaining insight into phenomena through data exploration and creating imagery that can be used to illustrate these phenomena to others. Interactive rendering has long been valued in visualization as a means of facilitating more effective exploration. More recently, non-photorealistic rendering (NPR) has been applied to scientific visualization, which consists of using artistically inspired techniques for the creation of more expressive visualizations [3, 4, 5].

In many cases, NPR has been shown to be more effective than photorealistic rendering in communicating subtle information about physical structures or phenomena. How the user chooses to portray a data set can have a significant effect on how accurately and efficiently a visualization communicates the information the user seeks to reveal. It is our belief that when NPR is made interactive, particularly with respect to the control of how NPR is applied, the user is able to more quickly derive expressive visualizations.

Interactivity is often associated with spatial exploration, where parameters such as position, zoom and light direction are varied over time. The resulting animations, controlled by the user, allow further insight to be gained in the subject being viewed. In visualization, interactive rendering includes giving the user the ability to change other rendering parameters related to the data itself. One example is the transfer function in volume rendering, which can be adjusted to

change voxel classification to emphasize different aspects of a data set.

NPR techniques typically have a set of rendering parameters associated with them which dictates the style of the resulting images. The required tuning of these parameters does not make these algorithms less desirable, but rather gives the user the ability to create the types of images they seek. In scientific visualization, there is no single set of "correct" rendering parameters as seen in the two images shown in Figure 1. Rendering

parameters can be selected that add emphasis and clarity to the aspects of the visualization the user is interested in.

In visualization, the user is seldom an artist, but is often a scientist who would like to generate images that illustrate a particular structure or phenomenon they are studying. Thus, the user cannot be expected to know which NPR techniques are appropriate, and might not even have a clear vision of what the resulting visualization should look like. Much like transfer function specification, the

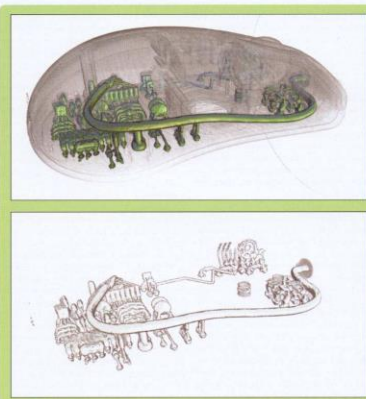
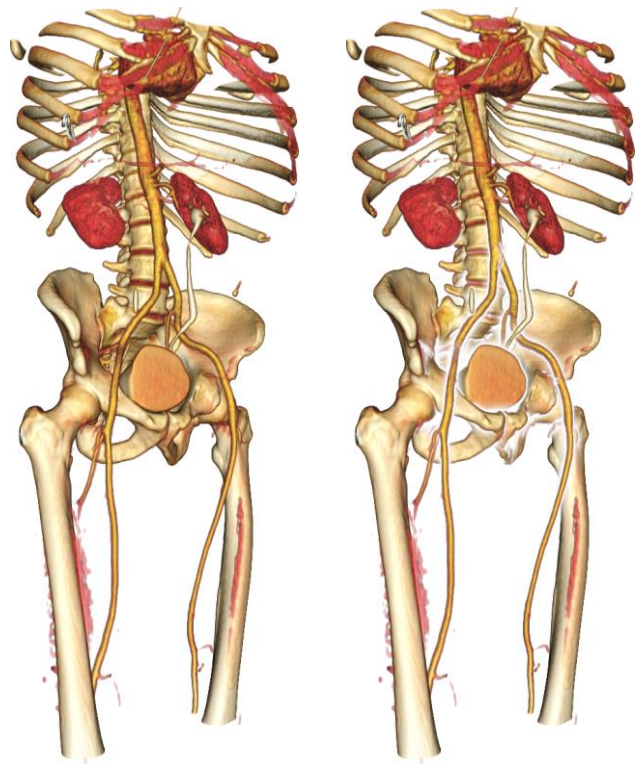
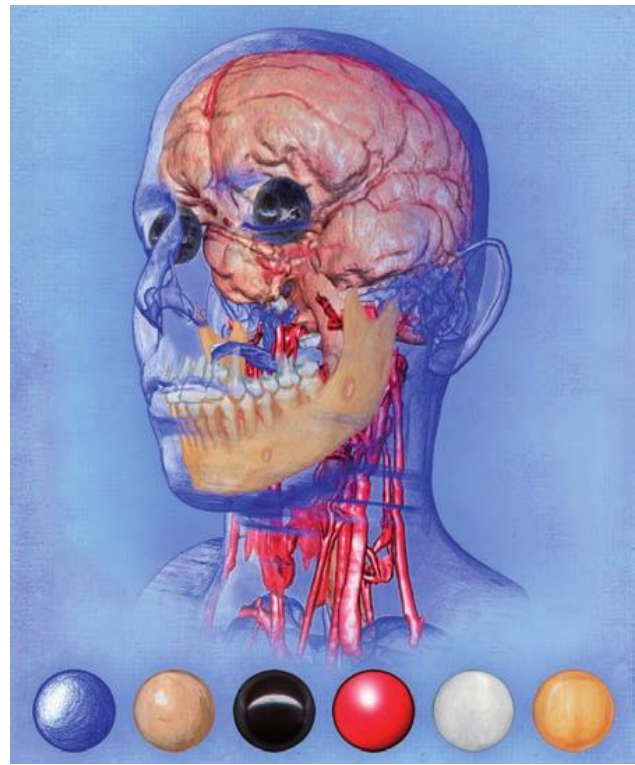


Figure 1: Two non-photorealistic volume renderings of a mouse data set with different sets of rendering parameters. Interactive rendering allows users to select rendering parameters appropriate for their application.

NPAR Tools for Scientists (& Science Illustrators)

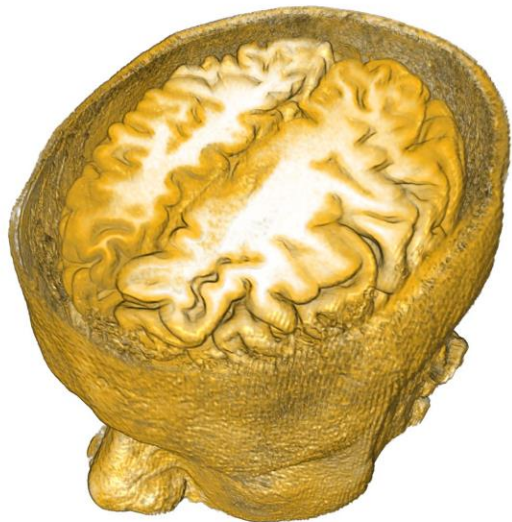


[Bruckner & Gröller, 2007a]

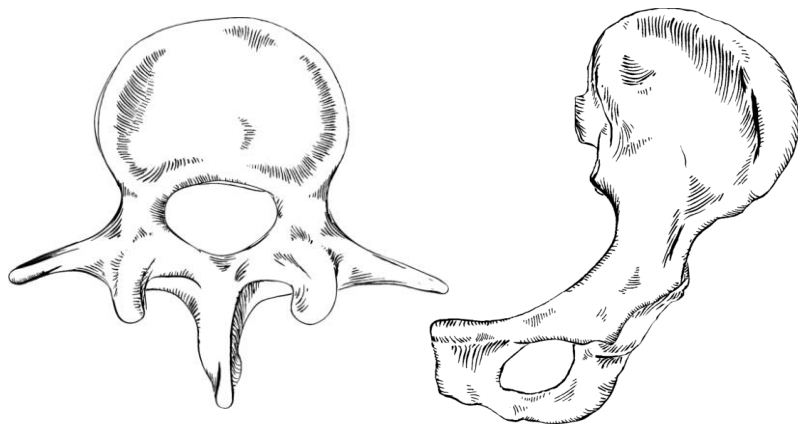
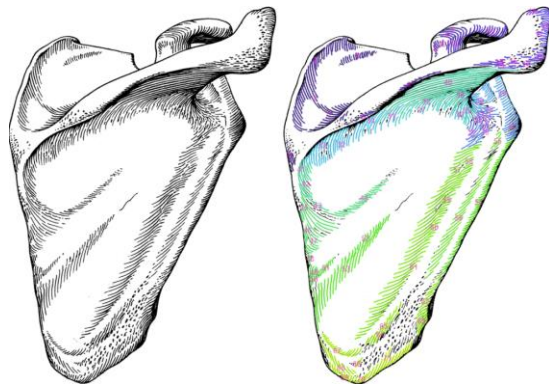


[Bruckner & Gröller, 2007b]

NPAR Tools for Scientists (& Science Illustrators)

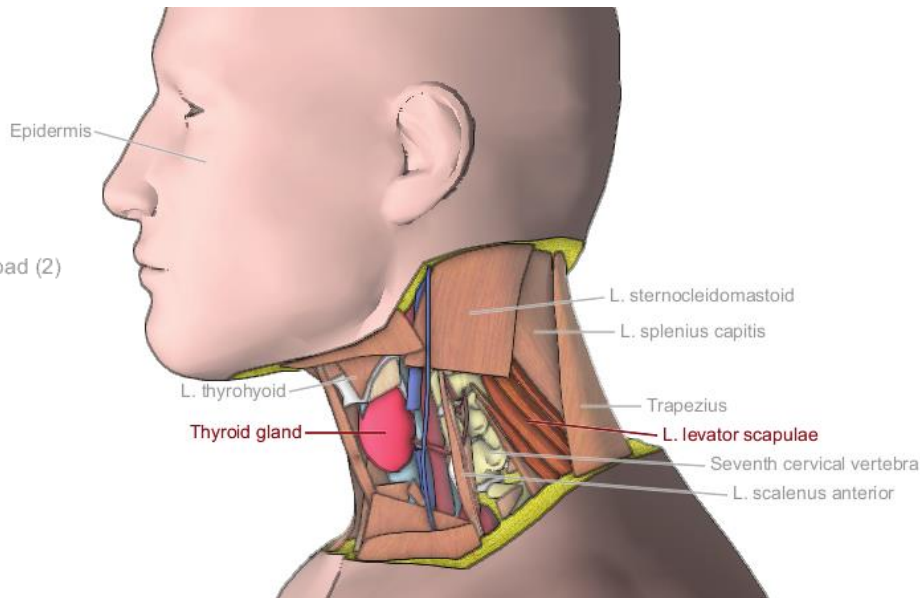
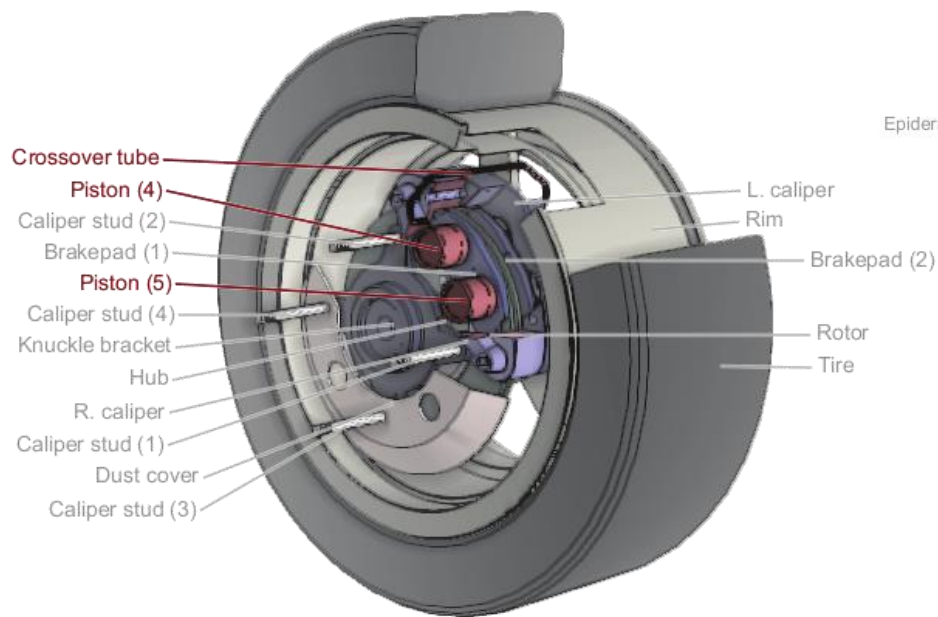


[Gerl & Isenberg, 2012]



[Gerl & Isenberg, 2013]

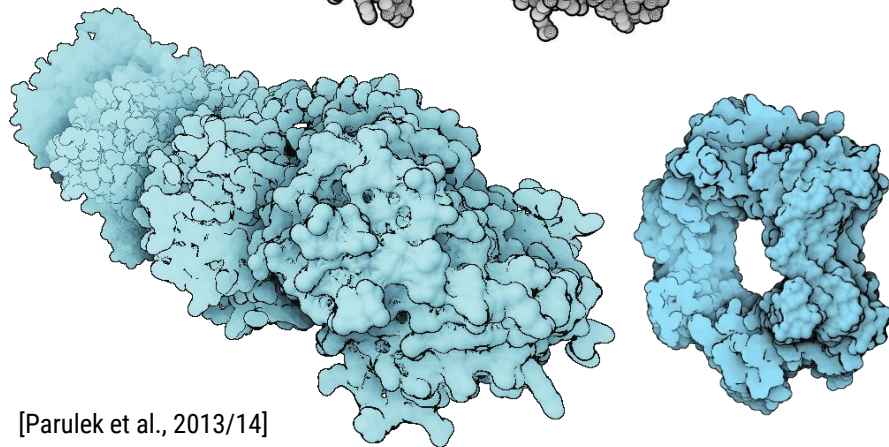
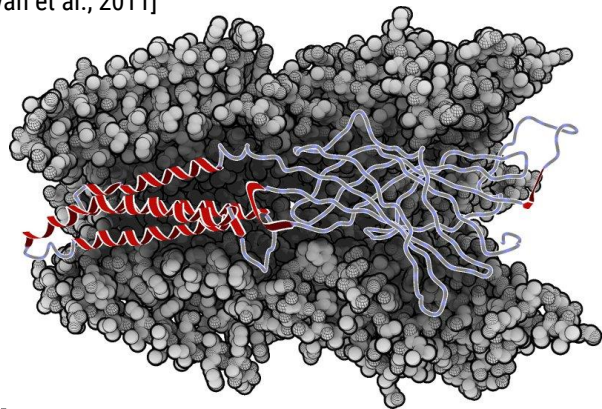
NPAR Tools for Scientists (& Science Illustrators)



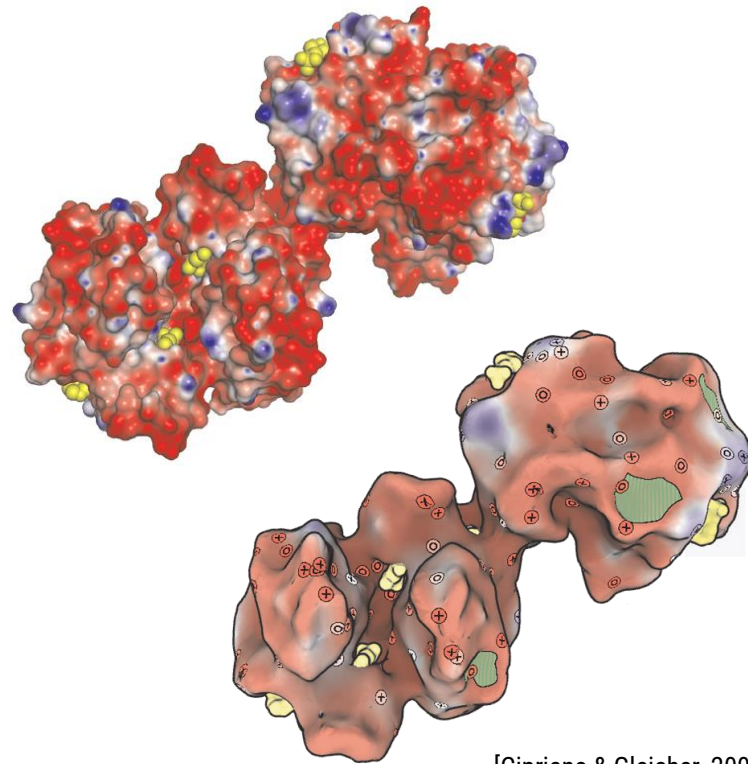
[Li et al., 2007]

NPAR Tools for Scientists (& Science Illustrators)

[van der Zwan et al., 2011]



[Parulek et al., 2013/14]

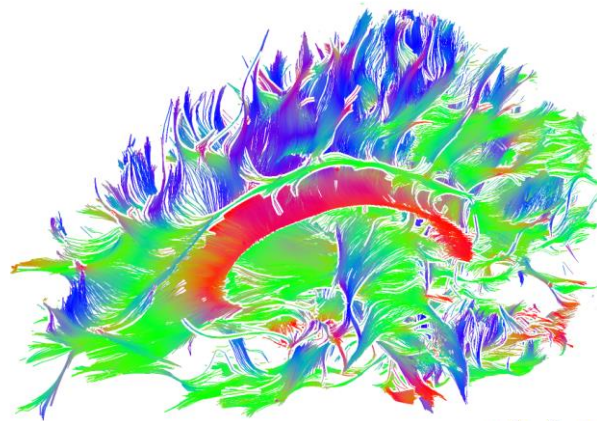


[Cipriano & Gleicher, 2007]

NPAR Tools for Scientists (& Science Illustrators)



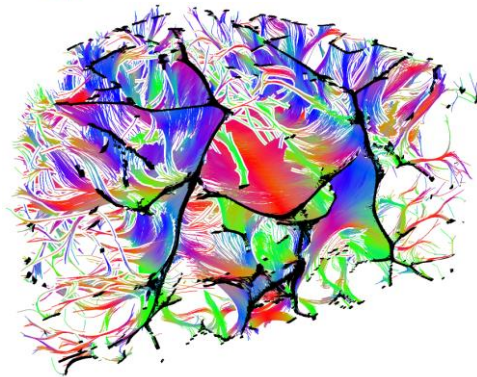
[Everts et al., 2009]



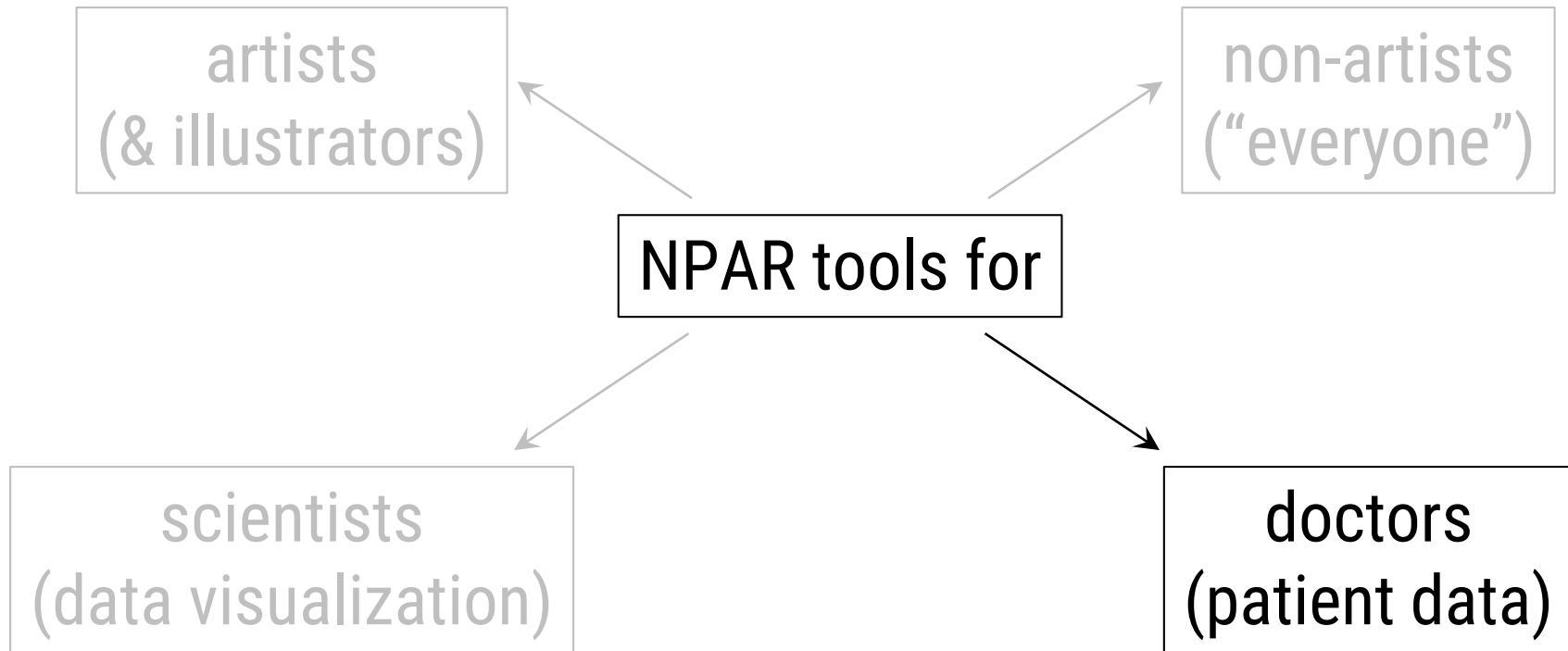
[Everts et al., 2015]



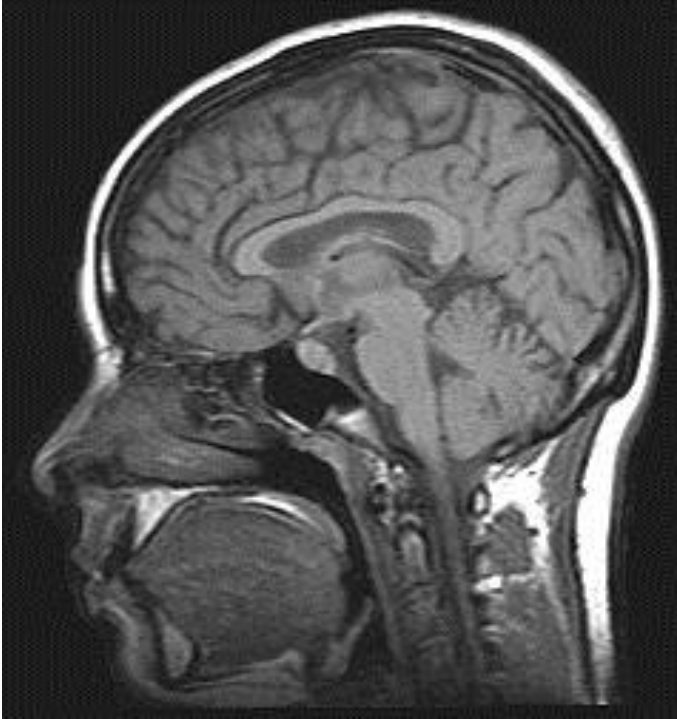
[Svetachov et al., 2010]



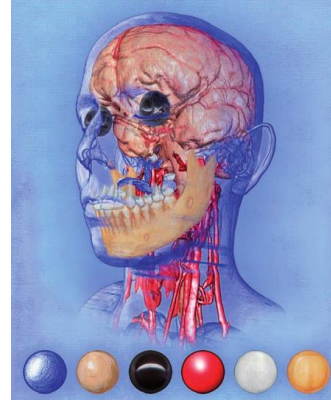
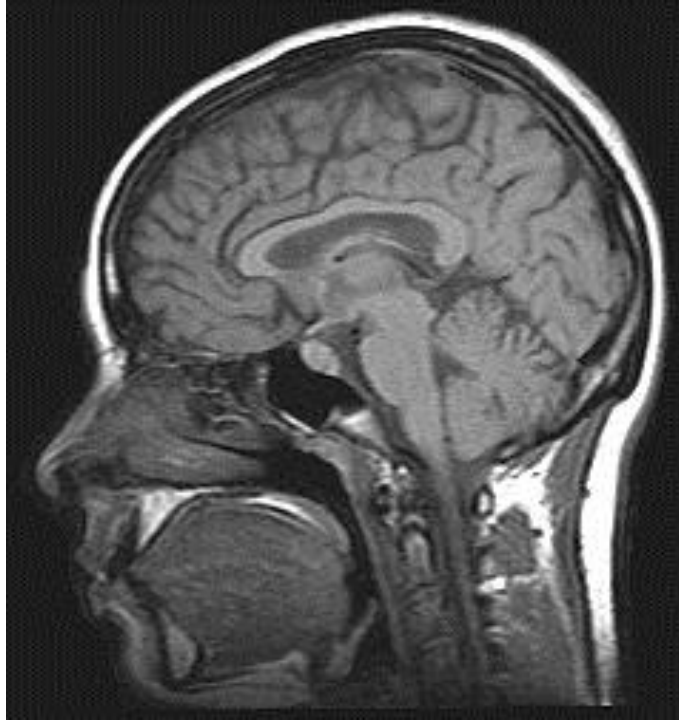
Goals & Application Domains of NPAR



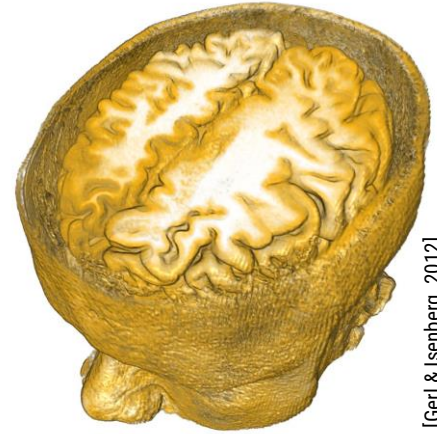
NPAR Tools for Doctors (and Patients)



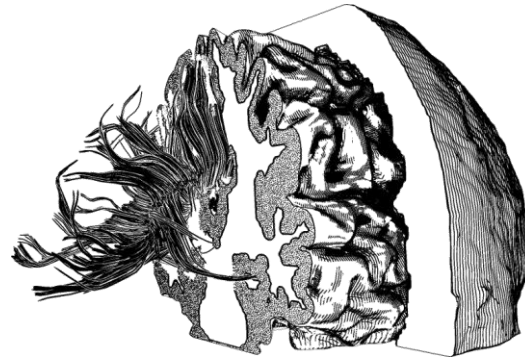
NPAR Tools for Doctors (and Patients)



[Bruckner & Gröller, 2007b]



[Gert & Isenberg, 2012]



[Svetachov et al., 2010]

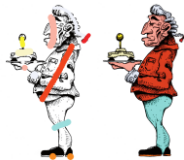
Low-level vs. High-level Tasks and Control

workload/control over result

high-level control



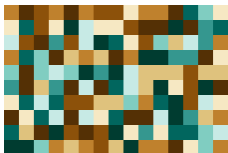
[Semmo et al., 2015/16]



[Sykora et al., 2009b]



[Curtis et al., 1997]



[<http://two-n.com/pi/>]

influence of input

low-level control

An Interaction Spectrum



RealBrush [Lu et al., 2013]



Sisley the abstract Painter
[Zhao & Zhu, 2010]



An Interaction Spectrum

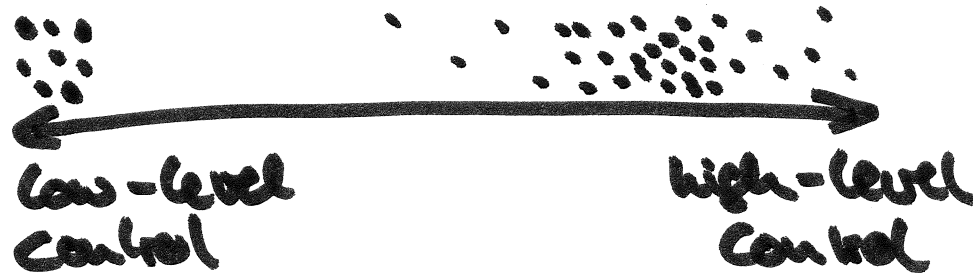


RealBrush [Lu et al., 2013]

artists
(& illustrators)



Sisley the abstract Painter
[Zhao & Zhu, 2010]



An Interaction Spectrum

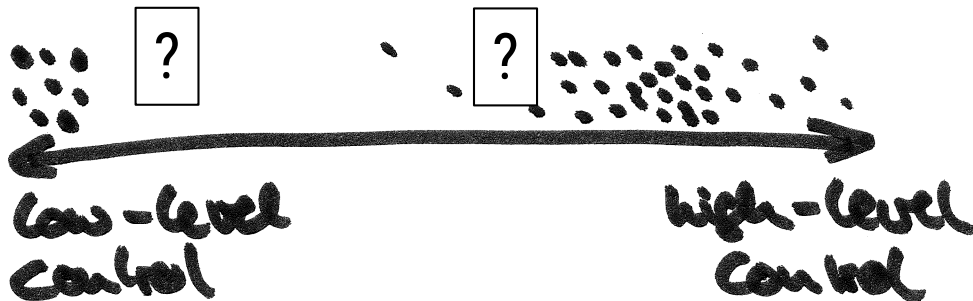


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An Interaction Spectrum



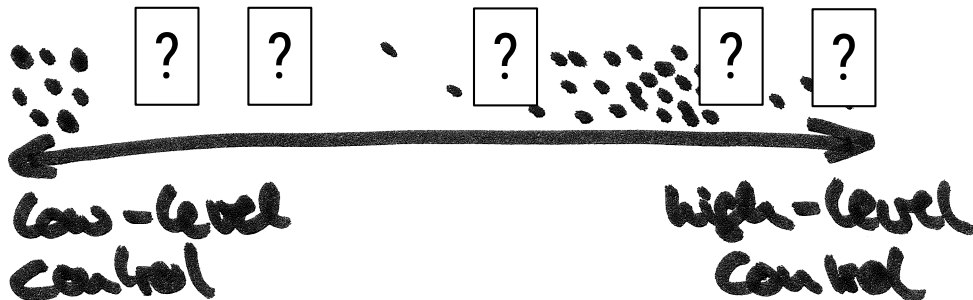
RealBrush [Lu et al., 2013]

artists
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non-artists
("everyone")



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An Interaction Spectrum



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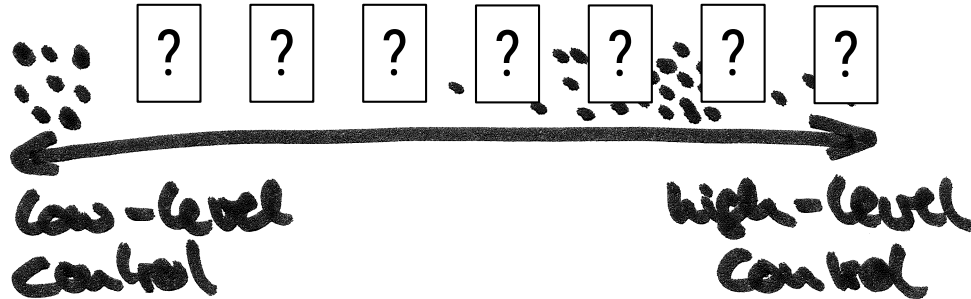
artists
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non-artists
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scientists
(data visualization)



Sisley the abstract Painter
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An Interaction Spectrum



RealBrush [Lu et al., 2013]

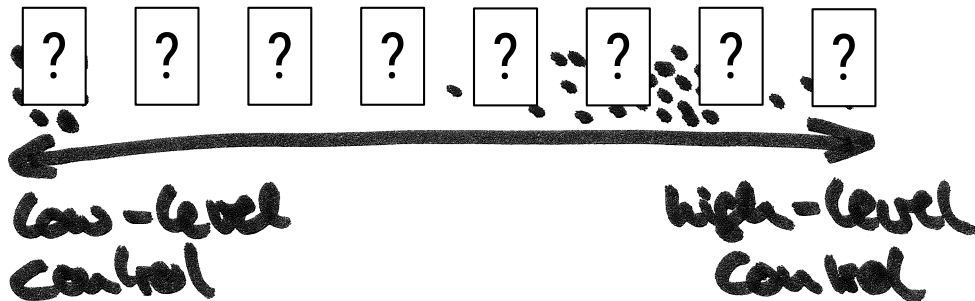
artists
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non-artists
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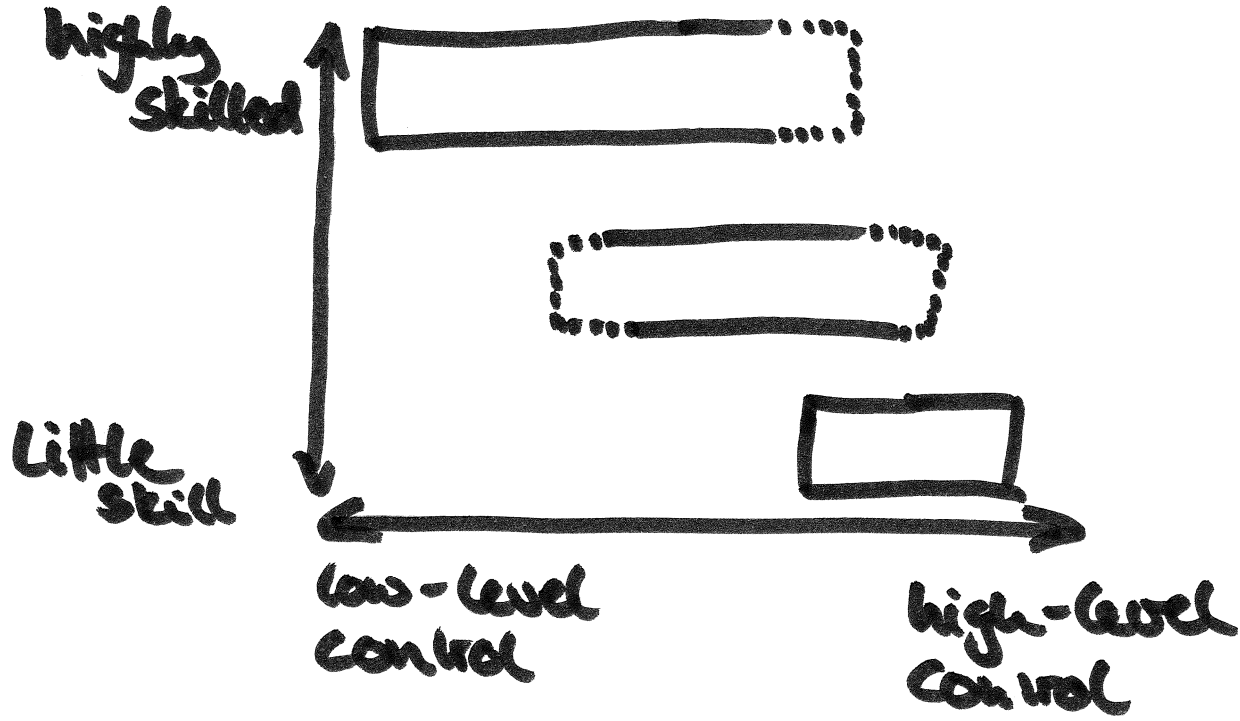
scientists
(data visualization)



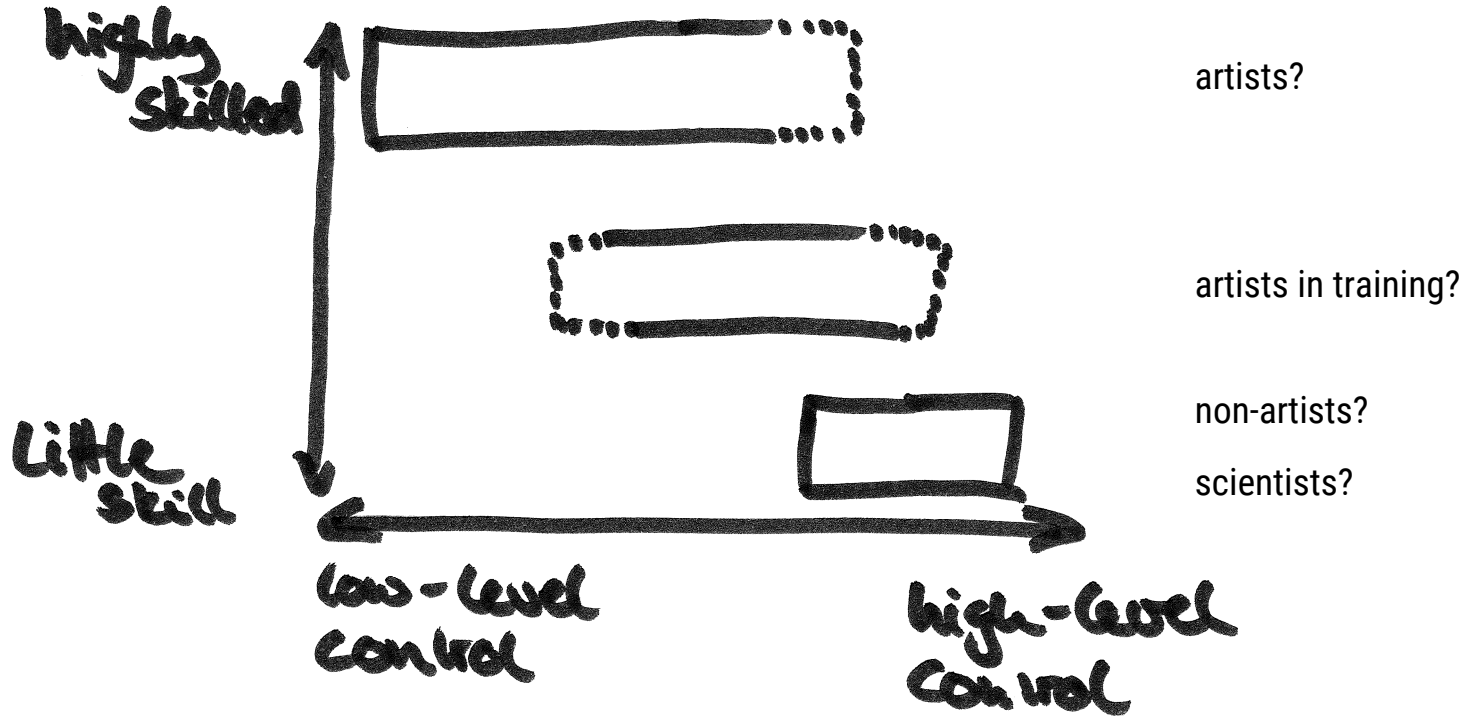
Sisley the abstract Painter
[Zhao & Zhu, 2010]



Mapping the Interaction Spectrum

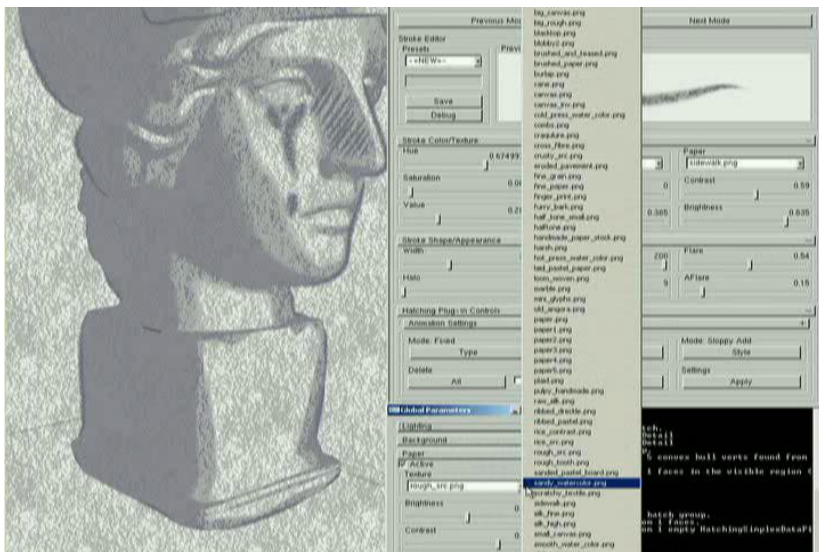


Mapping the Interaction Spectrum

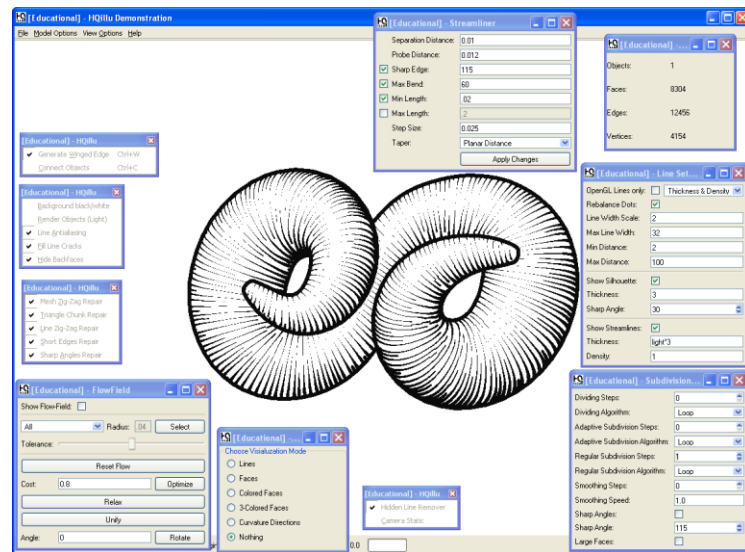


Challenges of Providing Appropriate Control

- How to cope with system complexity?



WYSIWYG-NPR [Kalnins et al., 2003]



[Zander et al., 2004]

A. Finkelstein: “The user interface provides a myriad of controls for paper and brush qualities ...”

Challenges of Providing Appropriate Control

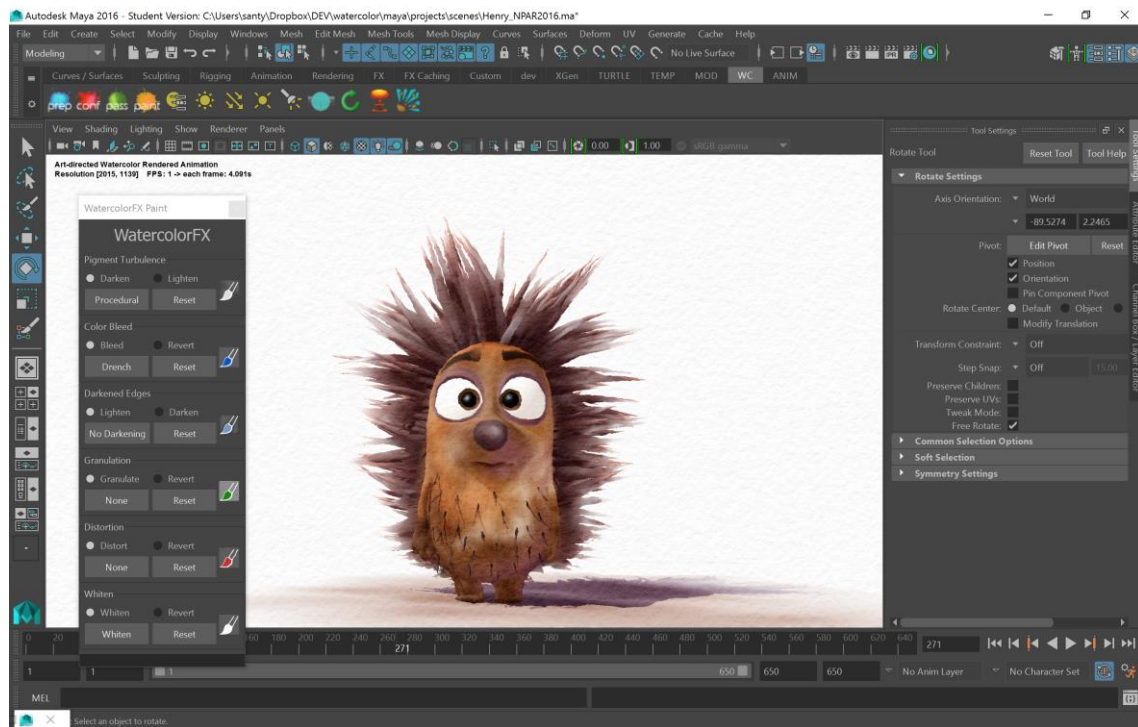
- How to cope with system complexity?



Paint by Relaxation [Hertzmann, 2001]

Challenges of Providing Appropriate Control

- How to cope with system complexity?



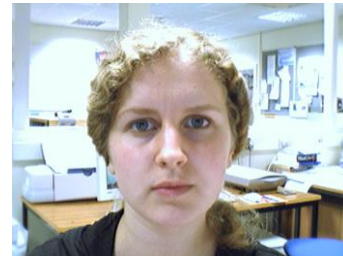
[Montesdeoca et al., 2016]

Challenges of Providing Appropriate Control

- How to cope with system complexity?



[Collomosse, 2006]



[Shugrina et al., 2006]

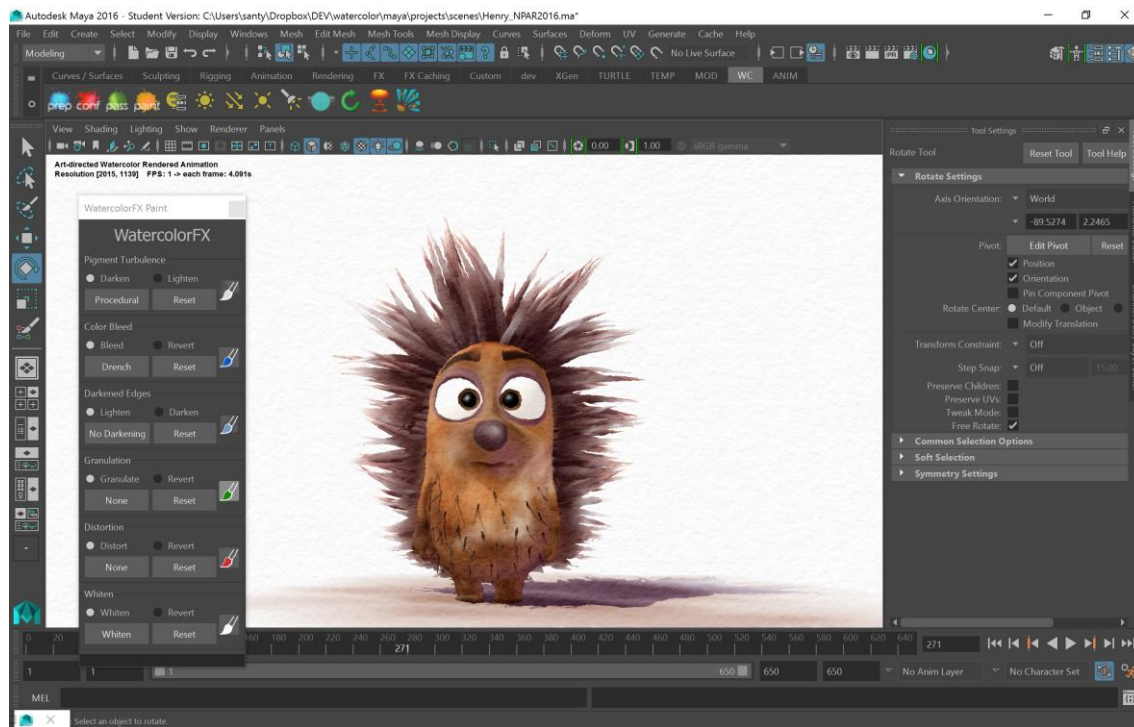
Challenges of Providing Appropriate Control

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Challenges of Providing Appropriate Control

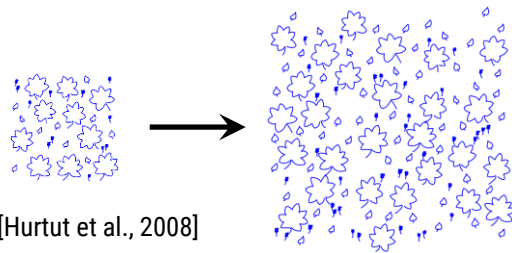
- How to cope with system complexity?



[Montesdeoca et al., 2016]

Challenges of Providing Appropriate Control

- example-based operators vs. media simulations:
adjustable level of control



[Lukáč et al., 2013]



WYSIWYG-NPR [Kalnins et al., 2003]



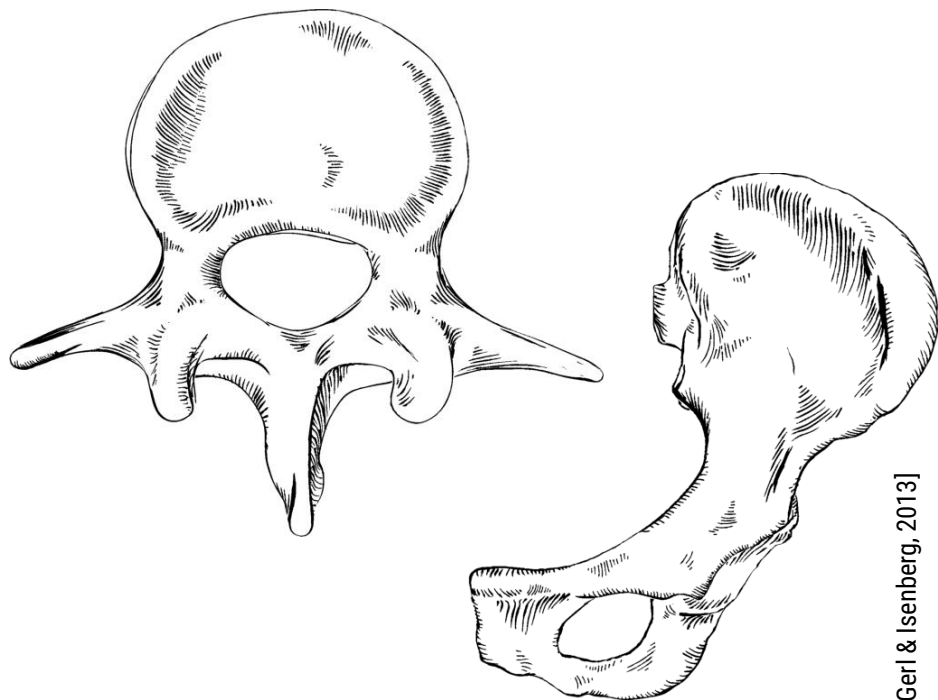
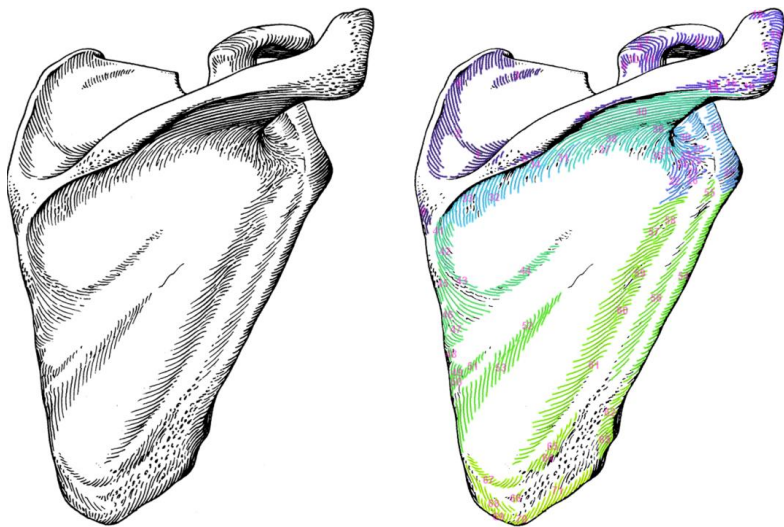
[Martín et al., 2010/11]



[Bénard et al., 2013]

Challenges of Providing Appropriate Control

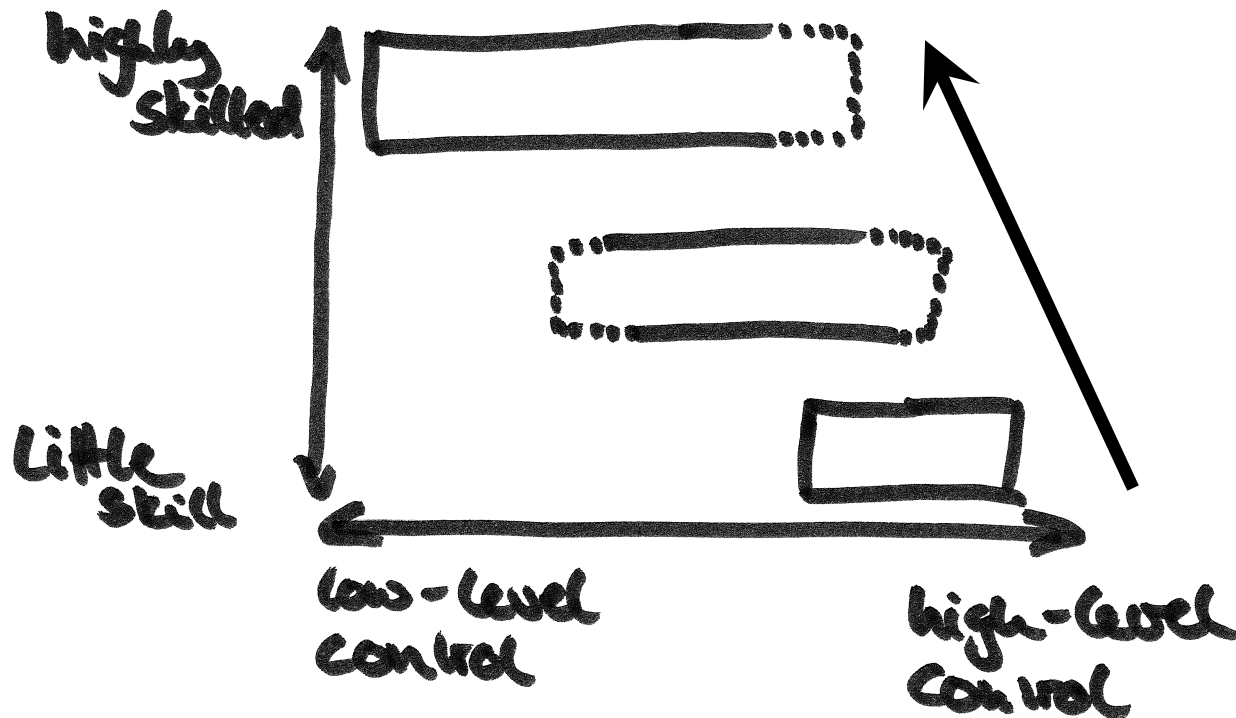
- example-based operators vs. media simulations:
adjustable level of control



[Gerl & Isenberg, 2013]

Challenges of Providing Appropriate Control

- How to evolve the interactivity with growing skill?



Challenges of Providing Appropriate Control

- learn from HCI (support of creative work); e.g., [Resnick et al., 2005]
 - Support Exploration
 - Low Threshold, High Ceiling, and Wide Walls
 - Support Many Paths and Many Styles
 - Support Collaboration
 - Support Open Interchange
 - Make It As Simple As Possible - and Maybe Even Simpler
 - Choose Black Boxes Carefully
 - Invent Things That You Would Want To Use Yourself
 - Balance user suggestions, with observation and participatory processes
 - Iterate, Iterate - Then Iterate Again
 - Design for Designers
 - Evaluation of Tools

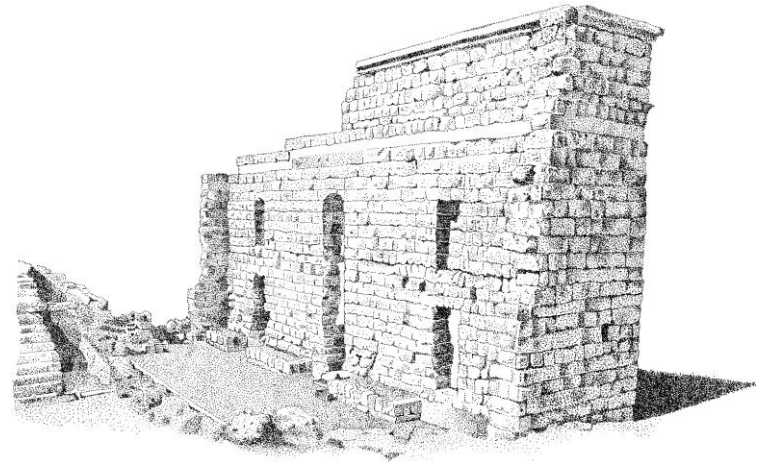
What Kind of Tools to Create? – Three Theses

1. better involve target audiences of the tools
 - [Bleser et al., 1988; Meier, 1999; Seims 1999]
 - “user-centric NPR” [Winnemöller, 2013]
 - evaluation

What Kind of Tools to Create? – Three Theses

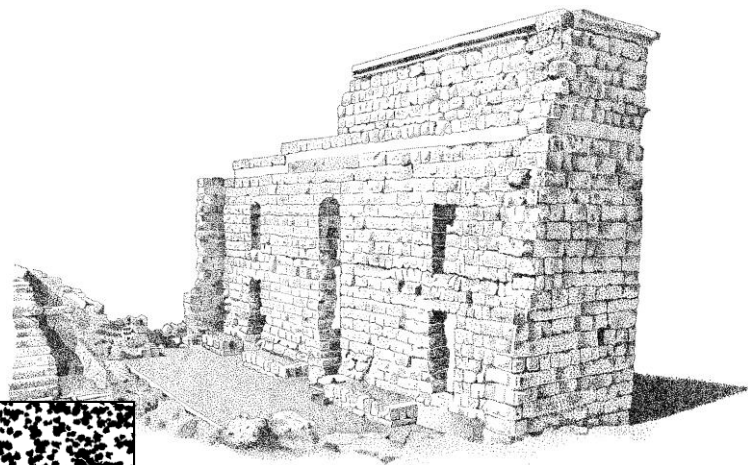
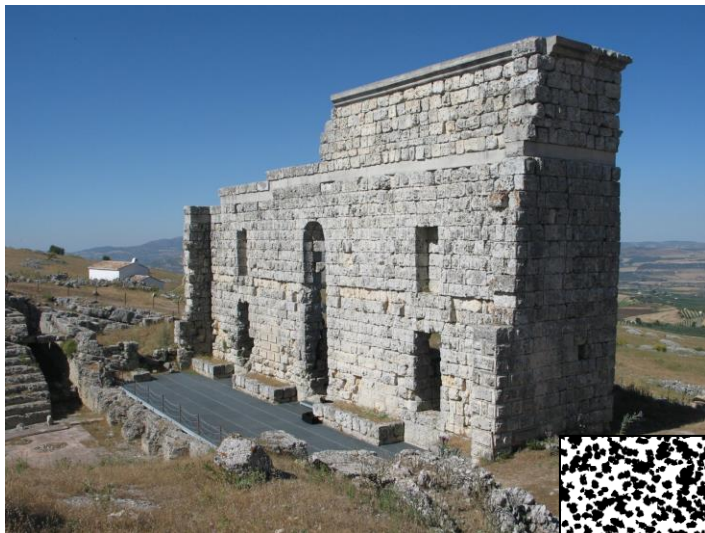
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What Kind of Tools to Create? – Three Theses



[Martín et al., 2010/11]

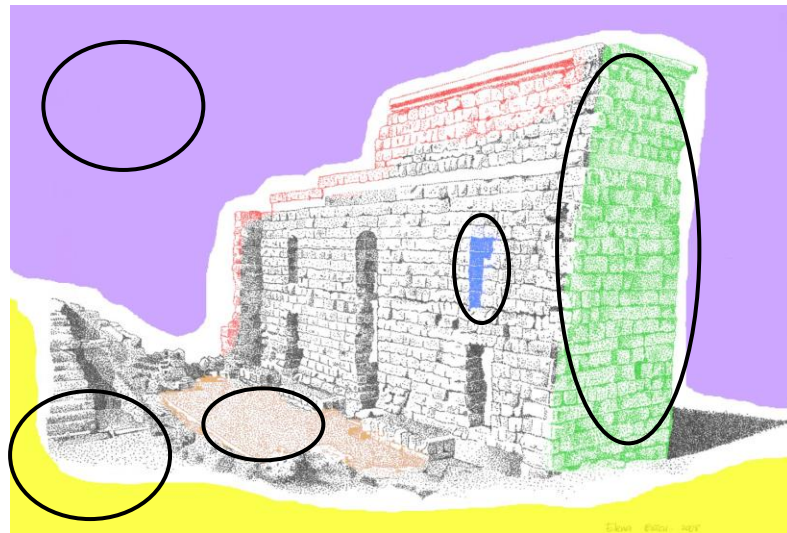
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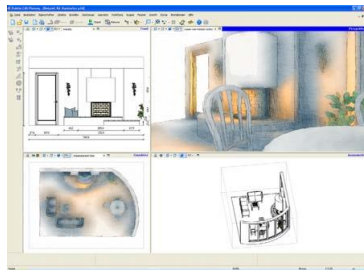


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2. cover larger ranges of the interaction spectrum
3. NPAR success stories



[PaintCan]



[Luft et al., 2008]



[Universal Pictures/Winnemöller, 2013]



[Harvill, 2007]



[Mitchell et al., 2007]

Interactive NPAR: What type of tools should we create?*

Tobias Isenberg



* The selection of examples is biased and many more excellent examples exist for the mentioned approaches.