Distortion-Based Techniques

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Overview

- **A Review and Taxonomy of Distortion-Oriented Presentation Techniques**
  - Y.K.Leung M.D.Apperley 1994
- **Techniques for Non-Linear Magnification Transformations**
  - T.A.Keahey E.L.Robertson 1996
- **Extending Distortion Viewing from 2D to 3D**
  - Carpendale Cowperthwaite Fracchia 1997
- Multi-Perspective Images for Visualization
  - S.Vallance P.Calder 2002
- Multiperspective Imaging
  - S.M.Sertz J.Kim 2003

A Review and Taxonomy of Distortion-Oriented Presentation Techniques (94')

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M.D.Apperley (Massey Univ., New Zealand)

About this paper

- **Distortion-oriented presentation techniques are to solve the problem of displaying a large information space through a relatively small window.**
- **This paper is a review of such techniques before 1994.**

Contribution of the paper

- (A good review)
- Uses transformation and magnification functions to describe different techniques, presents a taxonomy which demonstrates their underlying relationships.
- Presents a unified theory to reveal their roots and origins.
- Discusses issues related to the implementation and performance of these techniques.
- Provides the mathematical derivation of the transformation and magnification functions for various distortion-oriented presentation techniques in the appendix.

Basic law of distortion-oriented techniques

- "where there is a magnification, there will be an equal amount of demagnification to compensate for the loss of display area in the confined space; otherwise the area of that confined space will change." **– a corollary of Newton's third law of motion.**

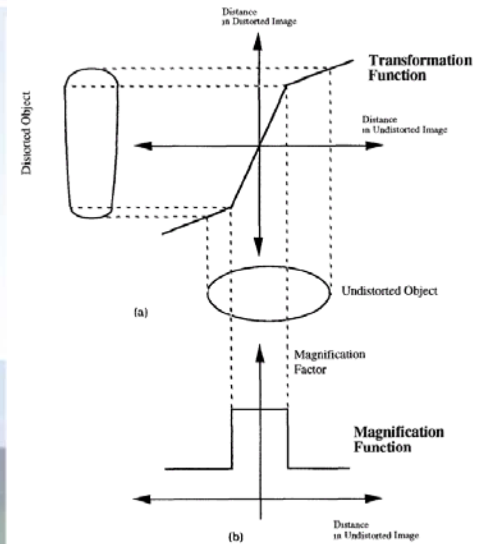
Content

- Essence of distortion-oriented techniques
- Review of representative works
- A taxonomy of these techniques
- A unified theory
- Discussion of implementation and performance issues

Essence

- Concurrent presentation of local detail with global context as reduced magnification, in a format which allows dynamic interactive positioning of the local detail without severely compromising spatial relationships.

Transformation function & Magnification function



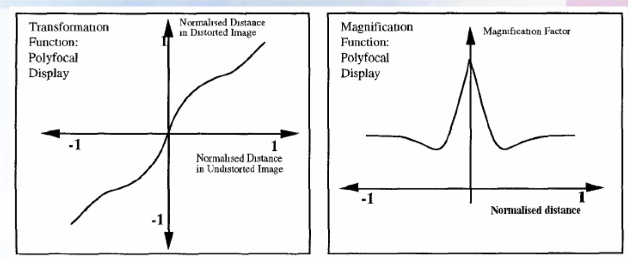
Review of Representative Works

- Polyfocal display [Kadmon & Shlomi 1978]
- Bifocal display [Spence & Apperley 1982]
- Fisheye view [Furnas 1986]
- Perspective Wall [Mackinlay et al.c 1991]
- Graphical Fisheye Views [Sarkar & Brown 1992]

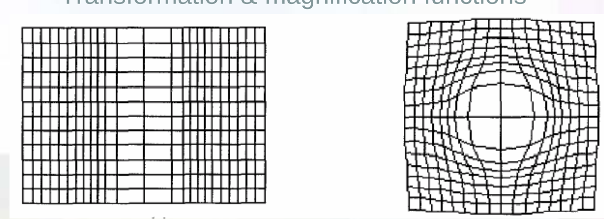
Polyfocal display

- Proposed a polyfocal projection for the presentation of statistical data on cartographic maps, and proposed an implementation of a multifocal display.
- Laid down a solid mathematical foundation for many later techniques.

Polyfocal display (cont)

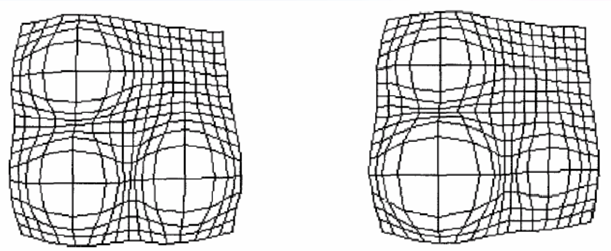


Transformation & magnification functions



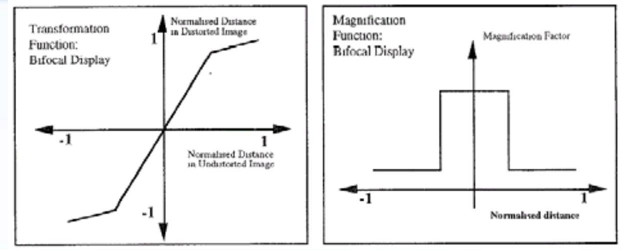
Polyfocal display on 1-D and 2-D

Polyfocal display (cont)

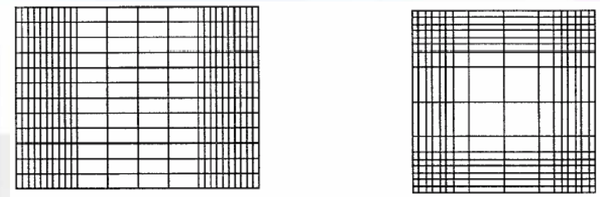


Multifocal polyfocal projection (multiple peaks)

Bifocal display

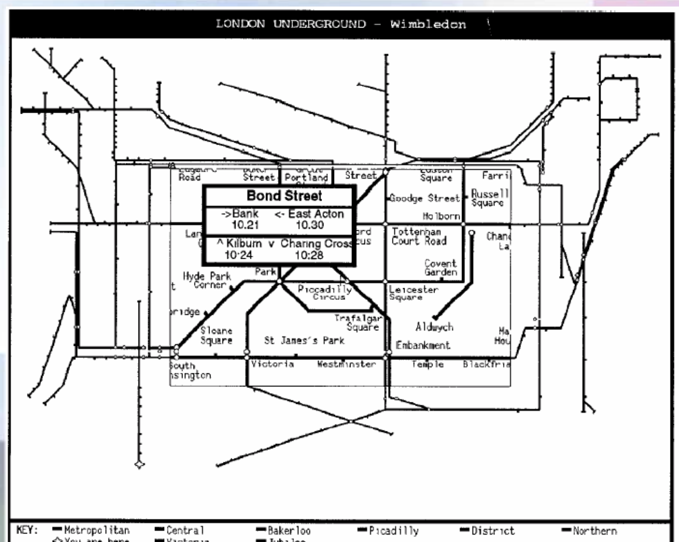


Transformation & magnification functions



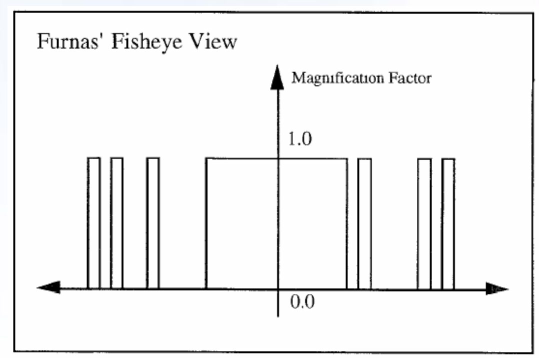
Polyfocal display on 1-D and 2-D

Bifocal 2-D application



London Underground Map

Fisheye view

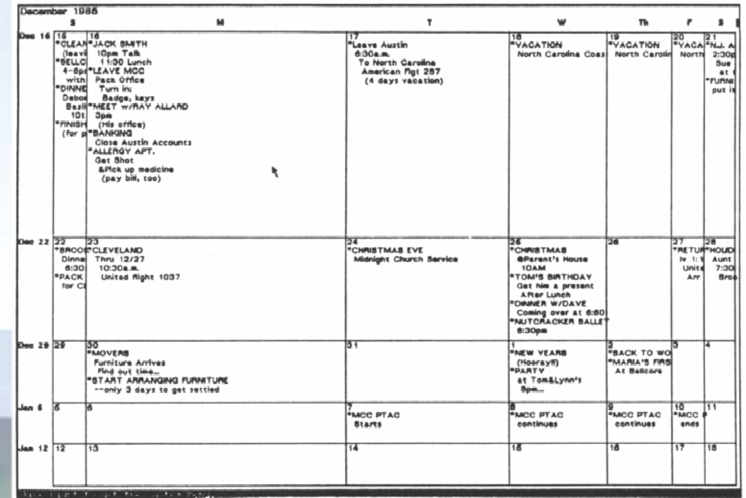


typical magnification function

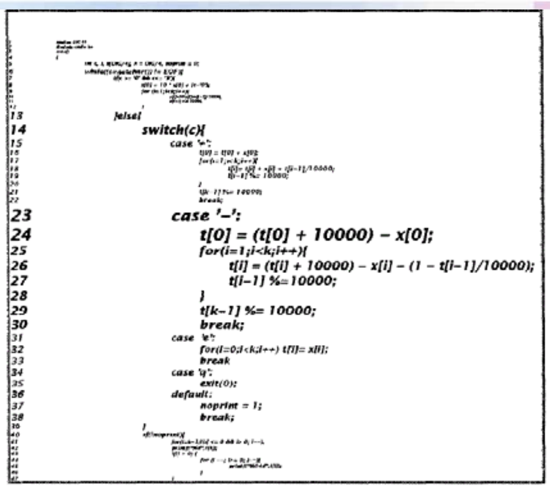
- DOI(a|.=b) = API(a) – D(a,b)

Fisheye view application

Fisheye view application (cont)

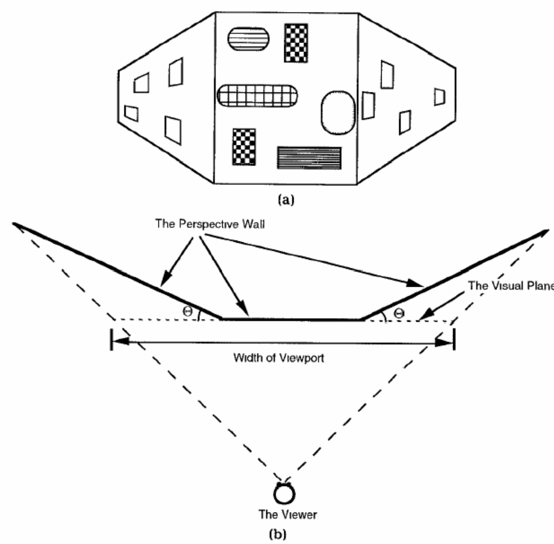


Fisheye view application (cont)

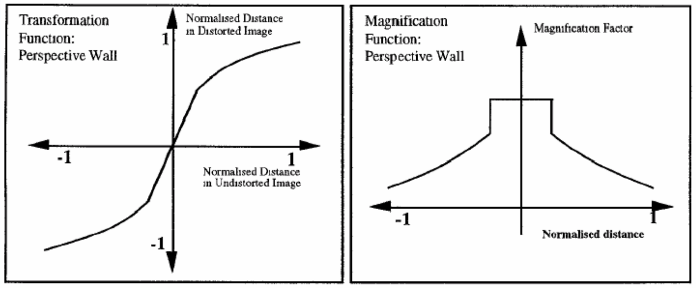


Refined with fractal algorithms. A multiscalable font mode is used.
Each line is displayed in a font size corresponding to the fractal value of the line.

Perspective Wall

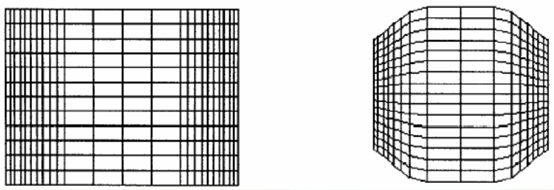


Perspective Wall (cont)

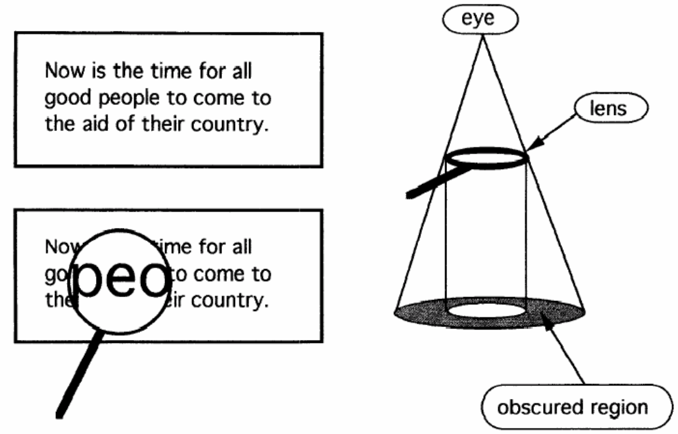


Transformation & magnification functions

A conceptual descendant of the bifocal display.

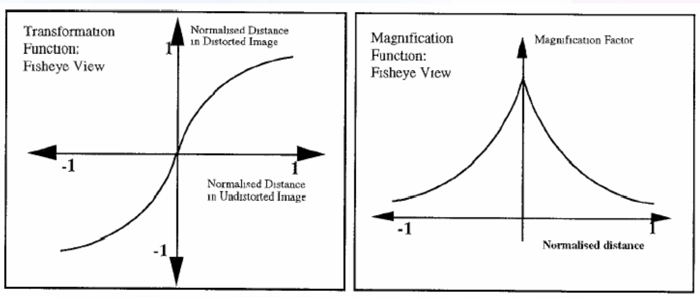


Perspective Wall application



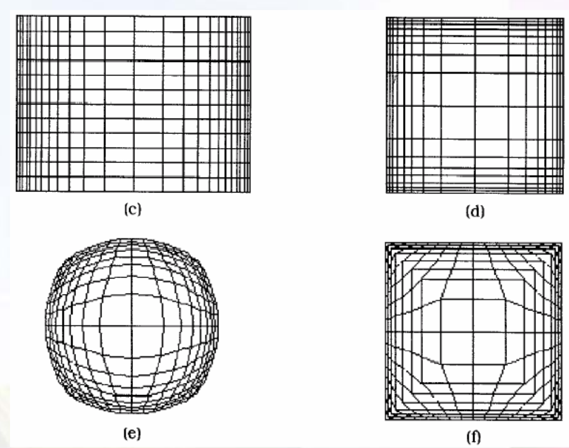
Document lens

Graphical Fisheye Views



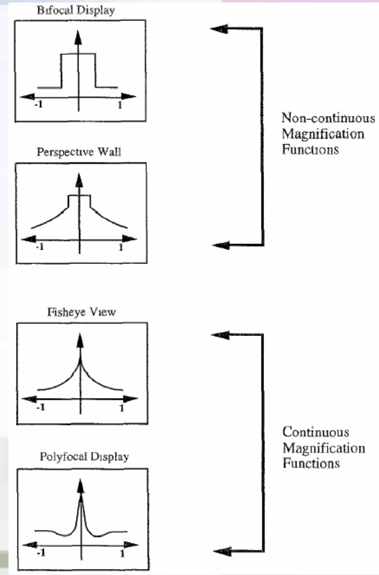
$$T(x) = \frac{(d+1)x}{(dx+1)} \quad \text{and} \quad M(x) = \frac{(d+1)}{(dx+1)^2},$$

Graphical Fisheye Views (cont)



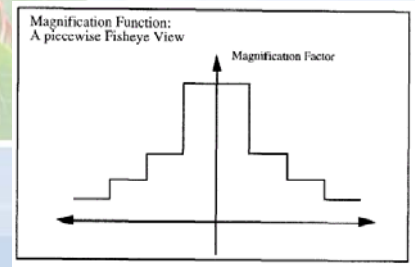
A taxonomy of these techniques

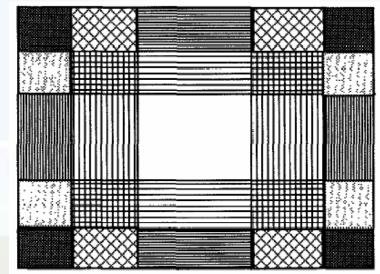
- Classified by the magnification functions:
  - Piecewise continuous
    - Constant function (bifocal display)
    - Varying function (perspective wall)
  - Continuous



Piecewise continuous functions

- Approximate the continuous functions



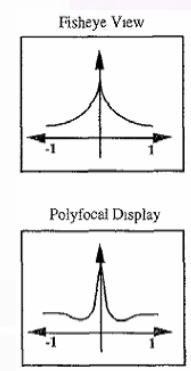


Continuous magnification functions

- The problem:
  - tend to distort the boundaries of the transformed image (e.g. Polyfocal display)
  - Can be overcome by
    - Applying transformation independently in the x and y directions, as the Cartesian fisheye view in [Sarkar and Brown 1992]
    - Remapping the distorted boundaries onto a rectangle size of the display area, as the Polar Fisheye view in [Sarkar and Brown 1992]

Continuous magnification functions (cont)

- The magnification functions of Fisheye View and Polyfocal Projection show strong similarities, except that the Polyfocal Projection has dips. The dips make it possible to support a multiple-focus presentation.
- Fisheye View : a special case of Polyfocal Projection.



A unified theory

- An analogy: To treat the displayed information as if it was printed on a stretchable rubber sheet mounted on a rigid frame.
- The information is dense in the unstretched form, the viewer can see only the global context of the information structure. To see the detailed information, the rubber sheet has to be stretched. The stretching of the rubber sheet is analogous to applying magnification to a section of the screen. As the rubber sheet is mounted on a rigid frame, any stretching in one part of the sheet results in an equivalent amount of "shrinkage" in other areas. The situation is similar in the case of a multiple-focus view. The only difference is that stretching or magnification will occur in a greater number of areas. The amount of stretching or magnification, and the manner in which it is applied on the sheet, depend entirely on the magnification function used.

Discussion

- Performance issues
  - Interactively change the focus region
  - The response time depends on three factors:
    - complexity of the mathematical transformations involved
    - amount of information and detail to be presented
    - computational power and suitability of the system used for implementation.

Performance issues (cont)

- Proper system response time:
  - Excessively long system response time will render an interface "unusable".
    - Use dedicated computer hardware to speed up mathematical transformation
    - Use some tricks in the implementation, by taking advantage of the memory management system. (covered later)
  - Too fast system response could also be disconcerting to the user. The effect is similar to watching a home video taken by an amateur who panned the view jerkily at high speed.
    - Slowing down is easy

Implementation issues

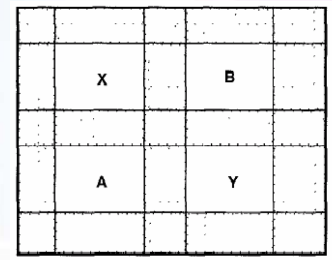
- The complexities of different techniques depend on the transformation functions used.
- For stepwise magnification functions, some tricks could be used, such as trading system memory for computational power,e.g.:
  - Have different view created and stored in memory in advance. Then in real time, just cut and past various sections of these bit maps to generate distorted views.

Implementation issues (cont)

- Continuous magnification function:
  - Have to cater to the continuum of magnification factors at every possible focus point, so it is impractical to use pre-generated view images.
  - Instead, use a piecewise continuous magnification function to approximate the continuous function. N * N bit maps for N-level function in 2-D application.
  - Dedicated hardware may be needed to provide computational power, if approximation of the transformation function is not desirable.

Implementation issues (cont)

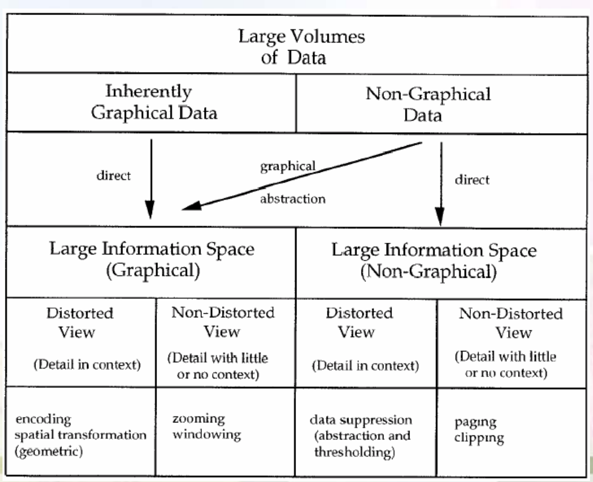
- Multiple-focus views
  - Useful to examine and compare two entities
  - Unintended focus views are created. (right figure)
  - This typically happens in techniques with no dips in the magnification functions (like that of the Polyfocal Projection) (lack of flexibility in the function)
  - Instead, integrate other mechanisms such as a pop-up window to support multiple views. May create additional navigation problems because of the discontinuity of the presentation in the detailed and the context.



Use pop-up windows

Conclusion

- Useful but should be used with caution, considering the type of information to be conveyed and how it will be perceived by the user.



Techniques for Non-Linear Magnification Transformations (96')

T. Alan Keahey and Edward L. Robertson
(Indiana University)

Outline

- Limitations of Linear Transformations
- Non-Linear Transformations
- Compound Transformations
- Filtering Transformations
- Piecewise Transformations
- Conclusion

Linear Transformations

- Constant level of magnification, easy but has limitations:
  - Forced to create a mapping between disjoint levels of resolution in the image
  - Forced to make abrupt transitions on two levels
  - Occlusion

Non-Linear Transformations

- Fisheye Zoom
- Hyperbolic
  - Allows infinite Euclidean space to be mapped into a finite disk with center bigger and periphery smaller.
- 3D Pliable Surfaces
  - Uses perspective projections of curved 3D surfaces to create non-linear magnification effects
- General Non-Linear

General Non-Linear

- One dimensional

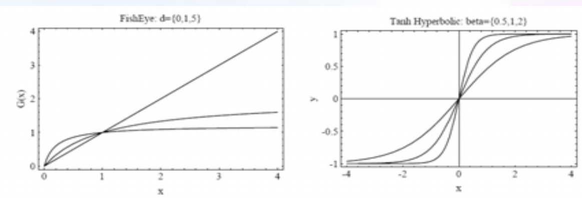


Figure 2. Fisheye and Tanh Basis Functions

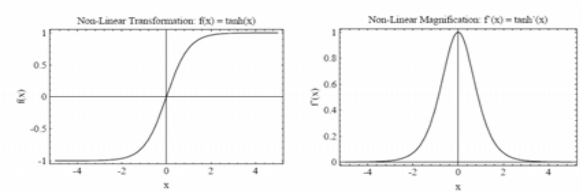
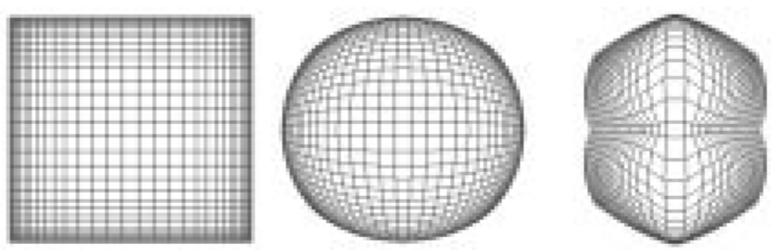


Figure 3. Tanh Transformation/Magnification

General Non-Linear (cont)

- Two dimensional
  - Orthogonal
  - Radial (Fisheye)
  - Bi-Radial (combination of the two)



General Non-Linear (cont)

- Hybrid Transformations
  - Combined linear/non-linear

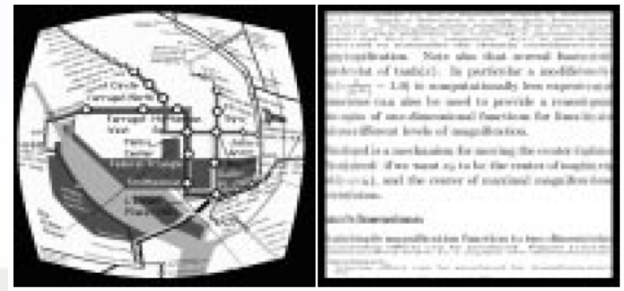


Figure 5. Combined Linear and Non-Linear

General Non-Linear (cont)

- Hybrid Transformations
  - Constraining transformations

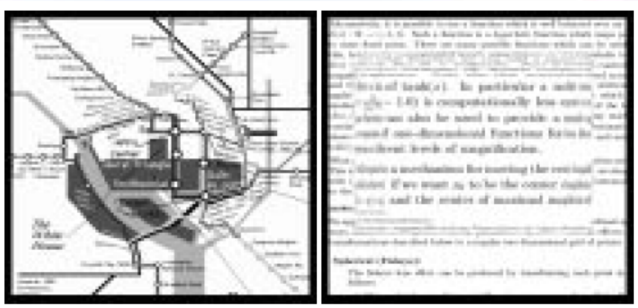


Figure 6. Constrained Domains

General Non-Linear (cont)

- Hybrid Transformations
  - Continuous/discrete domains

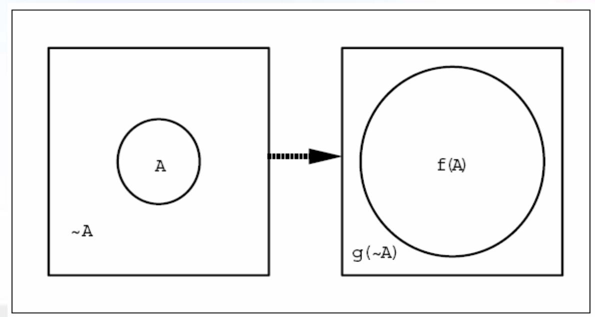


Figure 7. Boundary Conditions

Compound Transformations

- Maximal Ray Clipping
- Weighted Averaging
- Composition

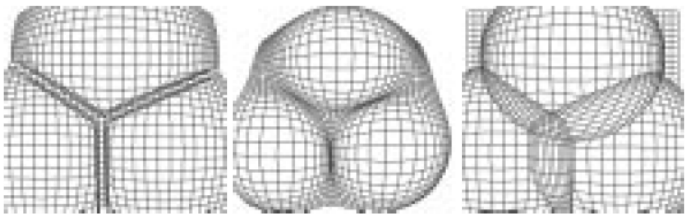


Figure 8. Clipped, Average, and Composition

Filtering Transformations

- Smoothly shift between the warped and unwarped views in order to control the degree of warping

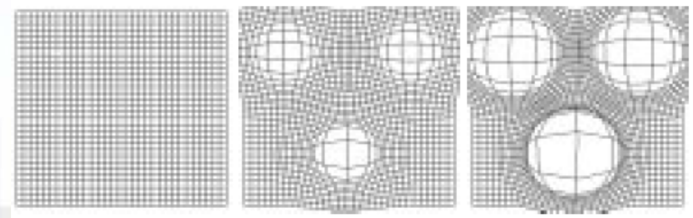


Figure 9. Filtering for s = 1.0, 0.65, 0.35

Piecewise Transformations

- 1D Piecewise Transformations

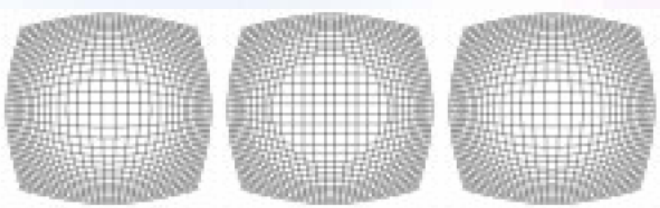


Figure 10. 1D Radial: tanh, piecewise n = 8, 16

piecewise approximation of tanh(x)

Piecewise Transformations (cont)

- 2D Piecewise Transformations

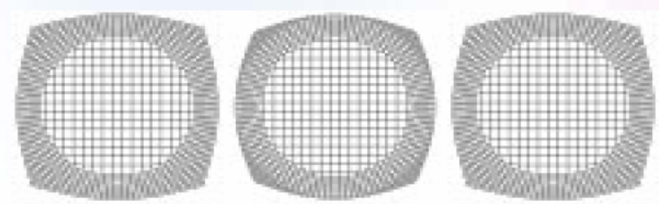


Figure 11. Flat/Radial: tanh, 1D, 2D Piecewise

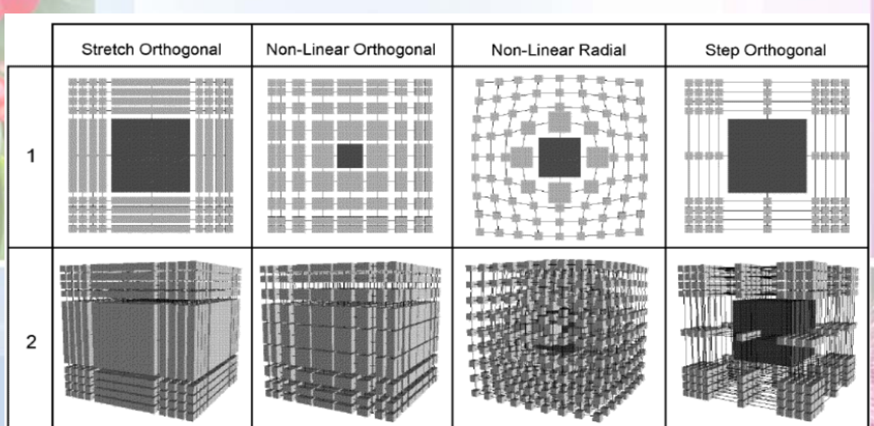
Conclusion & Contribution

- Summarizes the non-linear transformations
- Provides:
  - combination with linear magnifications
  - constrained transformation domains
  - combining multiple transformations
  - enhanced control of the overall degree to which transformations should take effect
  - approximation
- Occlusion-free

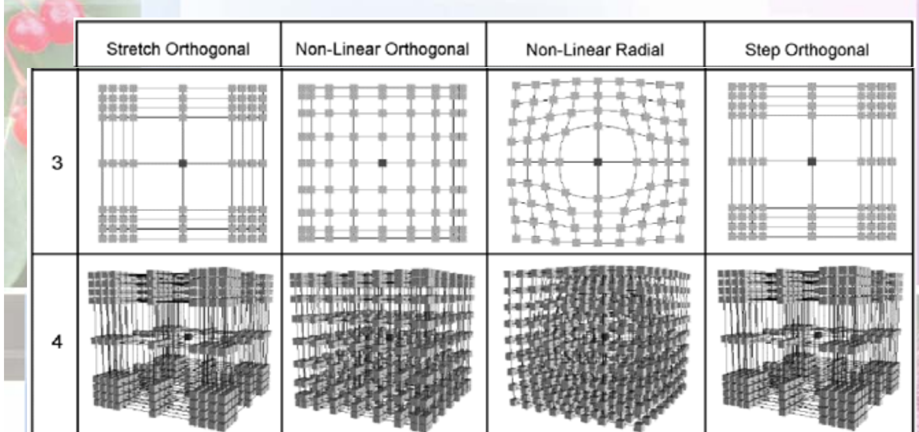
Extending Distortion Viewing from 2D to 3D (97')

M. Sheelagh T. Carpendale, David J. Cowperthwaite, and F. David Fracchia (Simon Fraser University)

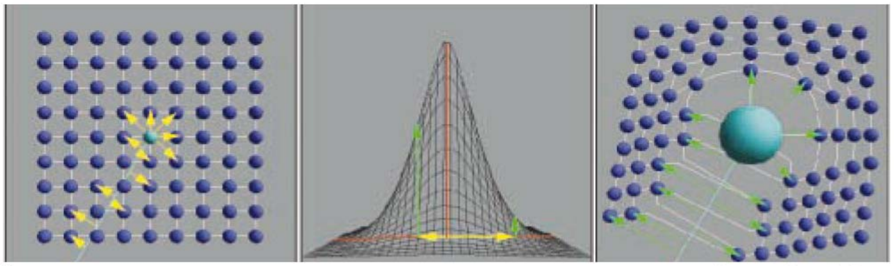
First try – direct extrapolation



Second try – displacement-only

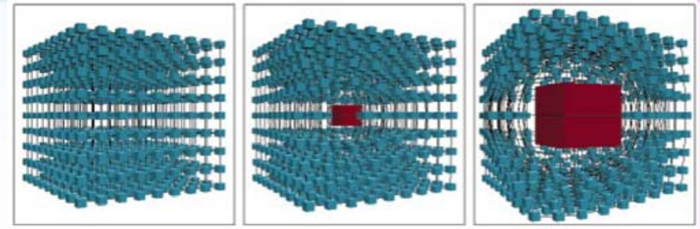


Visual access distortion

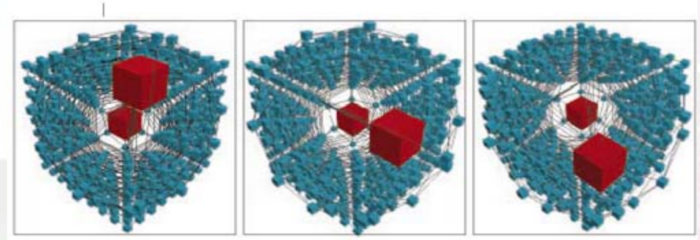


8 Cross-section views illustrate the visual access distortion algorithm: calculating the direction and distance from line of sight (left), calculating the displacement (center), and displacing the occluding objects (right).

Visual access distortion (cont)

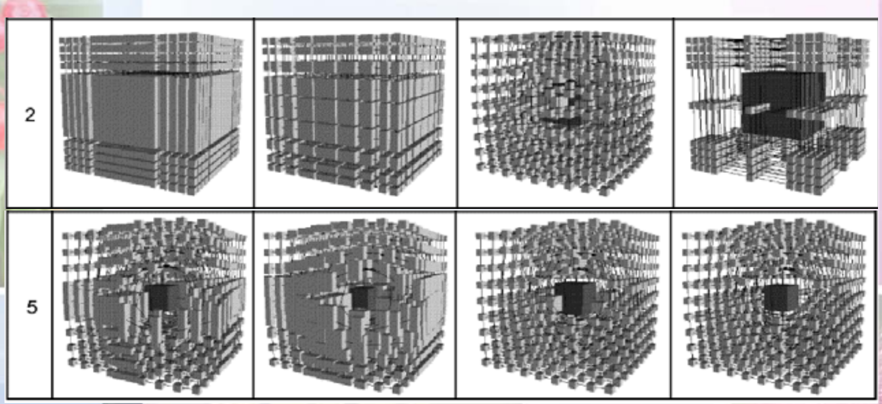


9 This series shows Gaussian visual access distortion applied progressively to the 3D grid.

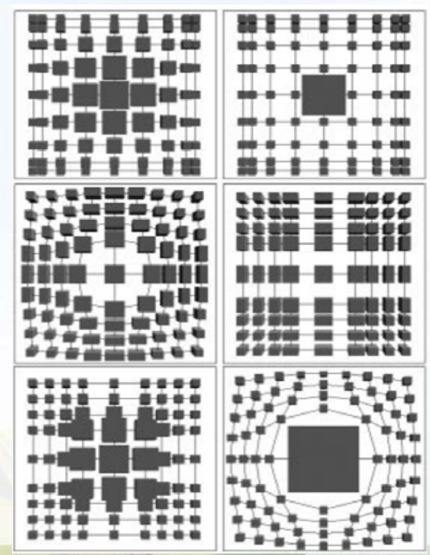


10 Even when the two foci are in line with the viewpoint, both remain visible because the distortion function from the furthest focus affects all occluding objects, including other foci.

Final result



Additional distortion variations



- **Thank you!**