



Interactions for Seamlessly Coupled Exploration of High-Dimensional Images and Hierarchical Embeddings

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An aerial night photograph of a city, showing a dense network of streets and buildings. The image is heavily lit by artificial lights from the buildings and street lamps, creating a vibrant glow against the dark sky. A prominent feature is a large, brightly lit stadium or arena on the left side. In the center, there's a large, curved, illuminated area that looks like a race track or a large stadium. The surrounding urban landscape includes various residential and commercial buildings, all contributing to the overall impression of a bustling city at night.

Image exploration

Pan



Zoom



Image exploration



Image exploration

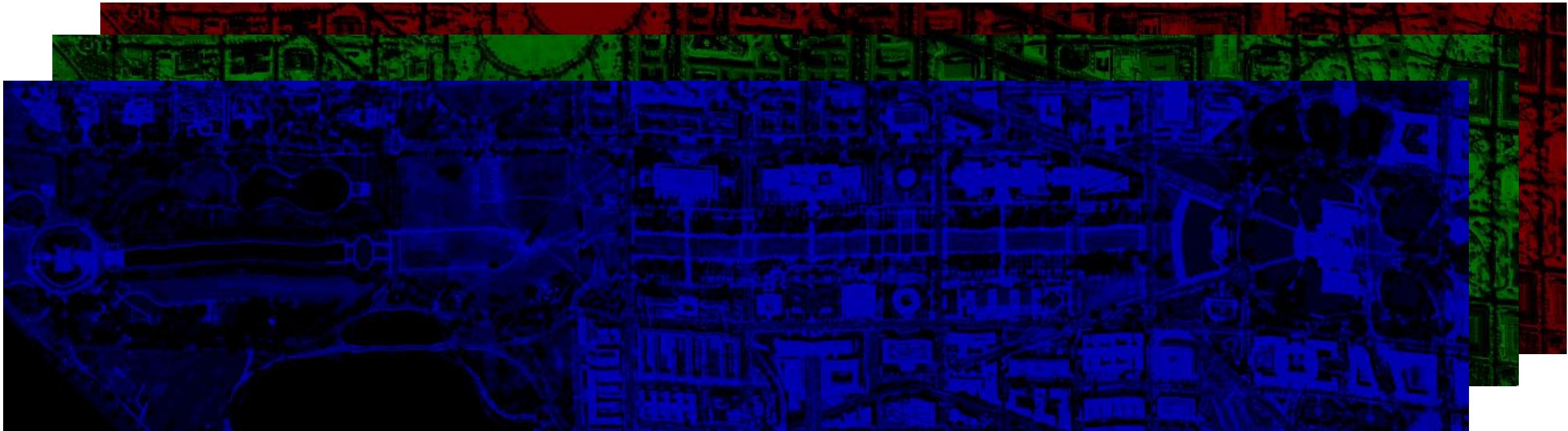


Image exploration

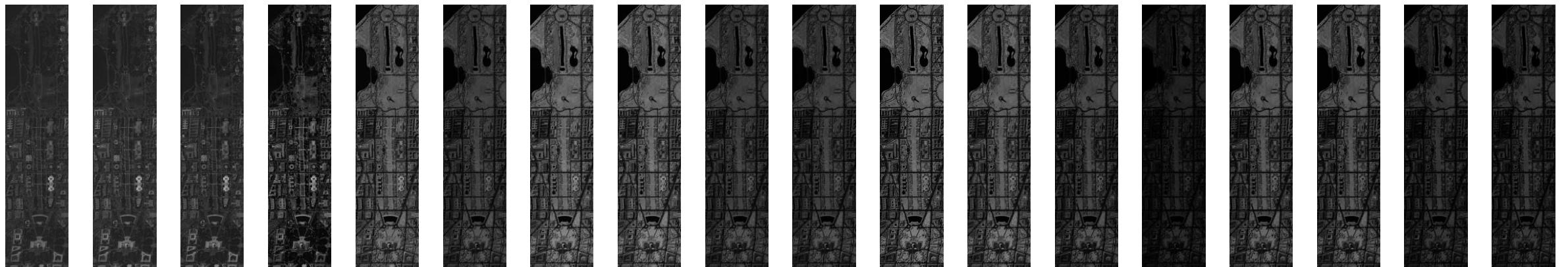
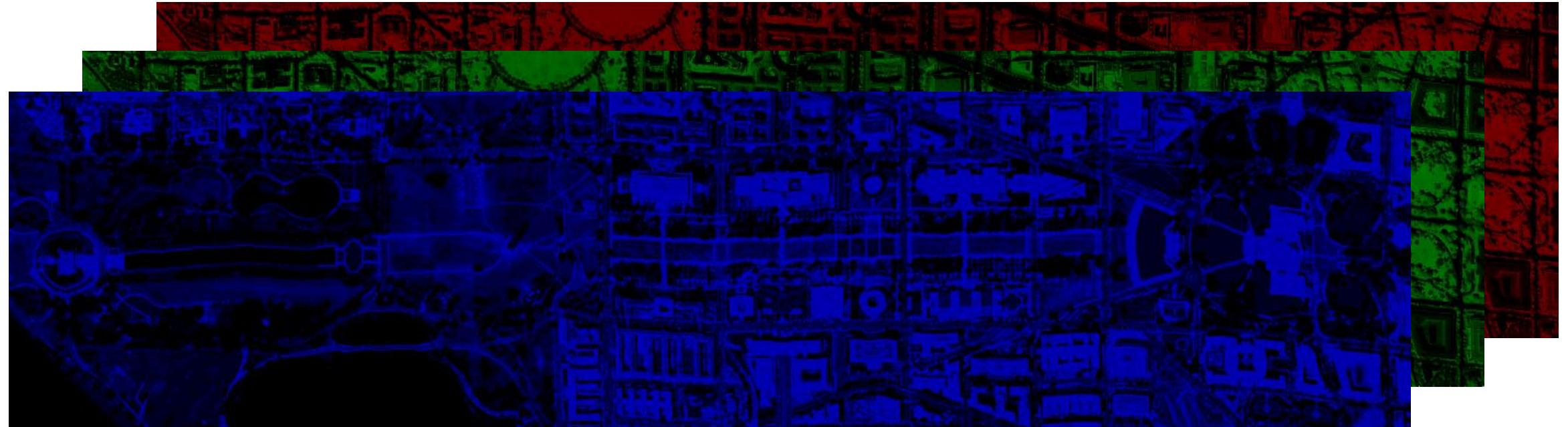


Image exploration

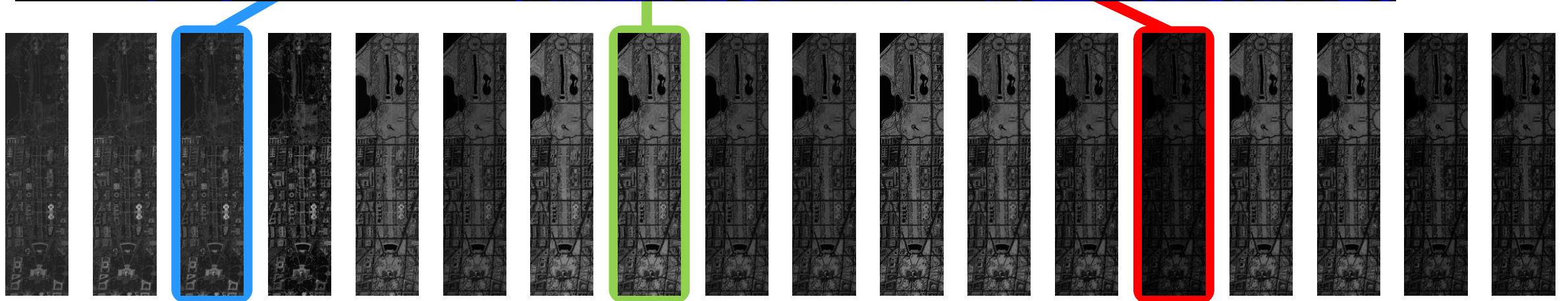
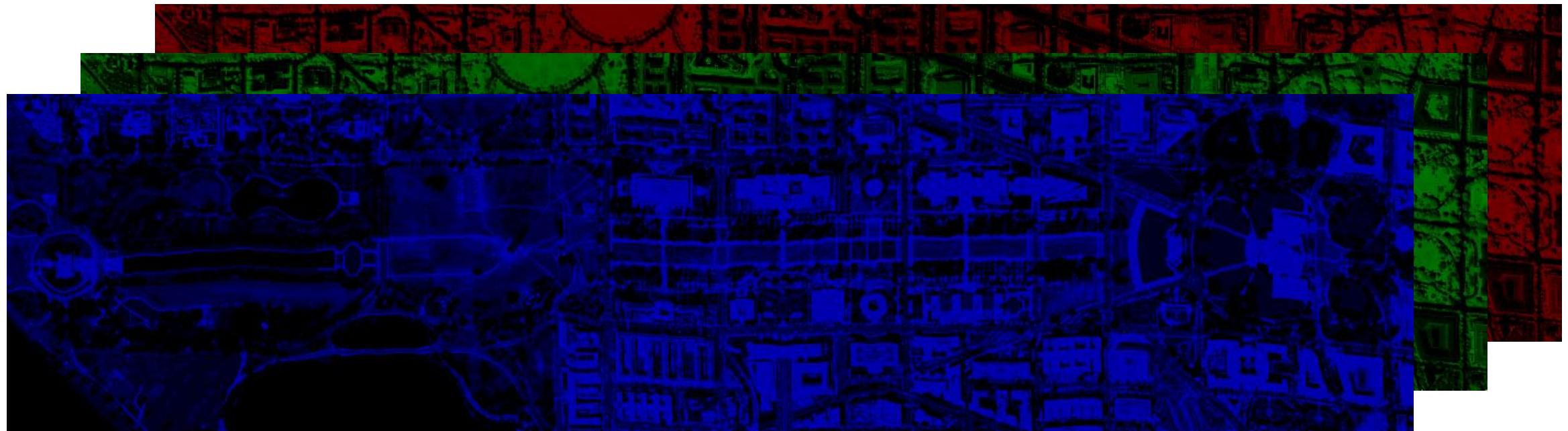


Image exploration

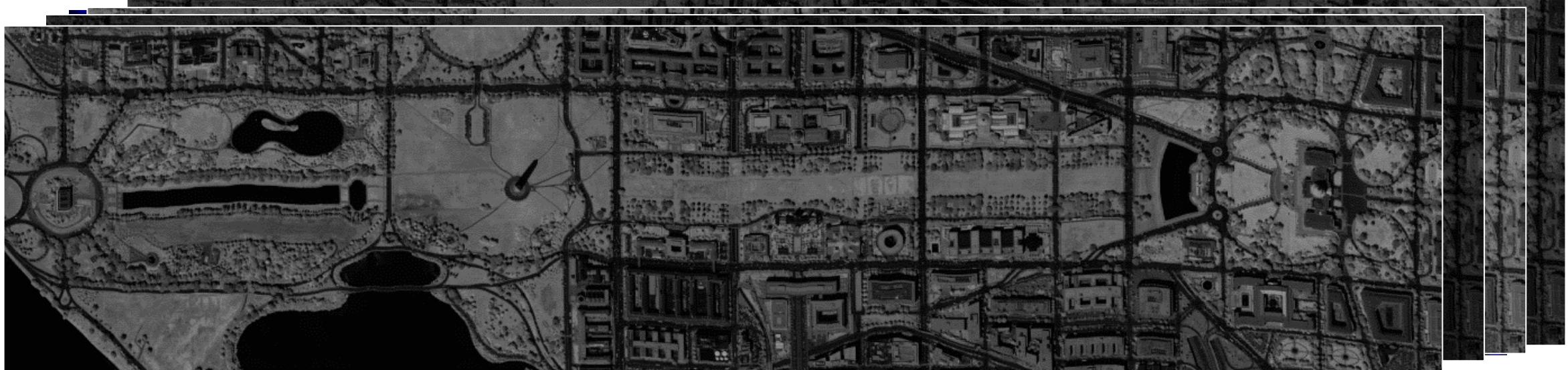


Image exploration

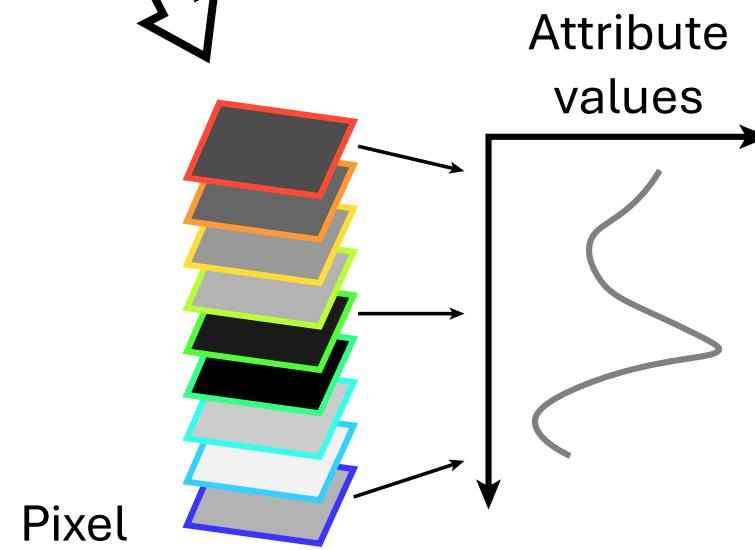
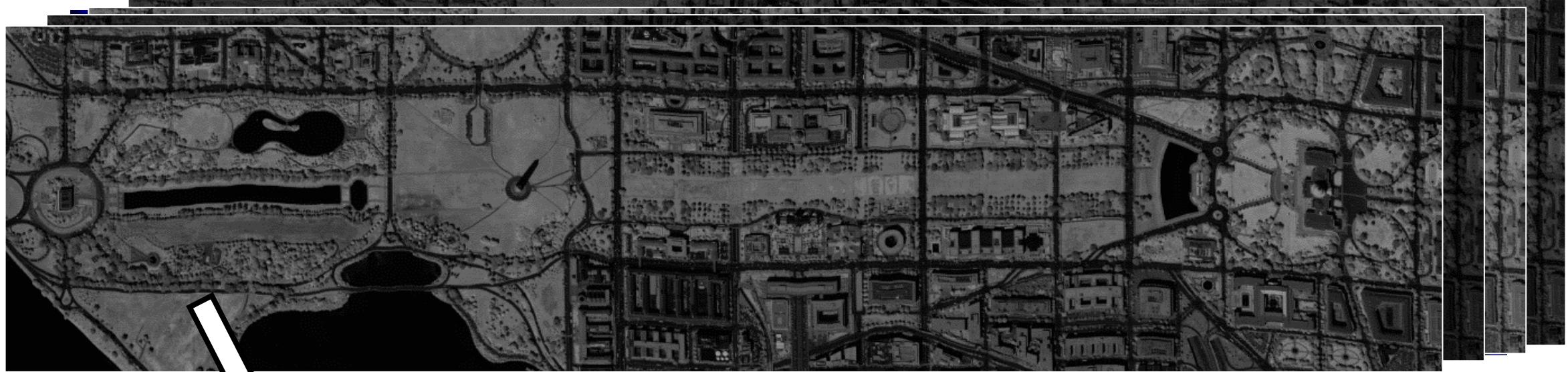


Image exploration

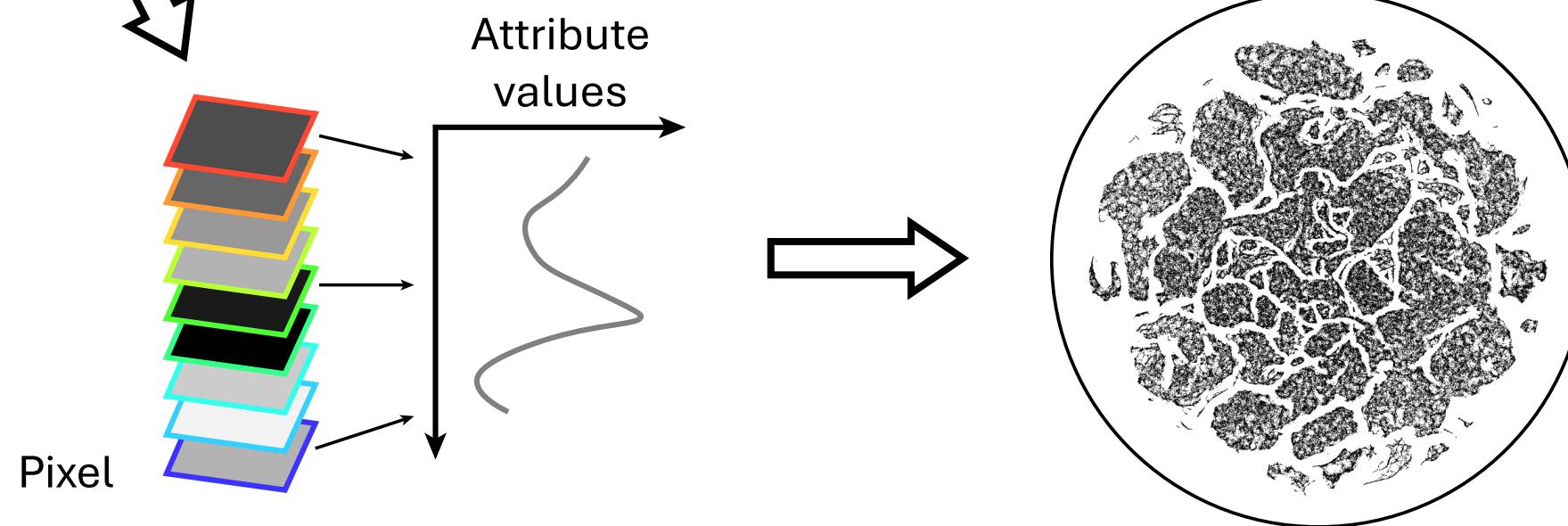
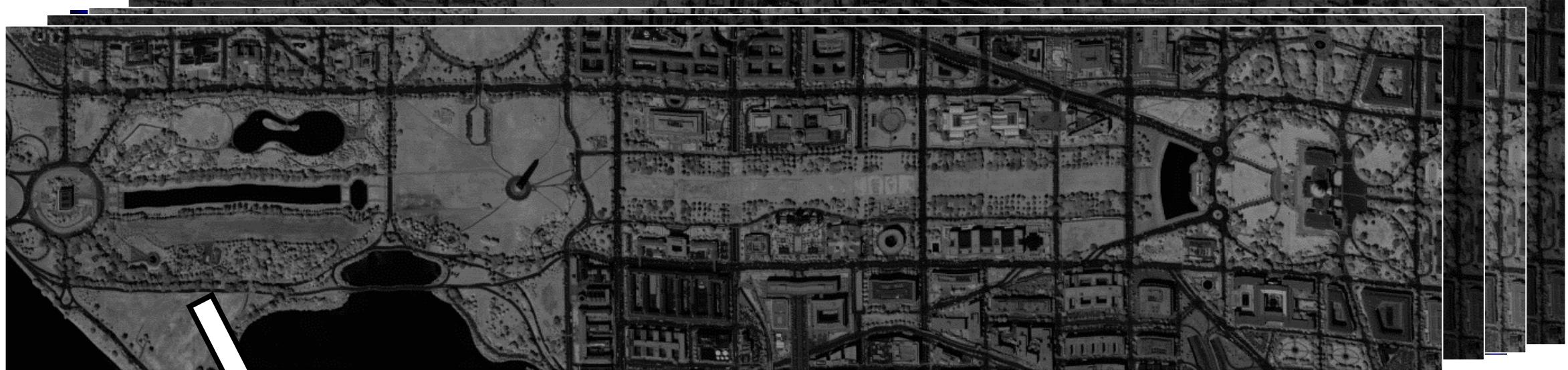


Image exploration

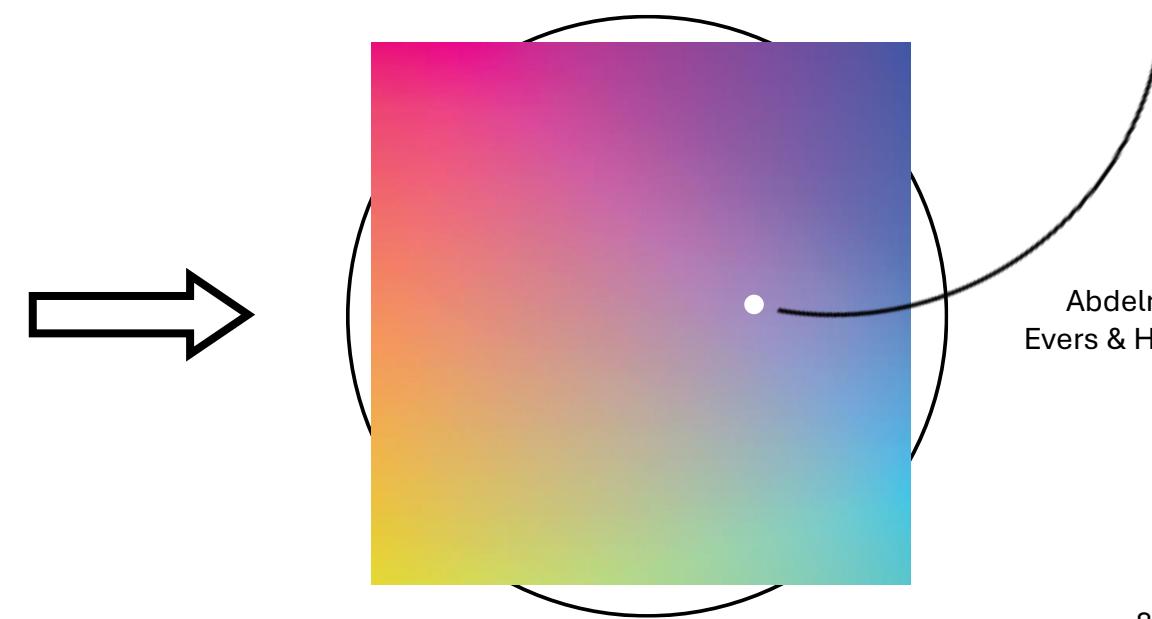
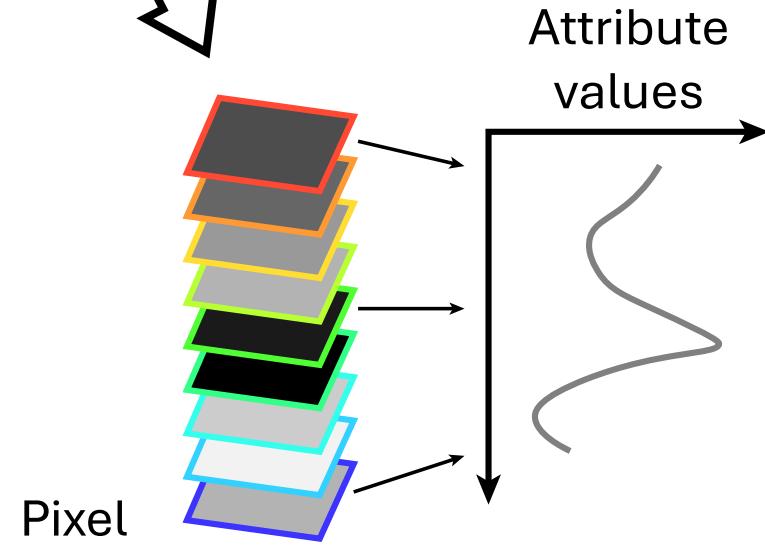
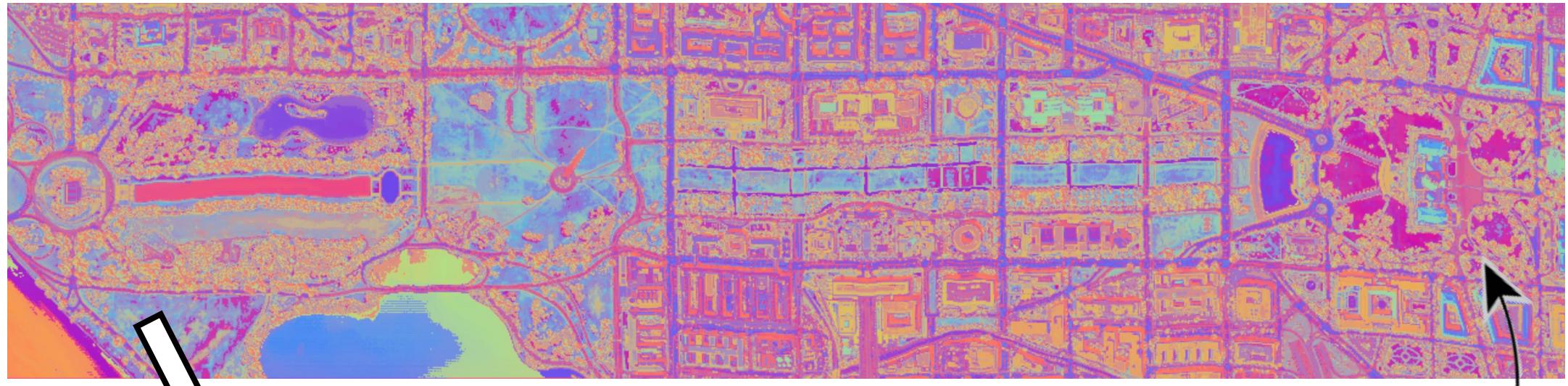
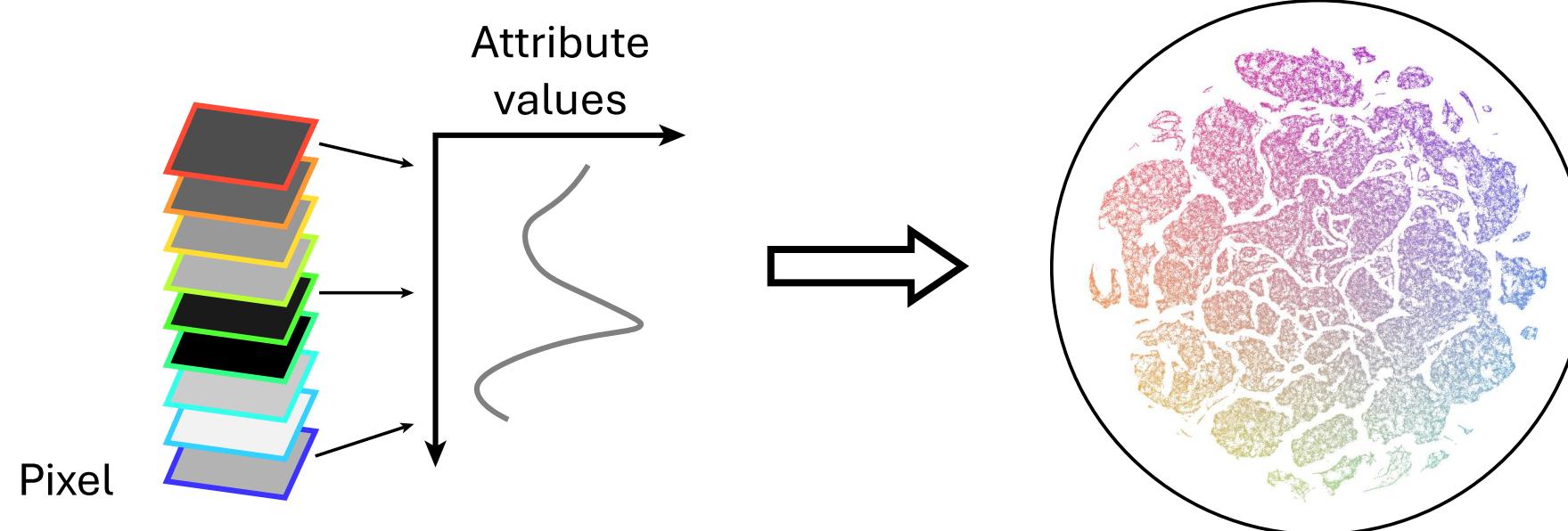
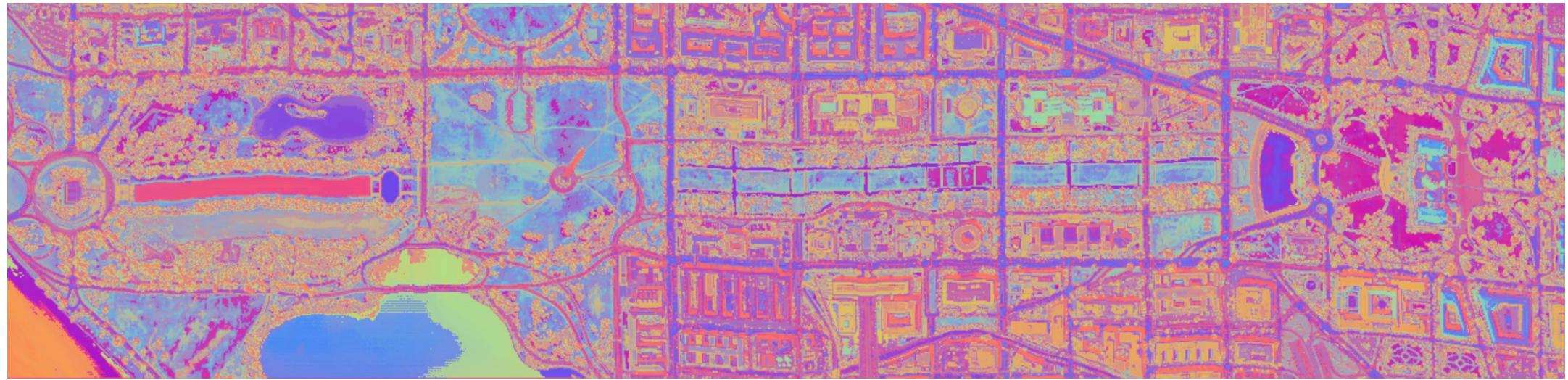
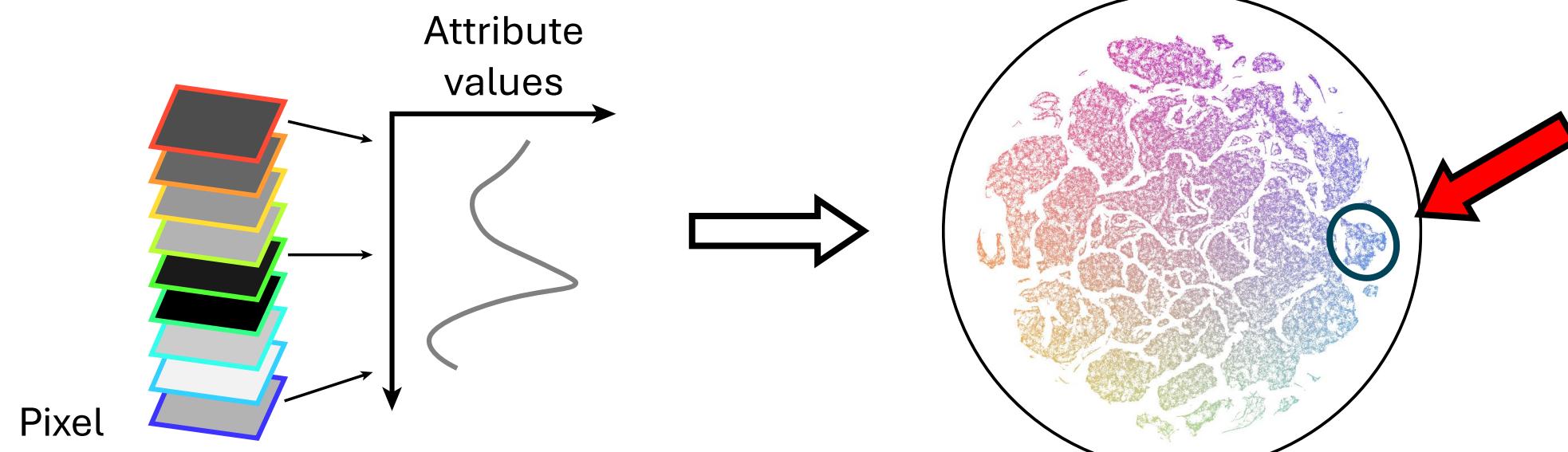
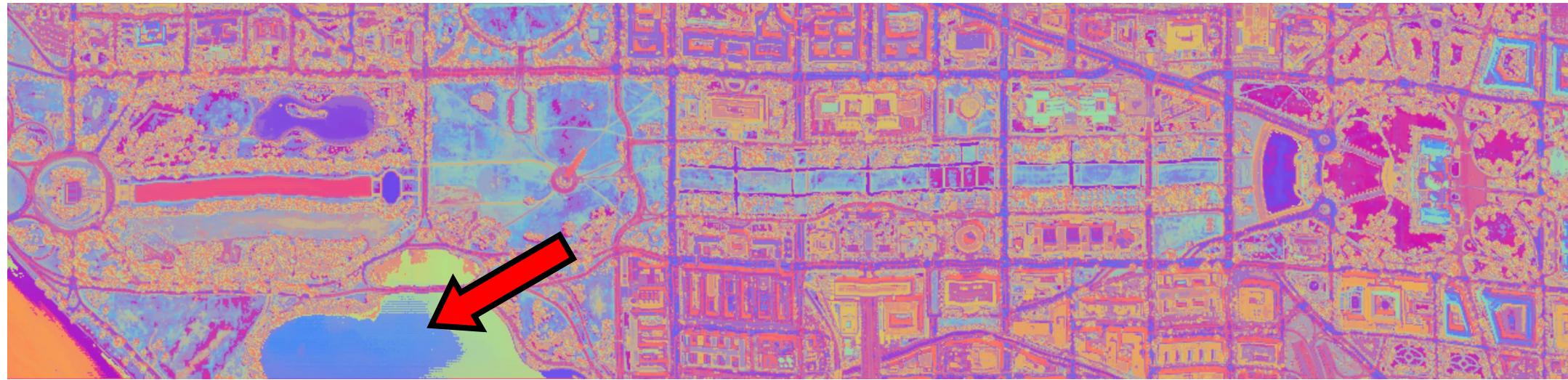


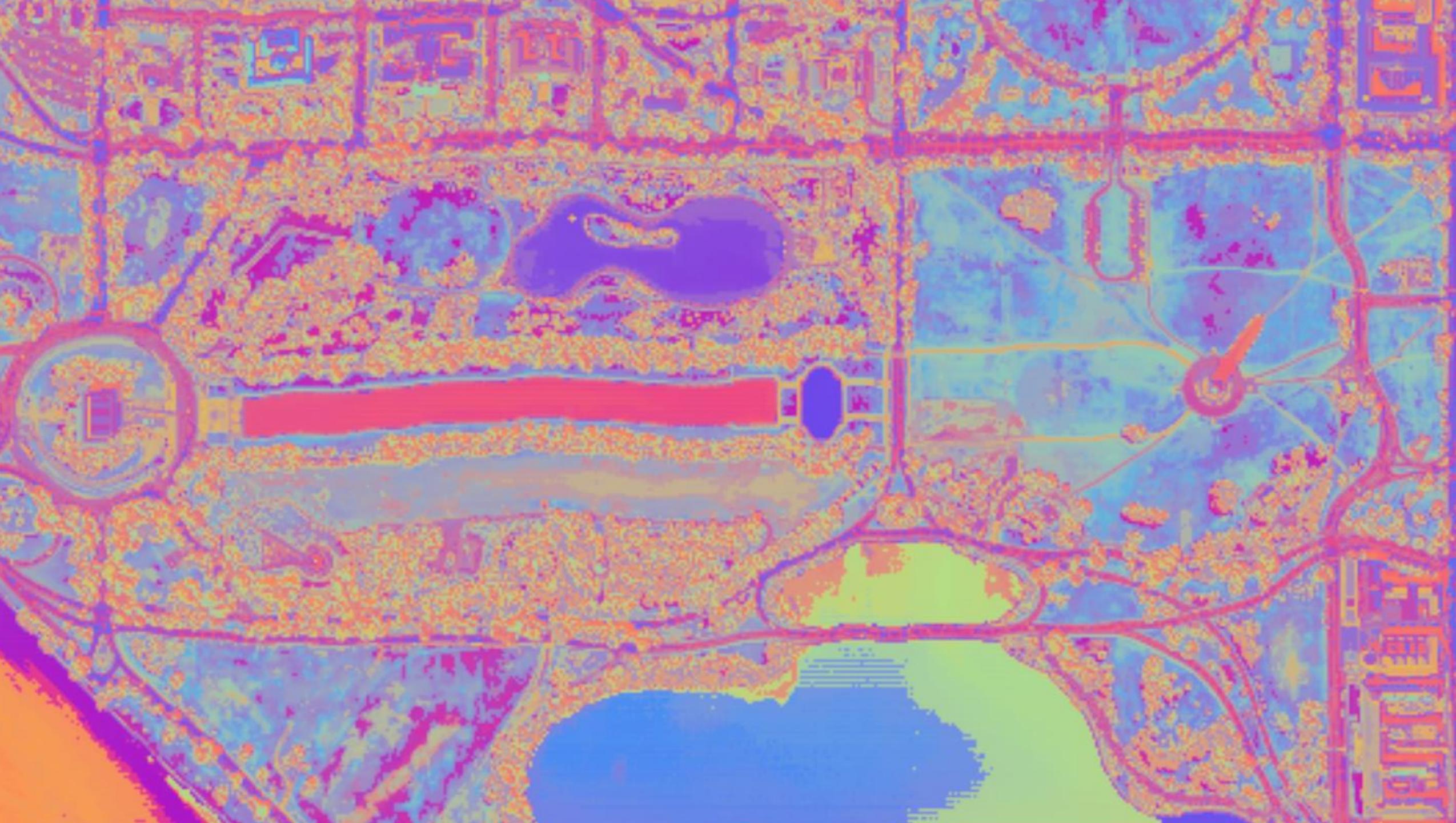
Image exploration



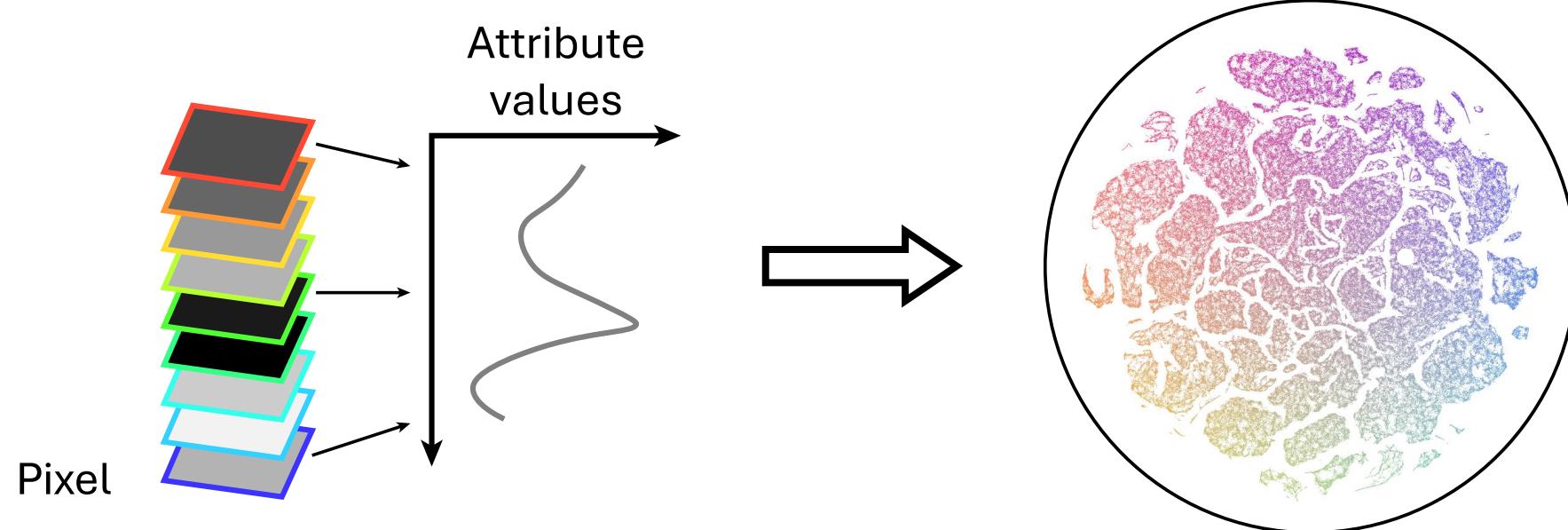
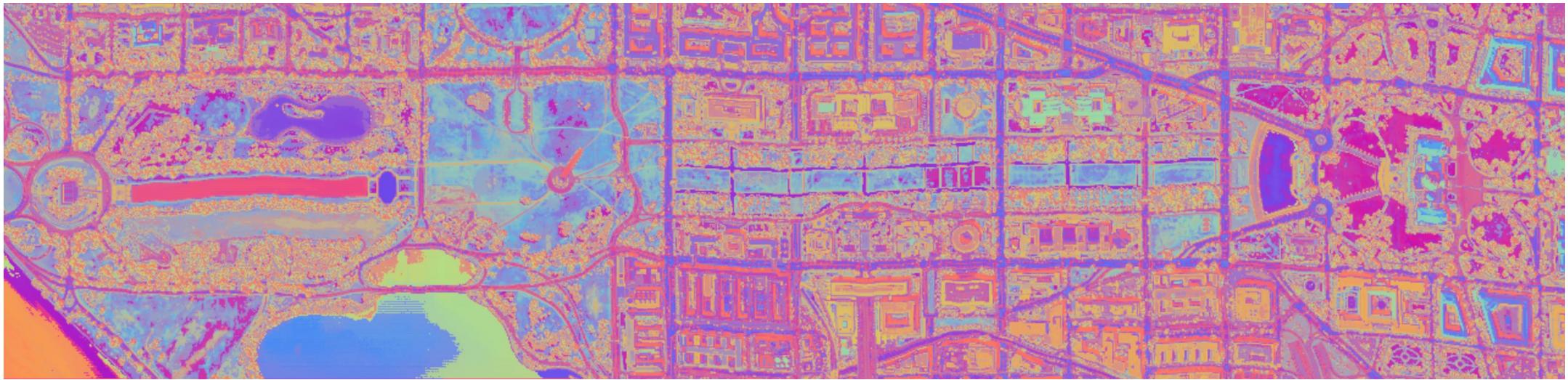
Abdelmoula (2016),
Evers & Huesmann (2021)

Image exploration



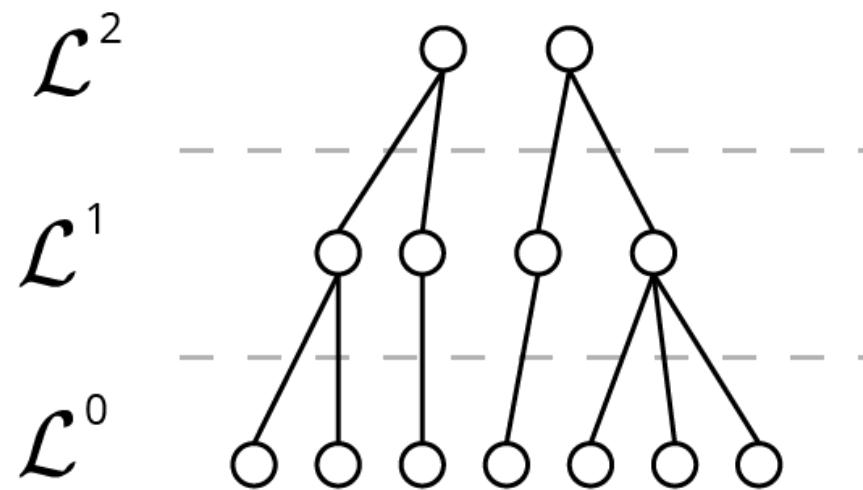


High-dimensional image exploration?



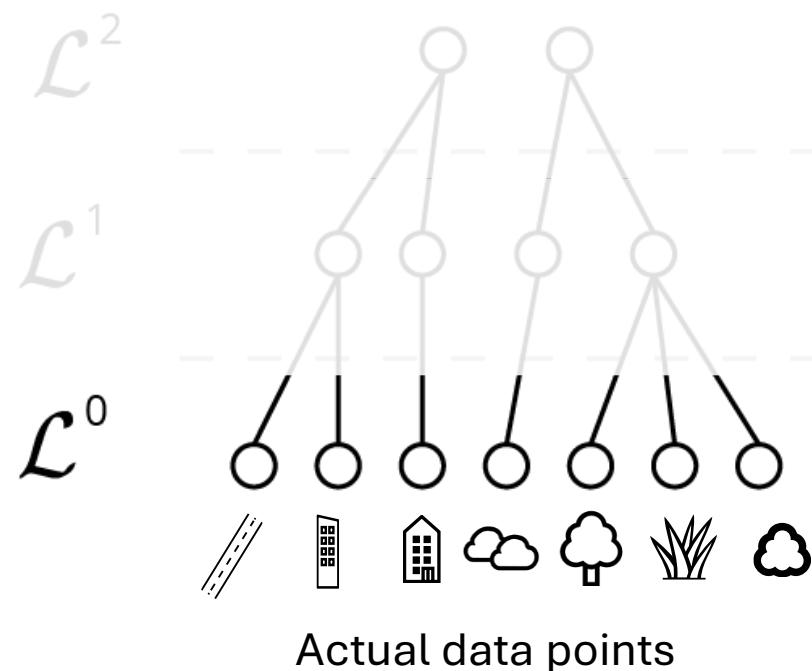
Hierarchical embeddings

Data Hierarchy



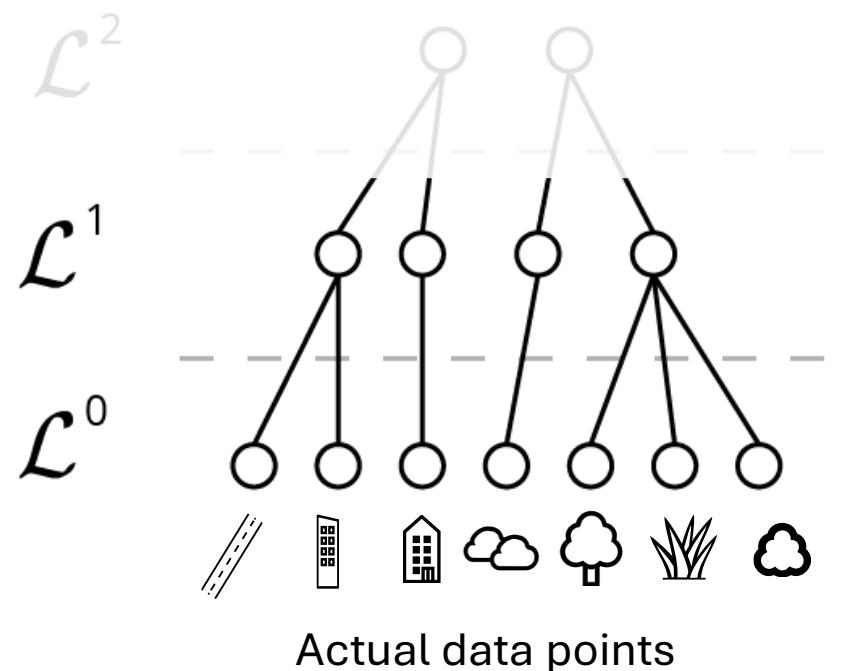
Hierarchical embeddings

Data Hierarchy



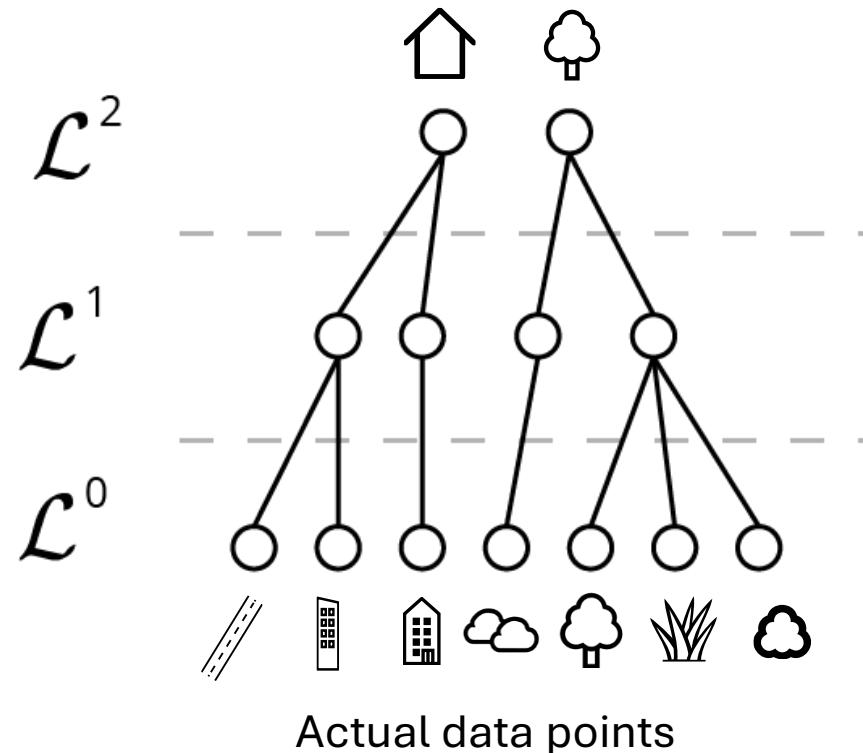
Hierarchical embeddings

Data Hierarchy



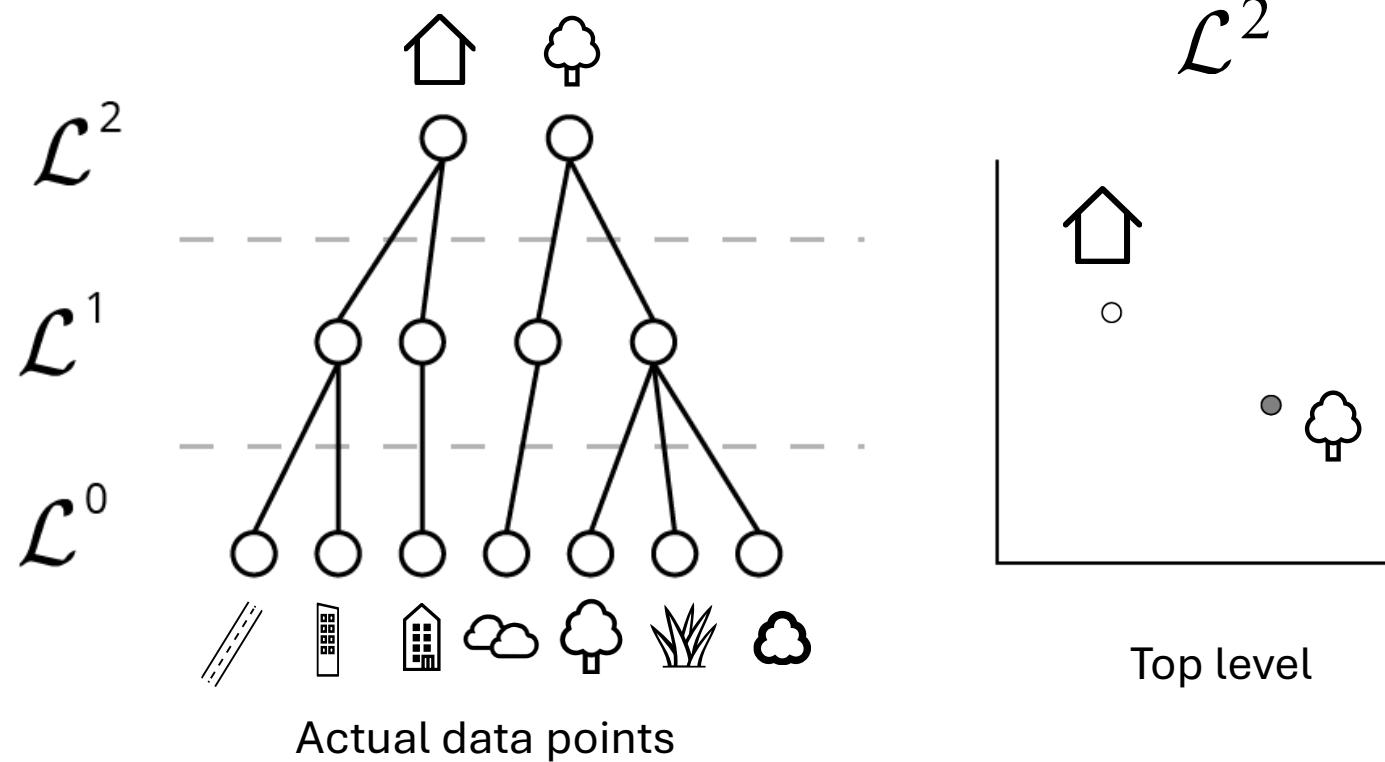
Hierarchical embeddings

Data Hierarchy



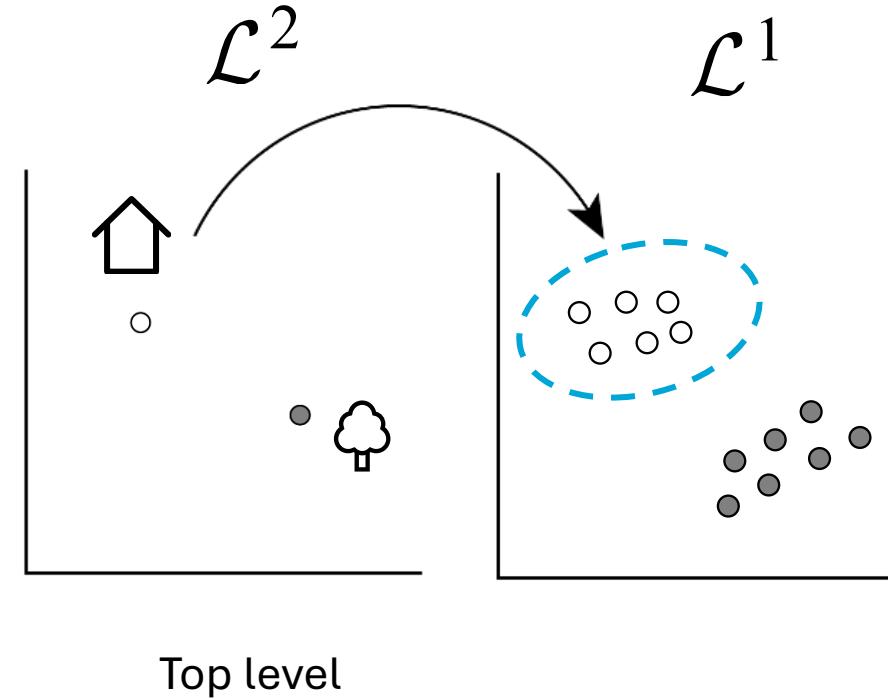
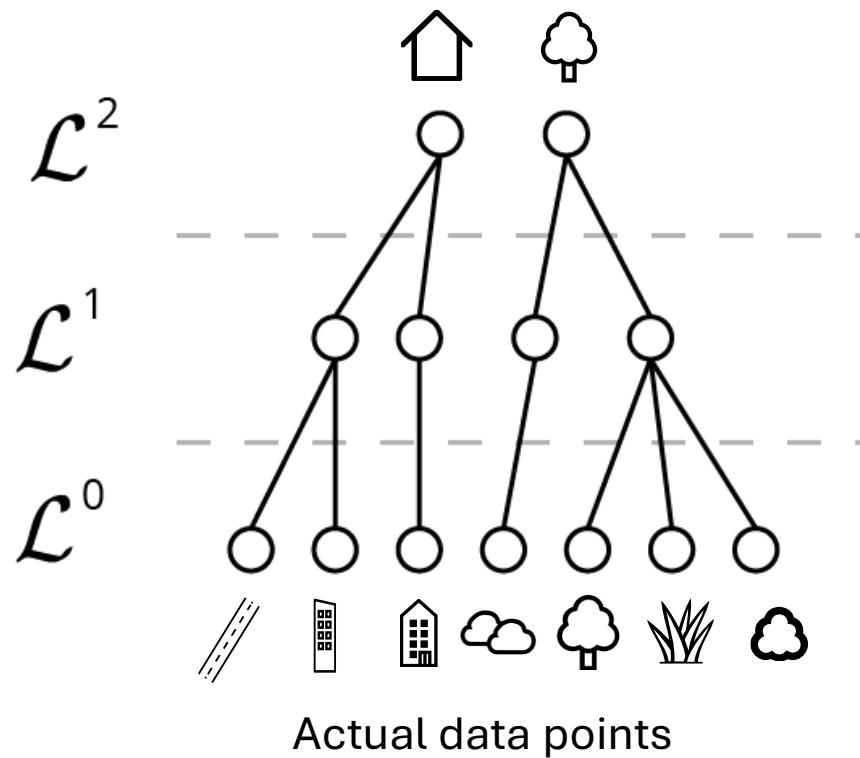
Hierarchical embeddings

Data Hierarchy



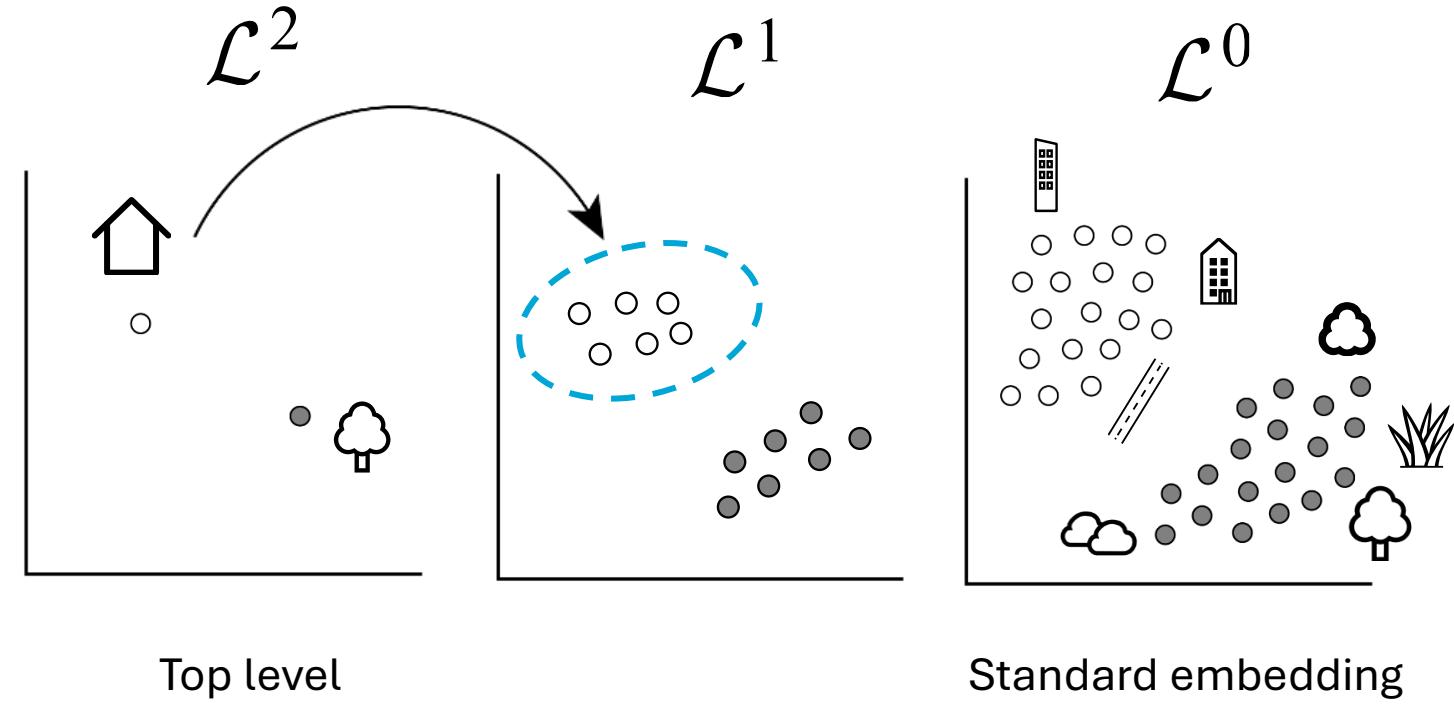
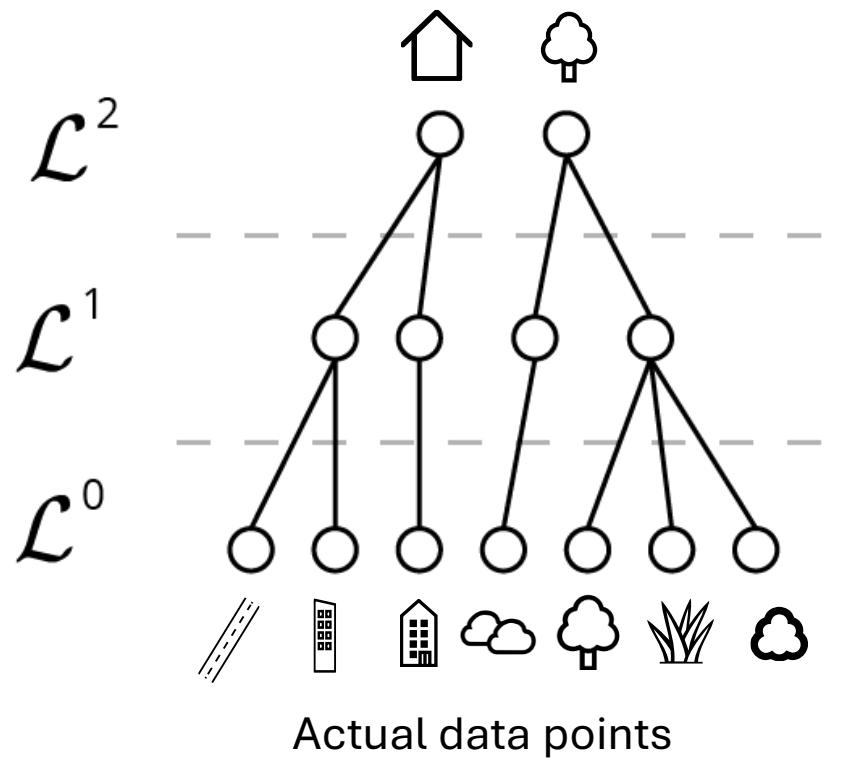
Hierarchical embeddings

Data Hierarchy

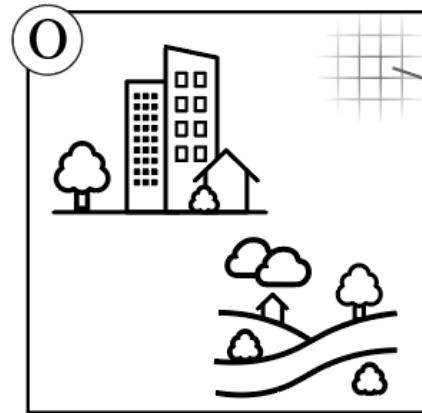


Hierarchical embeddings

Data Hierarchy

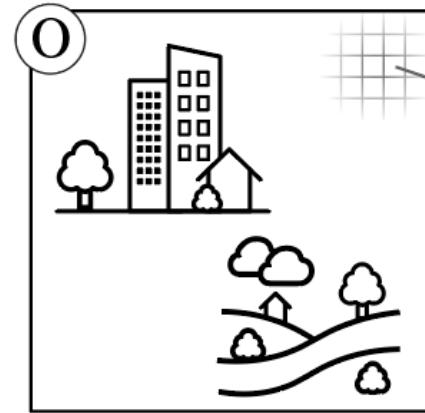


Goal: Coupled image-embedding exploration

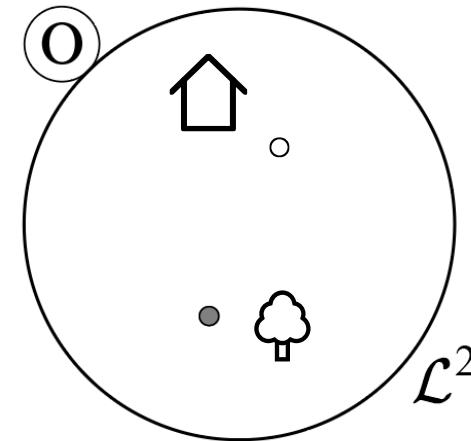


High-dimensional
attribute vector
per pixel

Goal: Coupled image-embedding exploration

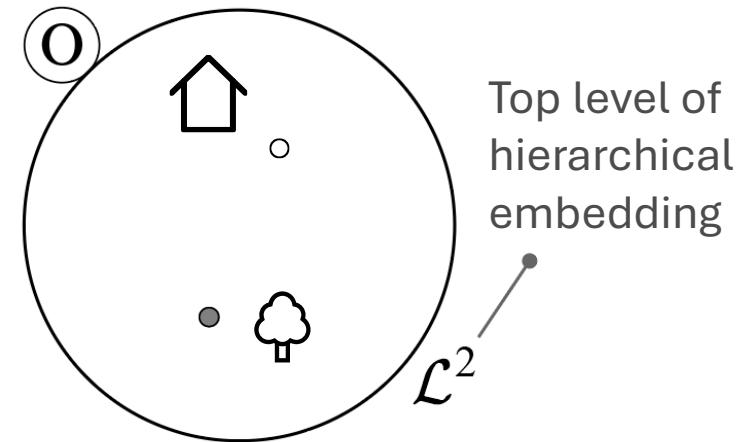
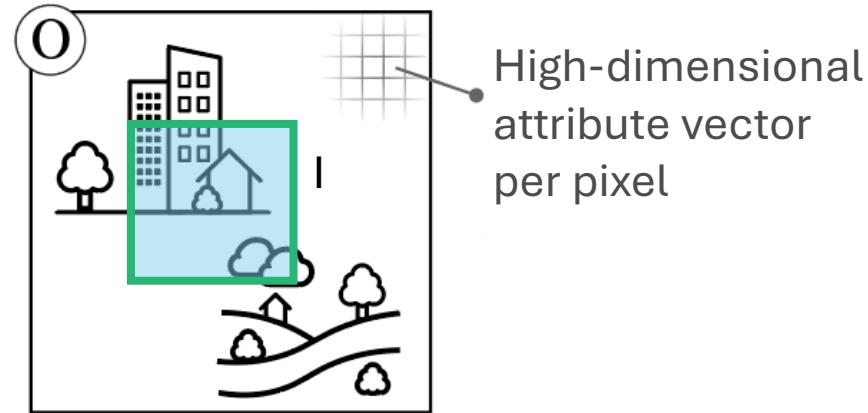


High-dimensional
attribute vector
per pixel

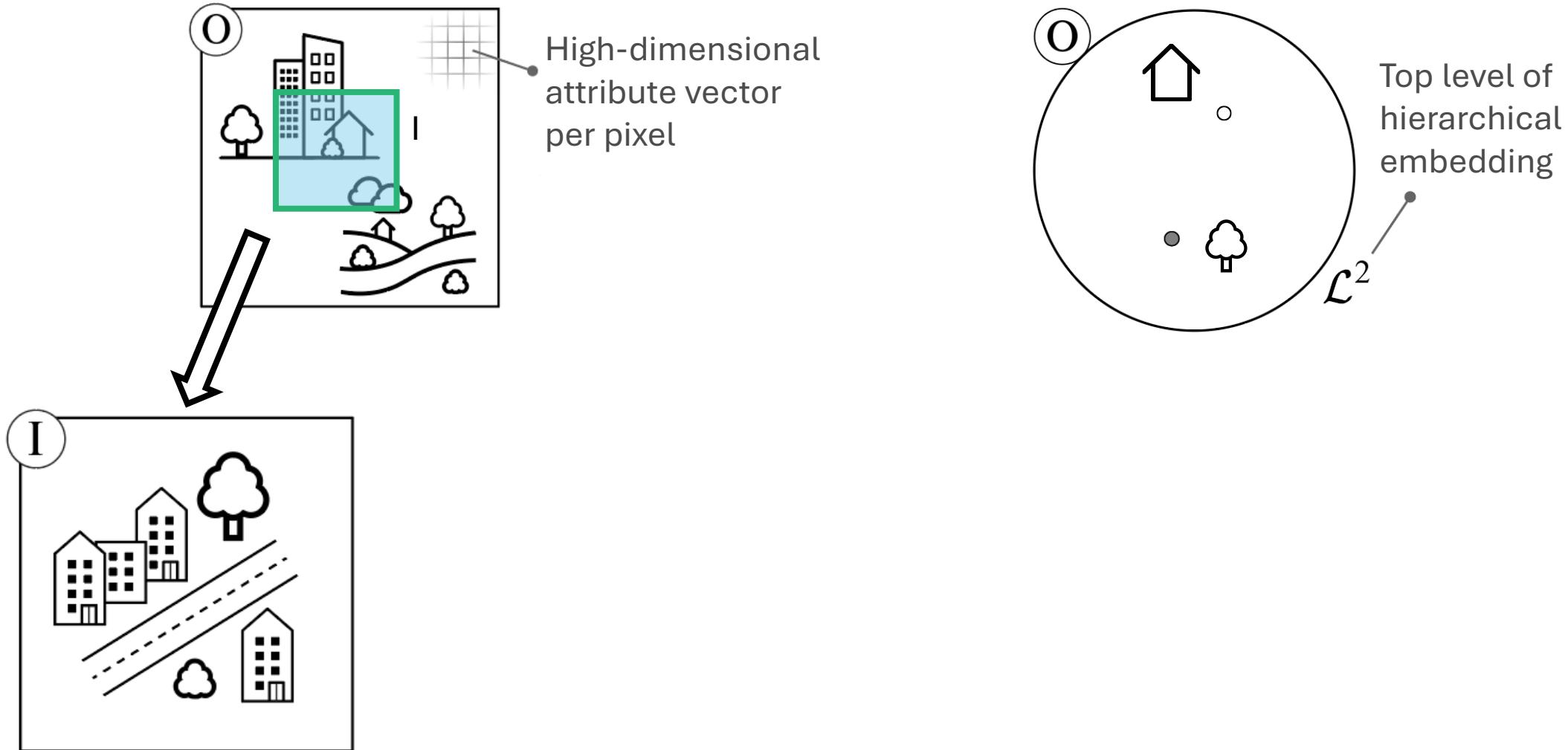


Top level of
hierarchical
embedding

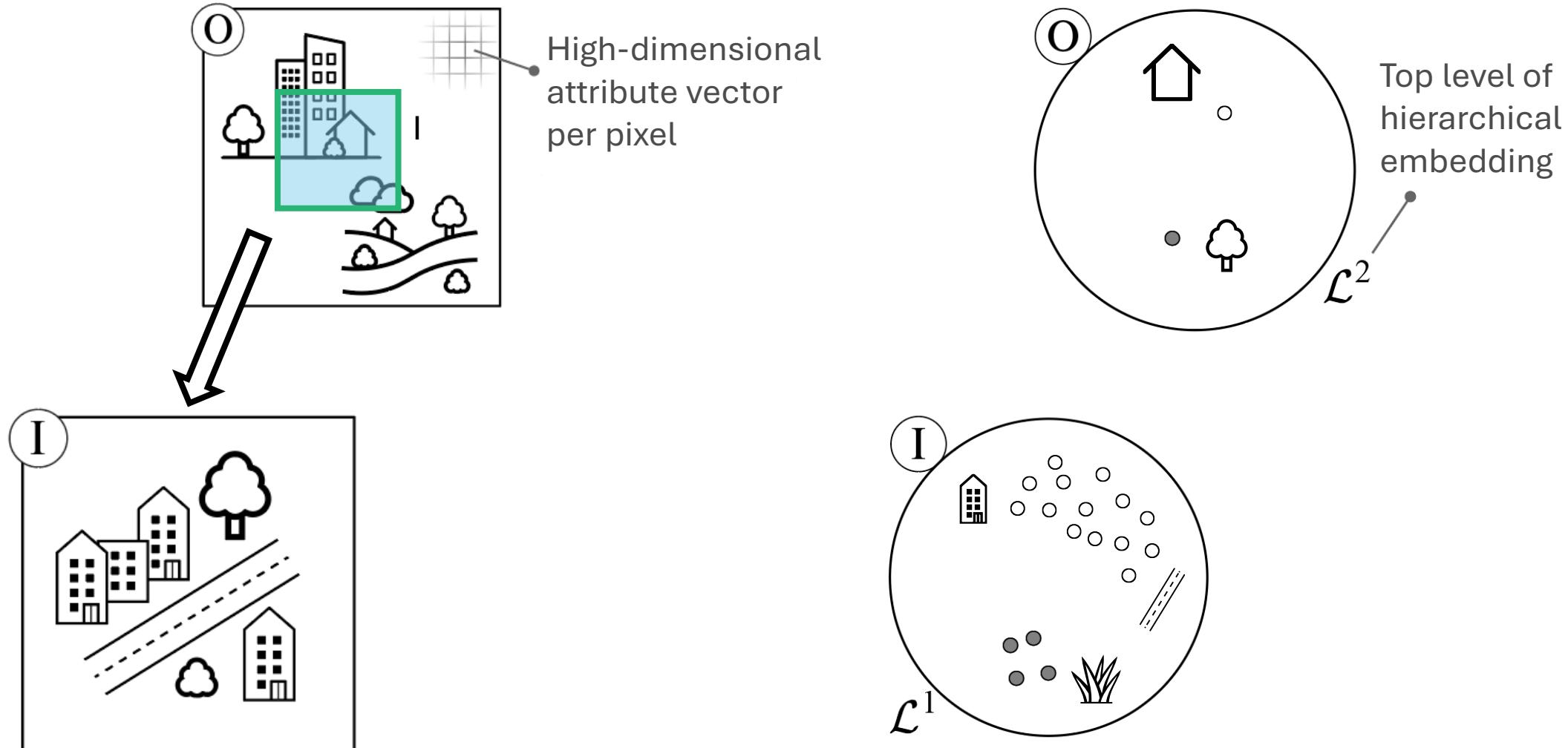
Goal: Coupled image-embedding exploration



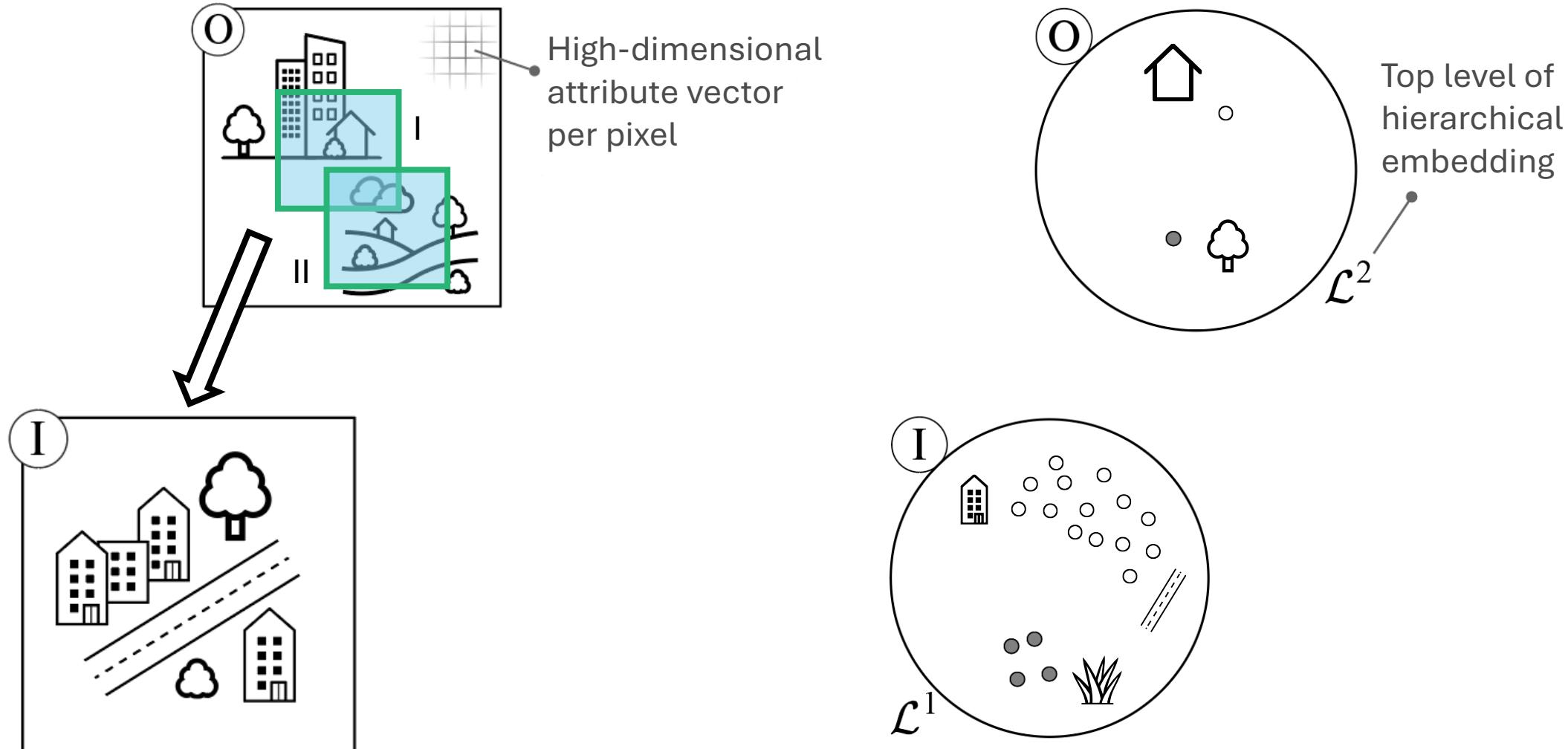
Goal: Coupled image-embedding exploration



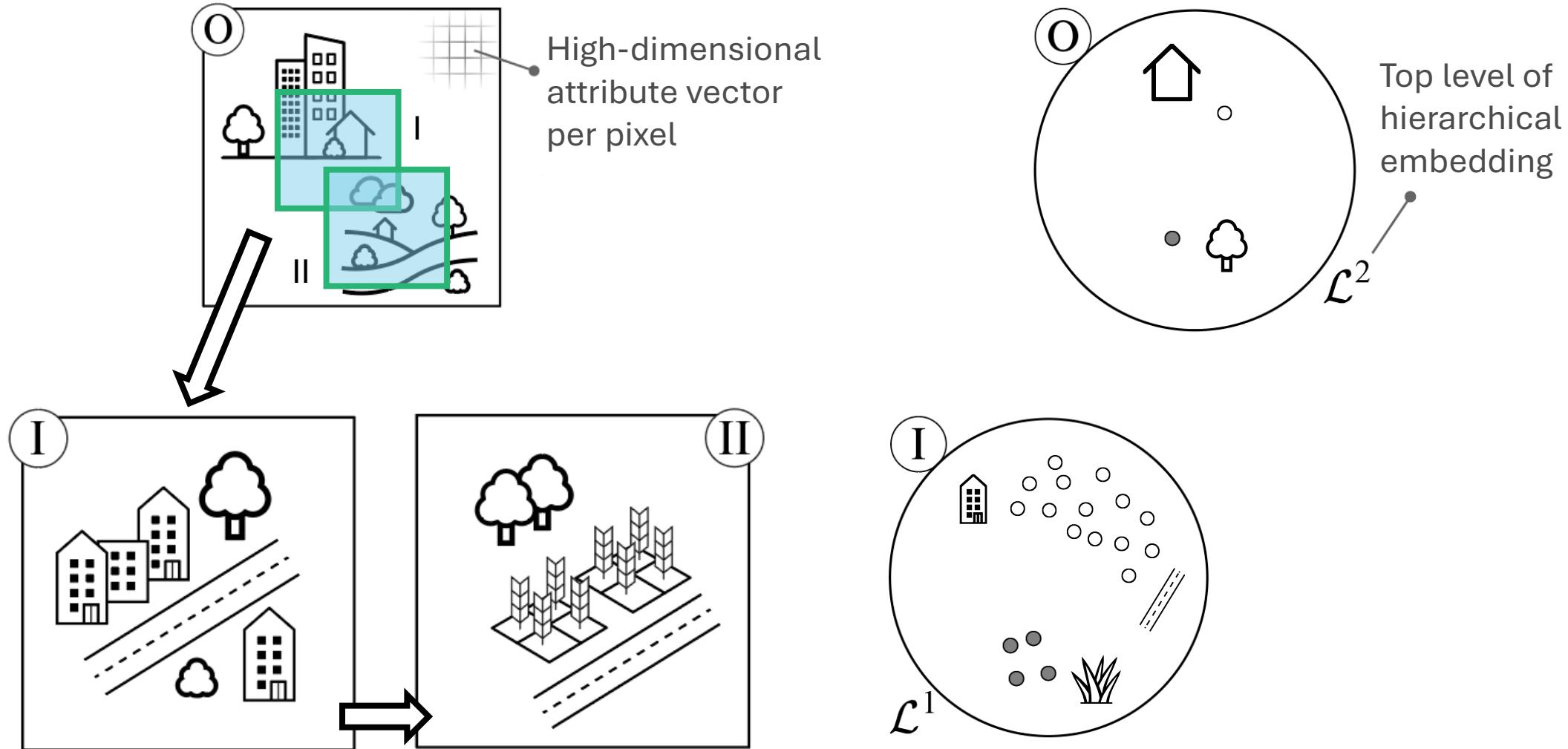
Goal: Coupled image-embedding exploration



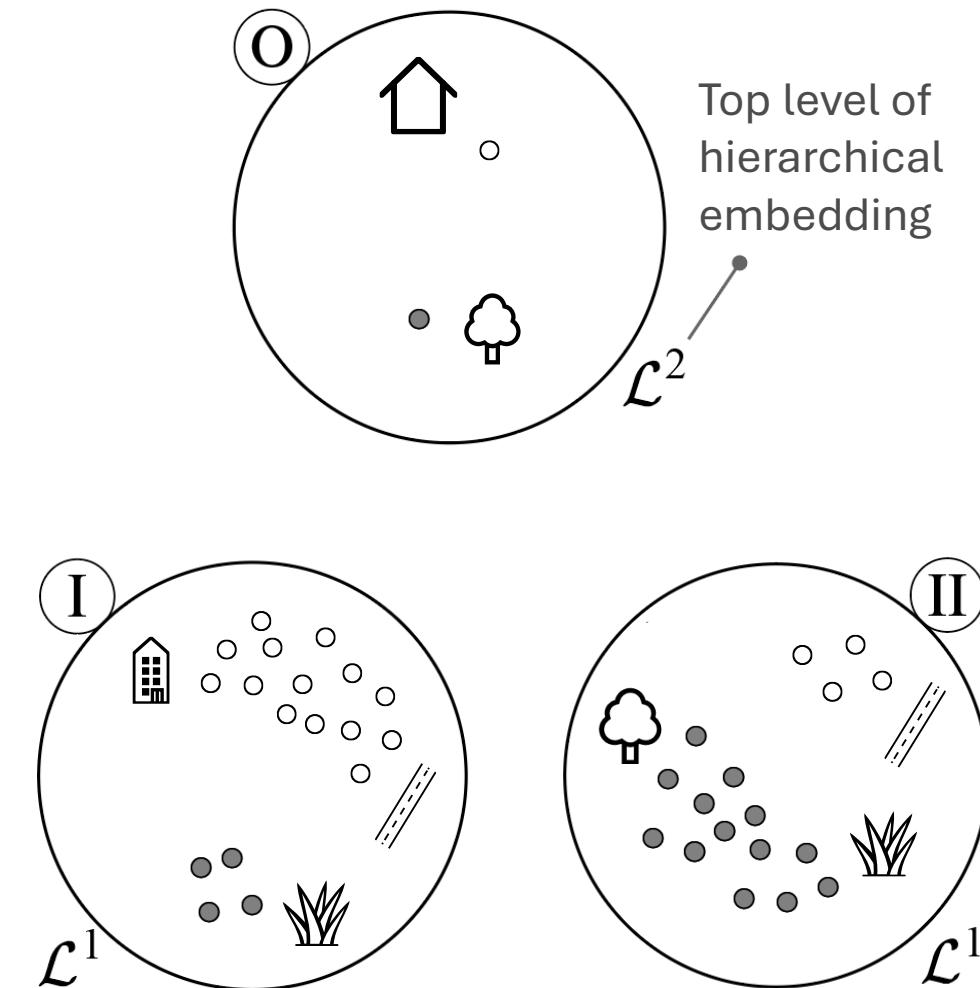
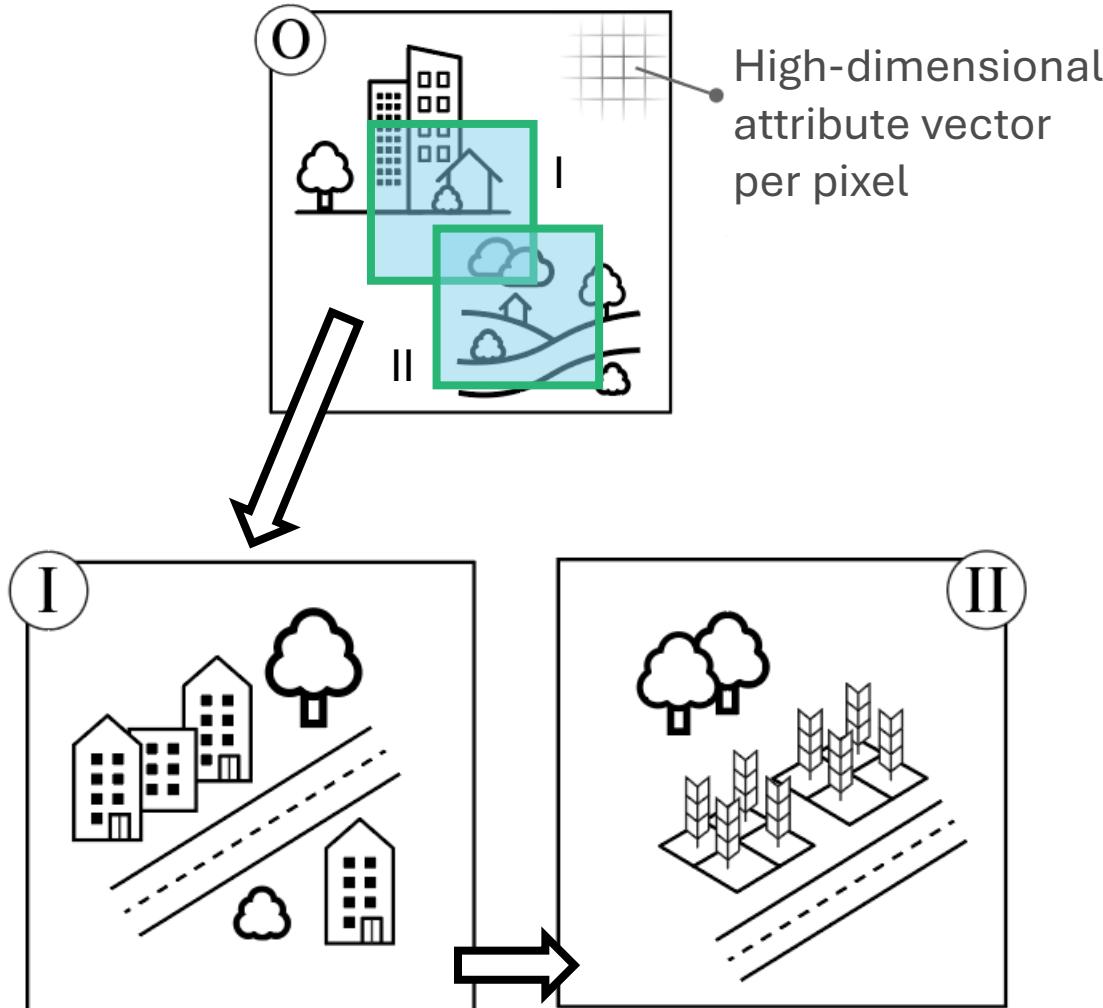
Goal: Coupled image-embedding exploration



Goal: Coupled image-embedding exploration



Goal: Coupled image-embedding exploration



Coupling image navigation & embedding hierarchy

Requirements

Coupling image navigation & embedding hierarchy

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R1 Follow the “overview first, details-on-demand” approach

Coupling image navigation & embedding hierarchy

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- R1** Follow the “overview first, details-on-demand” approach
- R2** Represent the ROI

Coupling image navigation & embedding hierarchy

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Coupling image navigation & embedding hierarchy

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- R3** Provide stable transitions between embeddings
- R4** Update at interactive exploration speeds

Coupling image navigation & embedding hierarchy

Requirements

R1 Follow the “overview first, details-on-demand” approach

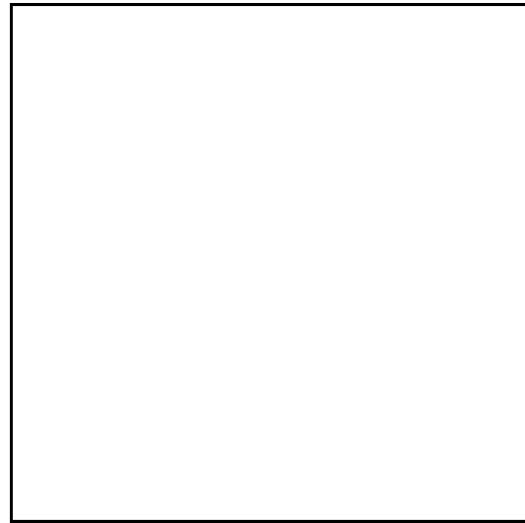
R2 Represent the ROI

R3 Provide stable transitions between embeddings

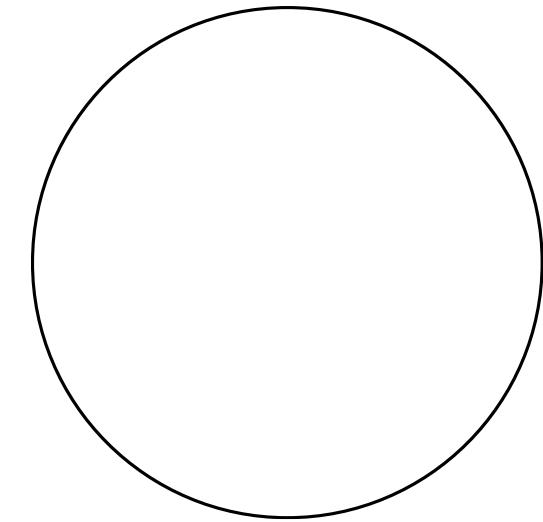
R4 Update at interactive exploration speeds

R5 Link selections between image and embedding space

Interactions coupling



Image

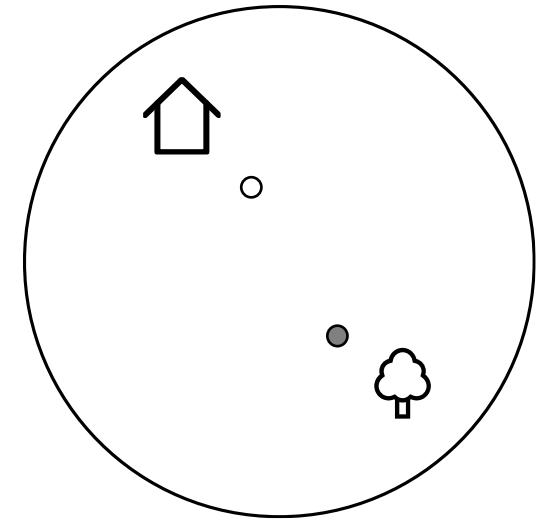


Embedding

Interactions coupling



Image

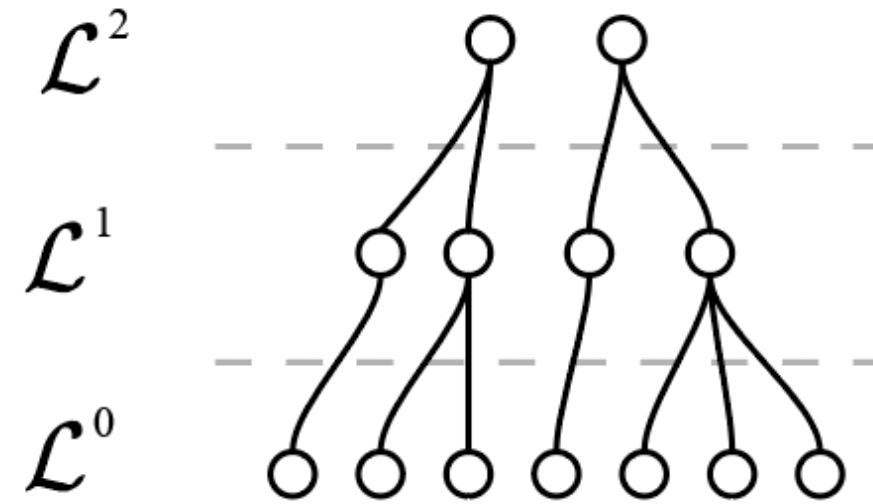


Embedding

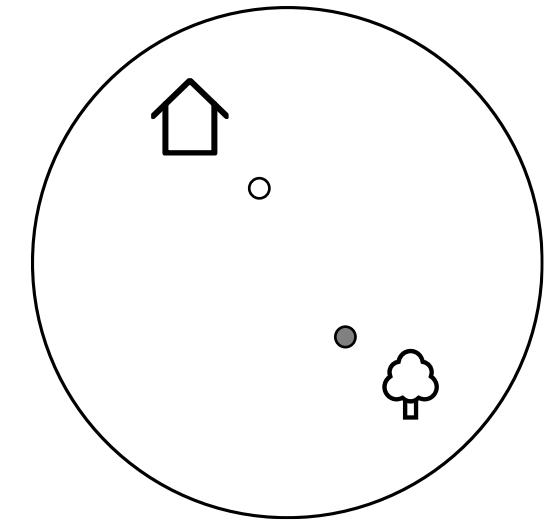
Interactions coupling



Image



Data hierarchy

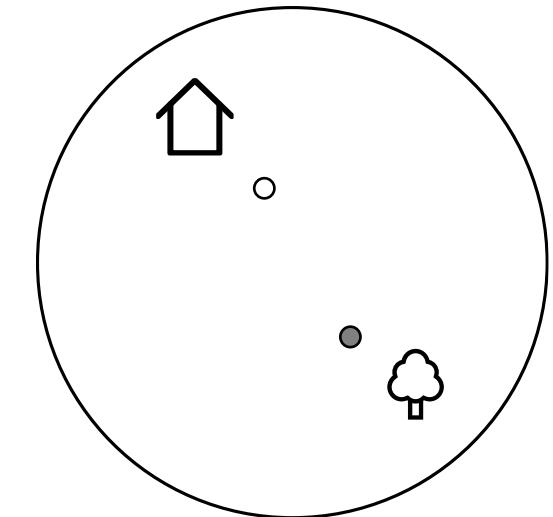
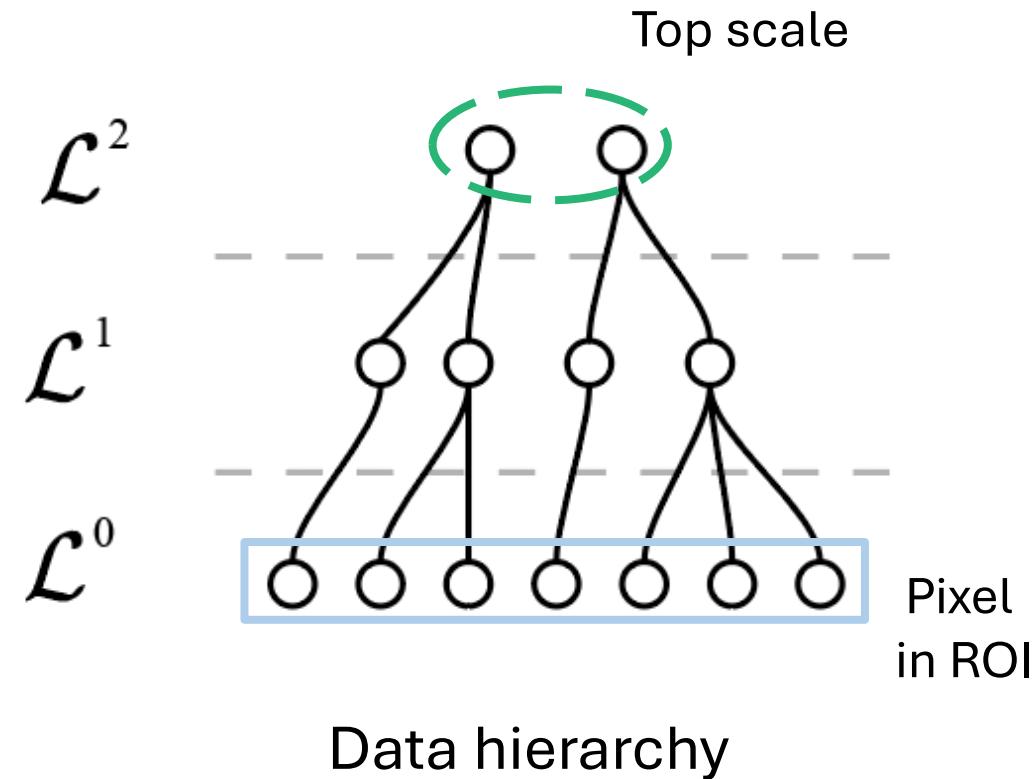


Embedding

Interactions coupling

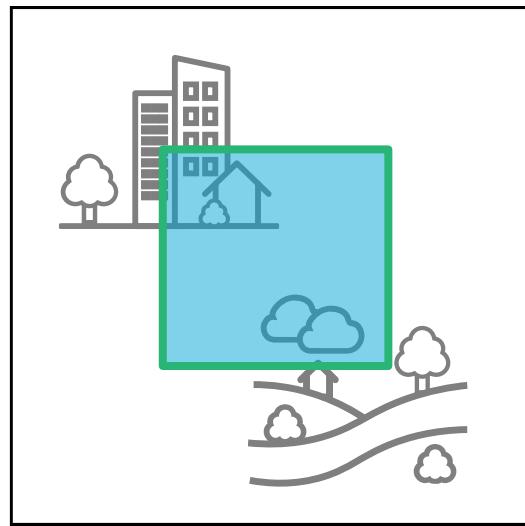


Image

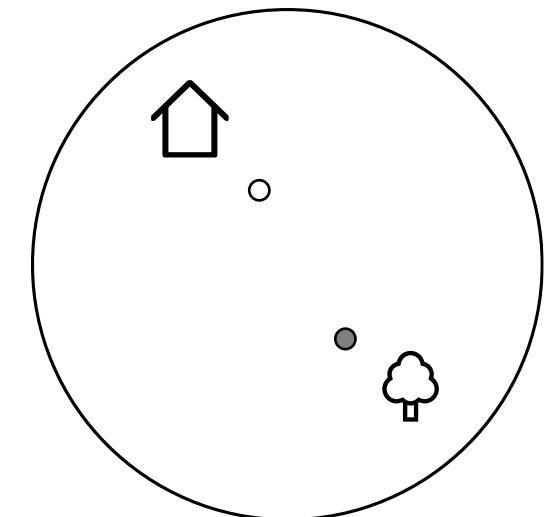
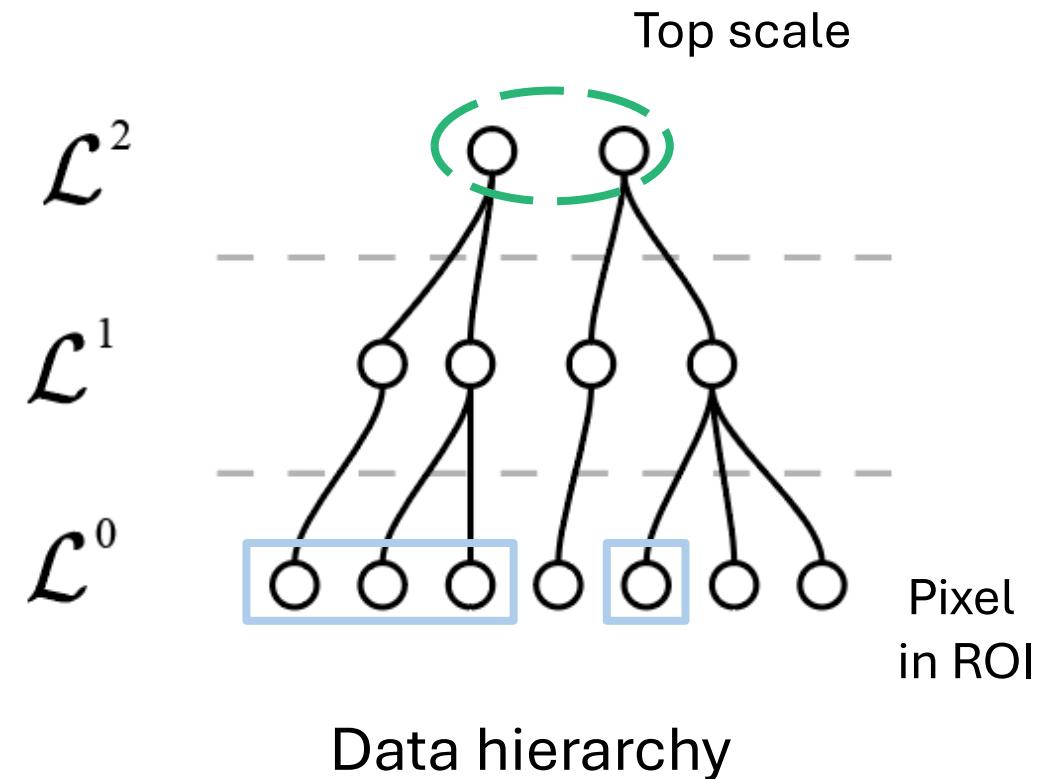


Embedding

Interactions coupling



Image

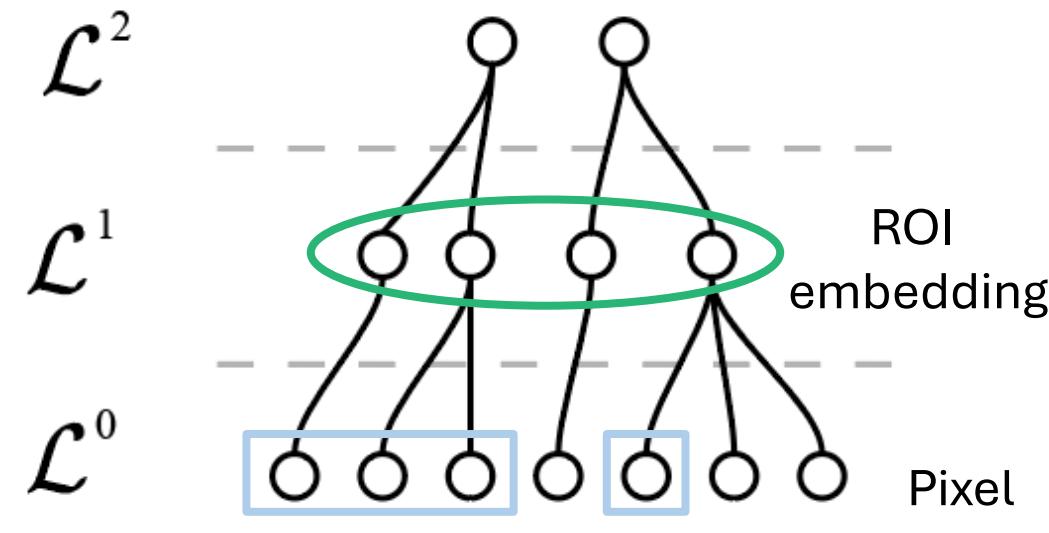


Embedding

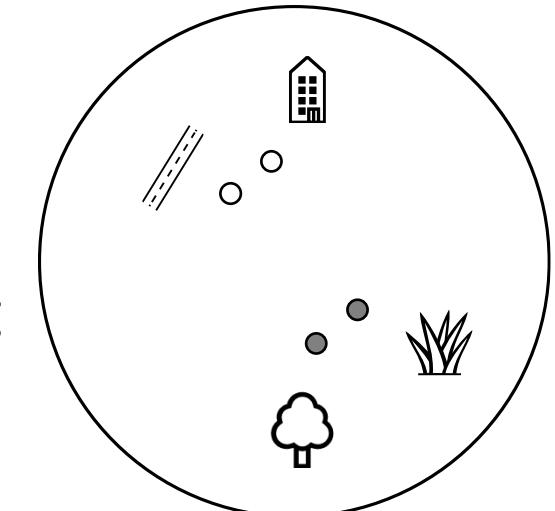
Interactions coupling



Image

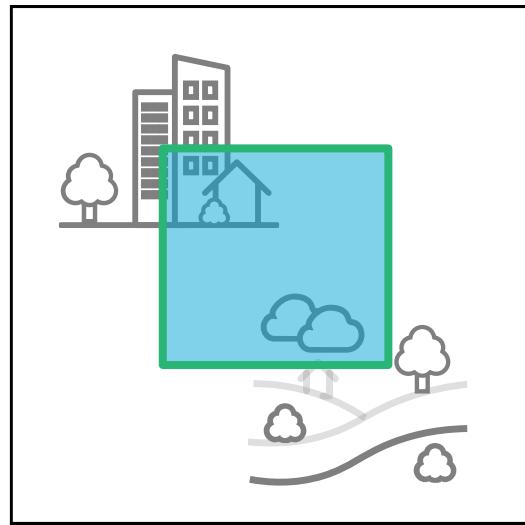


Data hierarchy

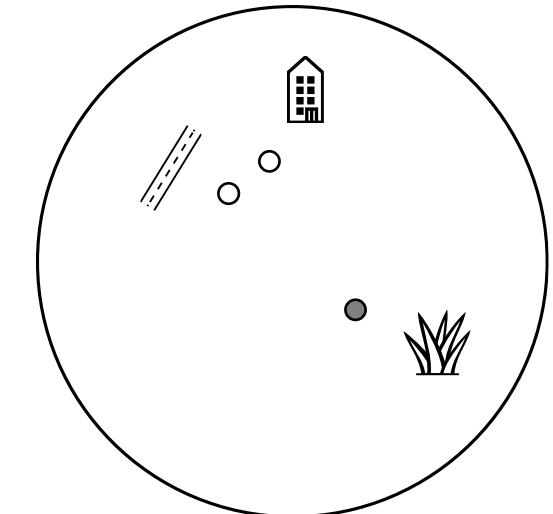
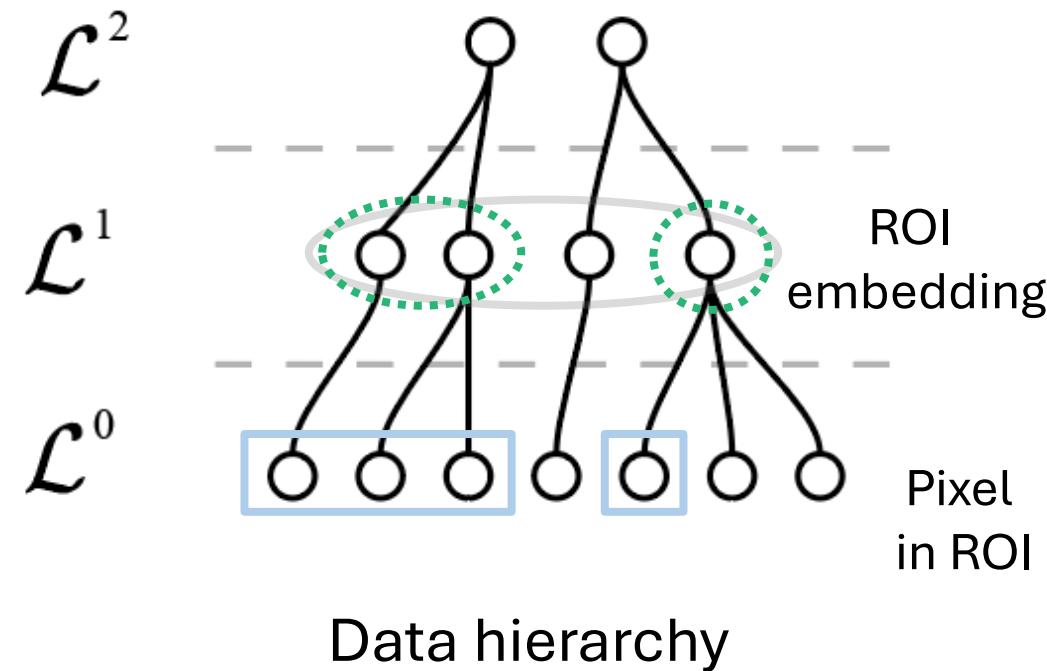


Embedding

Interactions coupling

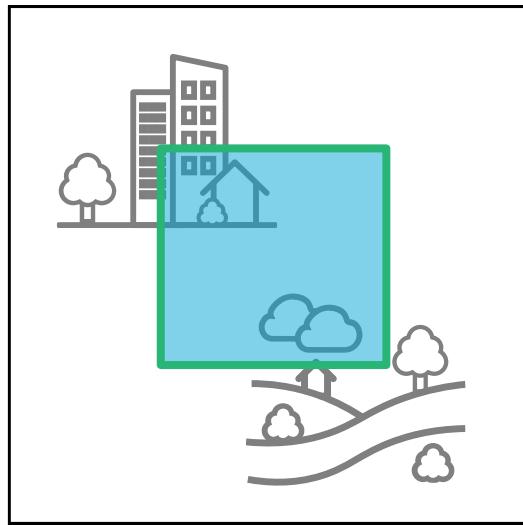


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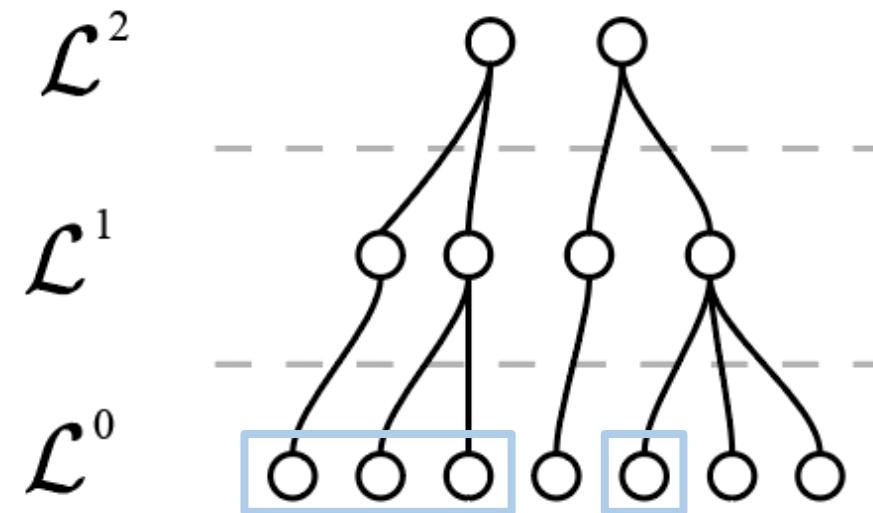


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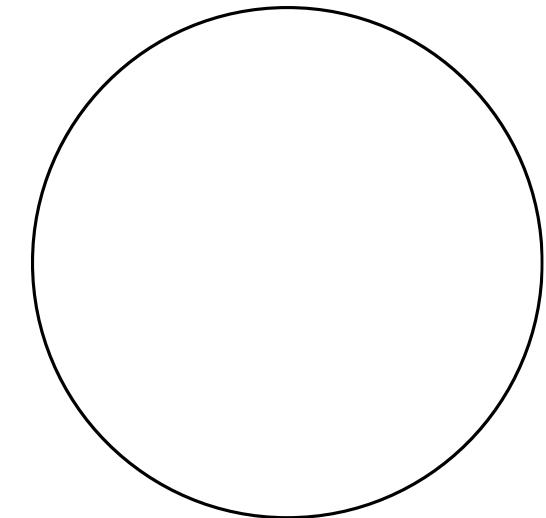
Interactions coupling: Top-down



Image

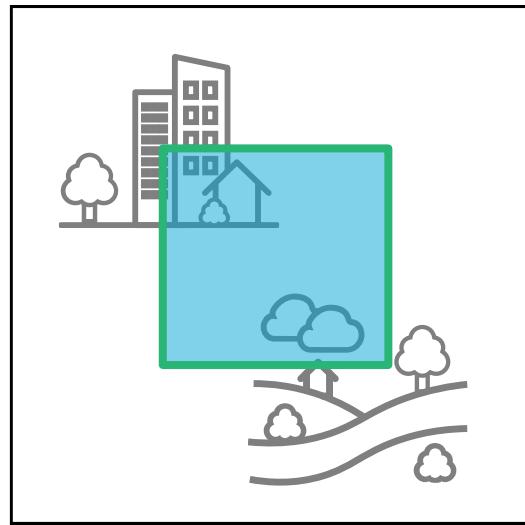


Data hierarchy

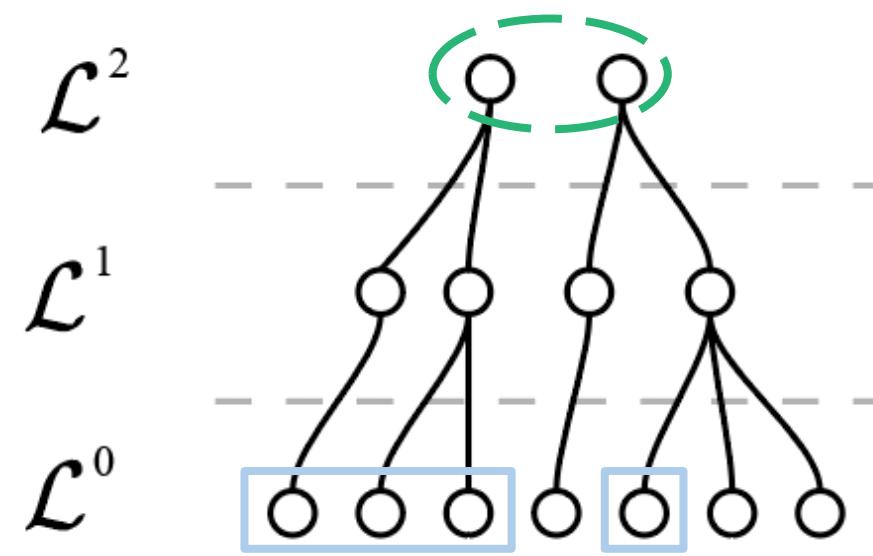


Embedding

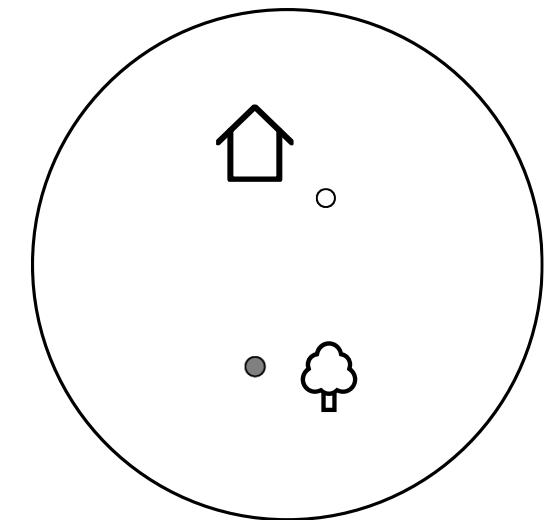
Interactions coupling: Top-down



Image

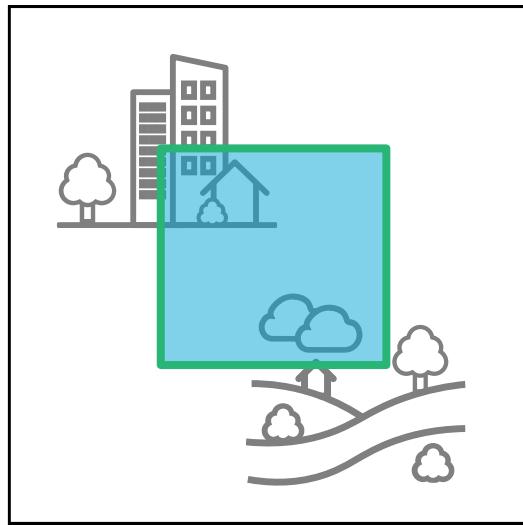


Data hierarchy

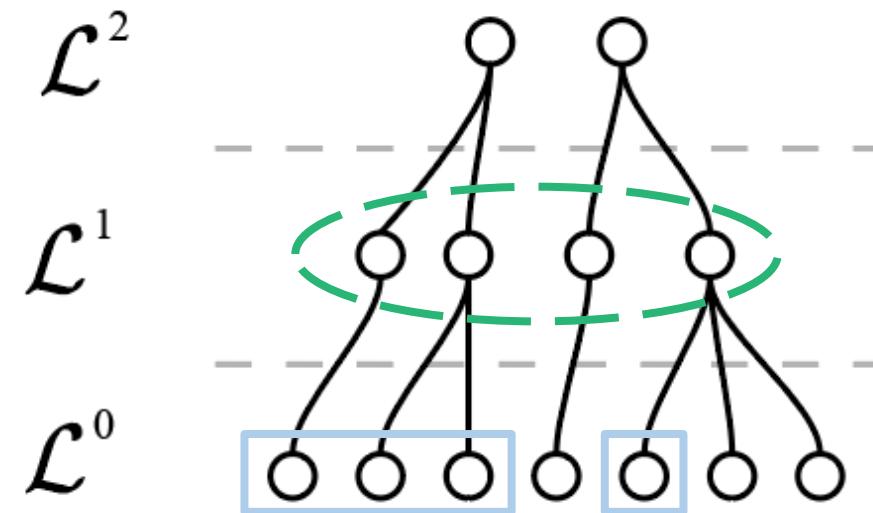


Embedding

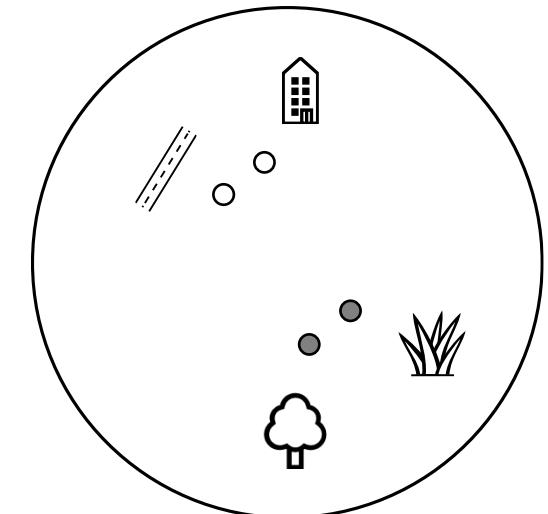
Interactions coupling: Top-down



Image



Data hierarchy

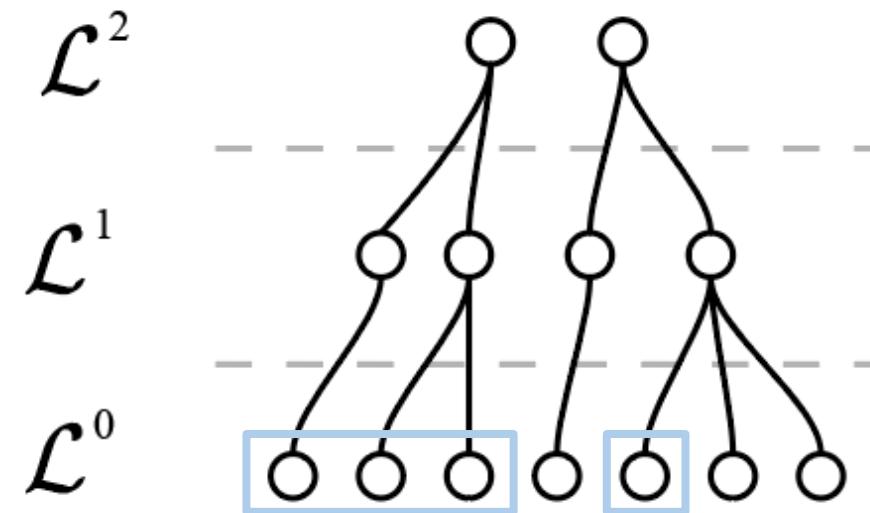


Embedding

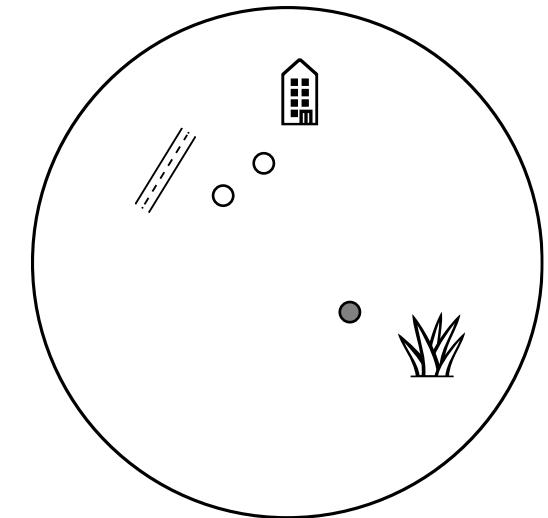
Interactions coupling: Bottom-up



Image

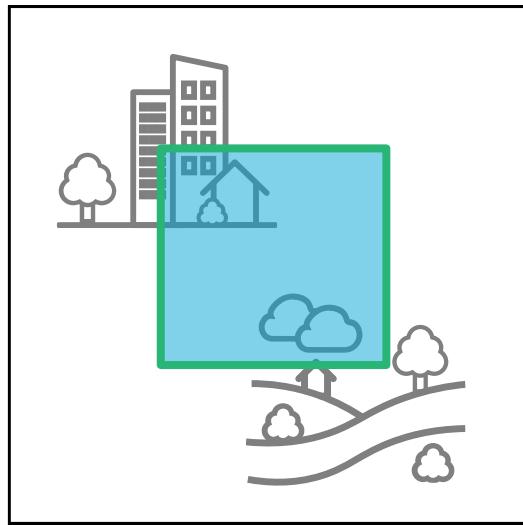


Data hierarchy

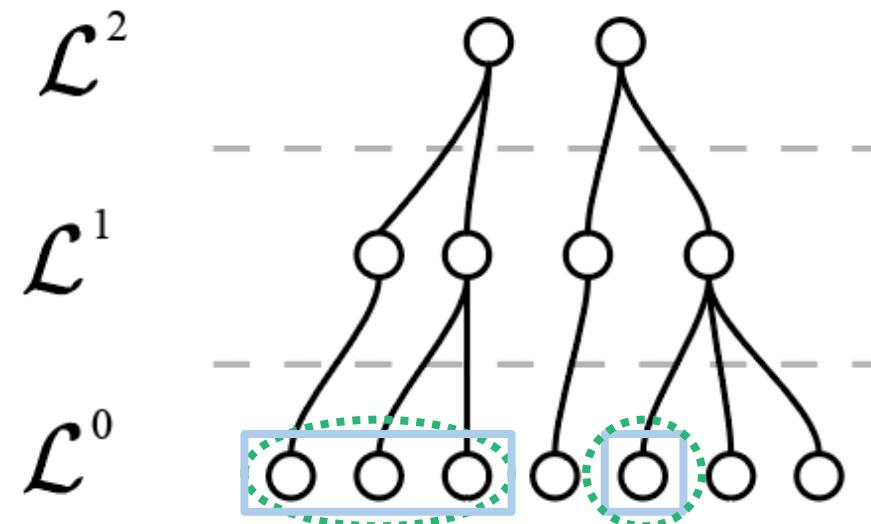


Embedding

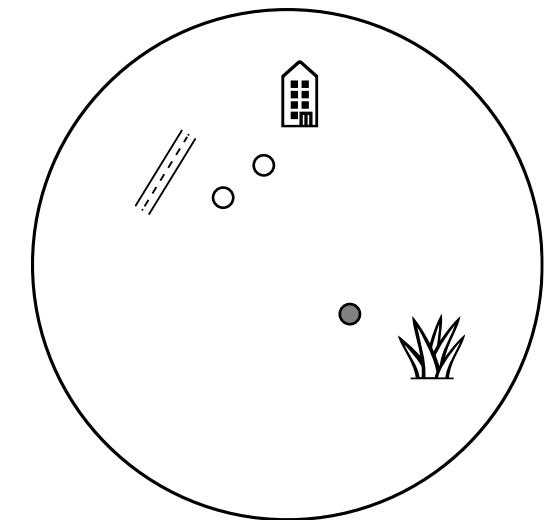
Interactions coupling: Bottom-up



Image

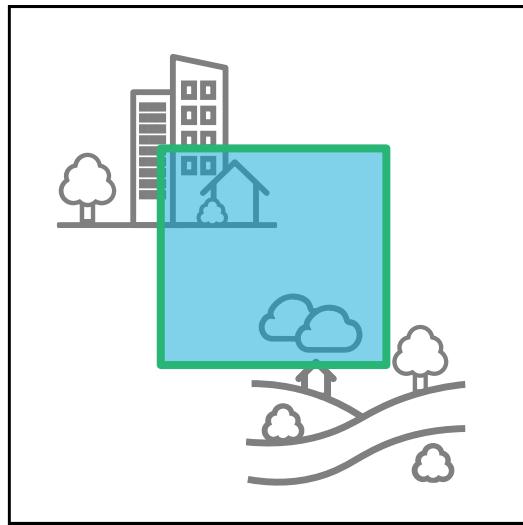


Data hierarchy

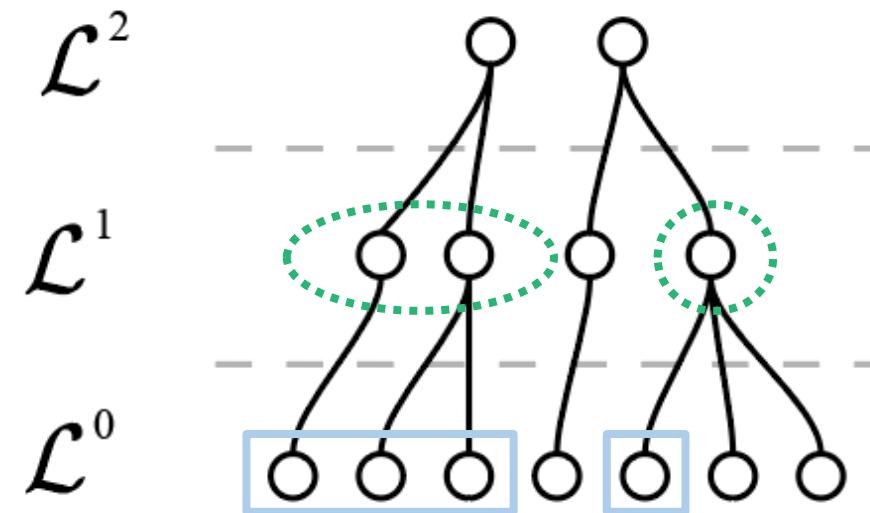


Embedding

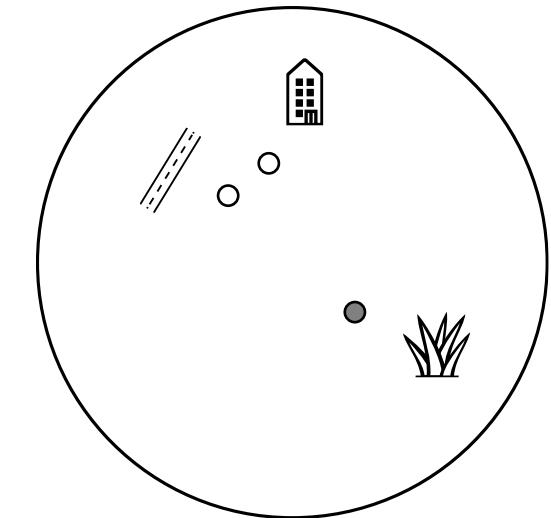
Interactions coupling: Bottom-up



Image

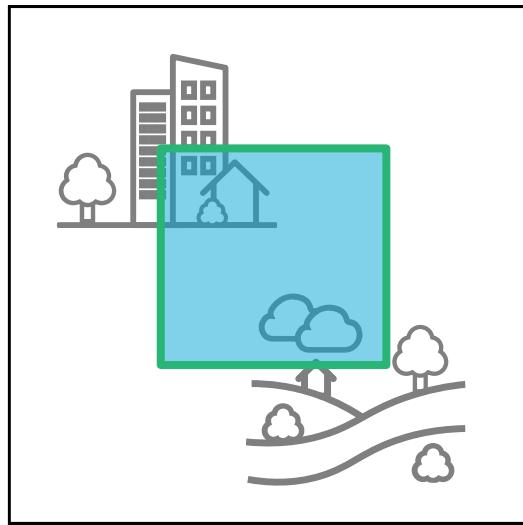


Data hierarchy

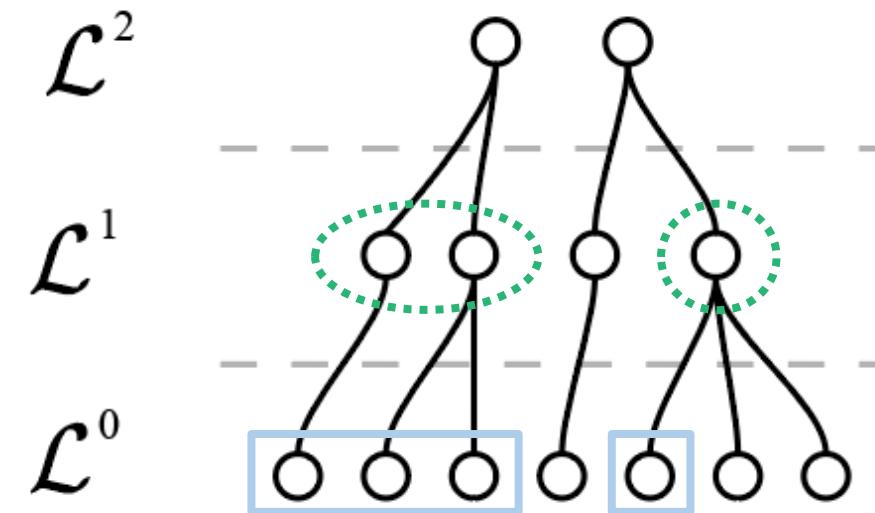


Embedding

Zoom-factor coupling



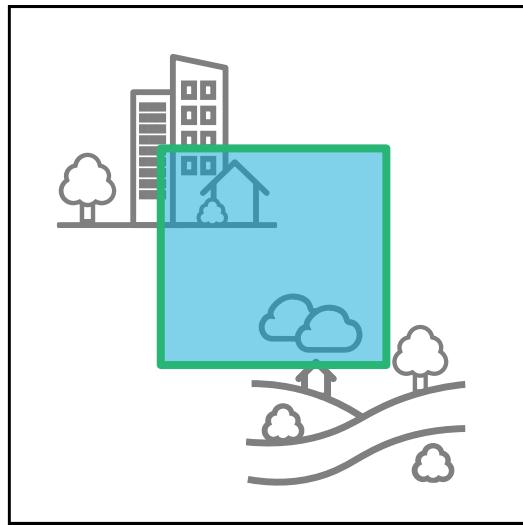
Image



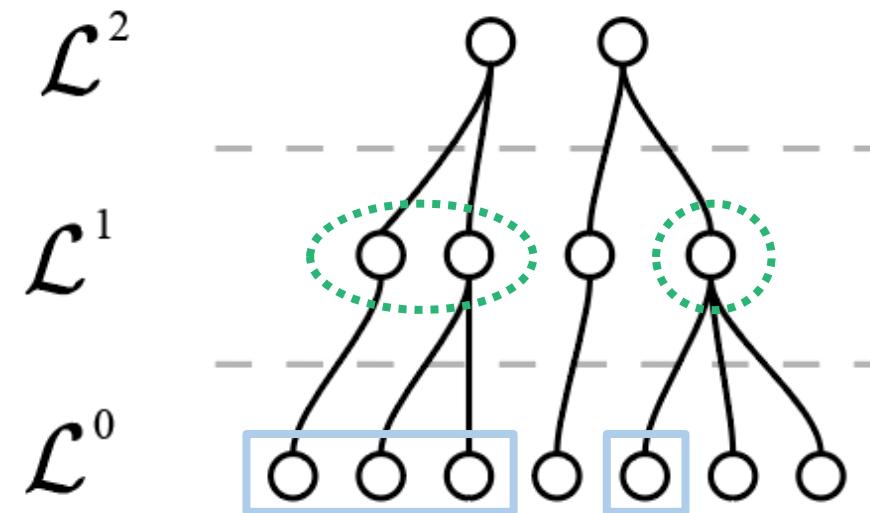
Data hierarchy

Which level?

Zoom-factor coupling



Image



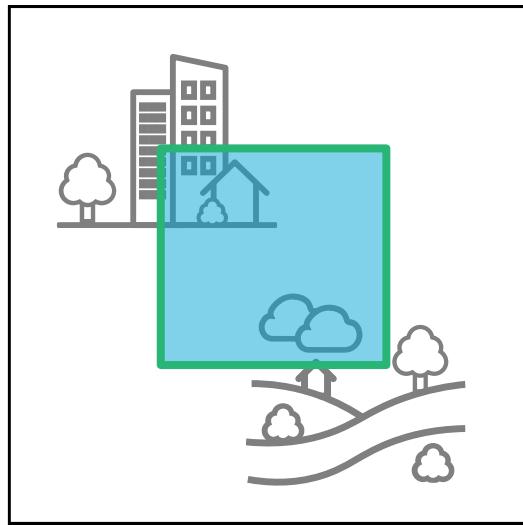
Data hierarchy

Which level?

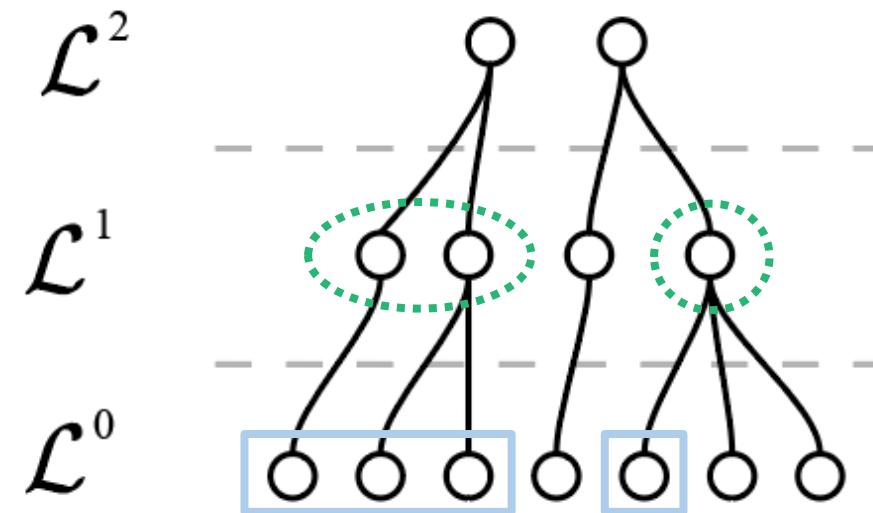


Target number
heuristic

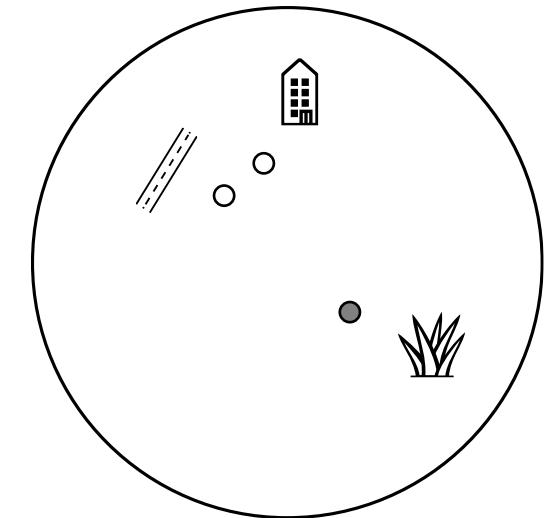
Transition stability



Image

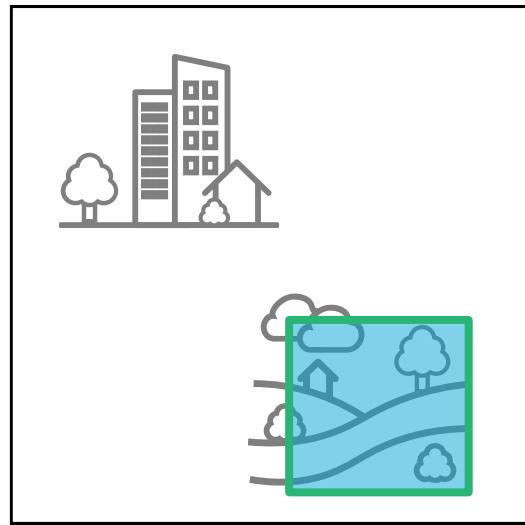


Data hierarchy

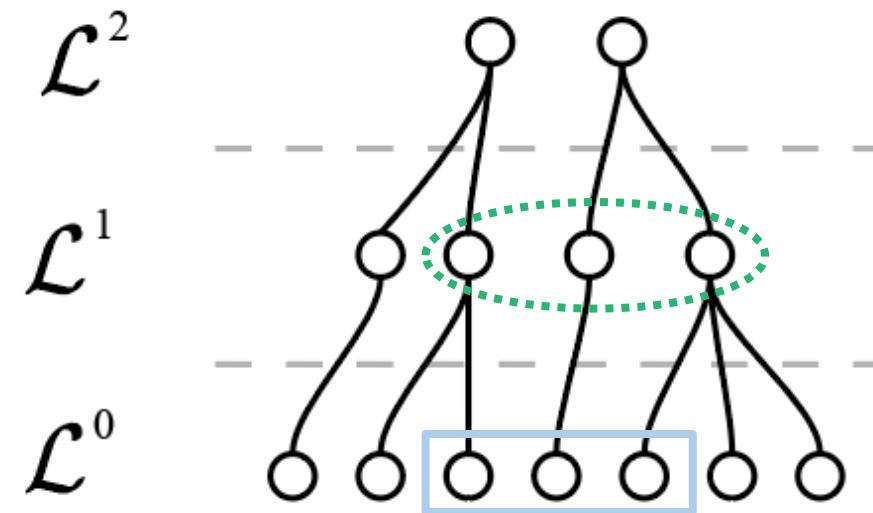


Embedding

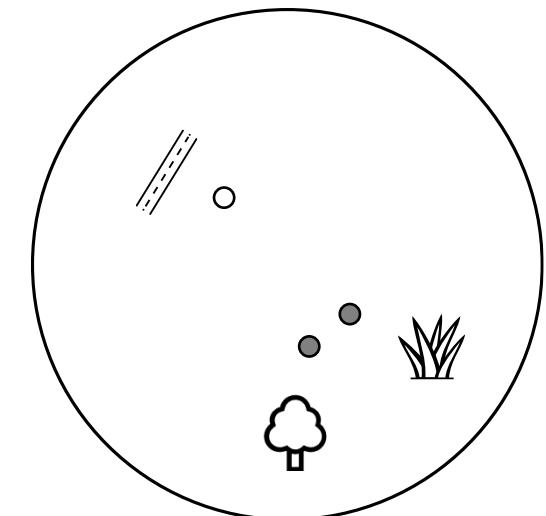
Transition stability



Image



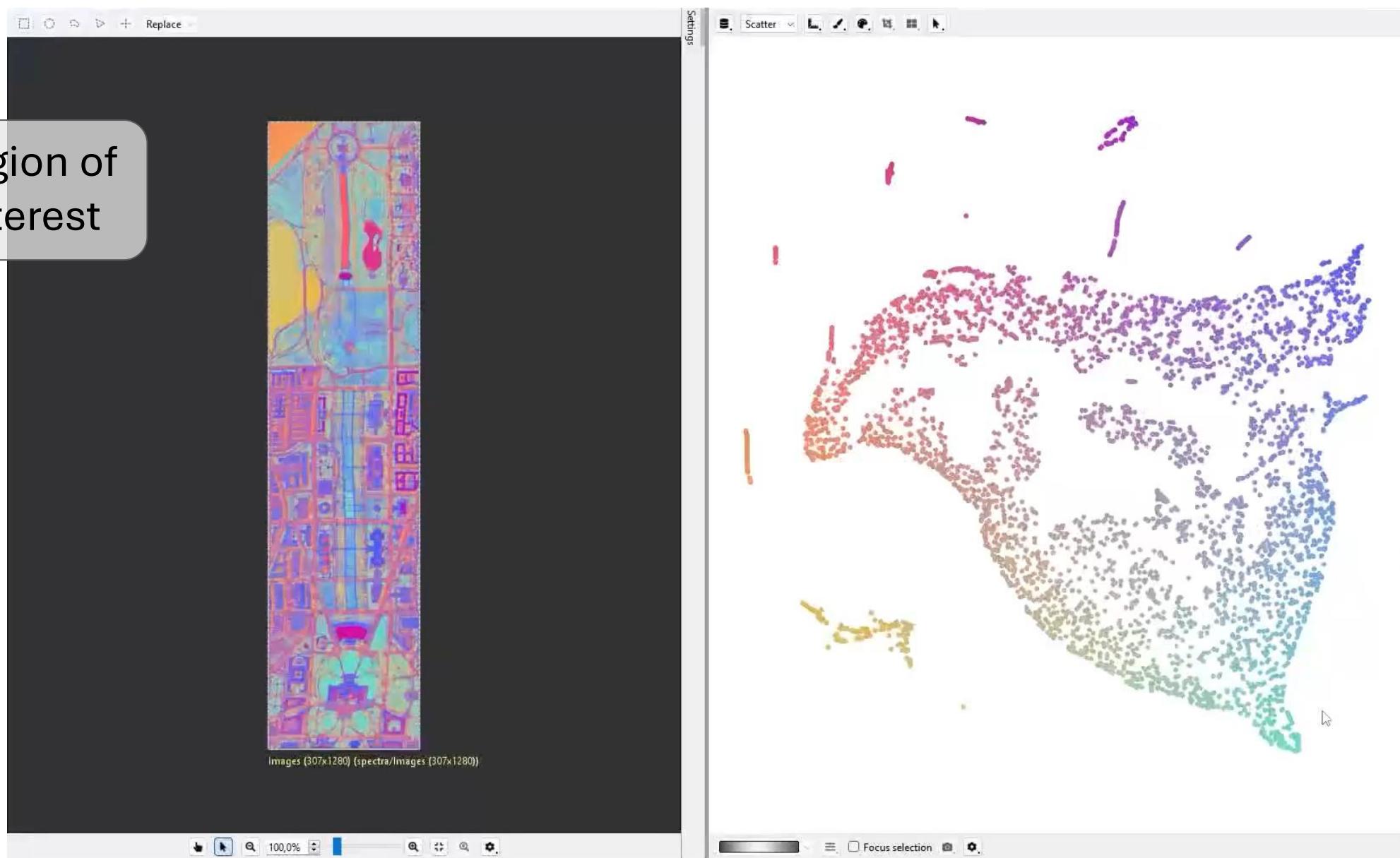
Data hierarchy



Embedding

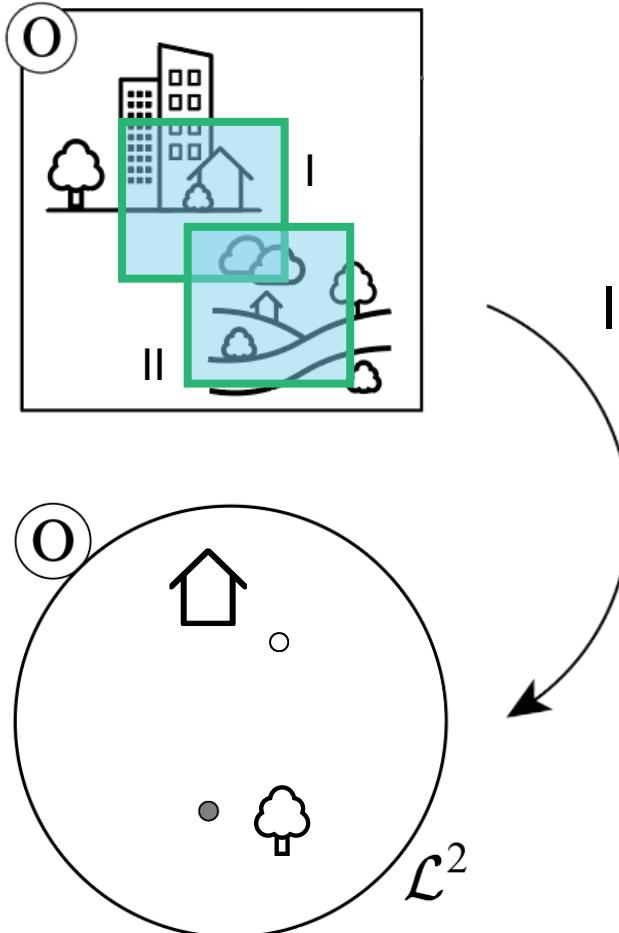
Demo

Region of
interest

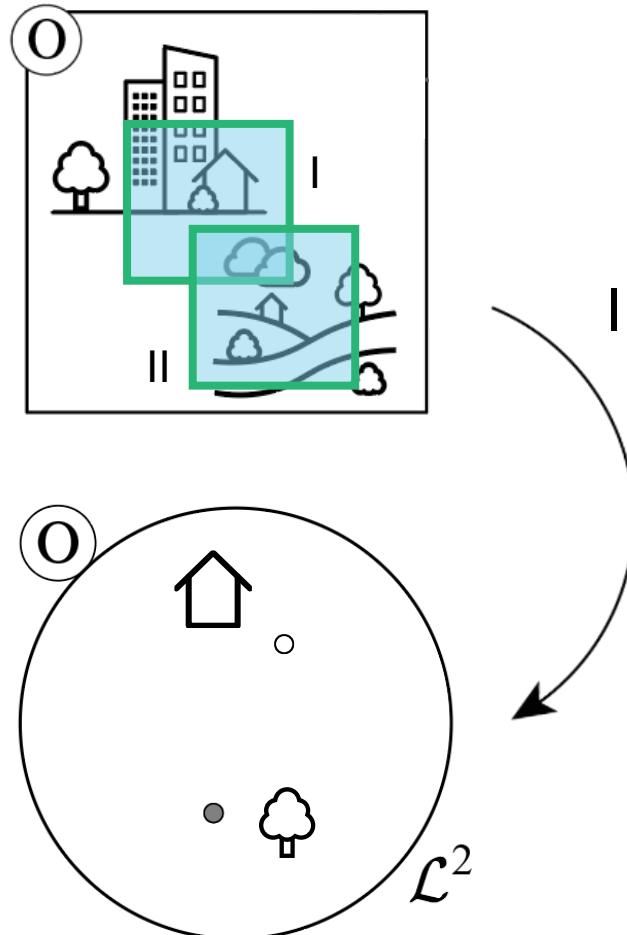


Coupled
embedding

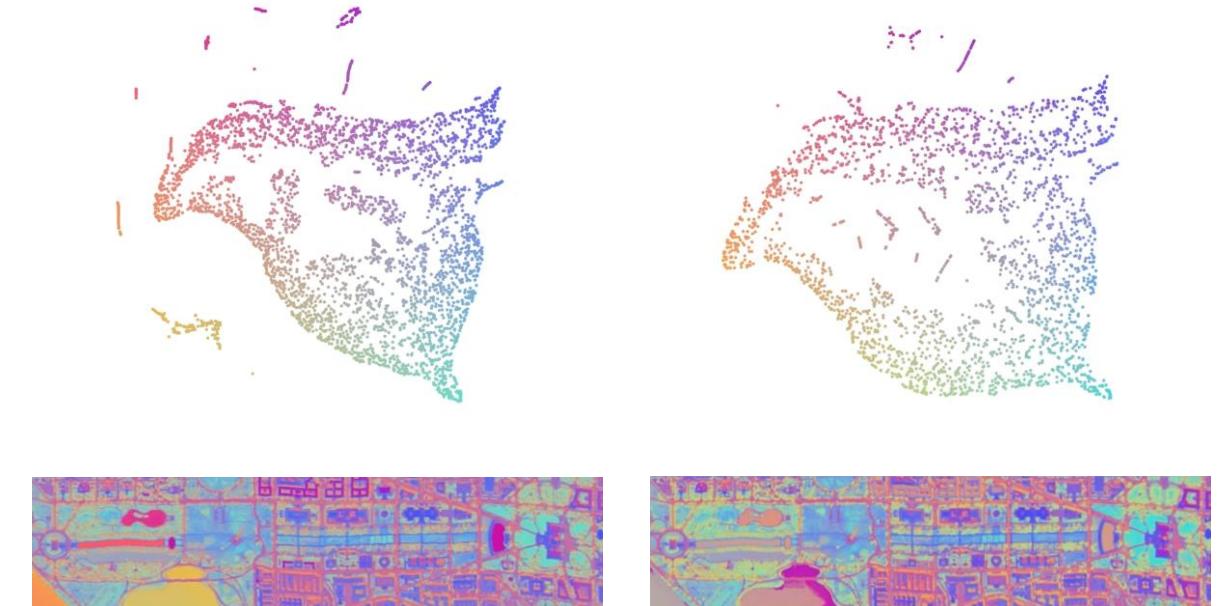
Conclusion



Conclusion



Some limitations:





ManiVaultStudio/ImageEmbeddingCoupling

Interactions for Seamlessly Coupled Exploration of High-Dimensional Images and Hierarchical Embeddings

Alexander Vieth, Boudewijn Lelieveldt, Elmar Eisemann, Anna Vilanova, Thomas Höllt