Multiple Levels of Detail in Computer Graphics

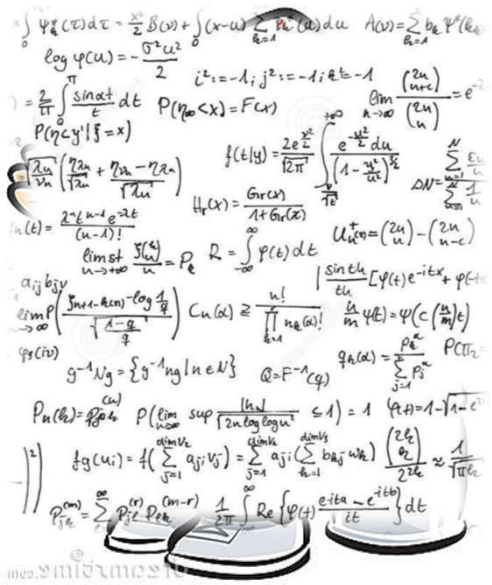
Prof. Dr. Elmar Eisemann

Delft University of Technology

Computer Graphics and Visualization

Simplified definition:

- Technology for producing images on a computer.



Principles:

- Mathematical Models and Algorithms
- Hi.Perf. Computing and Data Structures
- Problem-driven

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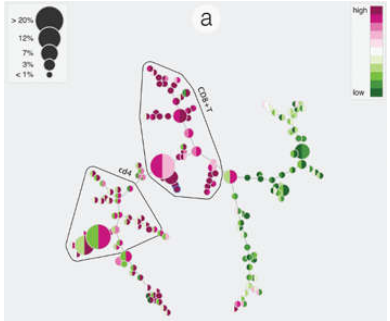
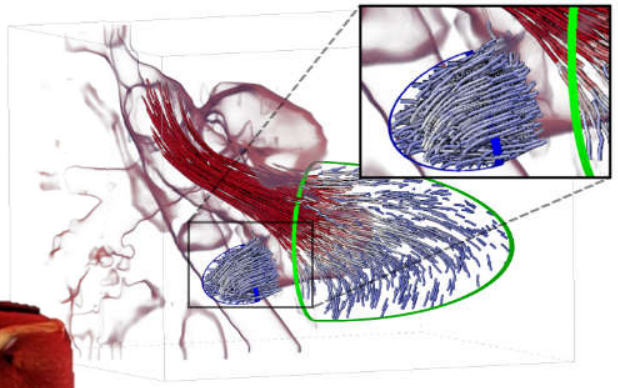
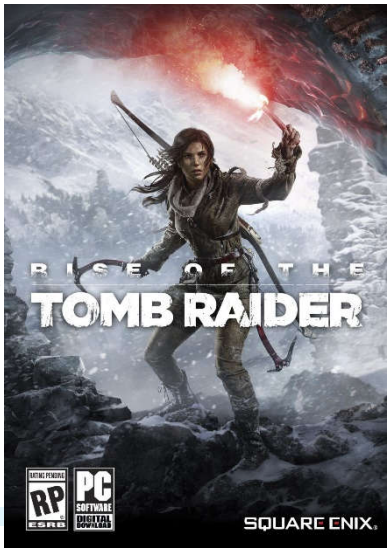
Computer Graphics and Visualization

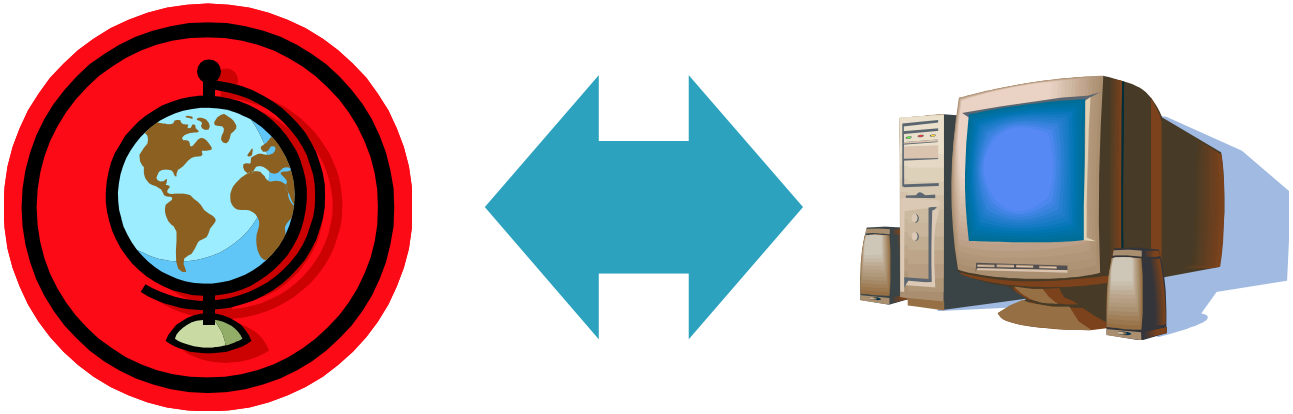
- Our work impacts many domains
  - Big Data Analysis
  - Scientific Visualization
  - Architecture/Design
  - Education
  - Entertainment
  - …







Linking the Real and the Virtual World



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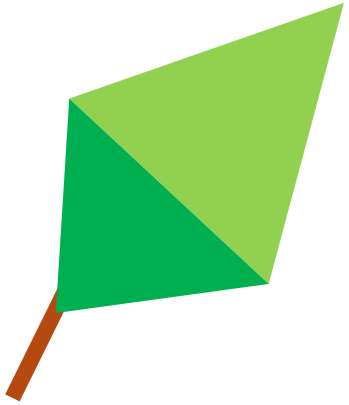
Introduction

- Details should be everywhere…



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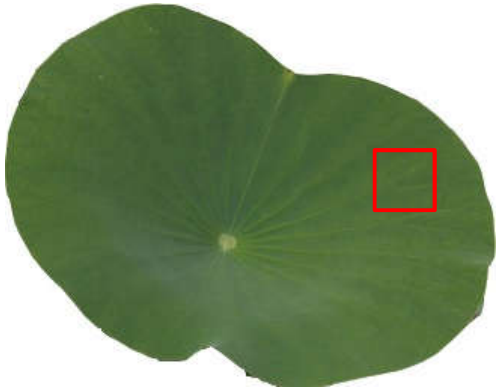
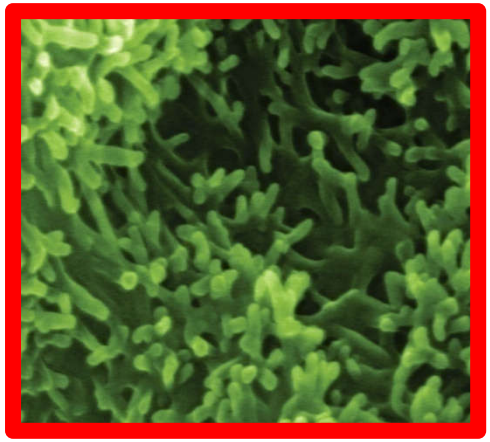


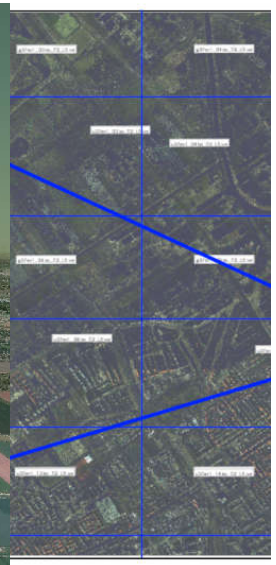


Introduction

- AHN2 dataset ~8 TB of data including colors

Introduction

- AHN2 dataset ~8 TB of data including colors
  - A 20 m tower of CDs



Sensors everywhere…

- Big brother is measuring you…

There will be a trillion (!) sensors within the next 5 years…

E.g., Google Earth already stores 21 Million Gigabytes

KNMI: 1.5Pb/year

How can we make use of this data?

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Data Development

- **Processing**
- **Analysis**
- **Interaction**
- **Visualization**

Data

Compute Power

Need new ways to deal with data!

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Data?

- SALEM OR 46 67 RAIN 52/61 RAIN 50/60 SALT LAKE CITY 58 86 PTCLDY 56/85 PTCLDY 54/78 SAN ANGELO 67 86 MOCLDY 68/91 PTCLDY 69/92 SAN ANTONIO 68 82 9.87 MOCLDY 71/89 MOCLDY 70/91 SAN DIEGO 60 68 MOCLDY 60/67 MOCLDY 61/68 SAN FRANCISCO 50 60 WINDY 53/62 MOCLDY 52/64 SAN JOSE 47 68 PTCLDY 52/69 MOCLDY 52/68 SAN JUAN PR 75 89 .55 SHWRS 77/87 SHWRS 78/85 SANTA FE 52 87 SUNNY 51/86 PTCLDY 48/83 ST STE MARIE 34 60 SUNNY 36/65 SUNNY 34/72 SAVANNAH 53 80 PTCLDY 53/84 PTCLDY 60/85 SEATTLE 51 64 CLOUDY 50/64 CLOUDY 51/64 SHREVEPORT 68 88 MOCLDY 69/87 PTCLDY 66/88 SIOUX CITY 56 72 .01 MOCLDY 61/78 MOCLDY 64/77 SIOUX FALLS 56 74 TSTRMS 56/73 MOCLDY 60/75 SOUTH BEND 39 66 MOCLDY 47/66 SHWRS 51/69 SPOKANE 40 61 MOCLDY 44/67 MOCLDY 47/66 SPRINGFIELD IL 47 58 .46 TSTRMS 53/72 TSTRMS 61/78 SPRINGFIELD MO 56 80 MOCLDY 62/80 PTCLDY 63/82 SYRACUSE 43 57 SUNNY 40/63 SUNNY 39/68 TALLAHASSEE 55 89 SUNNY 56/88 PTCLDY 62/90 TAMPA 73 92 SUNNY 67/89 PTCLDY 69/88 TOLEDO 36 66 PTCLDY 41/67 MOCLDY 44/69 TOPEKA 64 84 MOCLDY 66/83 WINDY 66/85 TUCSON 67 97 SUNNY 65/96 SUNNY 63/95 TULSA 64 84 MOCLDY 70/83 MOCLDY 69/85 TUPELO 51 82 PTCLDY 56/86 PTCLDY 61/87 WACO 67 84 MM MOCLDY 68/86 MOCLDY 67/88 WASHINGTON DC 46 68 SUNNY 47/73 SUNNY 50/77 W PALM BEACH 75 83 PTCLDY 72/82 PTCLDY 73/83 WICHITA 66 83 PTCLDY 65/85 WINDY 67/86 WICHITA FALLS 67 82 .11 WINDY 65/91 WINDY 66/92 WILKES BARRE 42 56 .15 SUNNY 39/65 SUNNY 37/72 WILMINGTON DE 47 65 SUNNY 44/71 SUNNY 46/77 YAKIMA 41 70 MOCLDY 46/63 MOCLDY 48/65 YOUNGSTOWN 30 61 SUNNY 33/64 SUNNY 34/70 YUMA 70 98 SUNNY 66/97 SUNNY 67/96

Appropriate Tools!

- Visualization
- Interaction

Appropriate Solutions

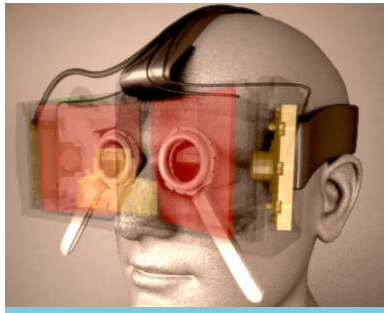
- There is a need to
  explore information and
  find relationships in data

Visual Analytics

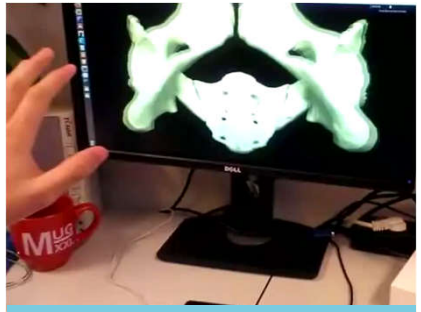
- Interactive Hypothesis Development
- Interfaces and Displays

Multi-touch Data Mining

3D Displays

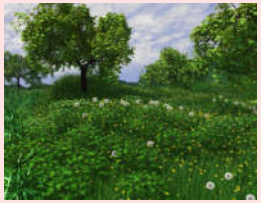


Virtual/Augmented Reality



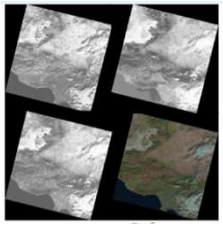
Gesture Interaction

Effective Data Visualization Requires



- Large-Scale Data Representations

- Visualization and Interaction



- Data Analysis

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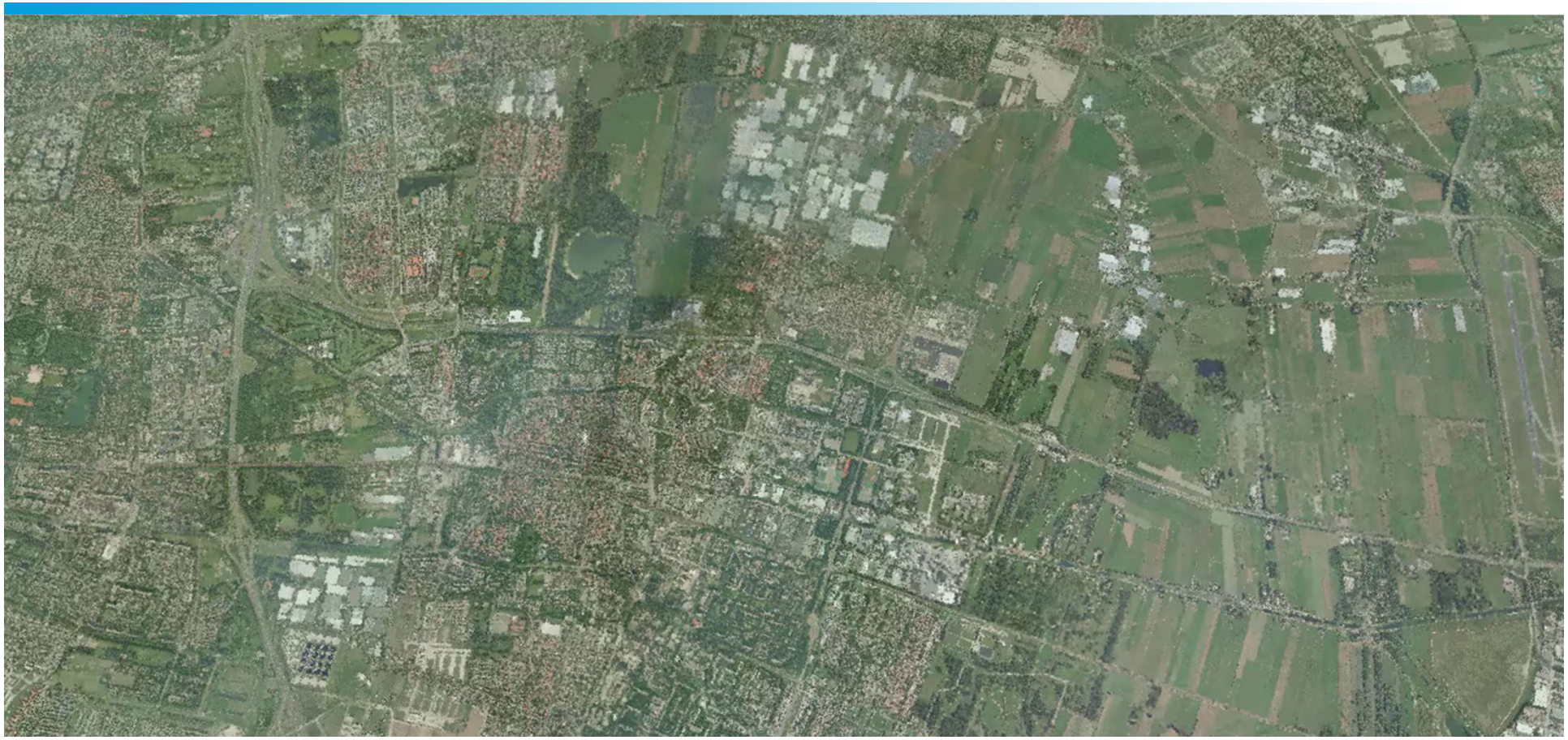
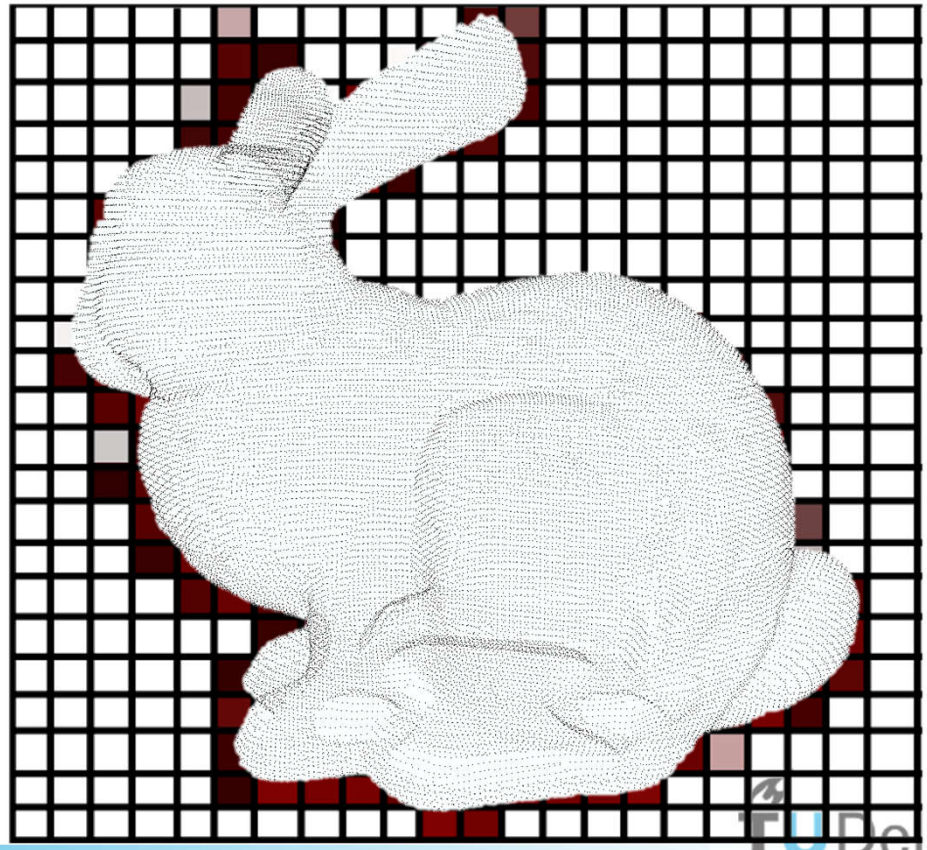
Large-Scale Data



Add structure…

- Voxel Representations



Voxel Representations

On The Loose, Exposition at Sydney Aquarium and Wildlife World

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Voxel Representations

- **Main problem:**
  - Memory is a key issue!
    - E.g. 2048^3 x RGBA = **32 GB**

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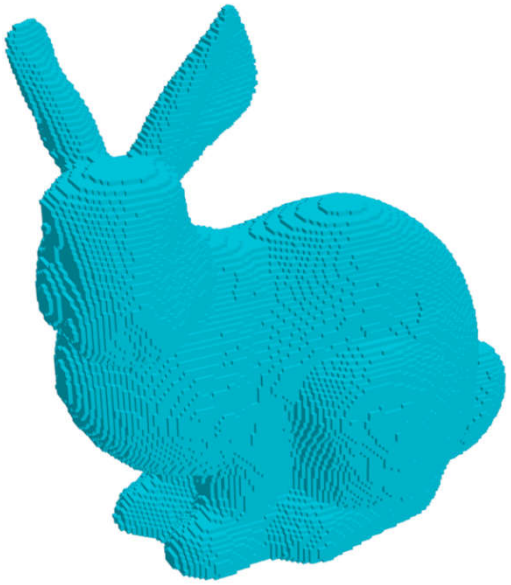
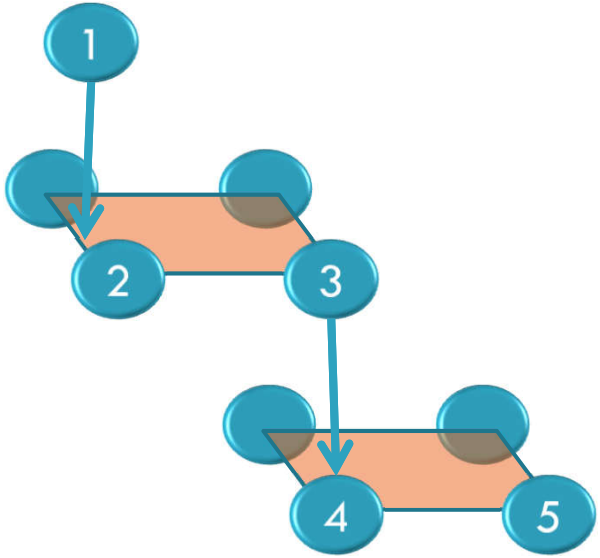
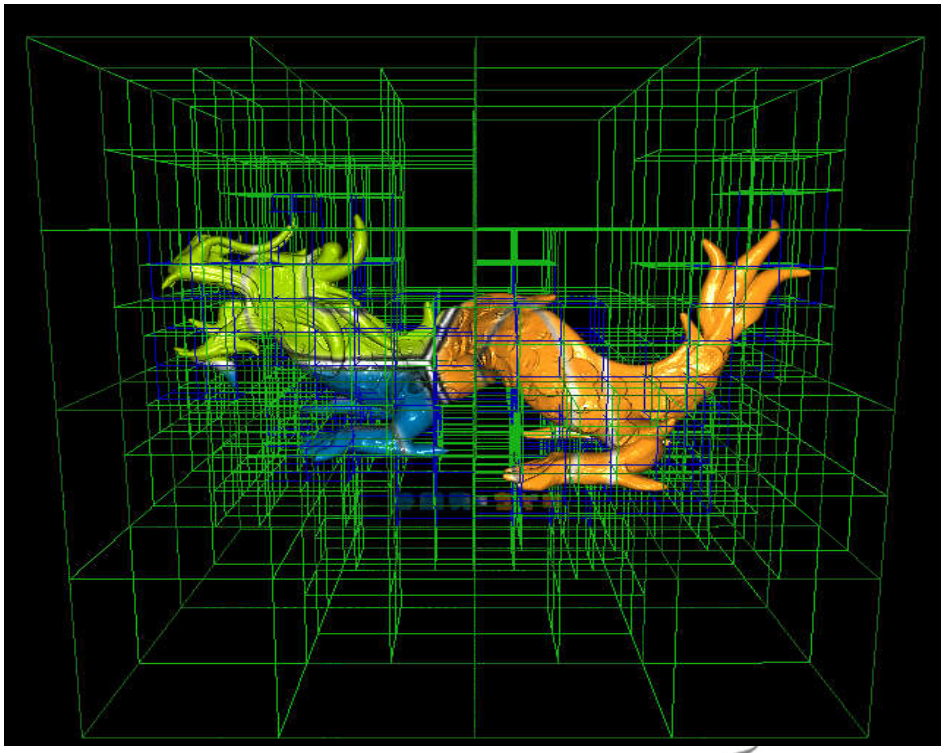
Voxel Representations



Octree of Small Voxel Blocks





Adaptive Display Algorithms

- Do not need same precision everywhere!
- Restrict to visible part

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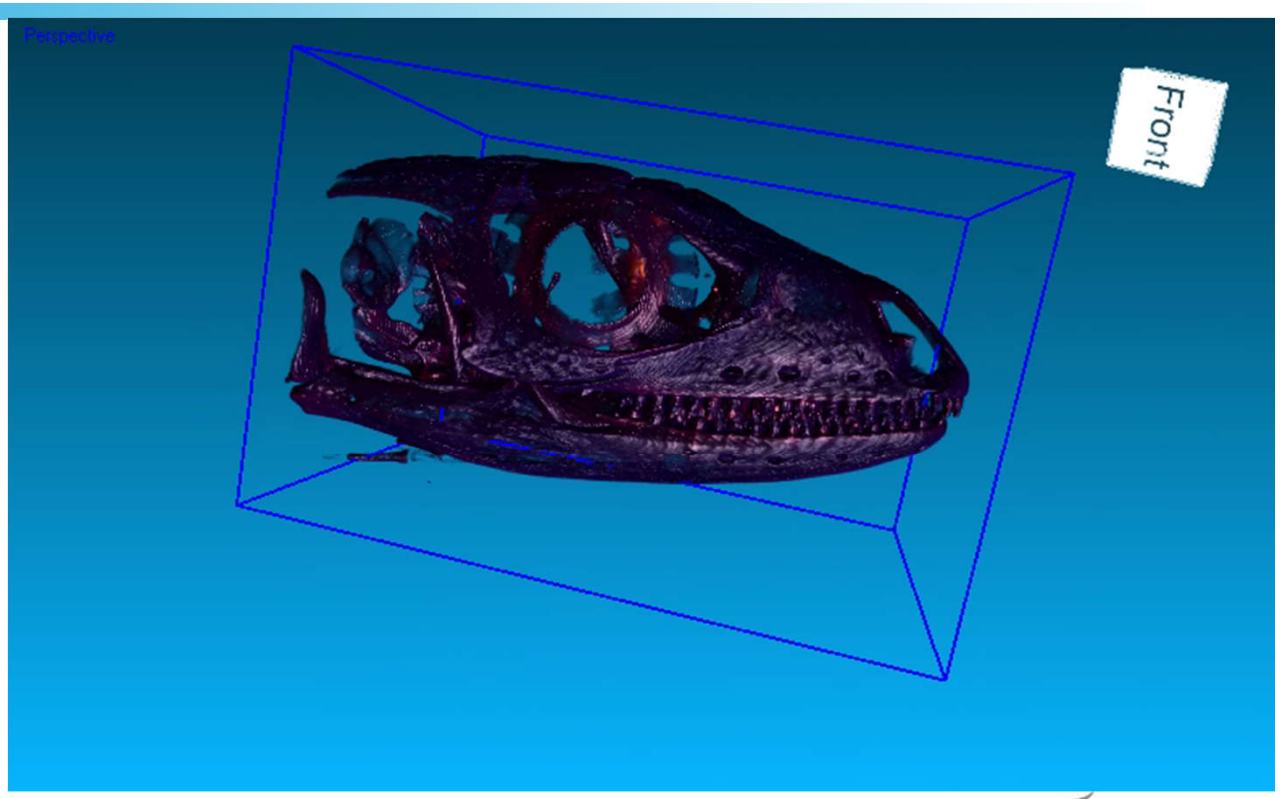
[Crassin, Neyret, Lefebvre, Eisemann – I3D 2009]
[Crassin, Neyret, Lefebvre, Eisemann – GPUPro2010]

Adaptive Display Algorithms

- Combine Simplification & Visibility
- Efficient memory updates



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[Crassin, Neyret, Lefebvre, Eisemann – I3D 2009]
[Crassin, Neyret, Lefebvre, Eisemann – GPUPro2010]

Large-Scale Data

Large-Scale Rendering

Major remaining challenges for less performant systems:

- Storage (volumes grow quickly)
- Data Transfer to Graphics Card

compression

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Compression

[Dado, Kol, Thiery, Bauszat, Eisemann – Eurographics 2016]

2^51 voxels = 2,251,799,813,685,248 Voxels

Compression

[Dado, Kol, Thiery, Bauszat, Eisemann – Eurographics 2016]

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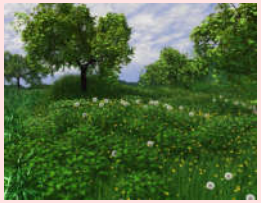
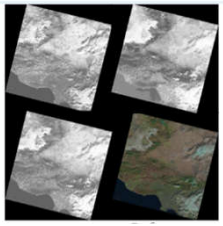
Effective Data Visualization Requires



- Large-Scale Data Representations

- Visualization and Interaction



- Data Analysis

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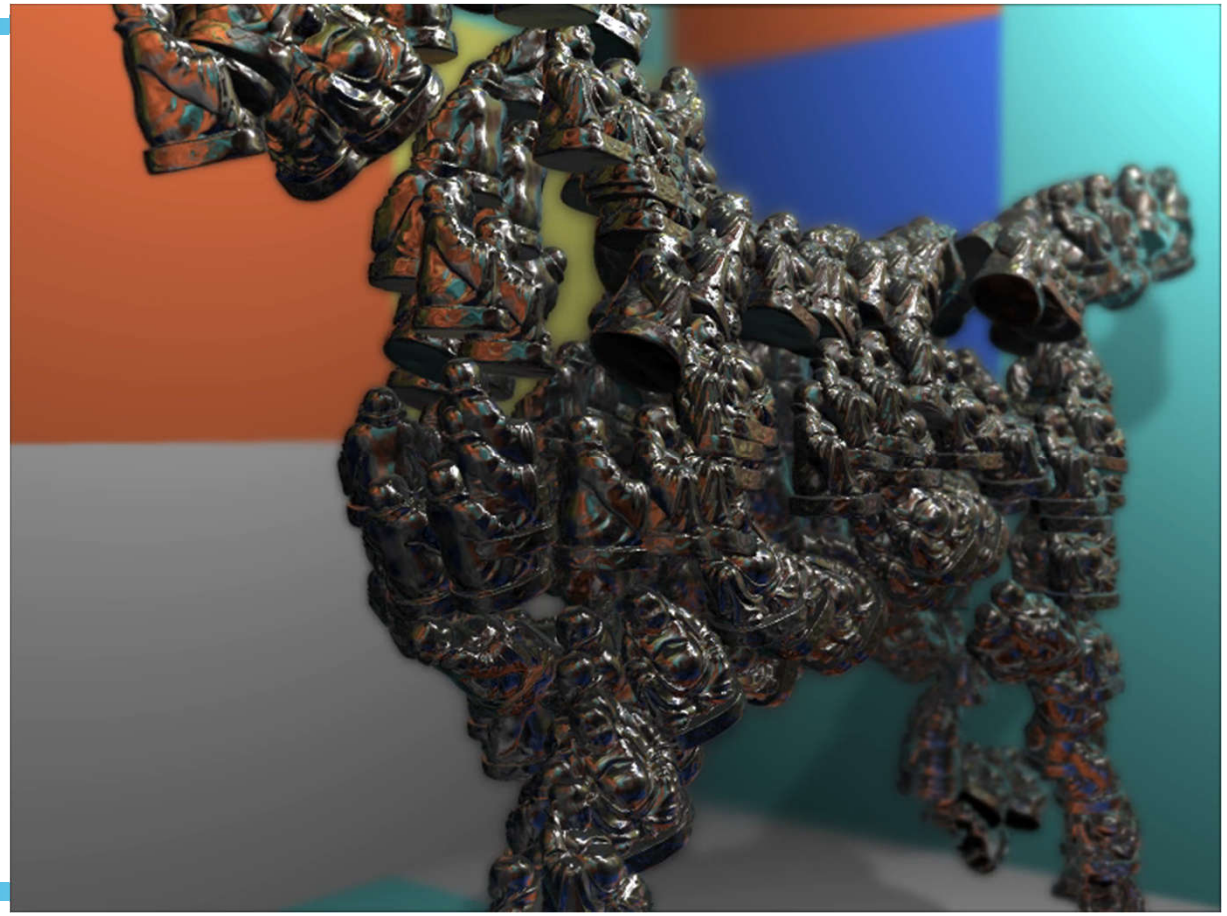
In all examples
SM resolution: 1024x1024
scattering: < 3 ms
Scene complexity and extent do only marginally

Light Physics

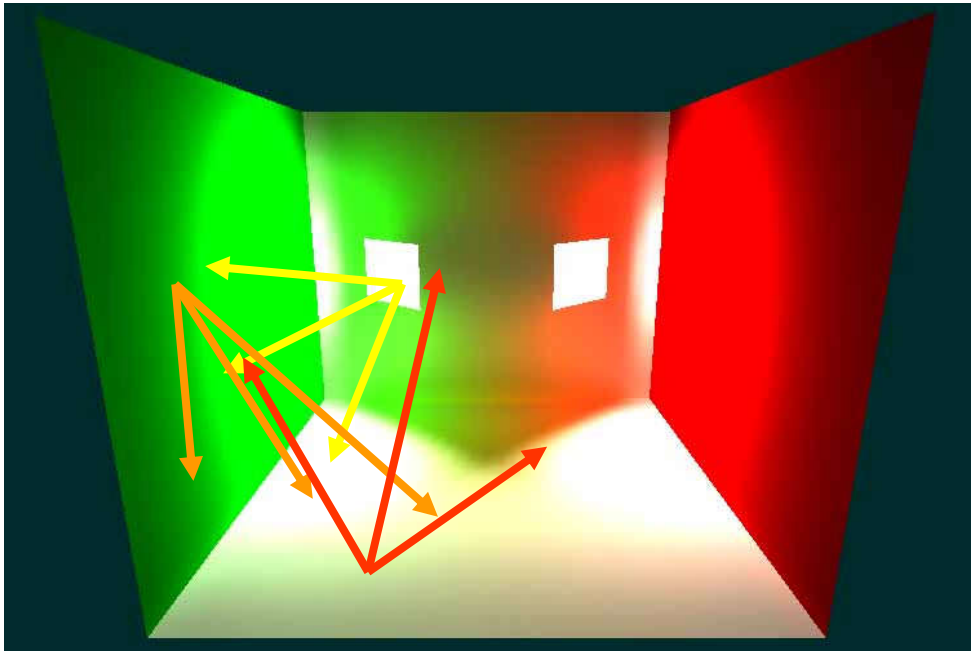
[Eisemann&Decoret - CGF 2008]
[Holländer, Ritschel, Eisemann, Boubekeur - EGSR 2011]
[Ritschel, Eisemann, Ha, Kim, Seidel - CGF 2011]
[Baboud, Eisemann, Seidel, TVCG 2012]

- Shadows
- Reflections
- Refractions
- Caustics
- Transparency
- Global Illumin.

…



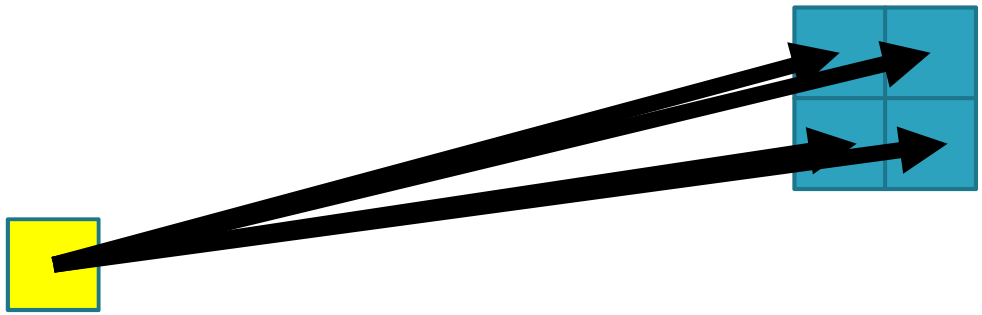
Light Physics



In 2002…
More than 4 hours
8 triangles

Voxel-Cone Tracing

- Voxel Hierarchies are convenient for light transport



Voxel-Cone Tracing

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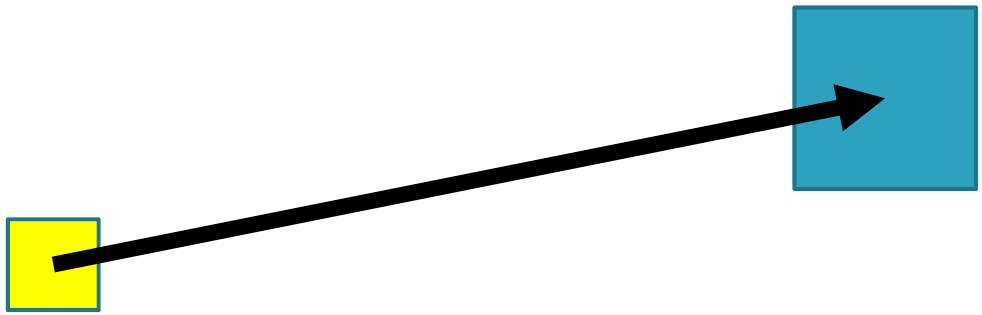
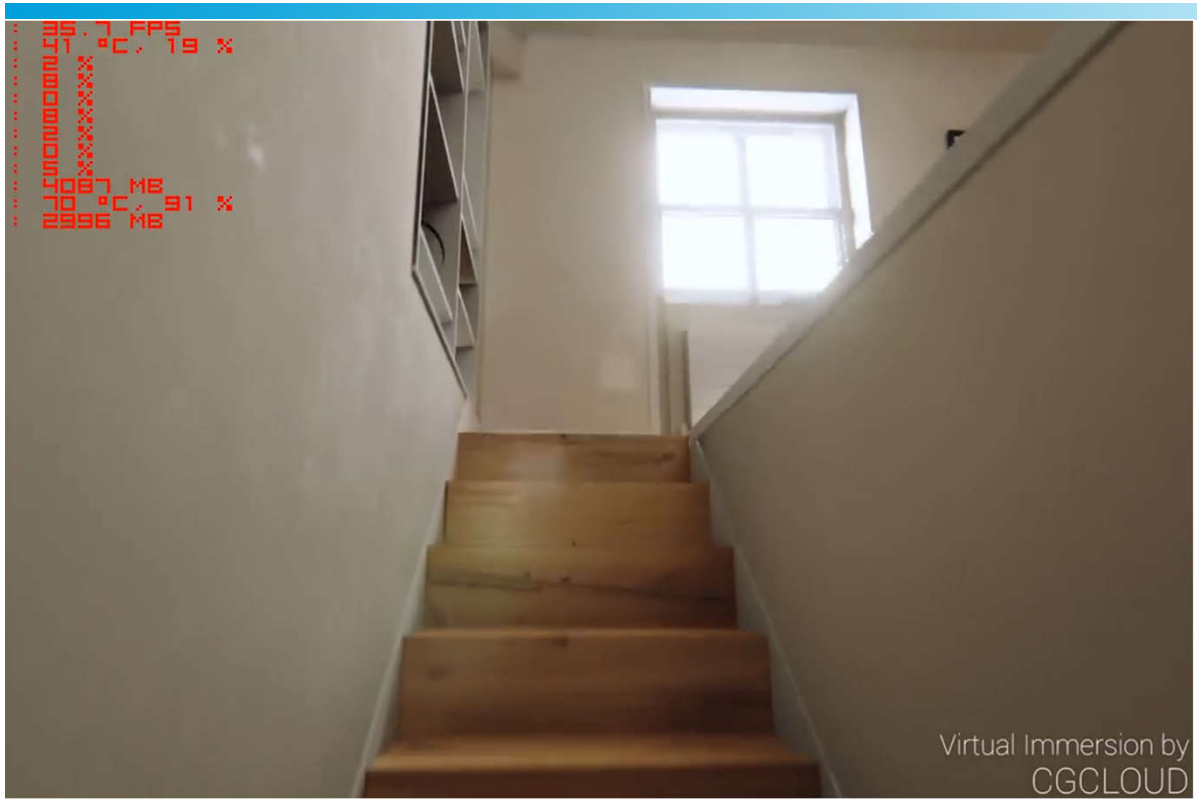


Voxel-Cone Tracing

[Kroes, Eisemannx2 - GI2015] , **Sweeney Award Winner**
[v. Radziewski, Kroes, Eisemannx2 - TVCG 2016]
[Crassin, Neyret, Sainz, Green, Eisemann, PG 2012]



- Cry Engine,
  Unreal Engine 4,
  VXGI,
  and Unity

http://thenextweb.com/gaming/2016/03/24/engine-dominating-gaming-industry-right-now/

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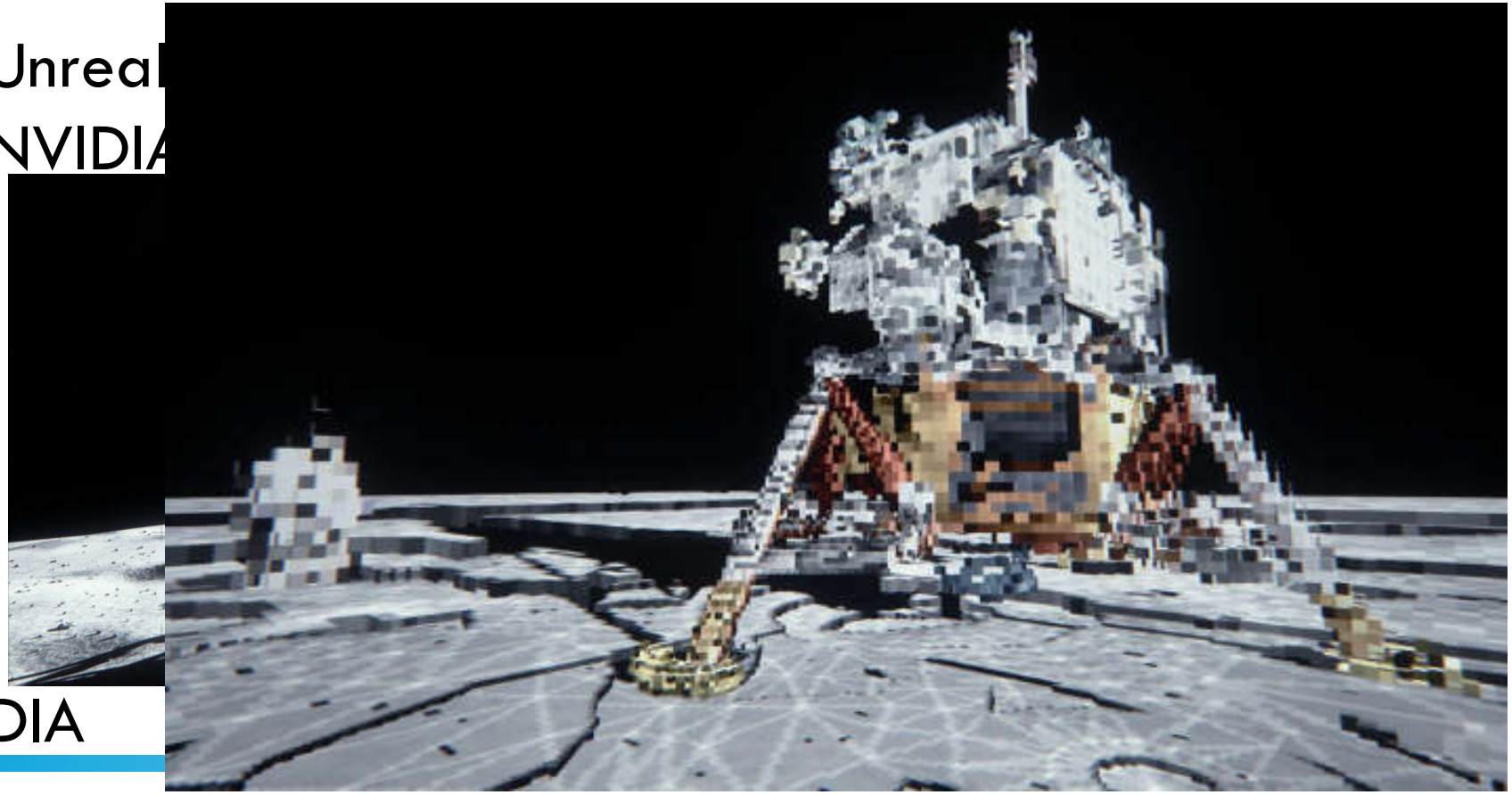
NVIDIA Debunks the Moon Landing…

- Unreal Engine 4 / Cry Engine ship our technology NVIDIA VXGI

© NVIDIA

NVIDIA Debunks the Moon Landing…

- Unreal
  NVIDIA



© NVIDIA

Scanned Data Sets

Realistic Visualization

Better understanding:

- Reproduction of 1953 flooding exhibited in the
  - Noodwatermuseum Zeeland
  - Delft Science Center

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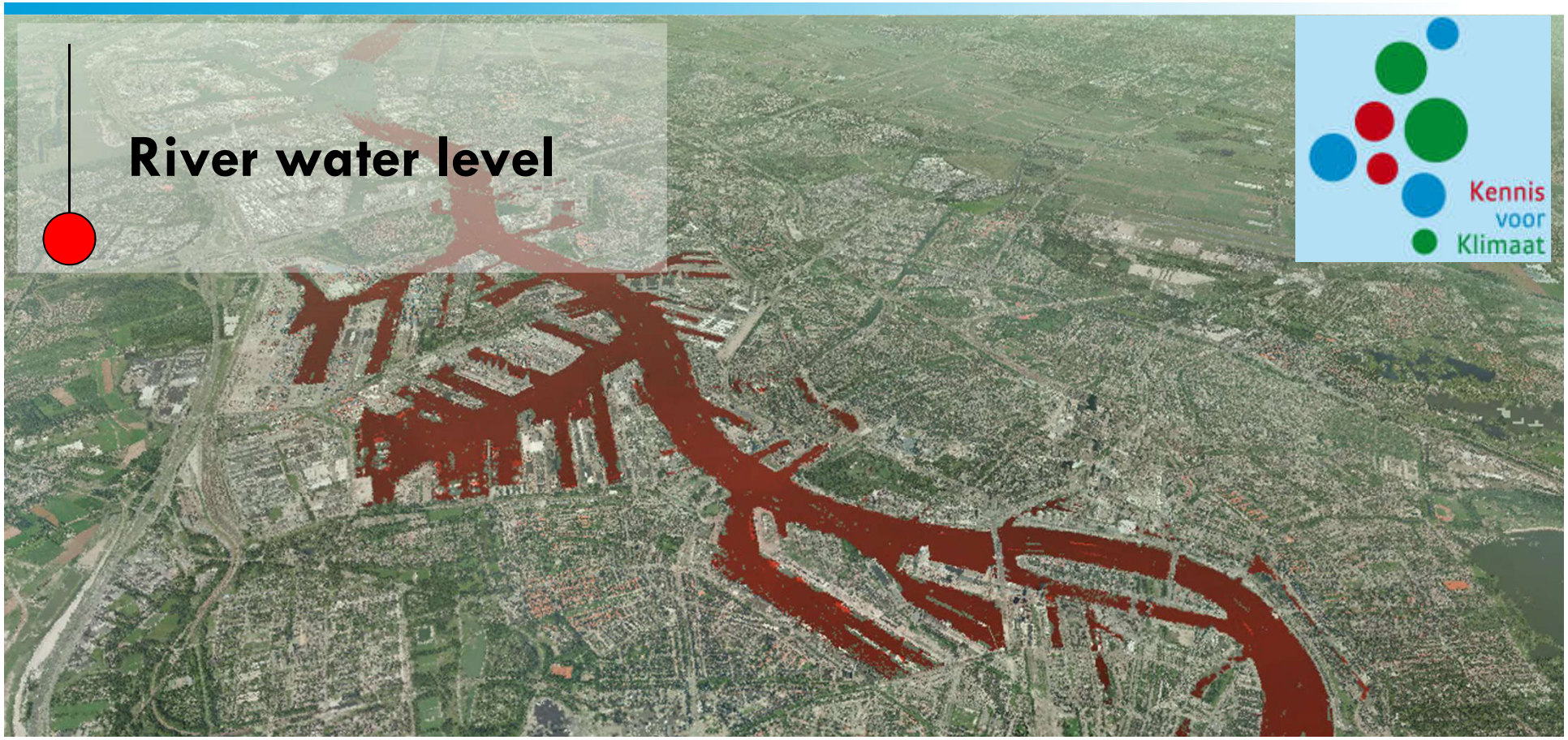
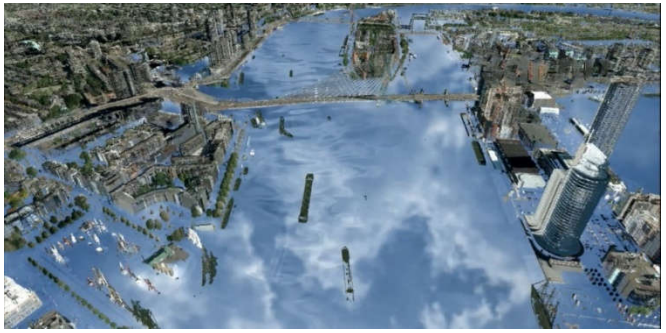
Collaborative Decision Making

Flooding Scenario



[Leskens, Kehl, Tutenel, Kol, de Haan, Stelling, Eisemann – Science Env. Pol./Mit.Glob.Change 2015]

Benefits of Realistic 3D Visualization



- Accessible to non-experts
- Useful for decision making
  - More involved discussions from all parties
  - Better estimation of damages/dangers
  - Better understanding of the context

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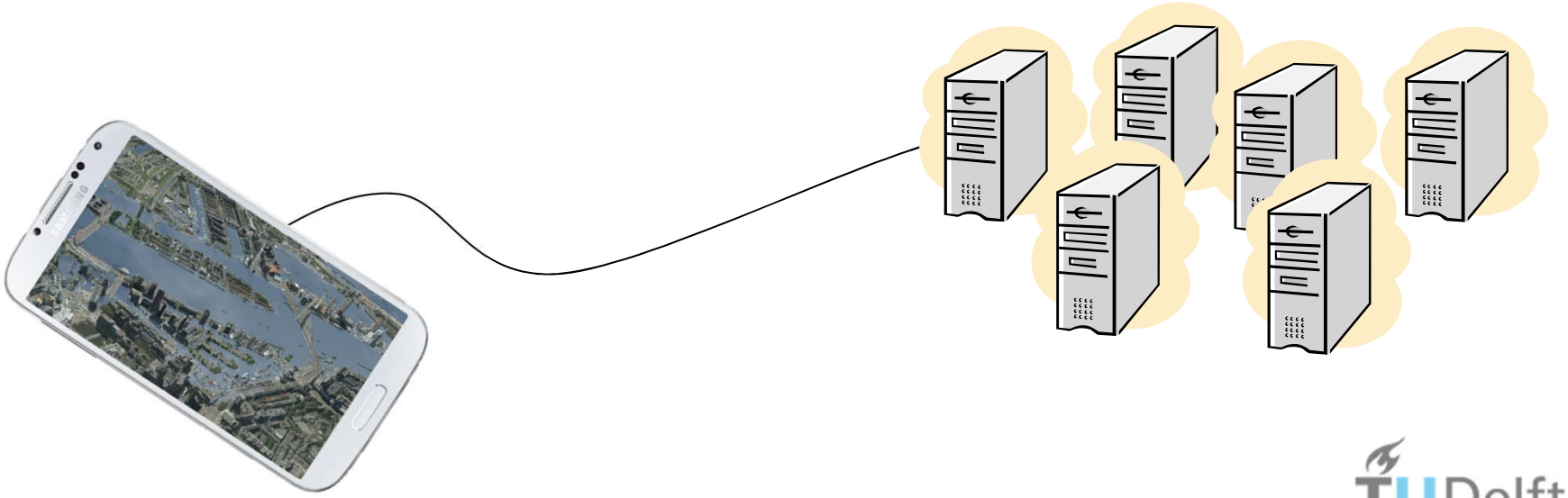
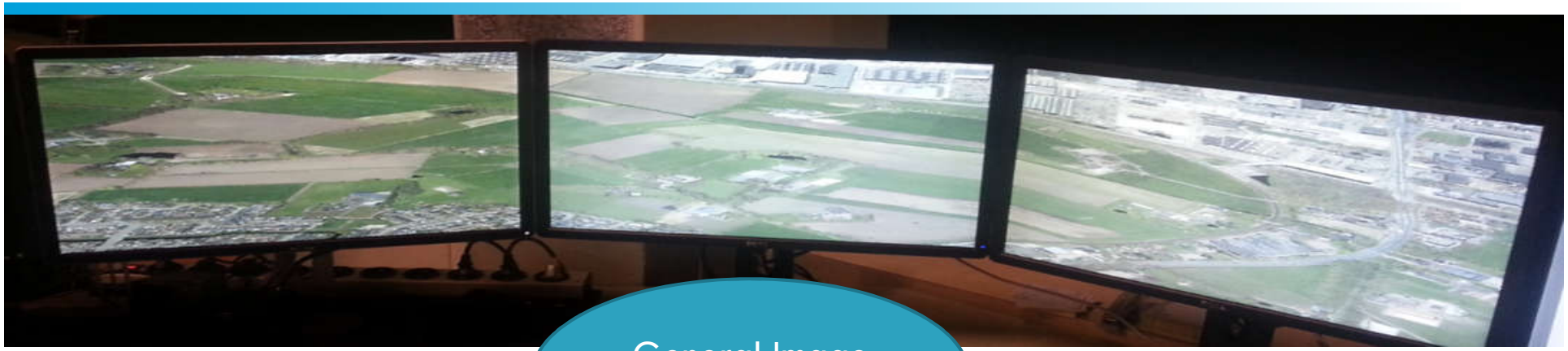
Remote Computing

[Pajak et al. EG 2014]



Remote Computing

Enlighten your Research
SurfSara



General Image
Synthesis Solution

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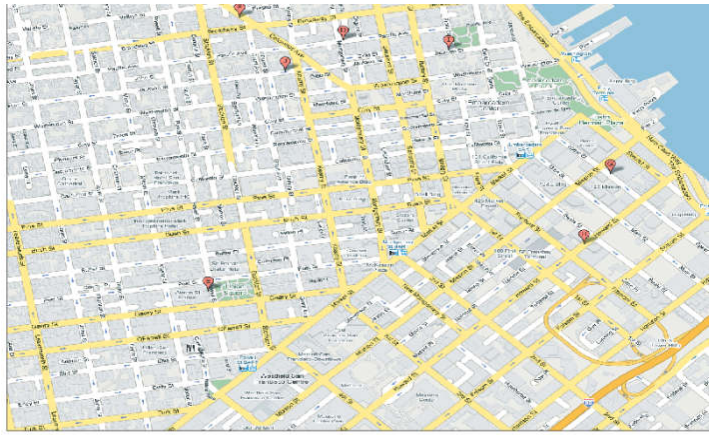
[Tutenel et al. GeoWorldForum 2013]

Interaction: Highlighting and Markup

Interaction: Improved Navigation



- Simplified representation for recognition
- Visual Context for orientation

Grabler et al. 2008

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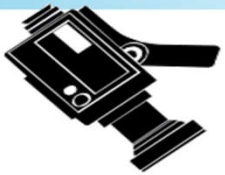
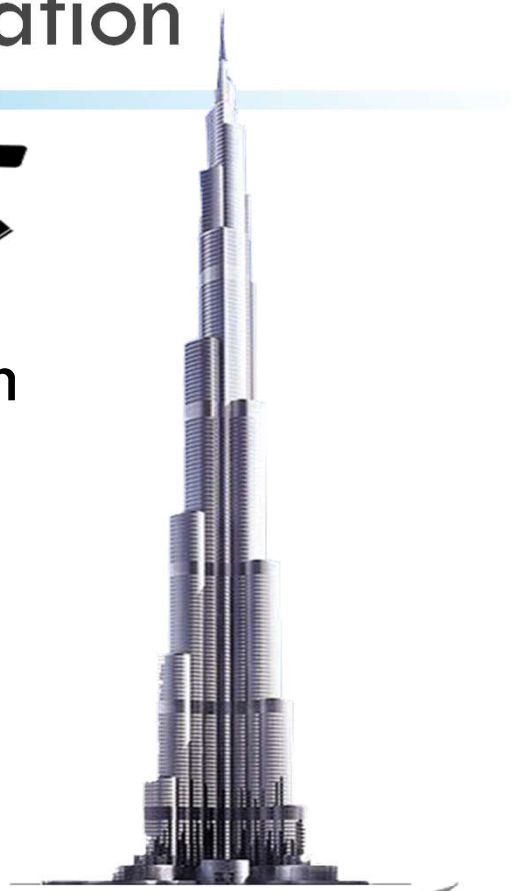
[Kol et al. VMV 2014]

Interaction: Improved Navigation



- Give a Context
- Optimize for building recognition
  - Canonical View
  - Real-time constraints



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Regular

Canonical

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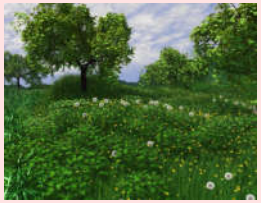
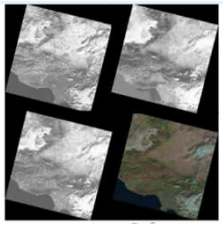
Effective Data Visualization Requires



- Large-Scale Data Representations

- Visualization and Interaction



- Data Analysis

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Data Development

- **Processing**
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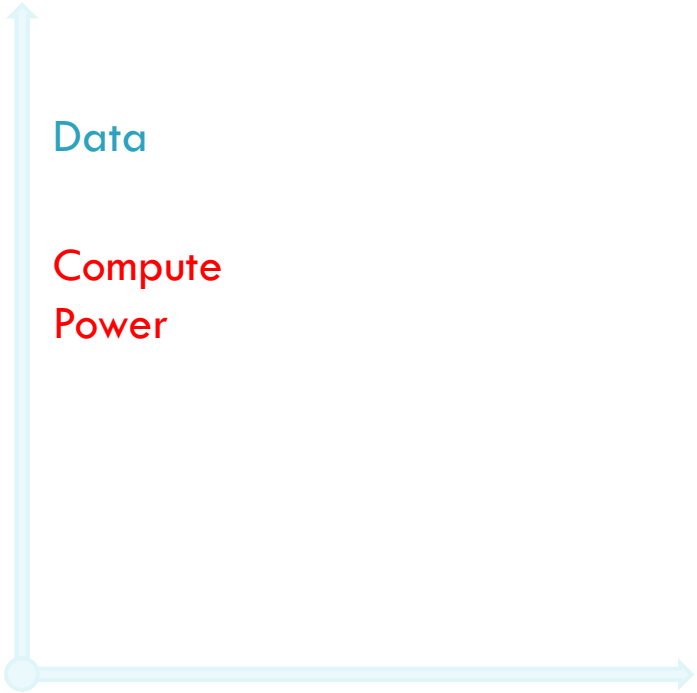
- **Visualization**
- **Guidance**



Need new ways to deal with data!

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Data Development

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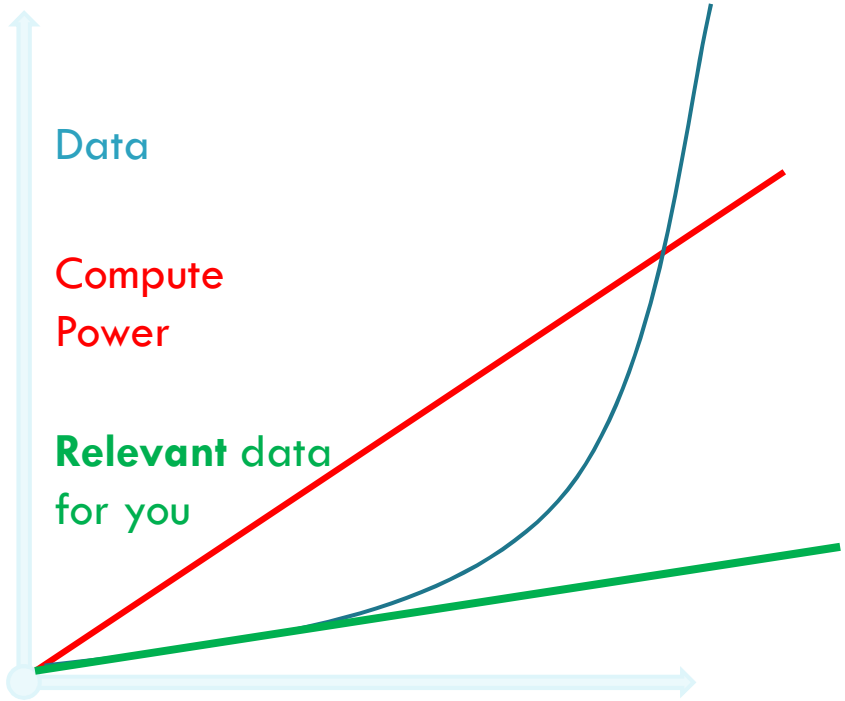

Need new ways to deal with data!

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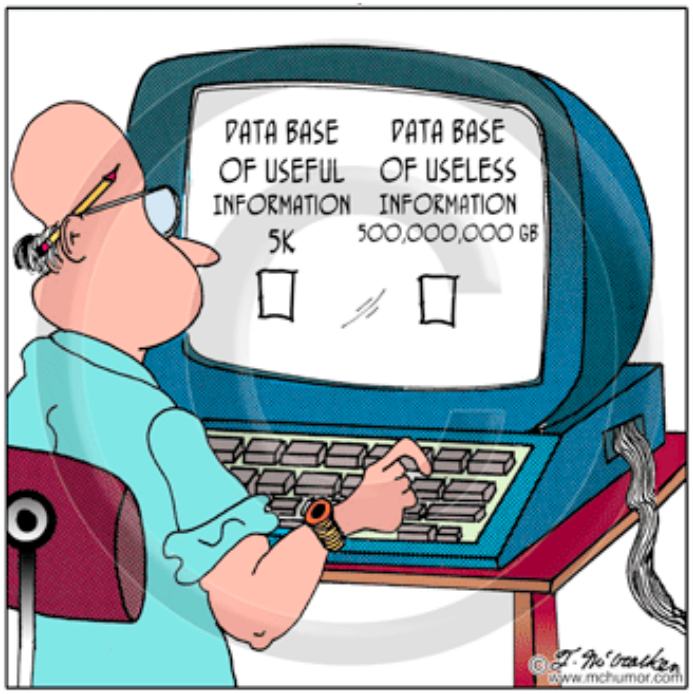
Data growth = increase in information?

- What if you do not know what "relevant" is?



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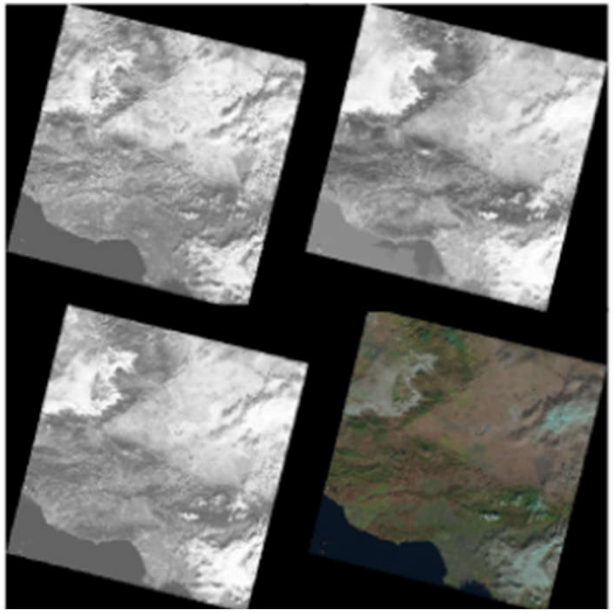
General Approach to Visual Analytics?

Visual Analytics:

Interactive hypothesis finding via Data



- Many challenges:
- Dimensionality
- Heterogeneity
- Size
- …

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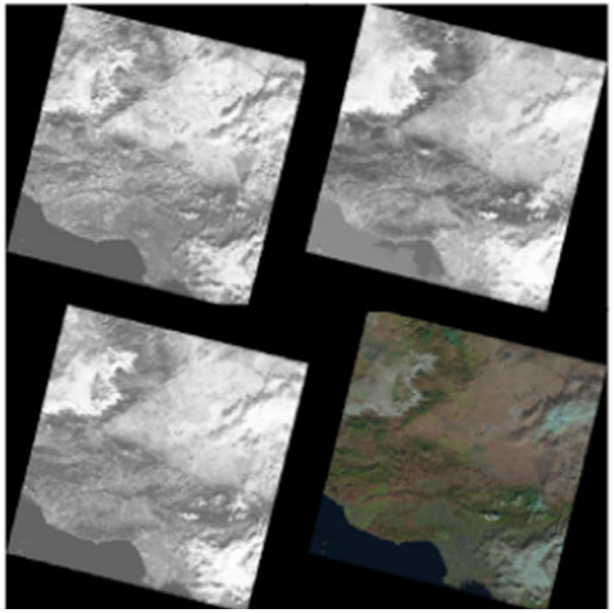
General Approach to Visual Analytics?

Visual Analytics:

Interactive hypothesis finding via Data



- Many challenges:
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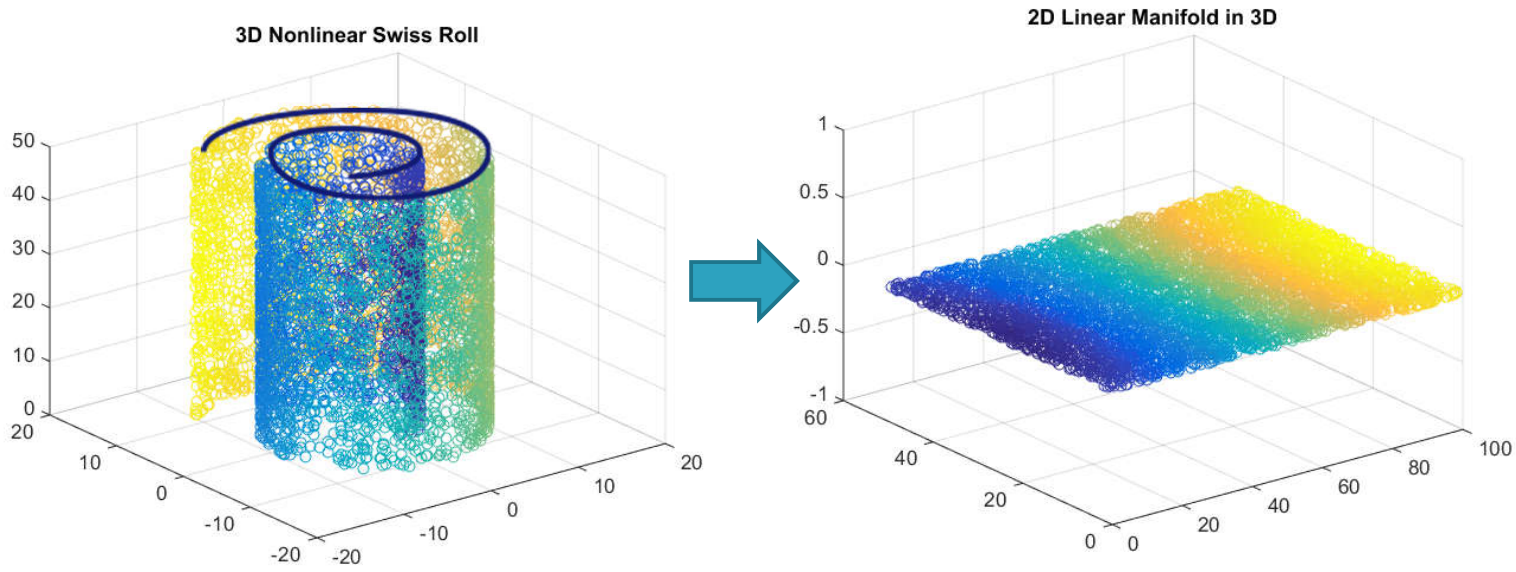
High-Dimensional Spaces

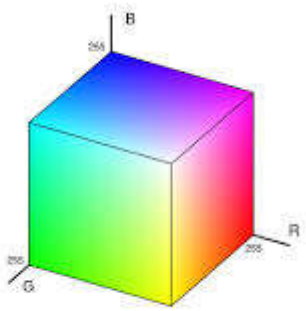
- A high dimensional space does not imply high dimensionality

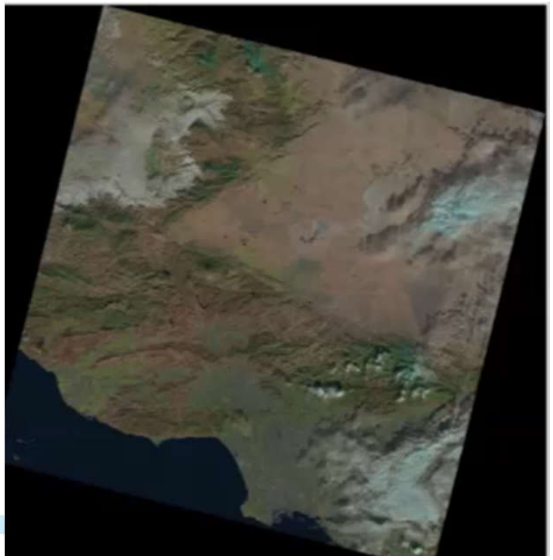


High-Dimensional Spaces

- High-Dimensional Data is everywhere!
  - E.g., satellite images can capture different light wavelengths and each represents one dimension

e.g., Red Green Blue Channel = 3 dimensions

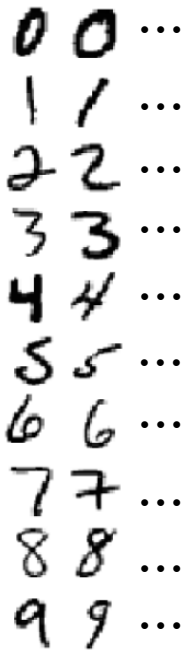


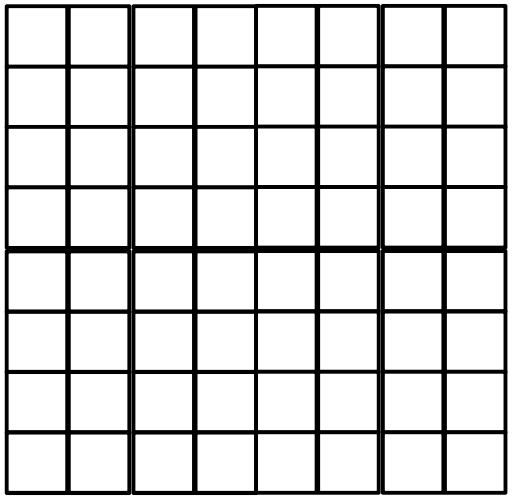


Example: Dimensionality Reduction

100K samples

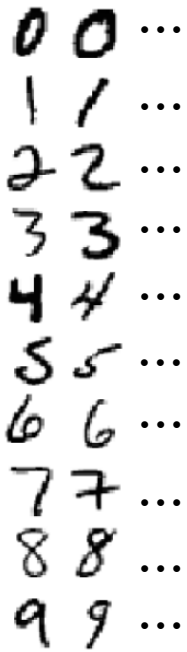
MNIST Dataset

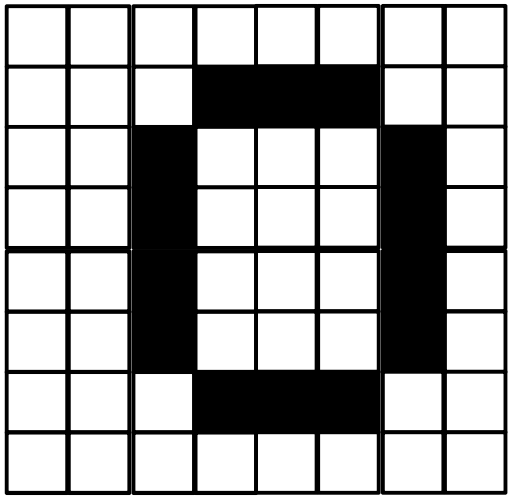




Example: Dimensionality Reduction

MNIST Dataset





Example: Dimensionality Reduction

- 4096 entries/pixels = 4096 dimensions

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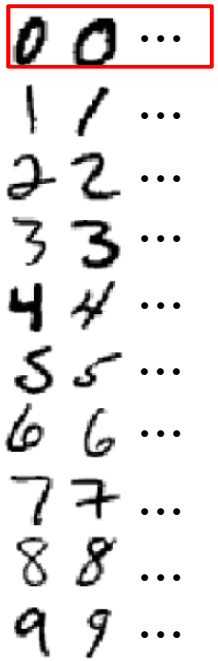
Example: Dimensionality Reduction

100K handwritten numbers

MNIST Dataset



t-SNE:

100K handwritten numbers embedded in 2D

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Challenges of Embedding

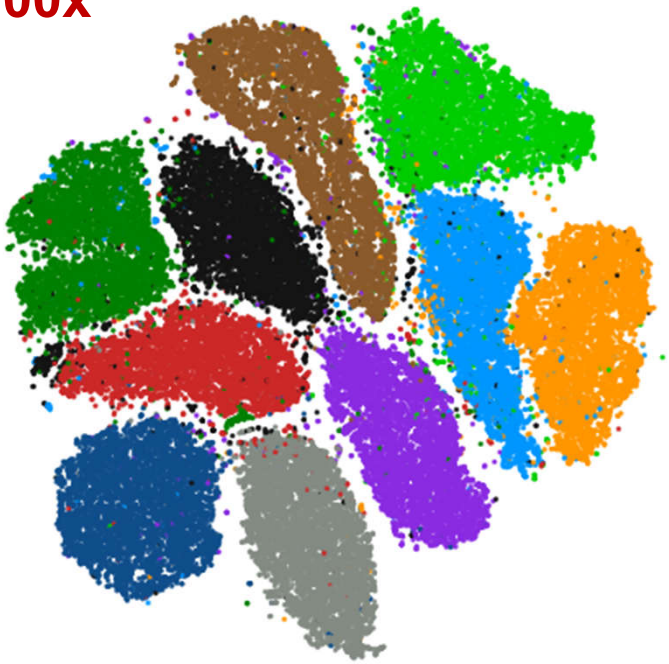
- Performance
  - Usually hours of calculation

[Pezzotti, Leliveldt, van der Maaten, Hoelt, Eisemann, Vilanova – TVCG2016]

Extreme Acceleration

Speed up: 100x

tSNE
Time: 3191.8 s



A-tSNE
Time: 30.1 s

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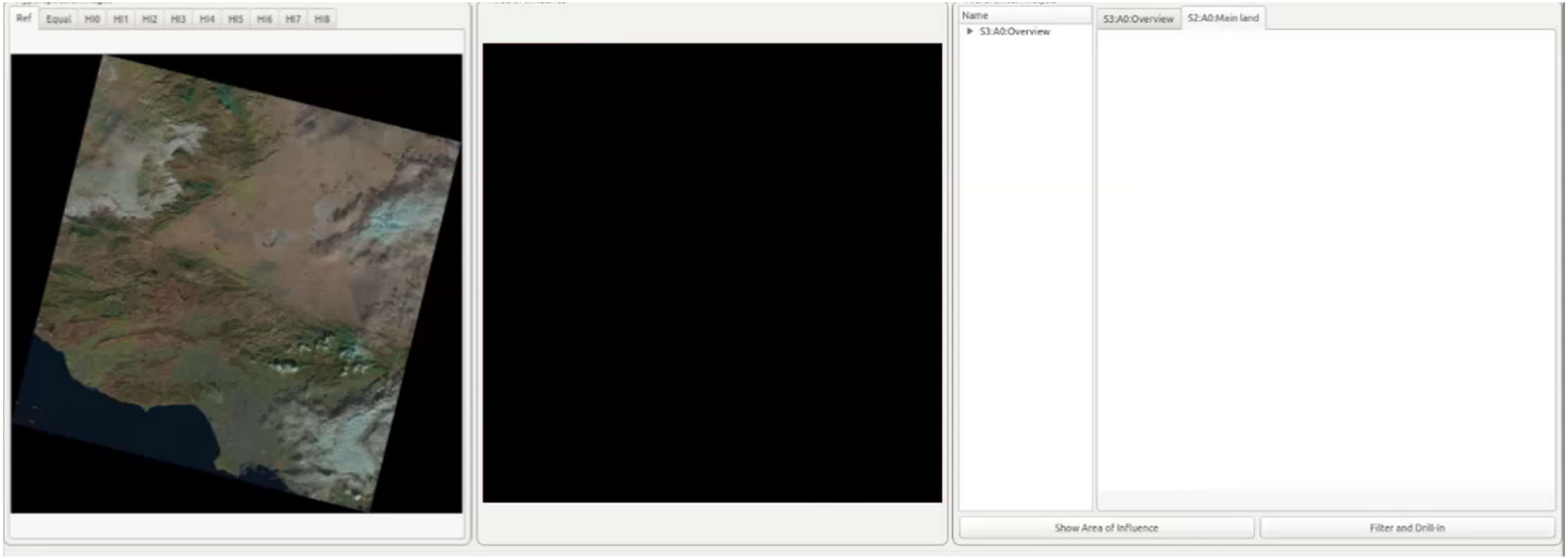
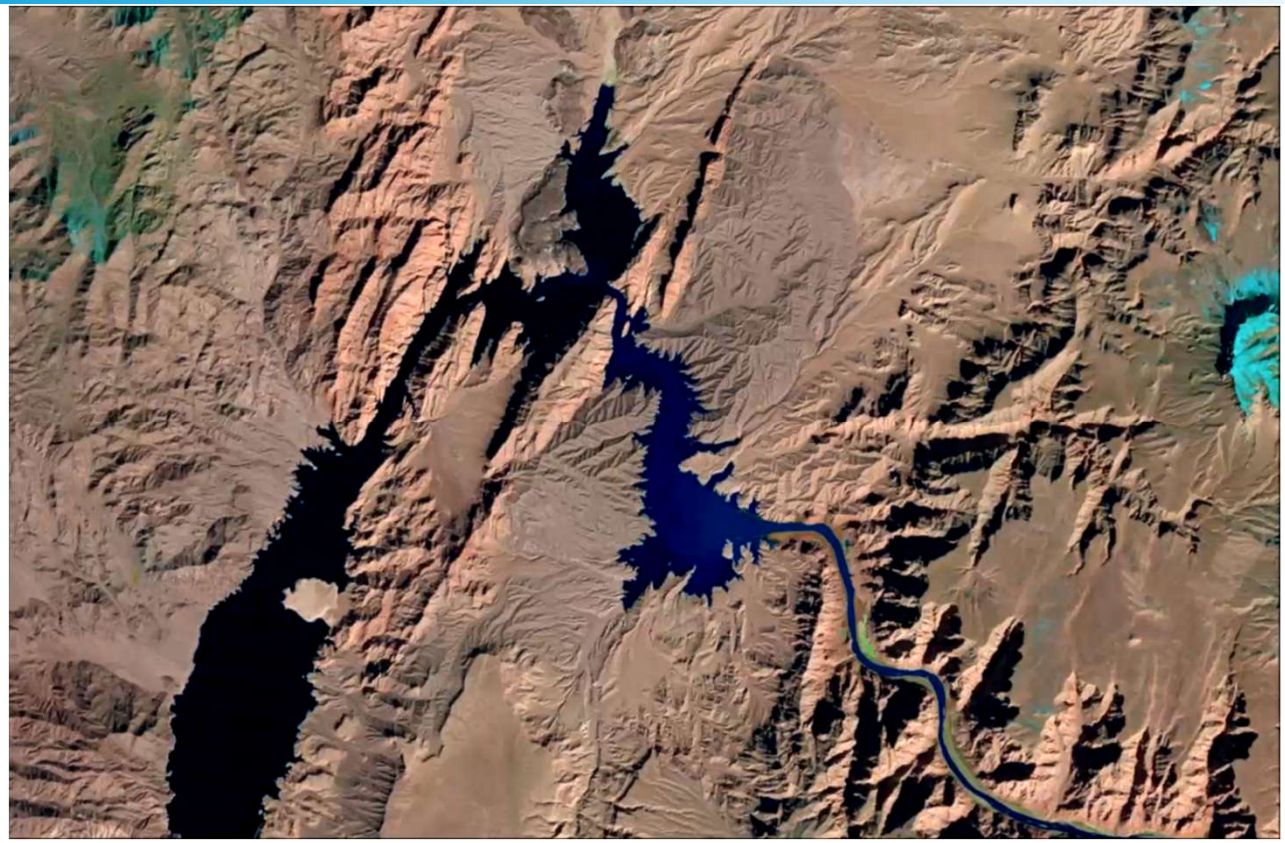
[Pezzotti, Höllt, Lelieveldt, Eisemann, Vilanova – EuroVis 2016]

HSNE - Hierarchical Stochastic Neighbor Embedding



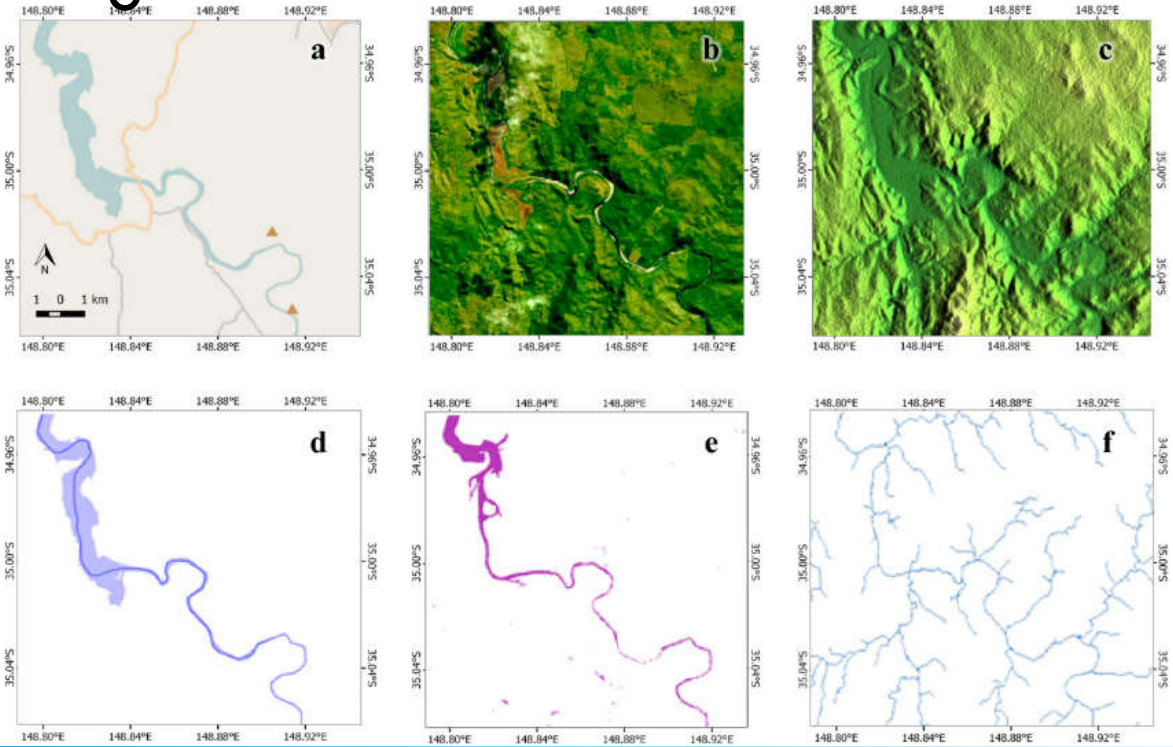
Data Sources - Google Earth Engine



[Donchyts, Schellekens, Winsemius, Eisemann, van de Giesen - Remote Sens. 16]

Water Detection

- Integrating Data Sets for River Validation



Deltares

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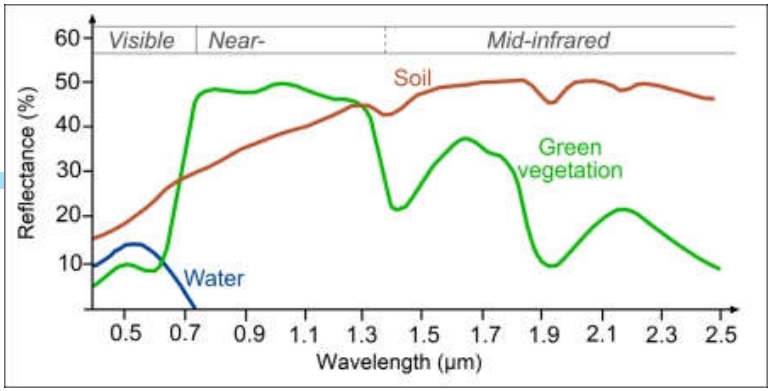
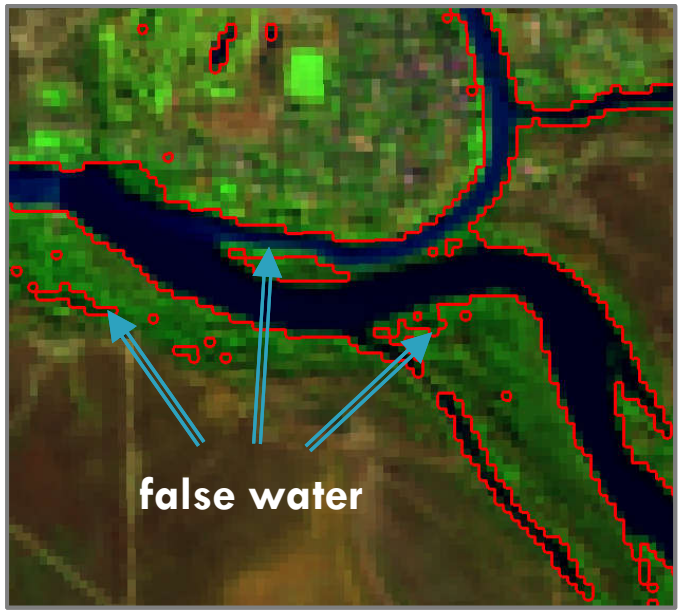
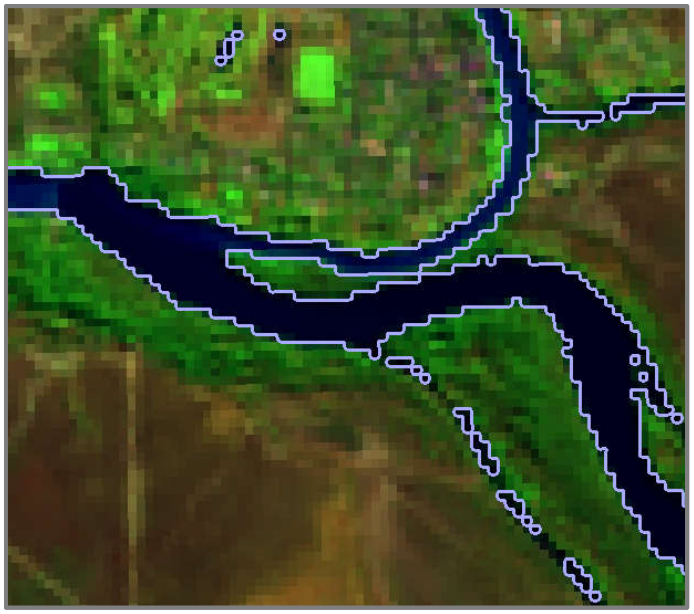
Water Detection







Deltares

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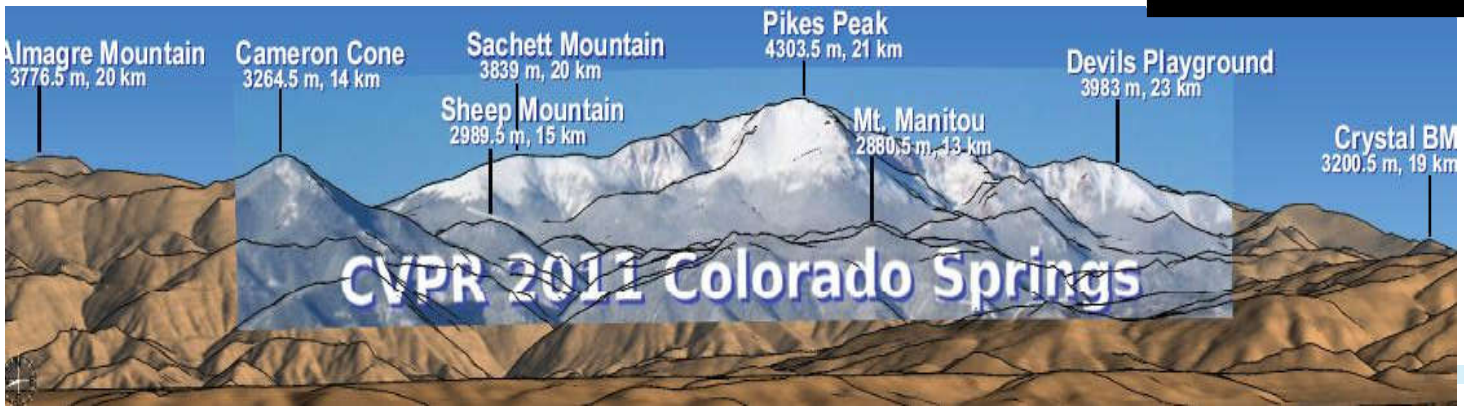
Data Sources

- Heterogeneous data

[Baboud, Cadik, Eisemann, Seidel – CVPR'11]



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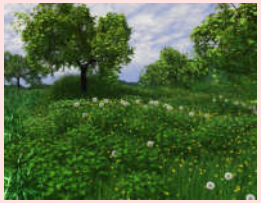
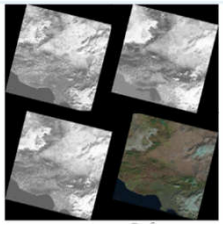
Effective Data Visualization Requires



- Large-Scale Data Representations

- Visualization and Interaction



- Data Analysis

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Conclusion

- Visualization is key for data science

- Many future challenges…
  but also exciting possibilities

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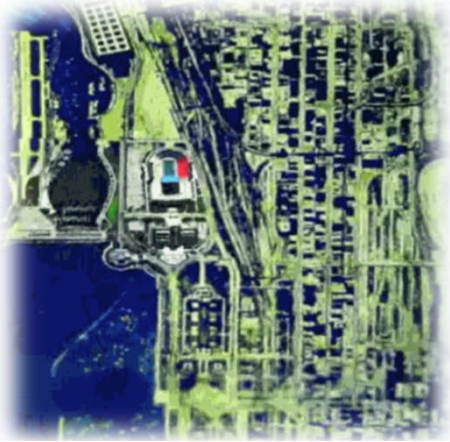
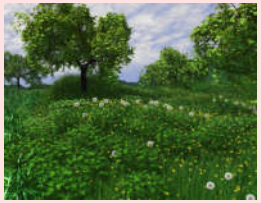
Thank you very much for your attention!



Elmar Eisemann
e.eisemann@tudelft.nl
http://graphics.tudelft.nl

Level of Detail in Computer Graphics



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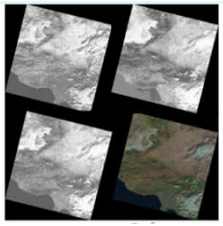

- Data Analysis

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