A Model of Spatial Directness in Interactive Visualization

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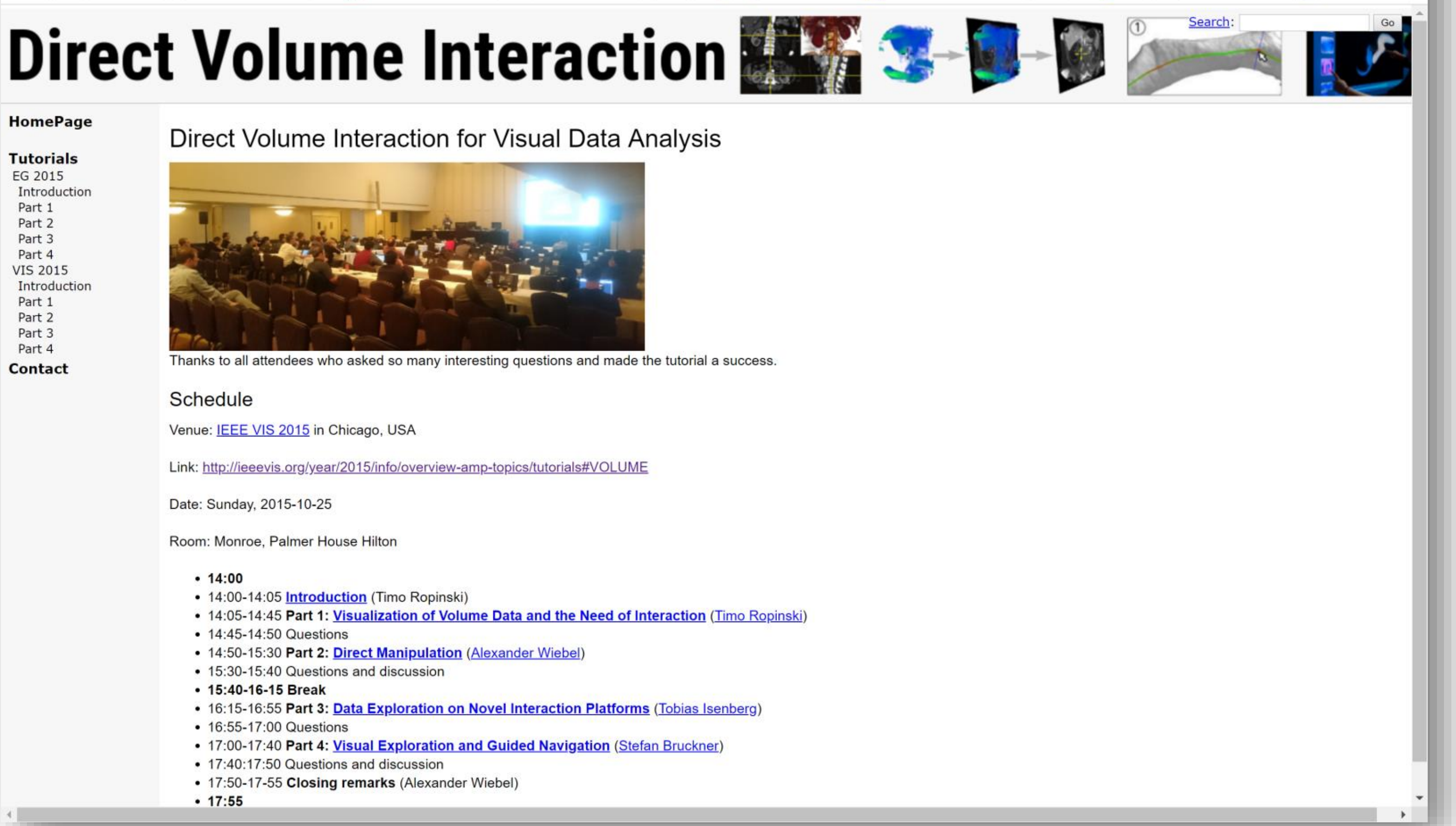
Motivation

http://tutorials.awmw.org/DirectVolumeInteraction



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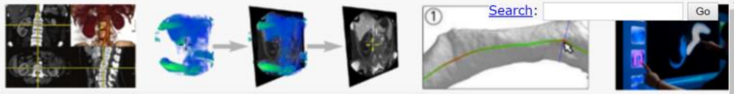
Direct Volume Interaction



Direct Volume Editing

Kai Bürger, Jens Krüger, and Rüdiger Westermann

Abstract—In this work we present basic methodology for interactive volume editing on GPUs, and we demonstrate the use of these methods to achieve a number of different effects. We present fast techniques to modify the appearance and structure of volumetric scalar fields given on Cartesian grids. Similar to 2D circular brushes as used in surface painting we present 3D spherical brushes for intuitive coloring of particular structures in such fields. This paint metaphor is extended to allow the user to change the data itself, and the use of this functionality for interactive structure isolation, hole filling, and artefact removal is demonstrated. Building on previous work in the field we introduce high-resolution selection volumes, which can be seen as a resolution-based focus+context metaphor. By utilizing such volumes we present a novel approach to interactive volume editing at sub-voxel accuracy. Finally, we introduce a fast technique to paste textures onto iso-surfaces in a 3D scalar field. Since the texture resolution is independent of the volume resolution, this technique allows structure-aligned textures containing appearance properties or textual information to be used for volume augmentation and annotation.

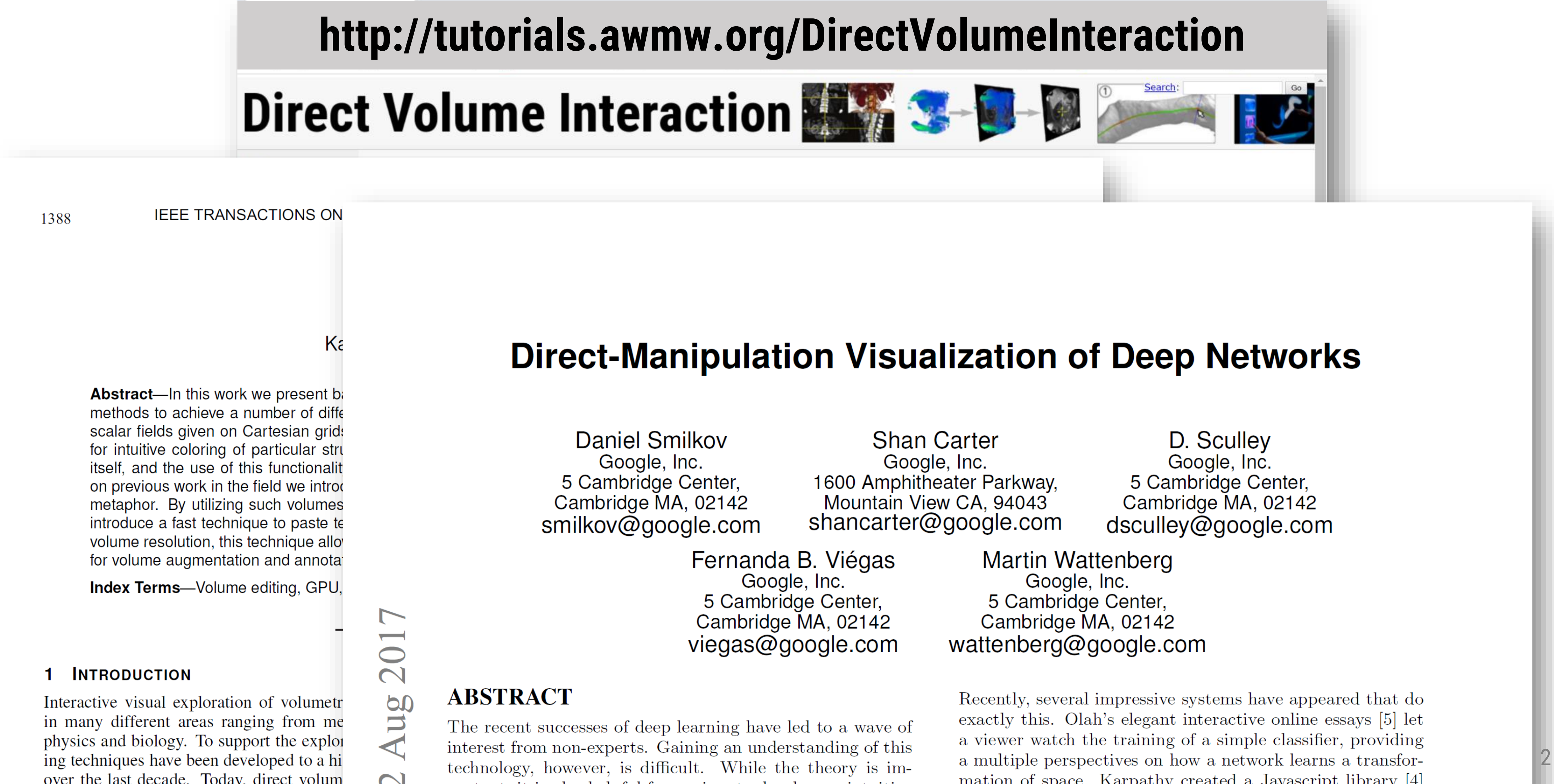
Index Terms—Volume editing, GPU, painting, carving, annotations.

1 Introduction

Interactive visual exploration of volumetric scalar fields is required in many different areas ranging from medicine and engineering to physics and biology. To support the exploration task, volume rendering techniques have been developed to a high degree of sophistication over the last decade. Today, direct volume rendering of data sets as

methodology, if designed in a generic way without the restriction to a particular application, then has the potential to be used in a number of different scenarios. In particular, to support the editing process and to avoid putting the burden completely on the user, optional constraints can be integrated into these methods.

Motivation



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1 INTRODUCTION
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Direct-Manipulation Visualization of Deep Networks
Daniel Smilkov
Google, Inc.
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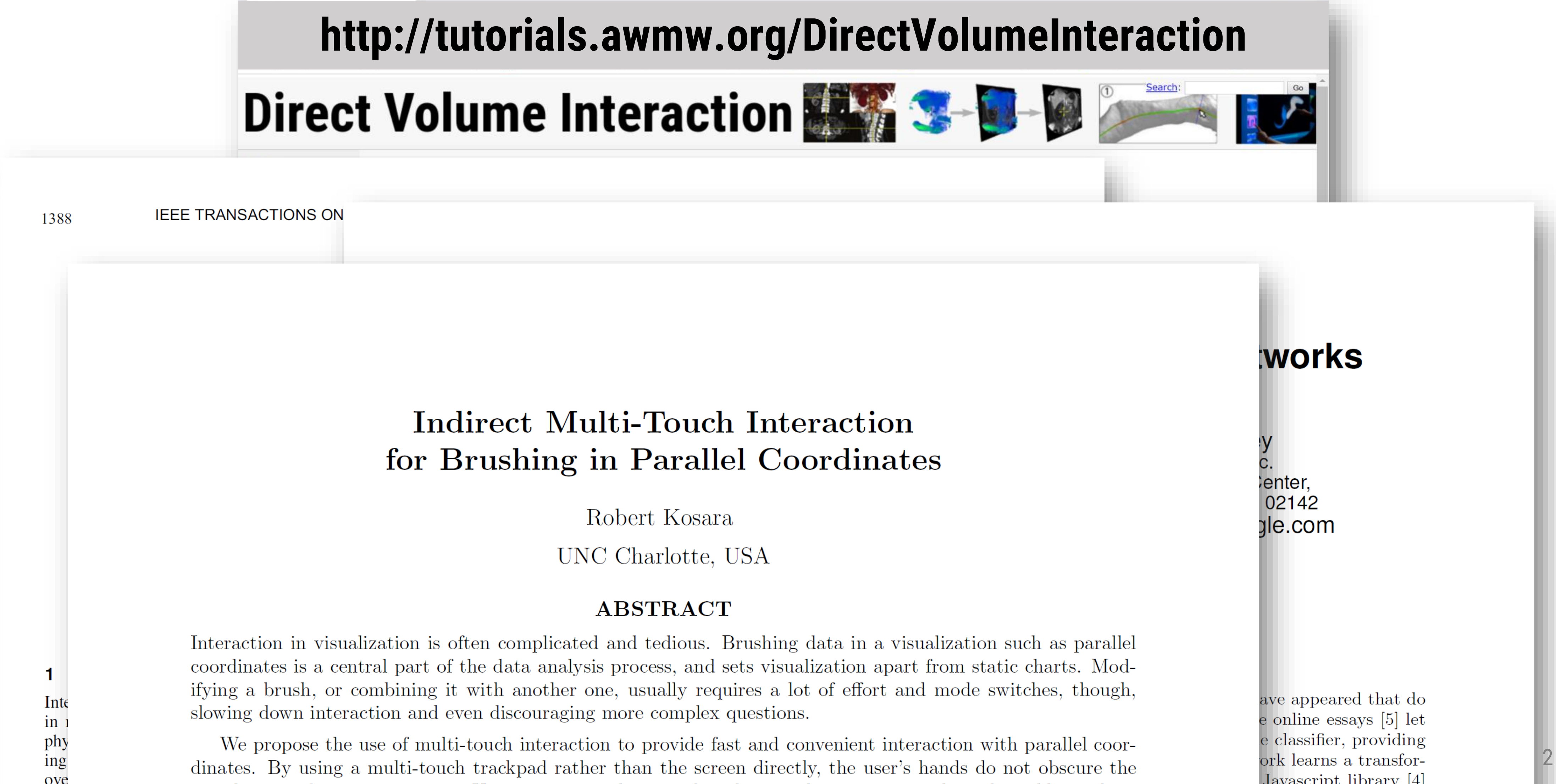
2 Aug 2017
ABSTRACT
The recent successes of deep learning have led to a wave of
interest from non-experts. Gaining an understanding of this
technology, however, is difficult. While the theory is im-
Recently, several impressive systems have appeared that do
exactly this. Olah's elegant interactive online essays [5] let
a viewer watch the training of a simple classifier, providing
a multiple perspectives on how a network learns a transfor-

Motivation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IEEE TRANSACTIONS ON
Indirect Multi-Touch Interaction
for Brushing in Parallel Coordinates
Robert Kosara
UNC Charlotte, USA
ABSTRACT
Interaction in visualization is often complicated and tedious. Brushing data in a visualization such as parallel coordinates is a central part of the data analysis process, and sets visualization apart from static charts. Modifying a brush, or combining it with another one, usually requires a lot of effort and mode switches, though, slowing down interaction and even discouraging more complex questions.
We propose the use of multi-touch interaction to provide fast and convenient interaction with parallel coordinates. By using a multi-touch trackpad rather than the screen directly, the user's hands do not obscure the
works
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ave appeared that do
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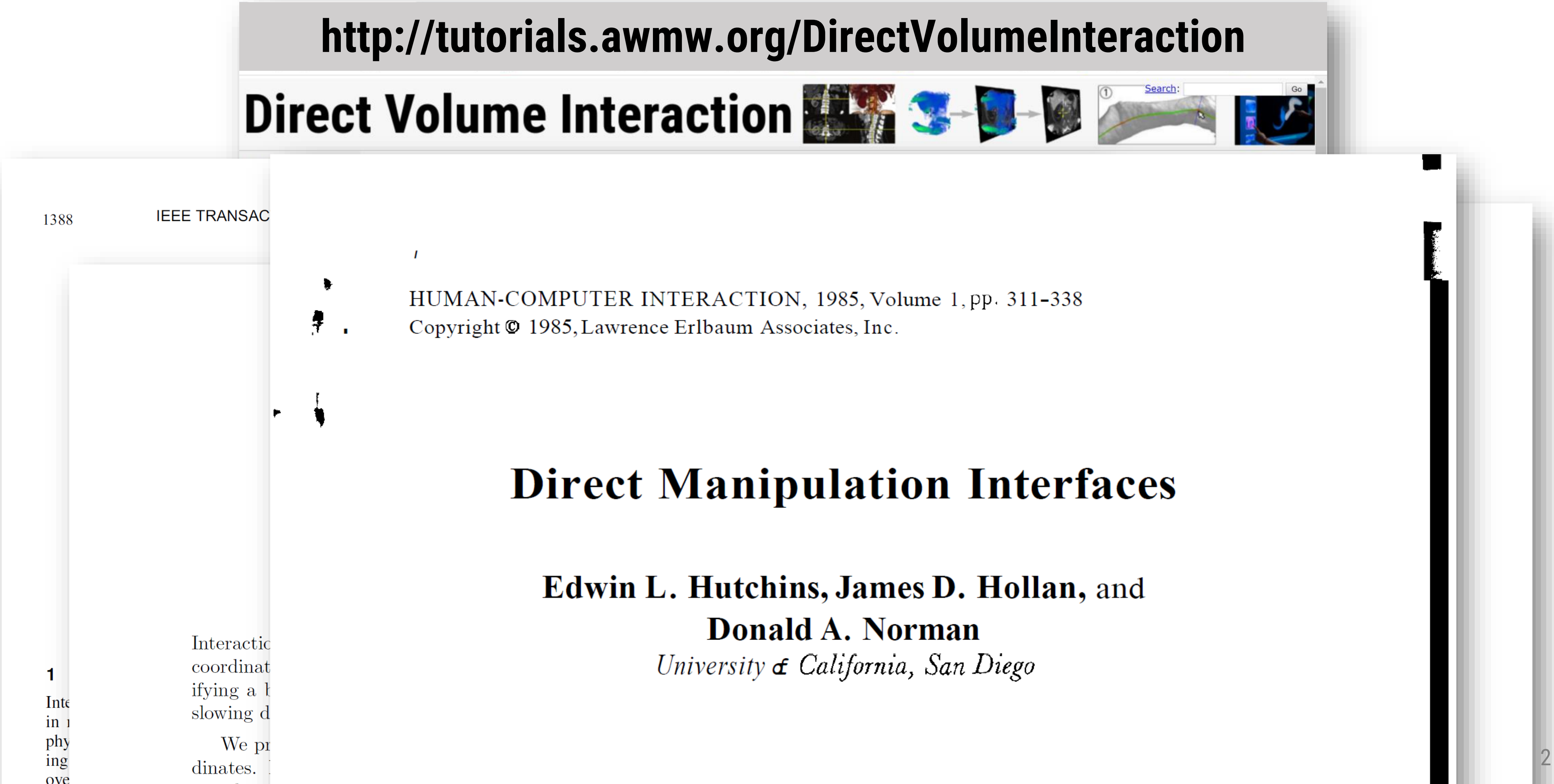
Motivation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HUMAN-COMPUTER INTERACTION, 1985, Volume 1, pp. 311-338
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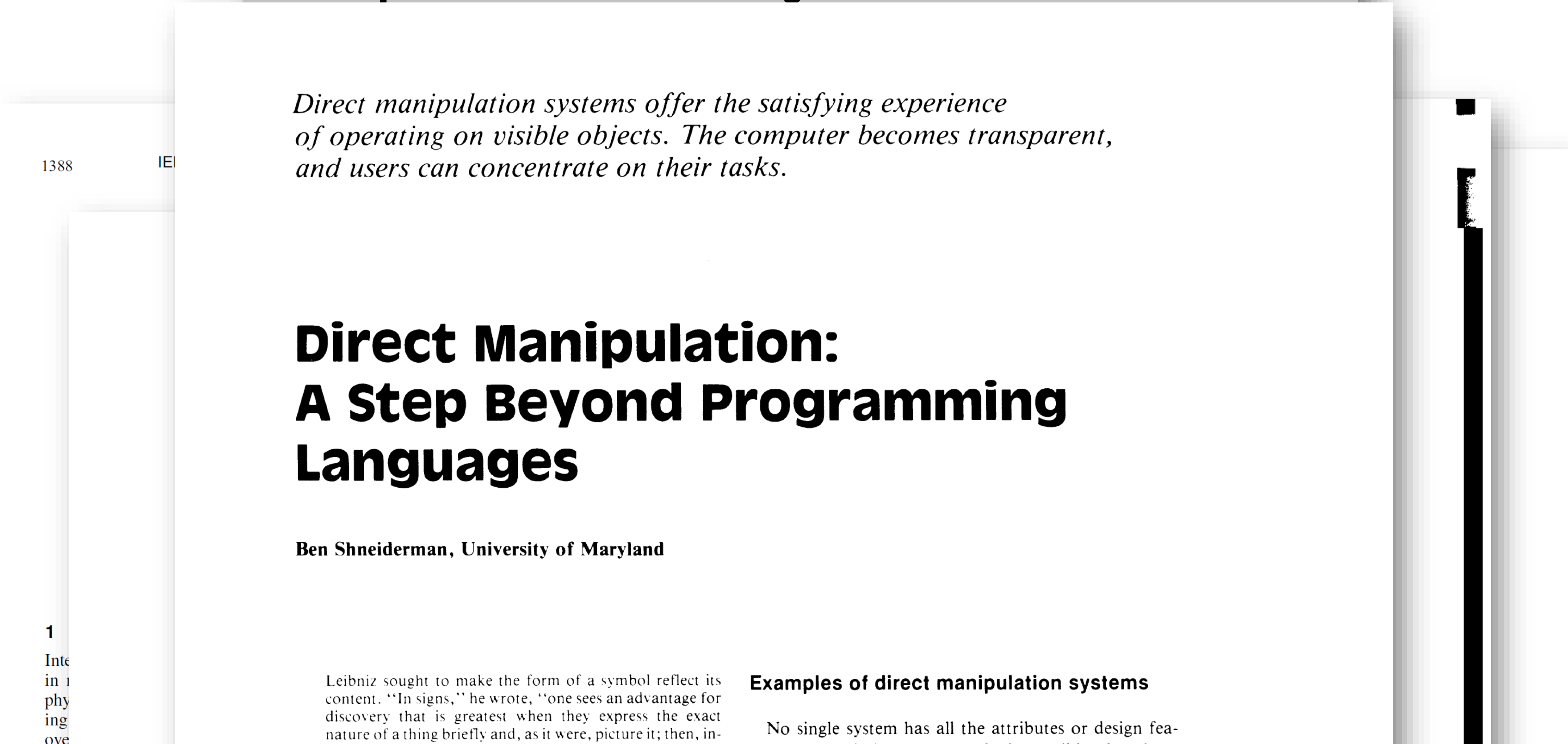
Direct Manipulation Interfaces
Edwin L. Hutchins, James D. Hollan, and
Donald A. Norman
University of California, San Diego

Motivation

http://tutorials.awmw.org/DirectVolumeInteraction



Direct manipulation systems offer the satisfying experience of operating on visible objects. The computer becomes transparent, and users can concentrate on their tasks.

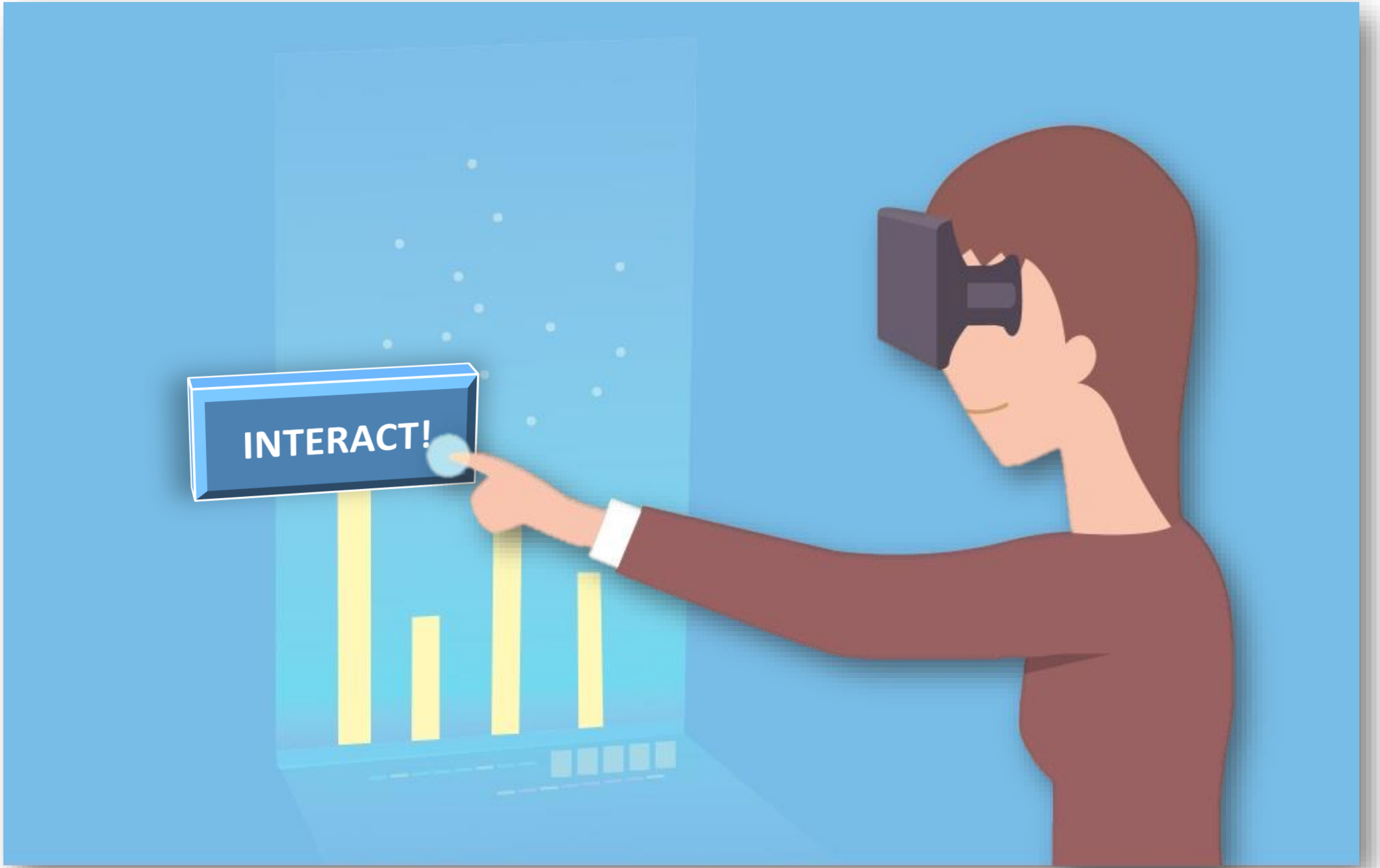
Direct Manipulation: A Step Beyond Programming Languages

Ben Shneiderman, University of Maryland

Leibniz sought to make the form of a symbol reflect its content. "In signs," he wrote, "one sees an advantage for discovery that is greatest when they express the exact nature of a thing briefly and, as it were, picture it; then, in-

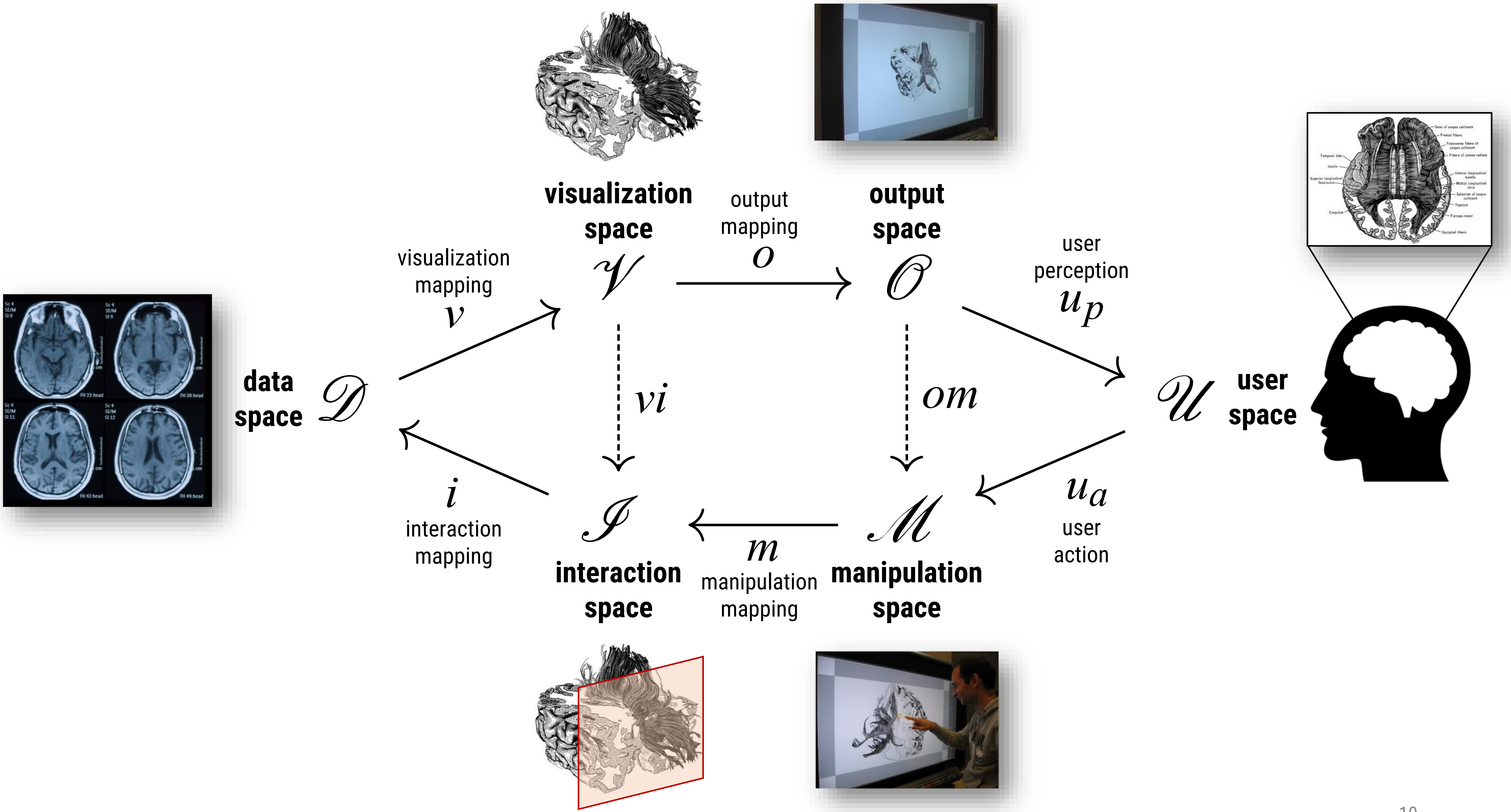
Examples of direct manipulation systems

No single system has all the attributes or design fea-


INTERACT!

Questions

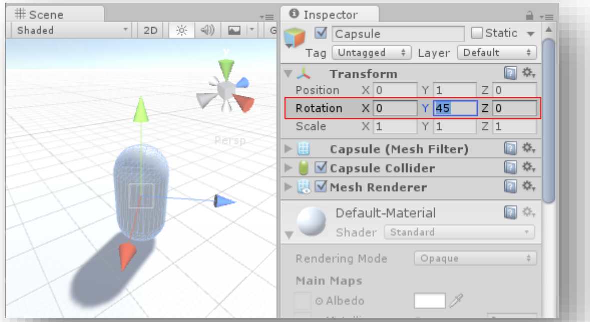
- What is “directness” in the context of interactive visualization?
- Is directness a useful notion for better understanding the interplay between visualization and interaction?
- What are the (sub-)dimensions of directness?
- Can we measure it? Can we predict it?

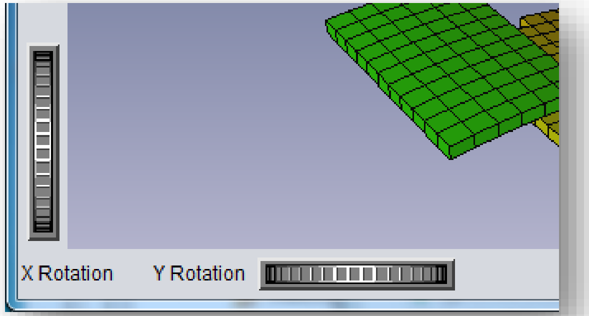


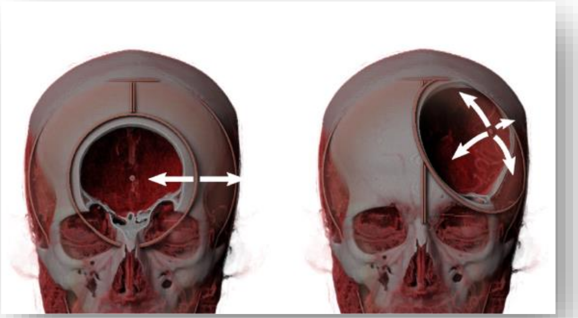
visualization space
$\mathscr{V}$
output mapping
o
output space
$\mathscr{O}$
visualization mapping
v
user perception
u_p
data space
$\mathscr{D}$
vi
om
$\mathscr{U}$
user space
i
interaction mapping
$\mathscr{I}$
$\mathscr{M}$
u_a
user action
m
manipulation mapping
interaction space
manipulation space

Dimensions of Directness

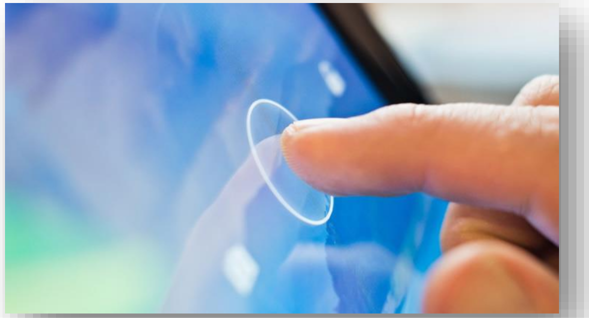
- Visualization-interaction (vi) directness





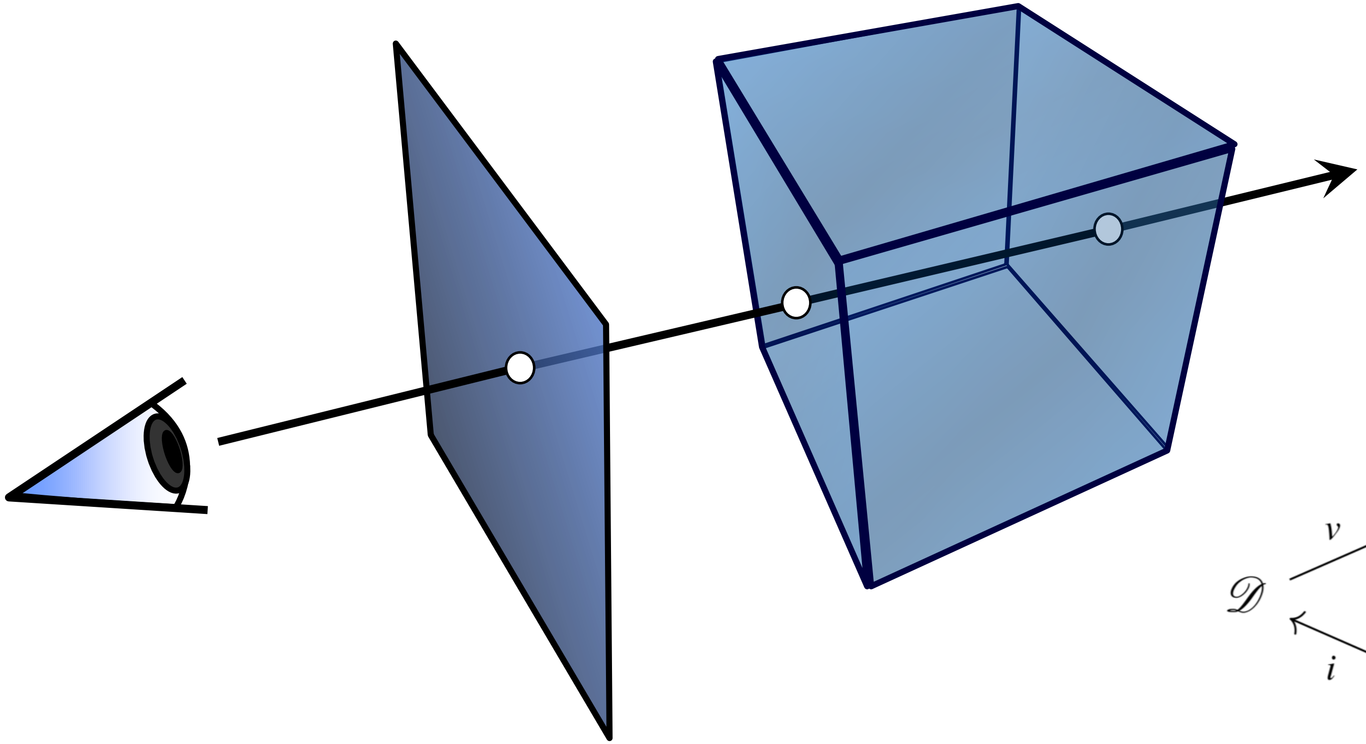


- Output-manipulation (om) directness



Example: Point Picking in VolVis

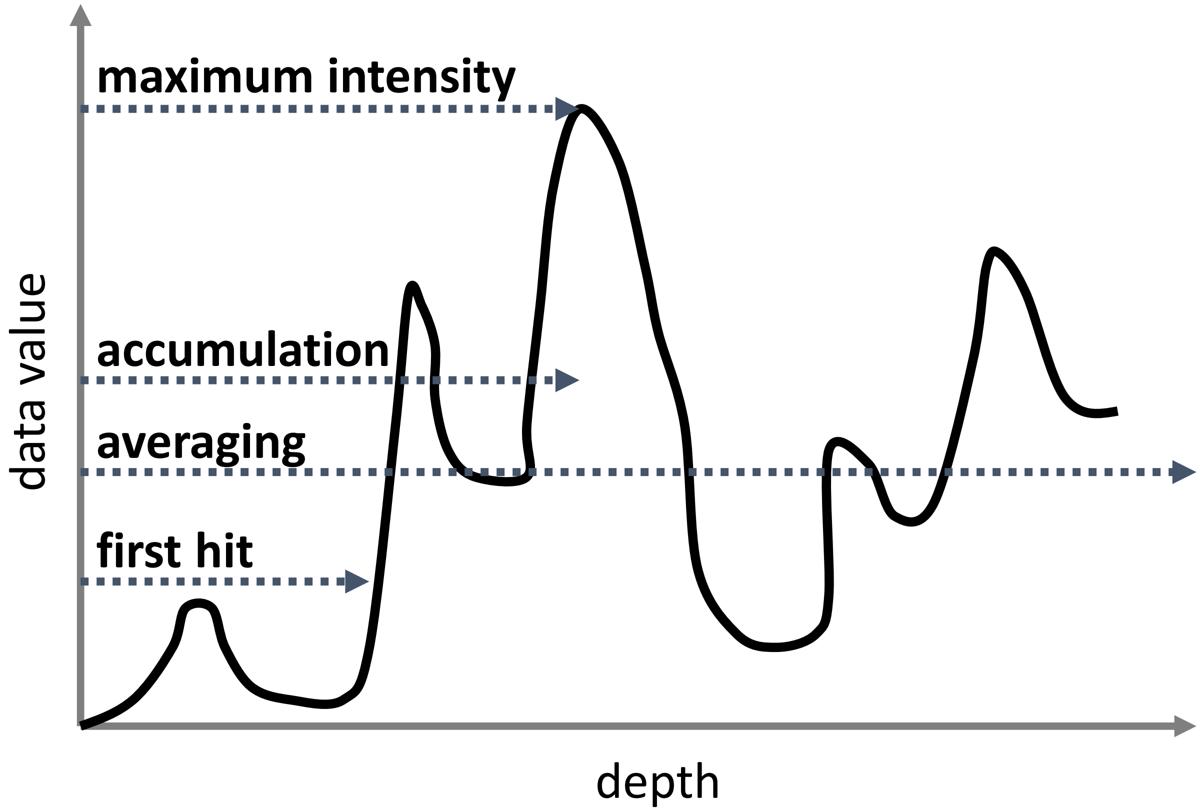
- Reconstruct 3D position from picked point in 2D image
  - We encounter many data values along a viewing ray
  - Compositing function defines how data values contribute to a pixel



$$\begin{tikzcd}
 & \mathscr{V} \arrow[r, "o"] \arrow[d, dashed, "vi"] & \mathscr{O} \arrow[d, dashed, "om"] \arrow[dr, "u_p"] & \\
\mathscr{D} \arrow[ur, "v"] & & & \mathscr{U} \arrow[dl, "u_a"] \\
 & \mathscr{I} \arrow[ul, "i"] & \mathscr{M} \arrow[l, "m"] &
\end{tikzcd}$$

Types of Compositing

intensity profile along a viewing ray



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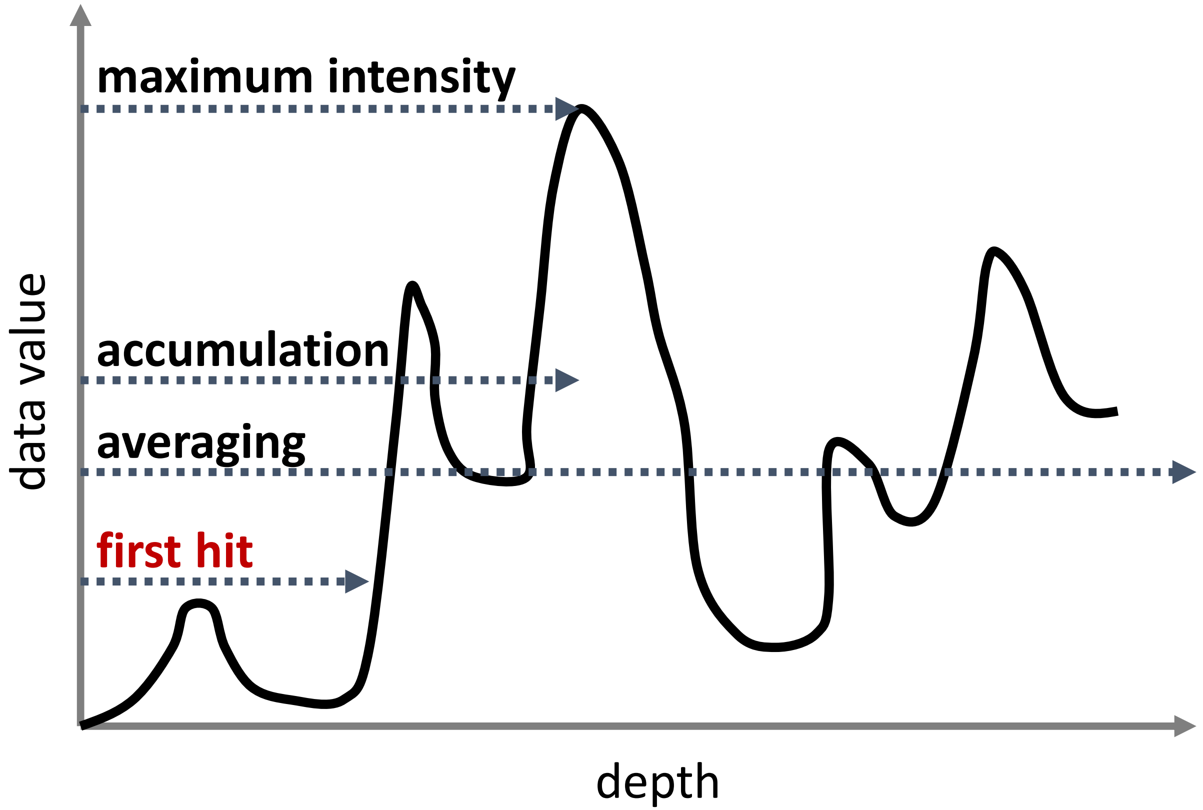

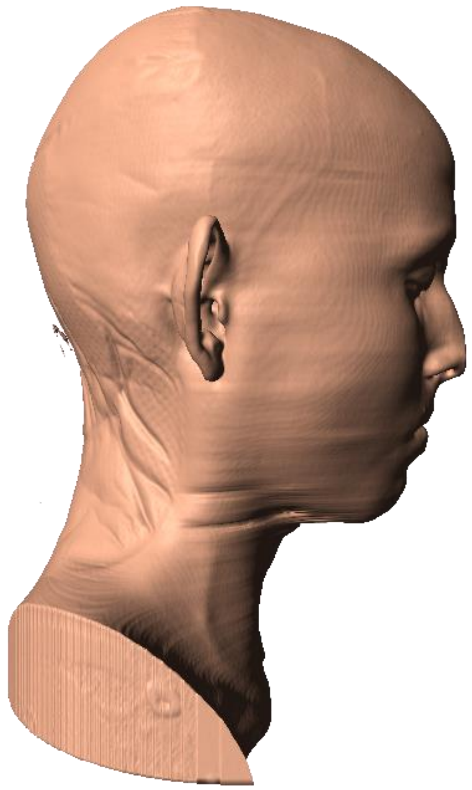

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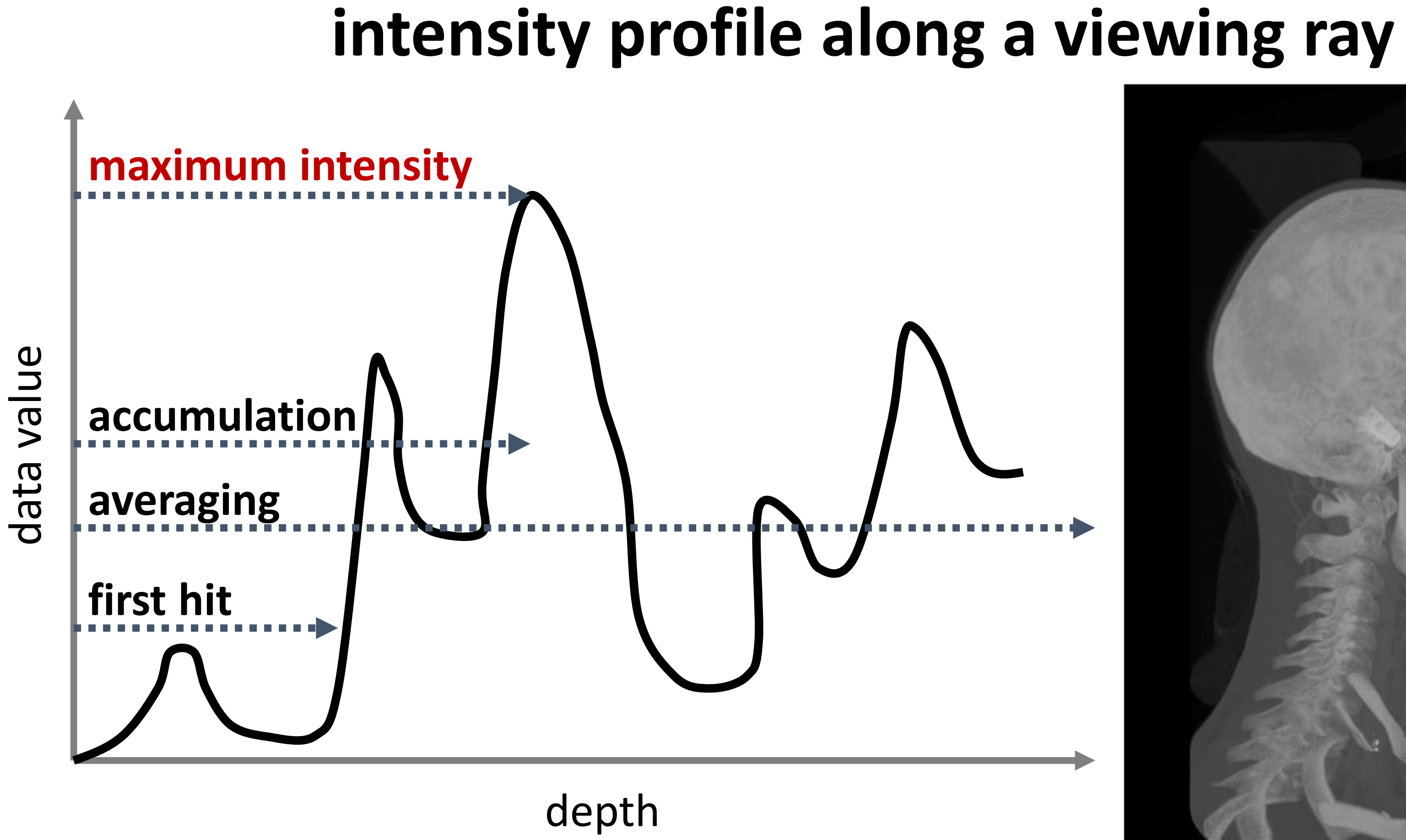

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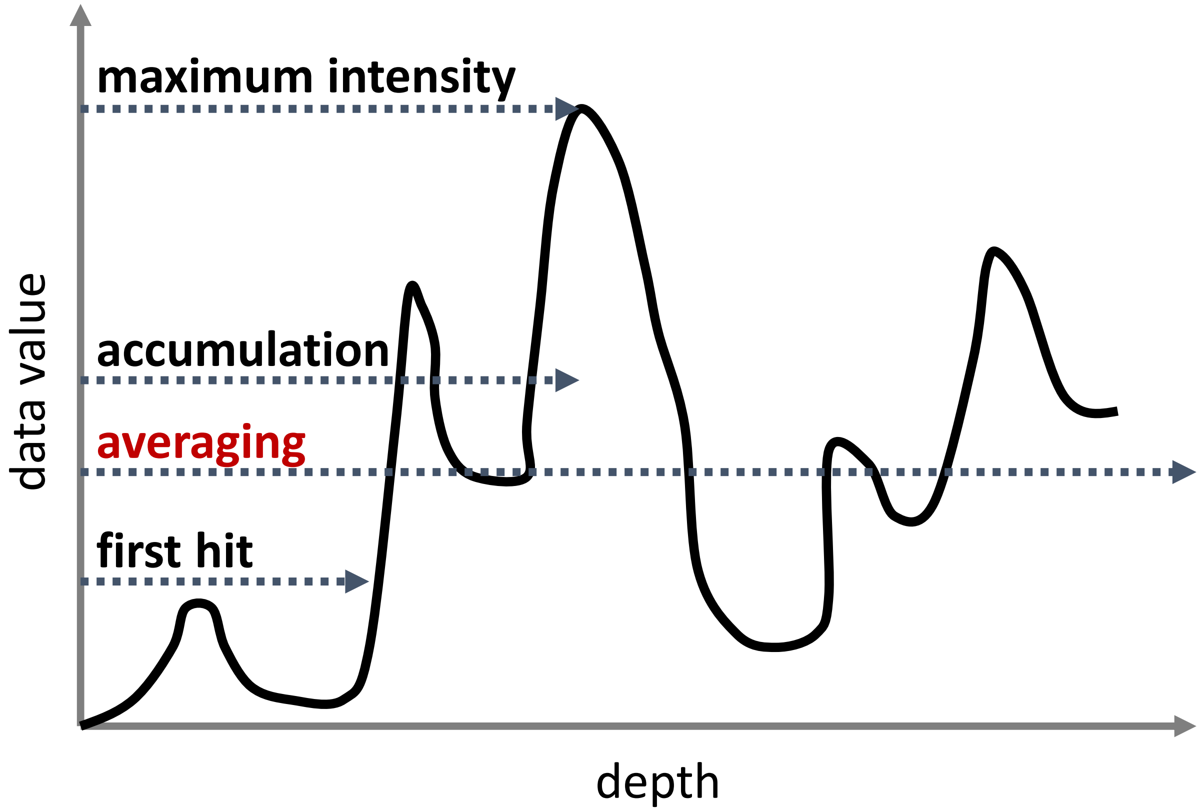

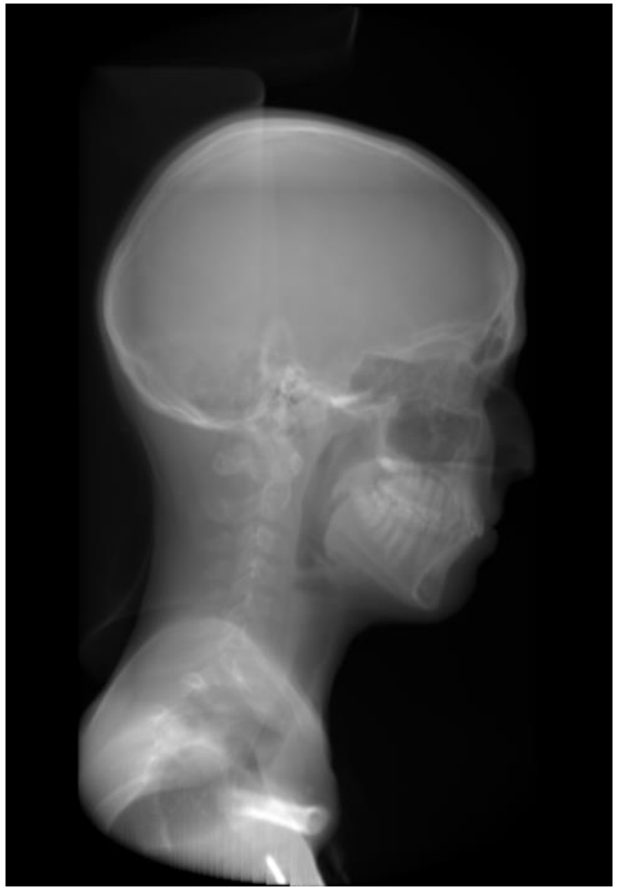

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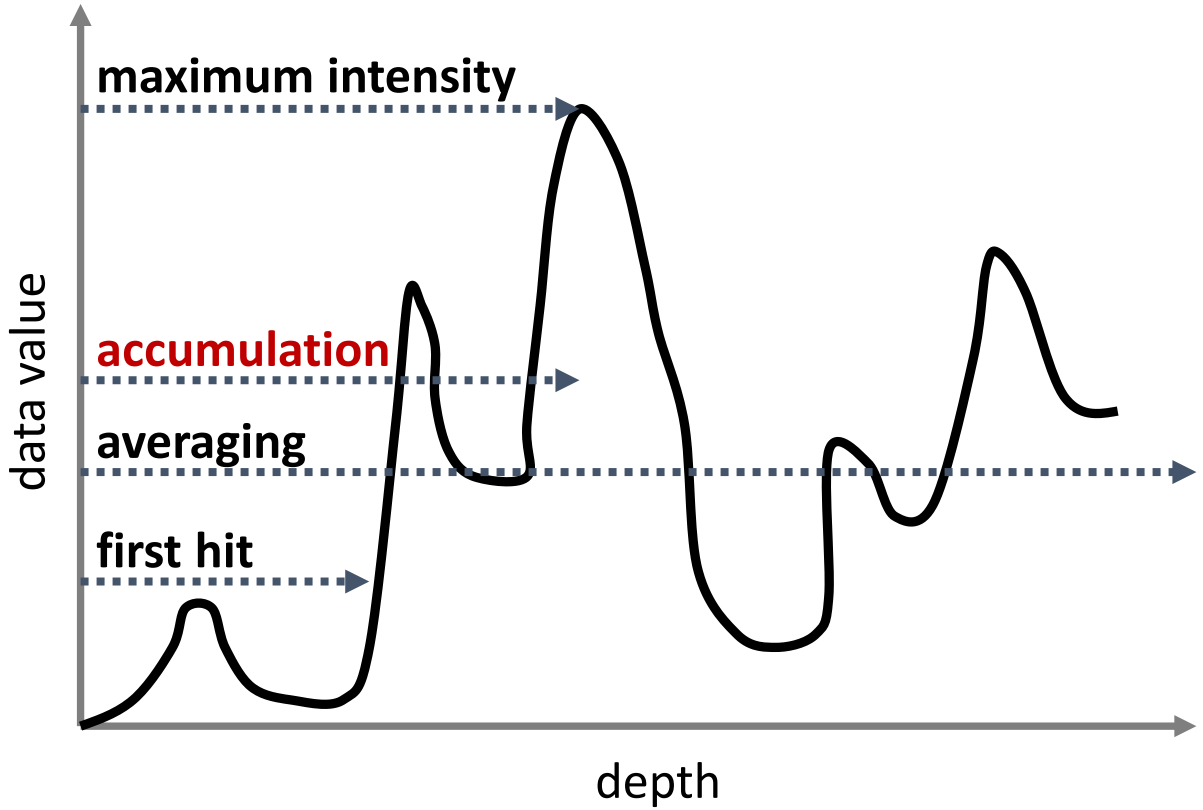
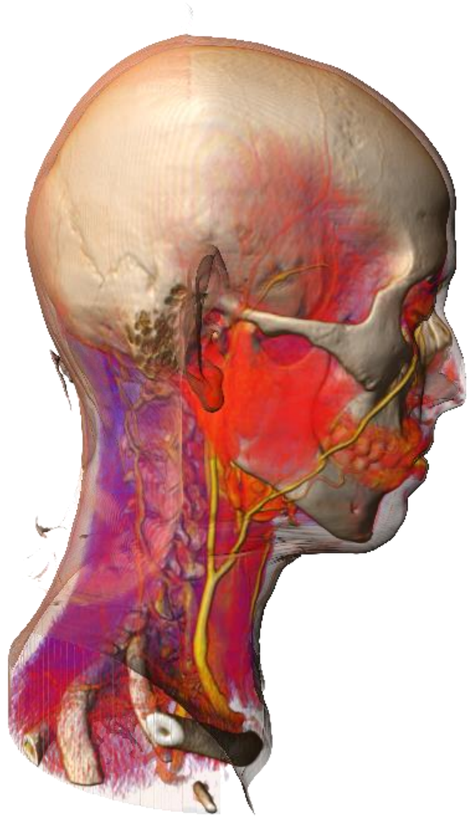




VolVis Point Picking Directness

- Illustrates limits in achievable vi-directness when dealing dealing with 3D data
- Higher vi-directness possible, if compositing function can be inverted
  - **First hit, maximum intensity:** can unambiguously reconstruct 3D position from 2D pixel location
  - **Averaging:** all samples contribute equally to the pixel, reconstruction not possible
  - **Accumulation:** may be able to heuristically reconstruct "close" 3D position in some cases (interaction mapping is a *quasi-inverse* of the visualization mapping)

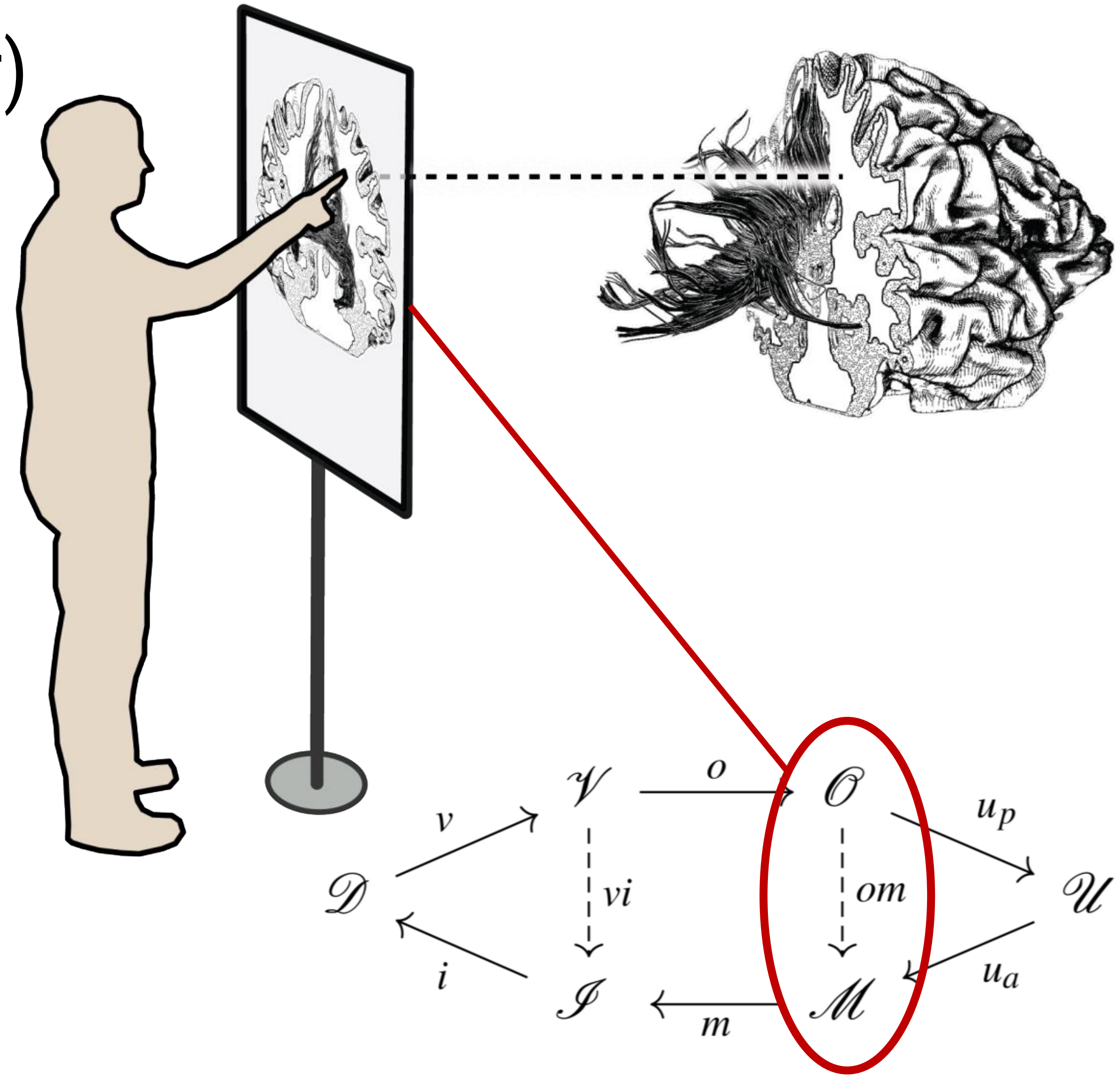
Direct Input for 3D Data?

- Manipulation space: 2 DOF (1 finger)
- Interaction space:
  - 3 DOF for position
  - 3 DOF for orientation
  - 1–3 DOF for scale
  - n DOF for additional parameters

- All per object/element

- typically control of only 4 DOF simultaneously (4–5 max.)*

** some scientific evidence for this limit*



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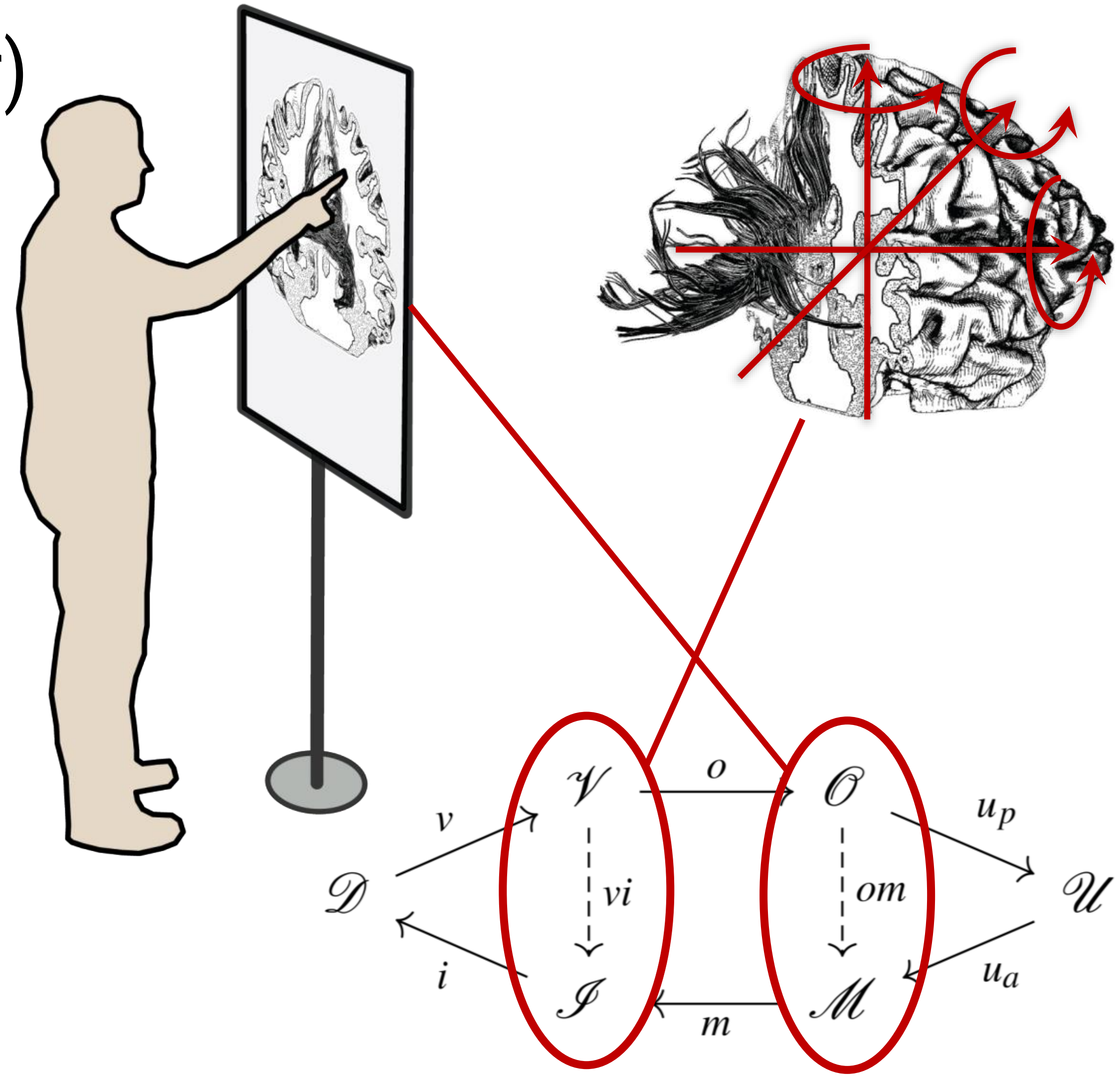

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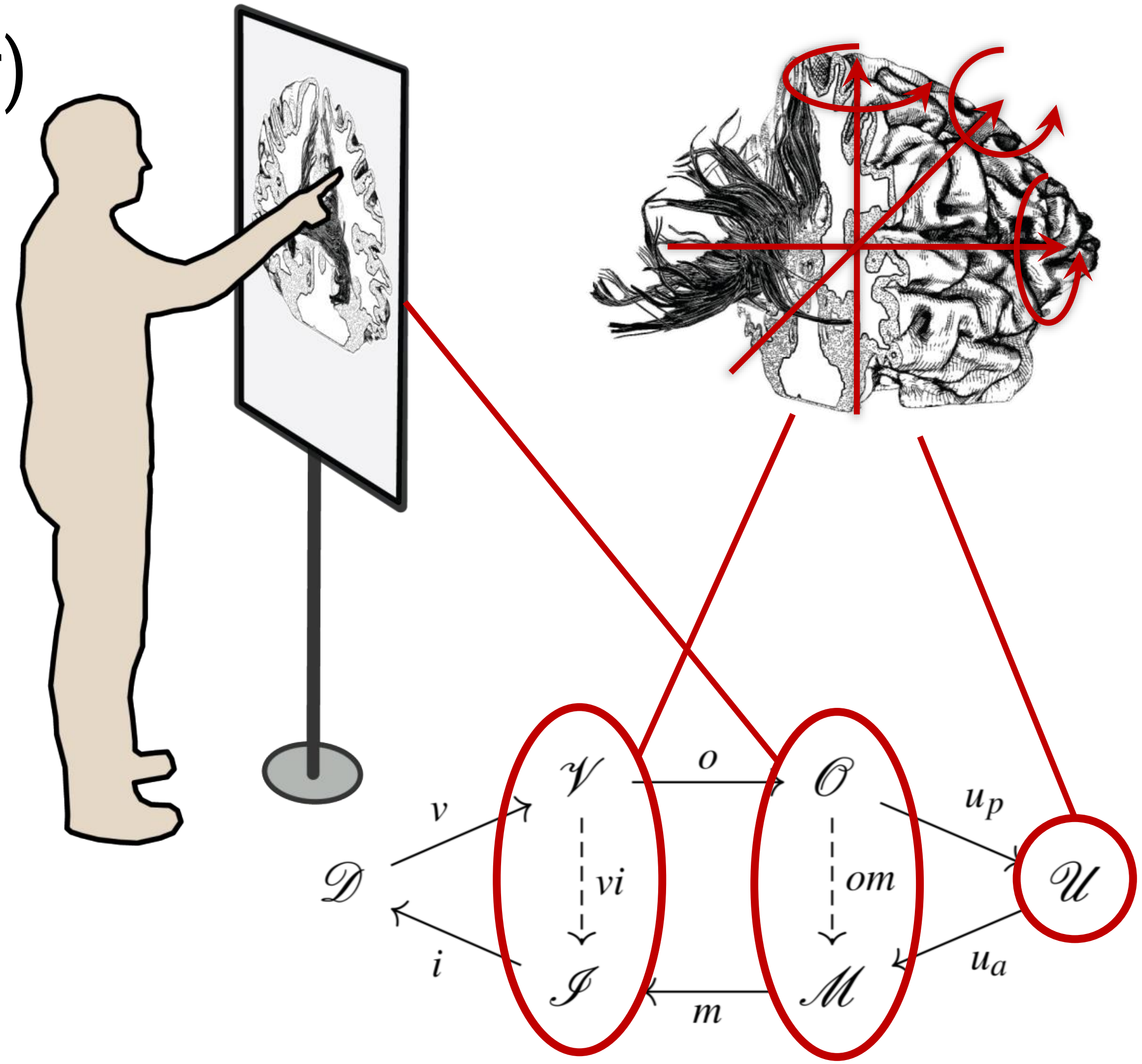

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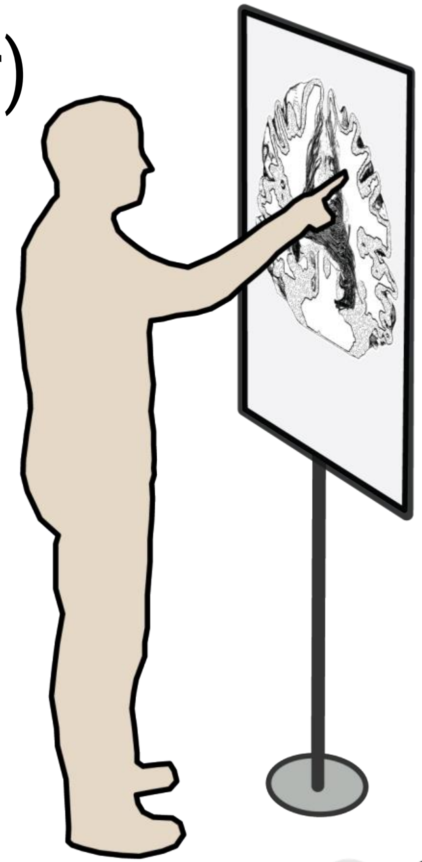

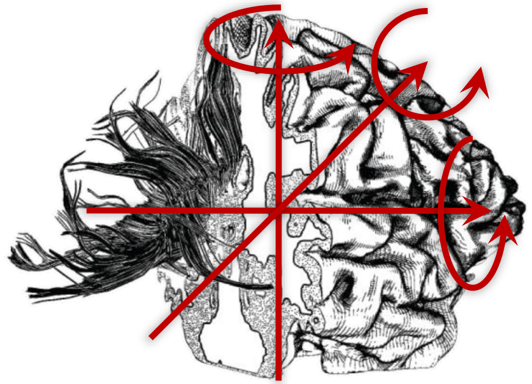

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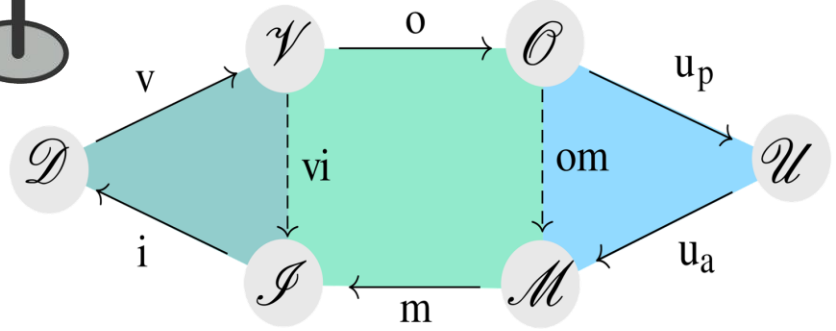

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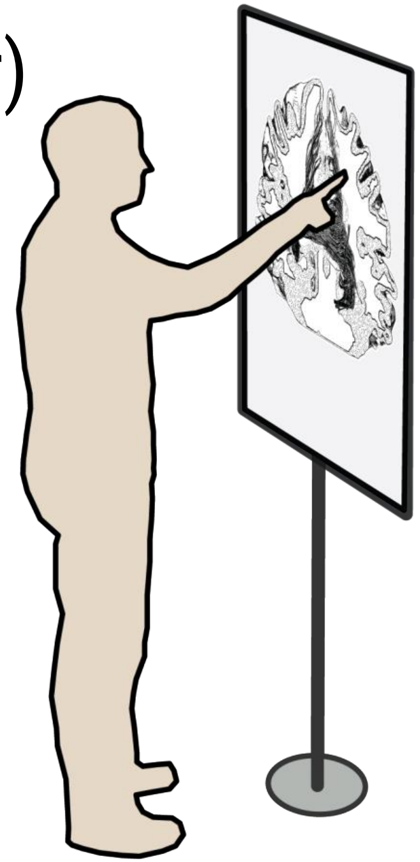
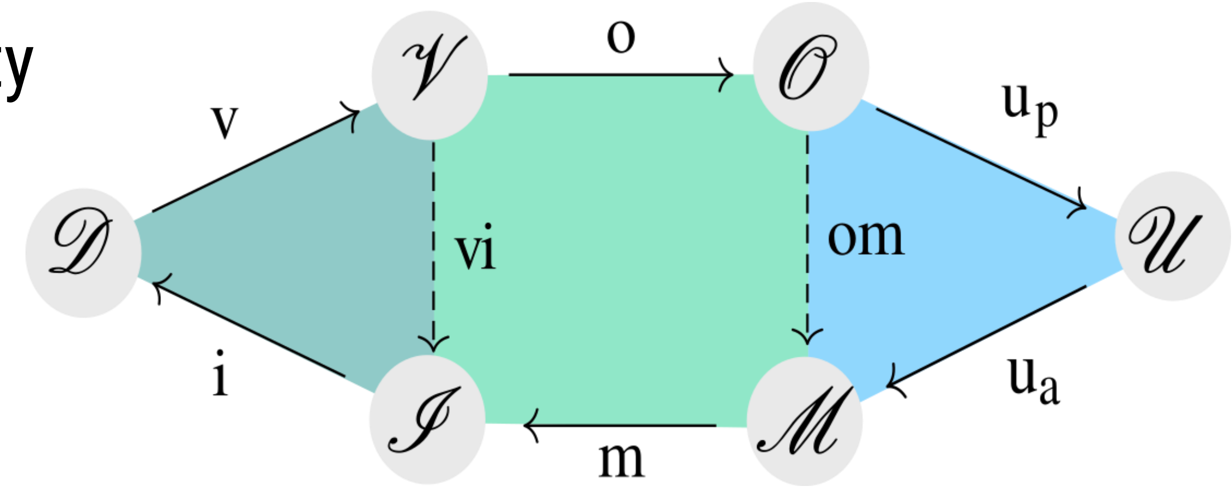


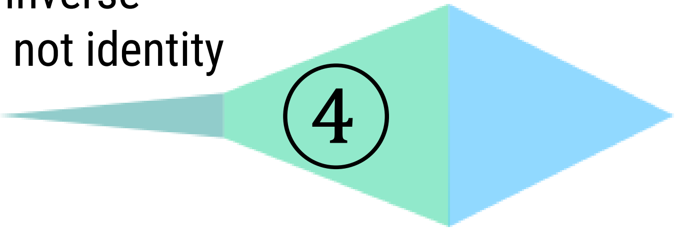
Classification of Directness by Mapping Type

- Visualization-interaction directness: 3 vi-mapping types
  - Inverse
  - Quasi-inverse
  - Non-Inverse
- Output-manipulation directness: 2 om-mapping types
  - Identity
  - Not identity



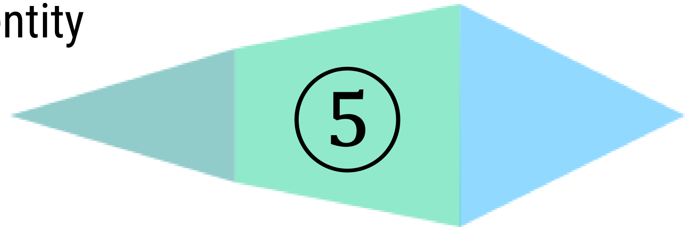
6 Classes (3 vi × 2 om)

v, i : inverse
om : not identity

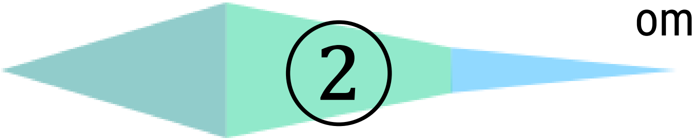


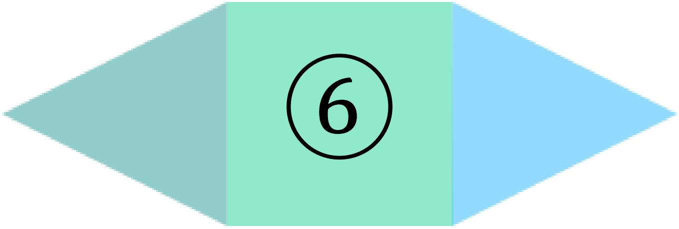
v, i : inverse
om : identity

v, i : quasi-inverse
om : not identity

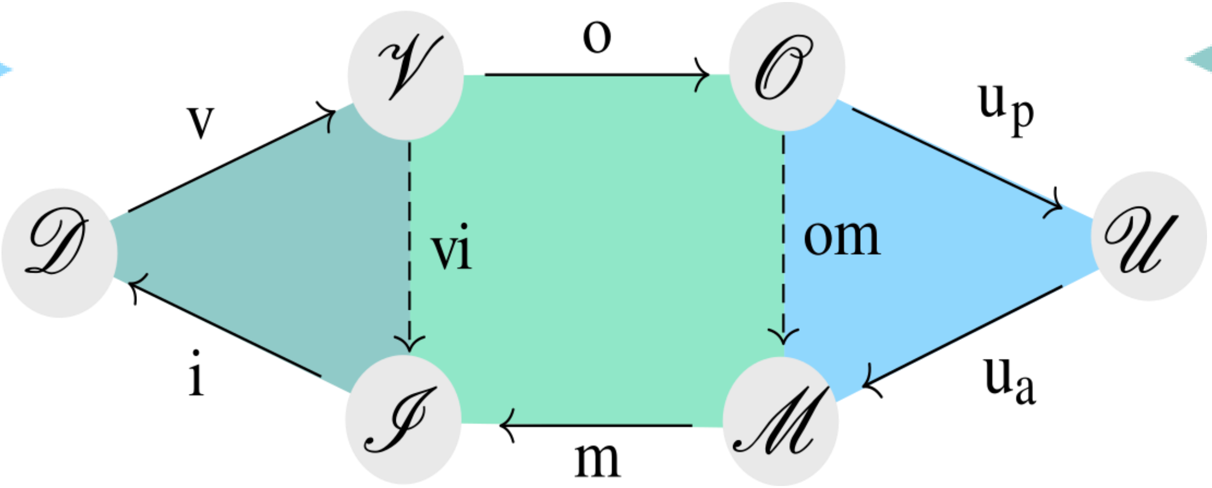


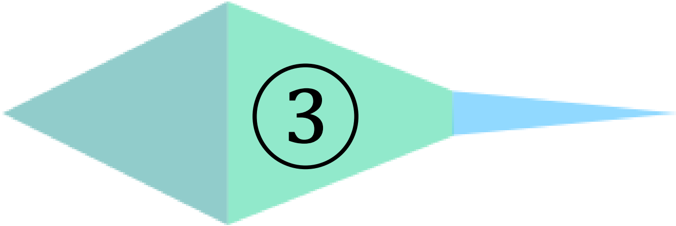
v, i : quasi-inverse
om : identity





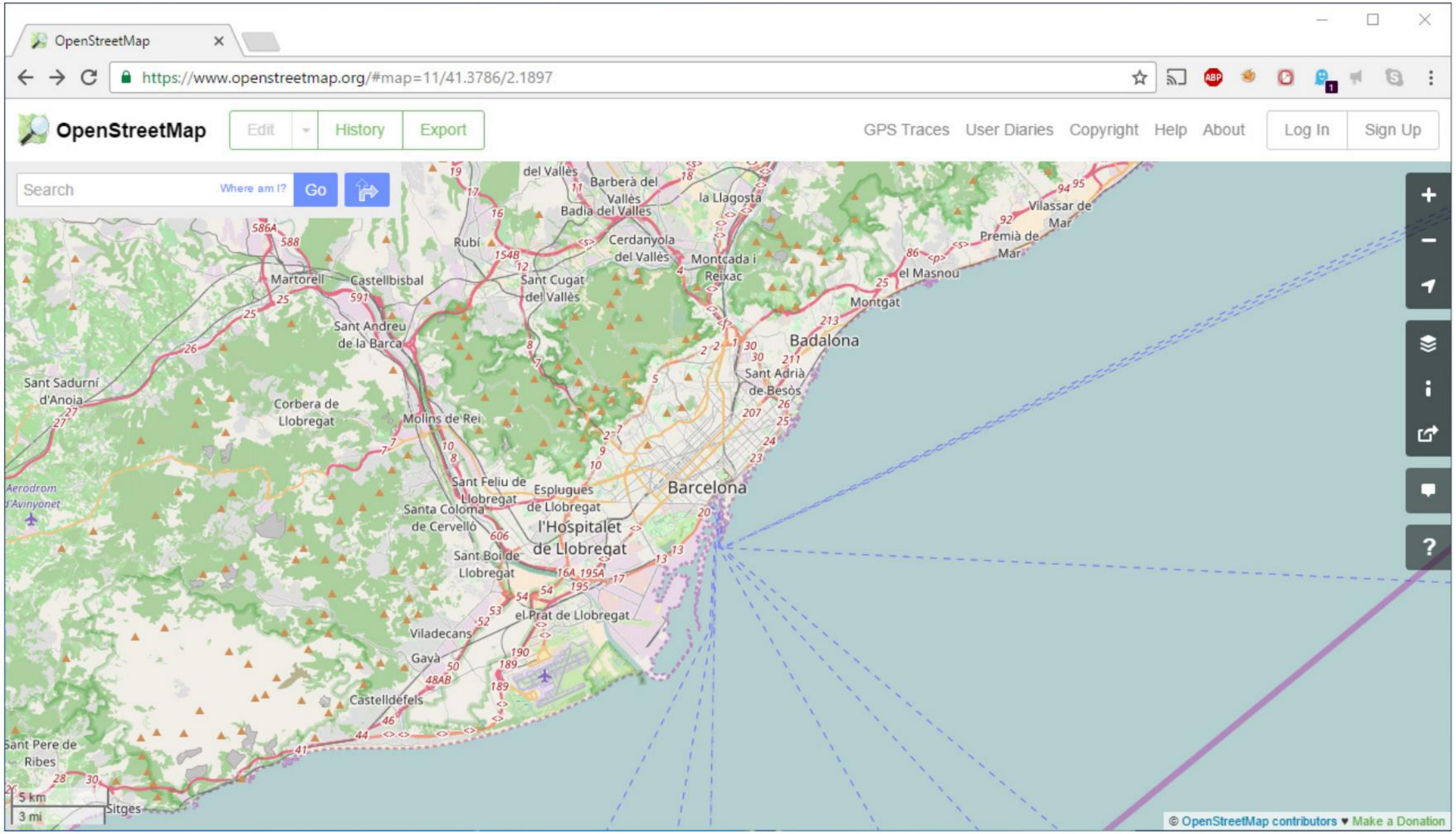
v, i : non-inverse
om : not identity





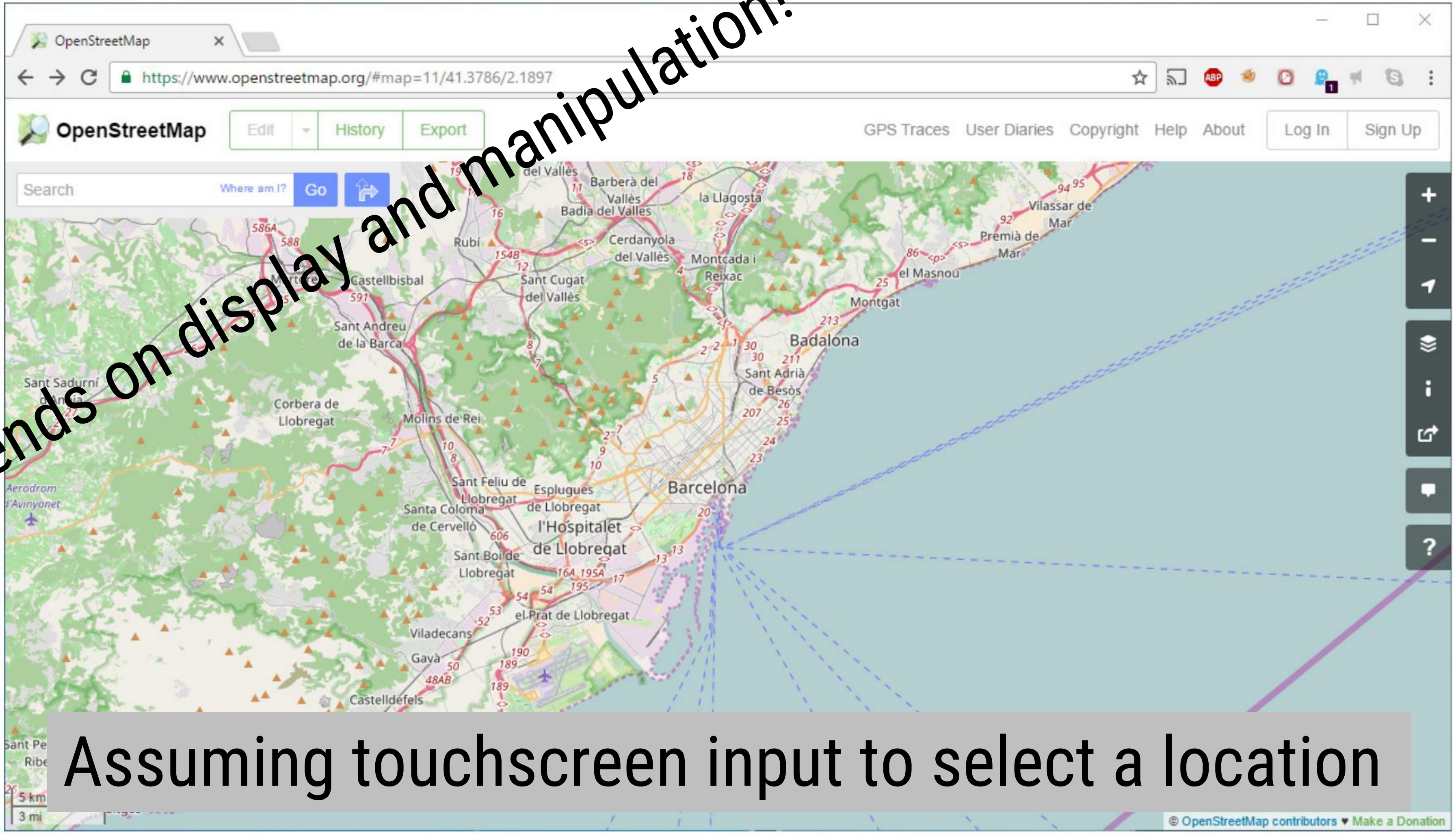
v, i : non-inverse
om : identity

Example: Which Class?



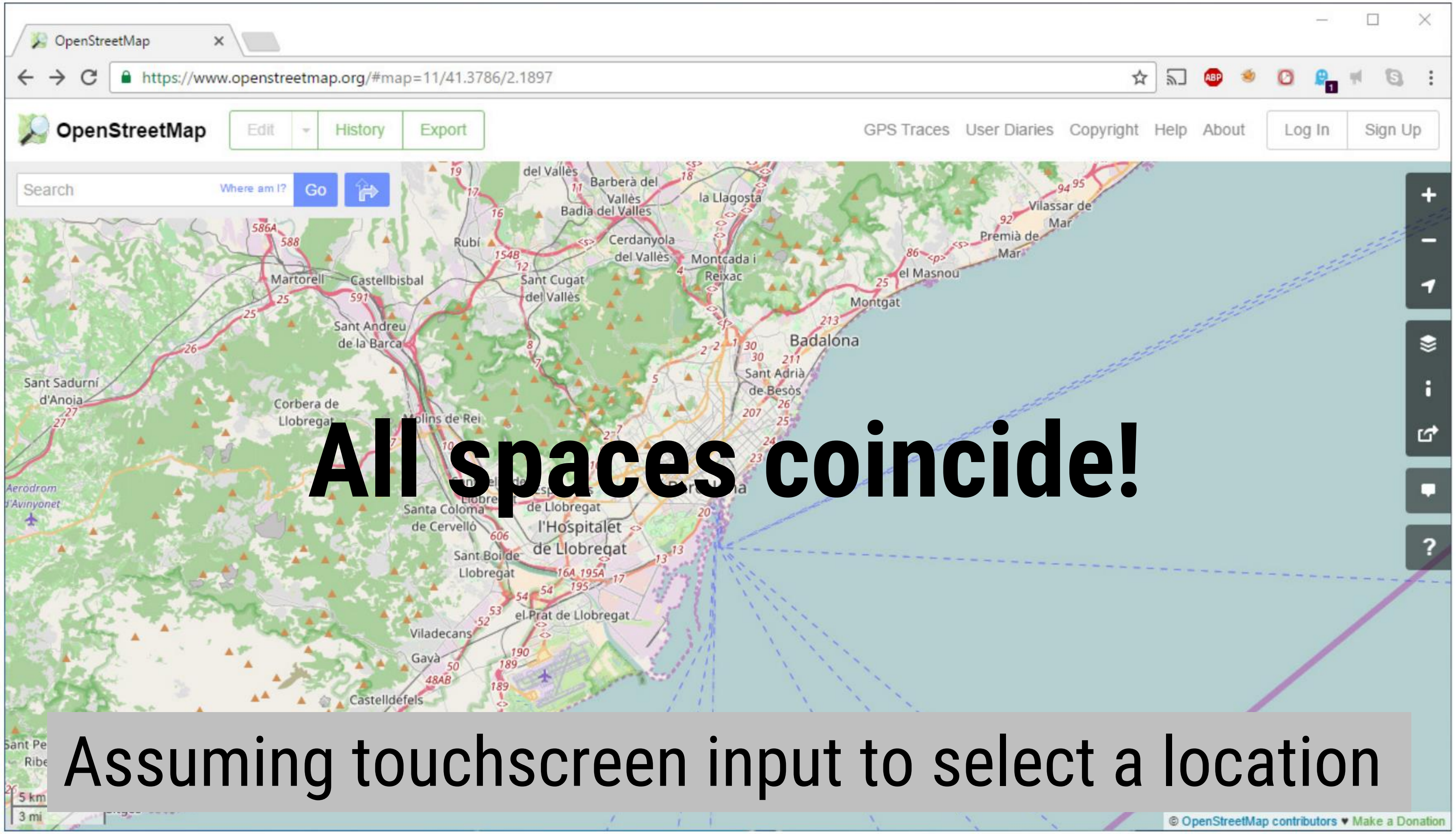
Example: Which Class?

Depends on display and manipulation!



Assuming touchscreen input to select a location

Example: Class 1



All spaces coincide!

Assuming touchscreen input to select a location

Example: Which Class?

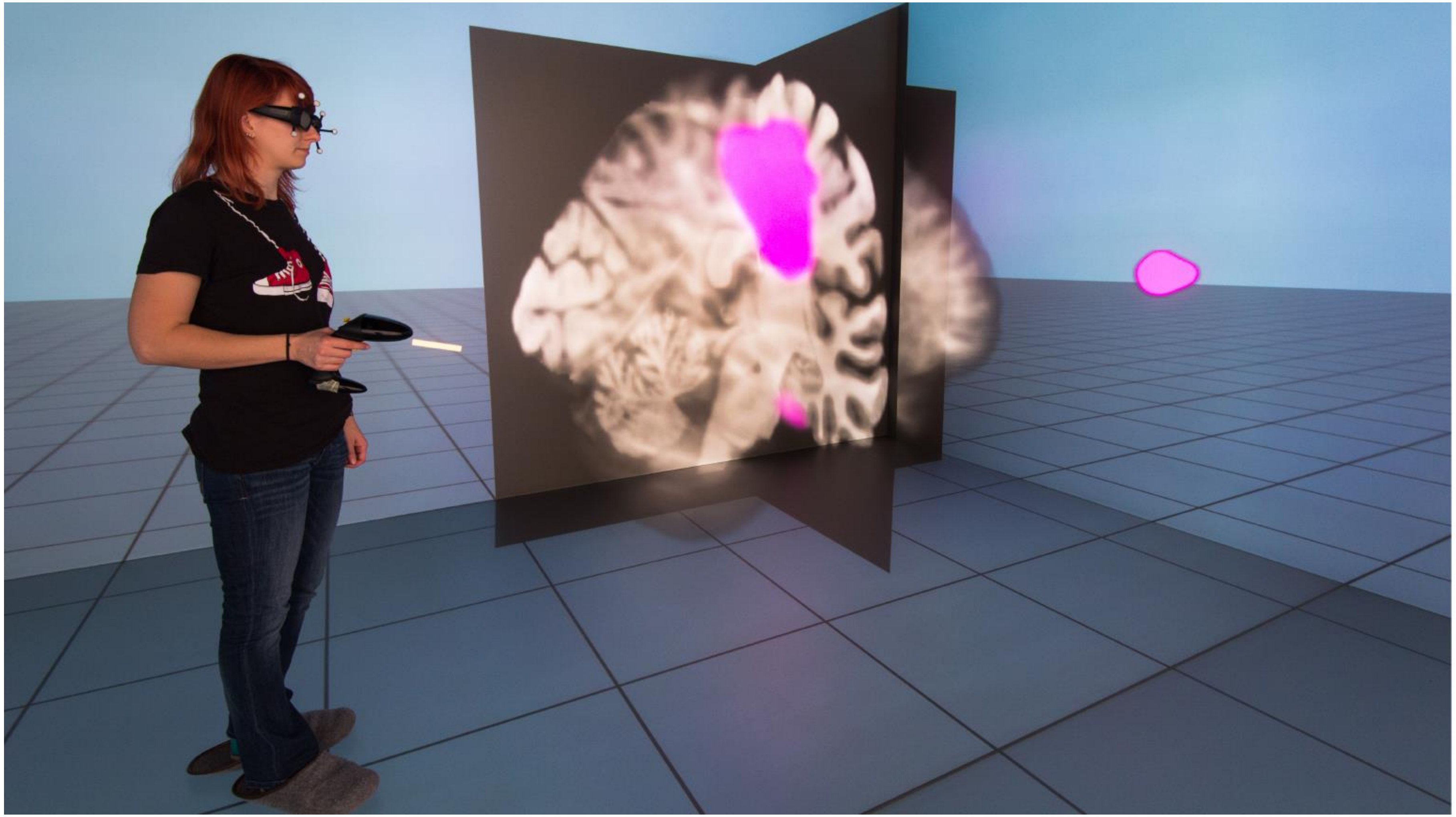


Image courtesy of and © Claudia Hänel and Bernd Hentschel, used with permission.

Example: Class 1

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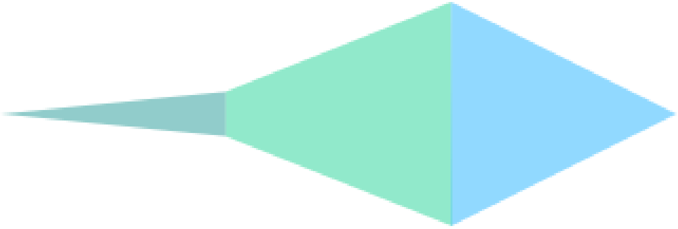
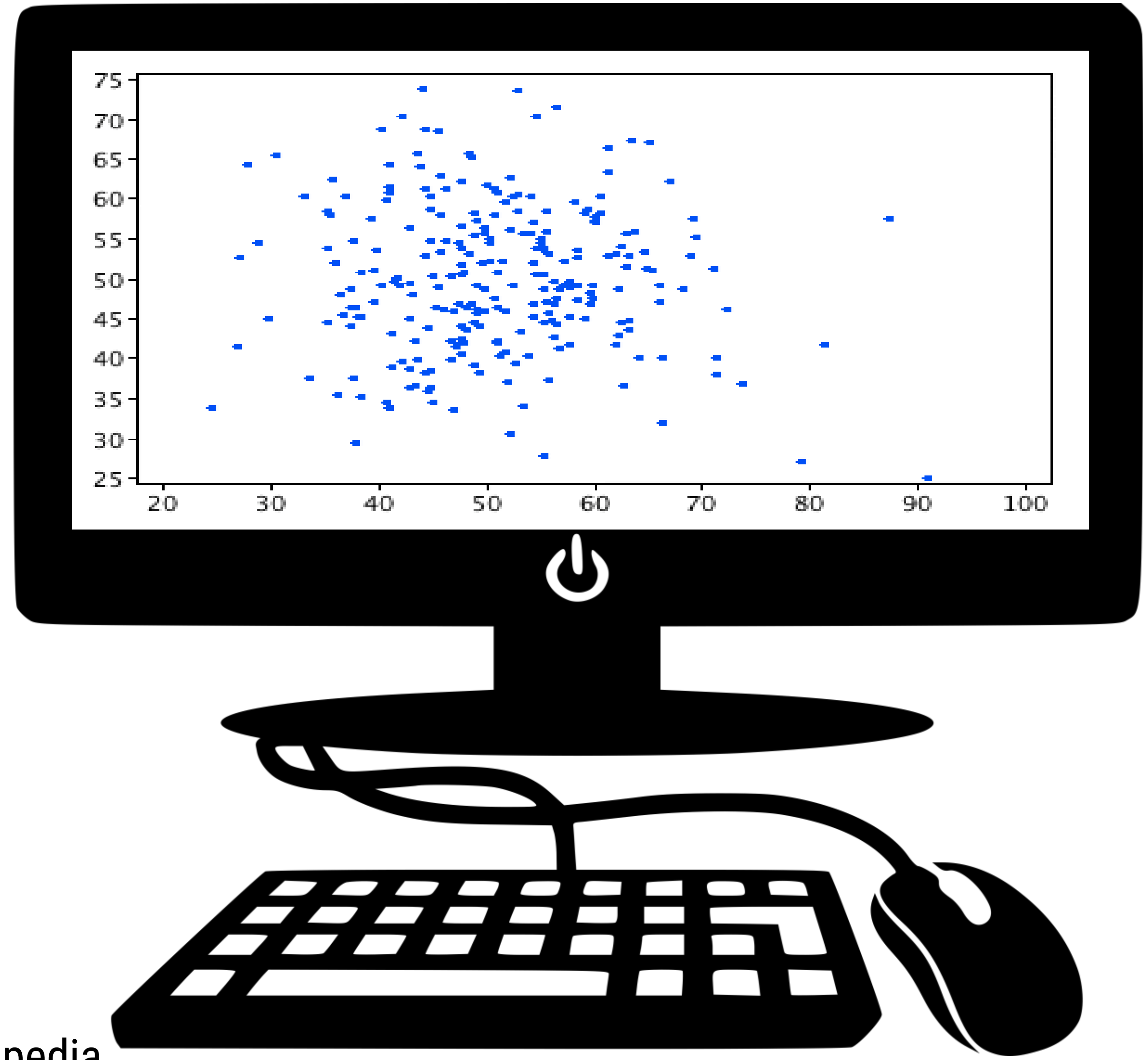
Example: Class 4





Images based on images from Wikipedia

Towards Measuring vi-Indirectness

$$\Delta_{v,i} = \int \underbrace{I(x)}_{\text{importance/relevance of a data location x; models user tasks}} \left| x - i(vi(v(x))) \right| dx$$

See the paper for a **detailed example** where we actually **implemented** the measure

Conclusion

Descriptive usage

- Term directness precisely defined
- More Characteristics
- Captures more aspects of directness

Evaluative usage

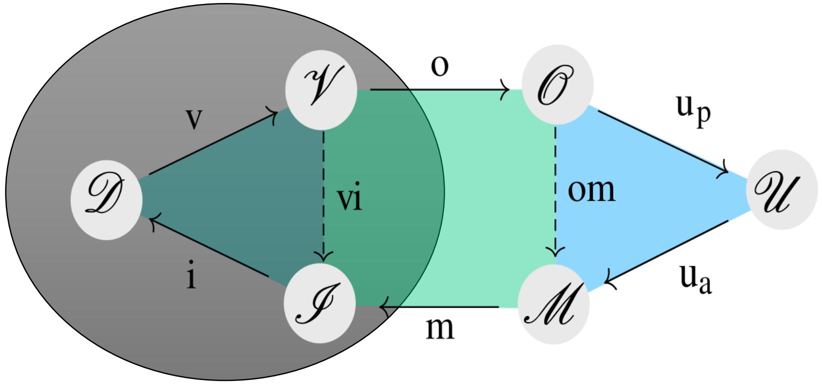
- Classify ore even measure directness of existing techniques
- Relate directness to efficiency

Vision:

- **Generative usage**
- Automatically suggest appropriate interaction

Final Notes

- Often *direct* is interepreted as „better“ than *indirect/less direct*.
  - **This is definitely not always the case!**
  - For certain cases less direct might be advantageous
    - More flexible
    - Faster
- Spatial in the title does not mean spatial data
  - **Abstract data** changes only left part of model



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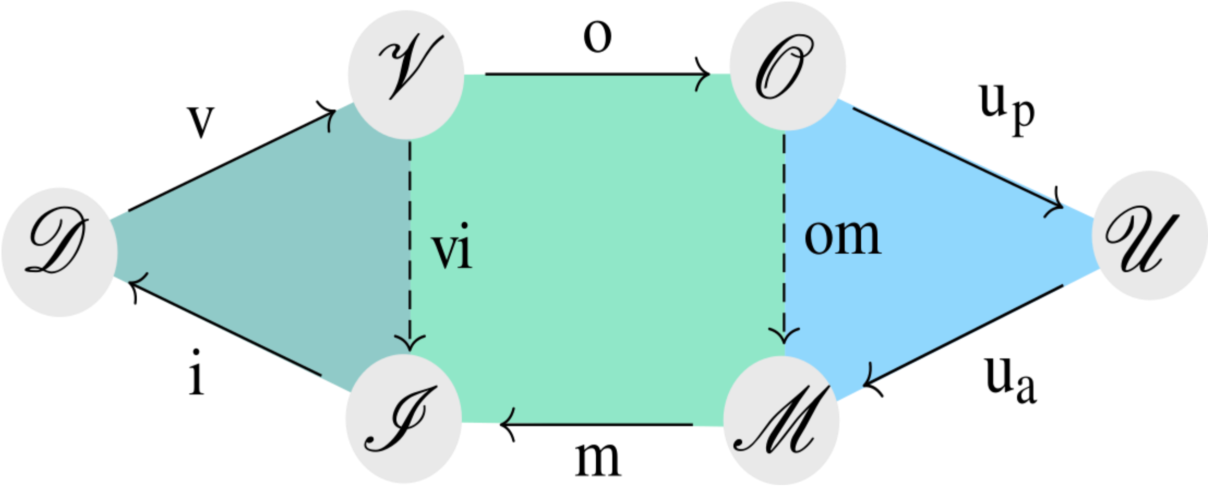
Questions?



We are **very grateful** for the **reviewers'** very helpful and constructive feedback!