SemanticAxis

Exploring Multi-attribute Data by Semantics Construction and Ranking Analysis

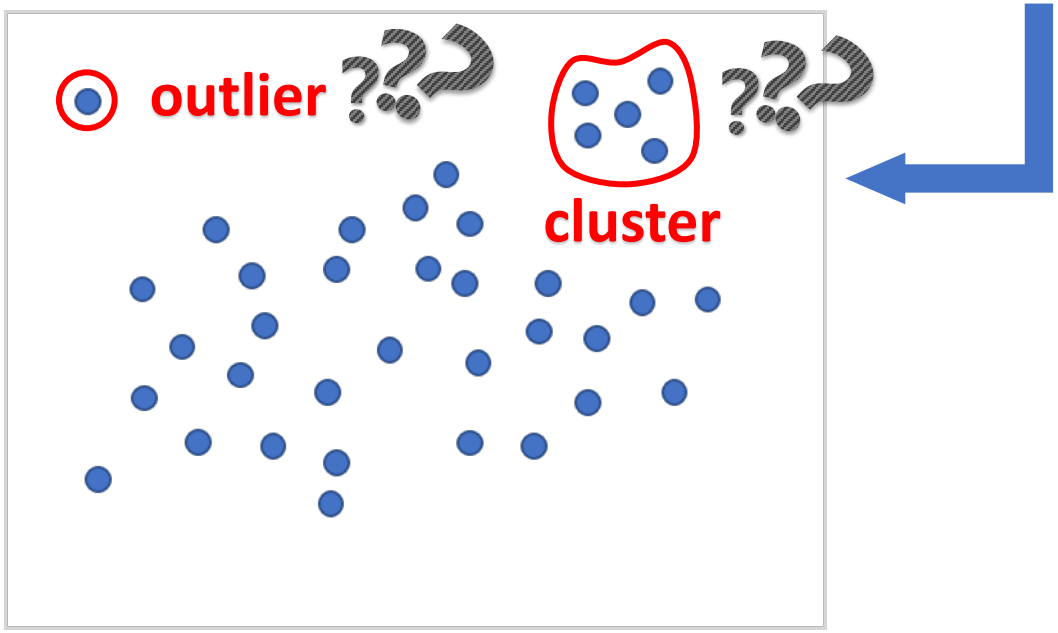
Zeyu Li, Changhong Zhang, Yi Zhang, Jiawan Zhang
Tianjin University

Motivation

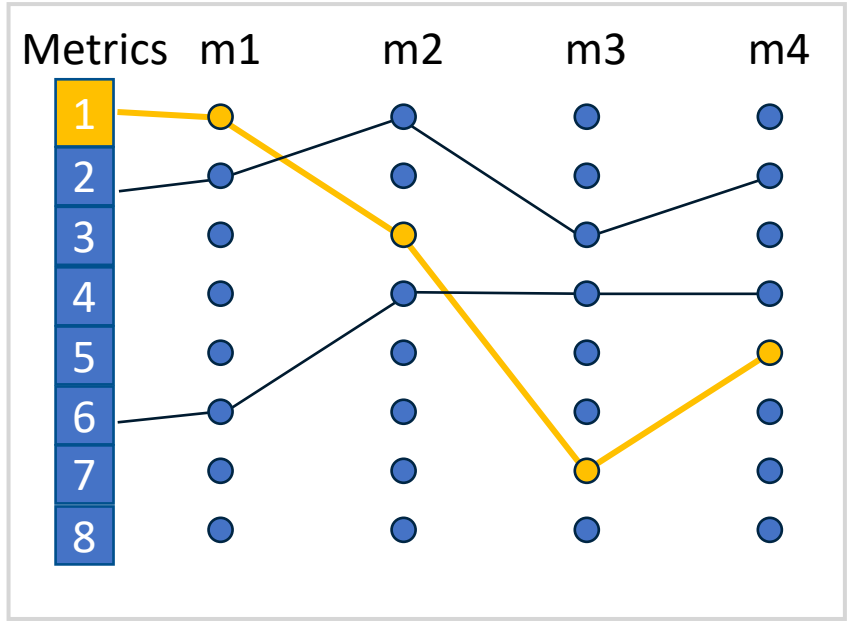
Two common tasks for multi-attribute data analysis:

Pattern recognition

Dimension Reduction (DR)



Multi-attribute rankings

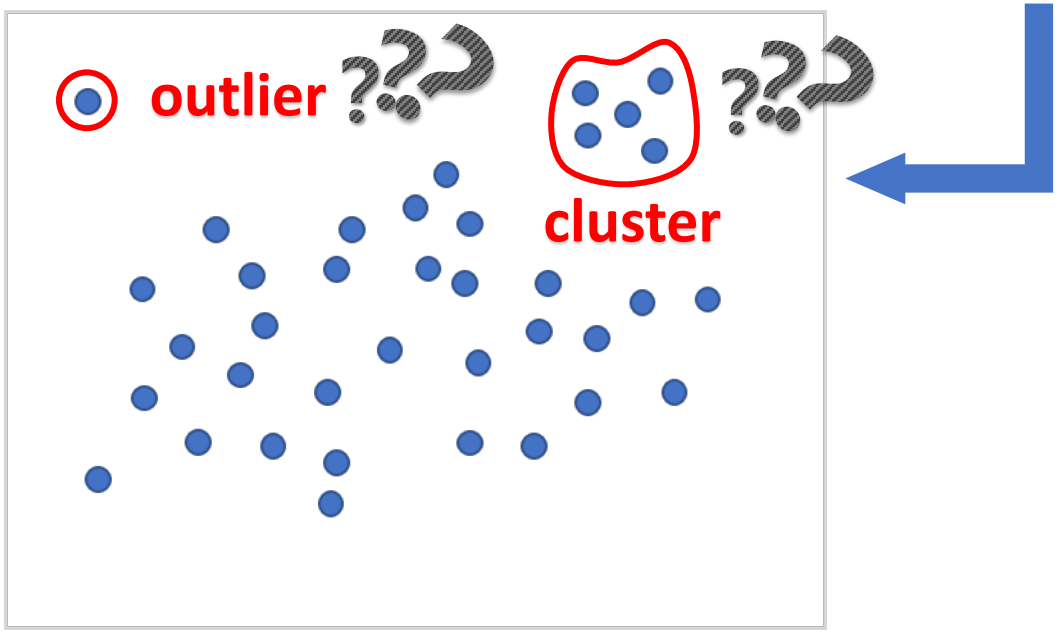


Motivation

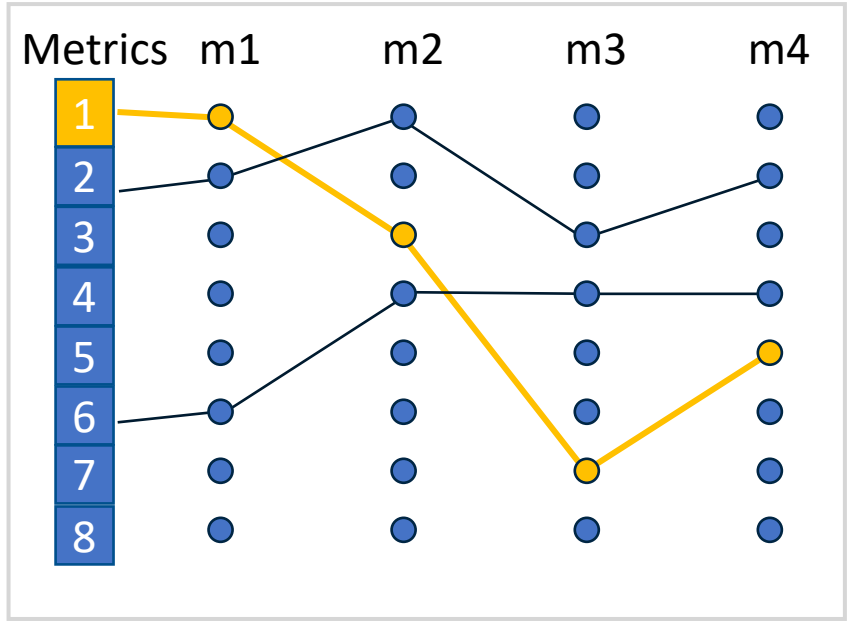
Two common tasks for multi-attribute data analysis:

Pattern finding in DR results

Dimension Reduction (DR)



Multi-attribute rankings

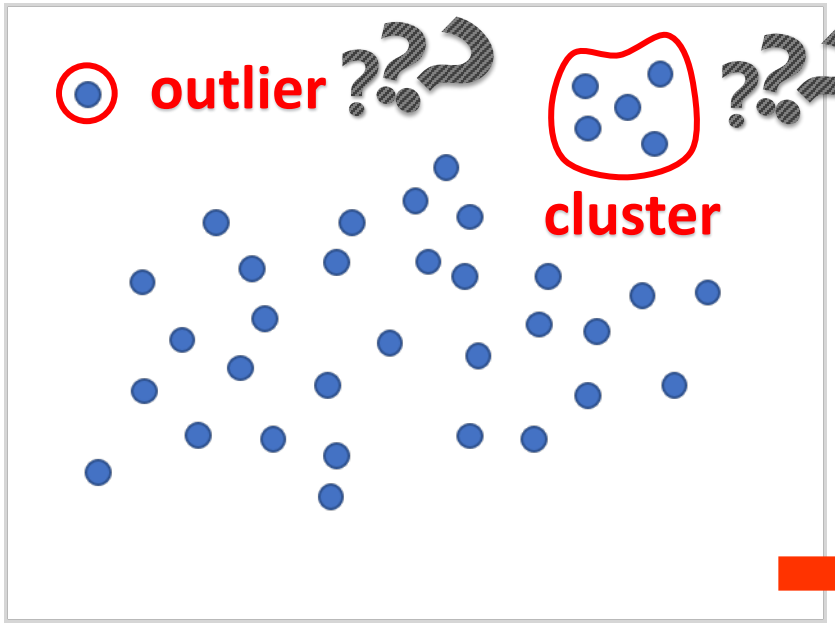


Motivation

Two common tasks for multi-attribute data analysis:

Understanding DR results

Dimension Reduction (DR)



Multi-attribute rankings

Attribute weights

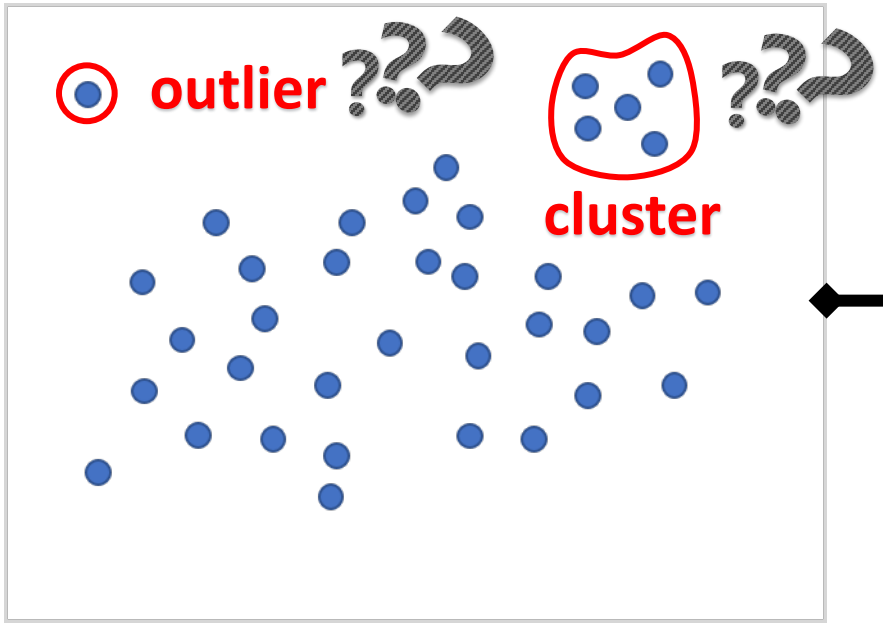
Ranking metrics

Ranking semantics

Motivation

Two common tasks for multi-attribute data analysis:

Understanding DR results



SemanticAxis

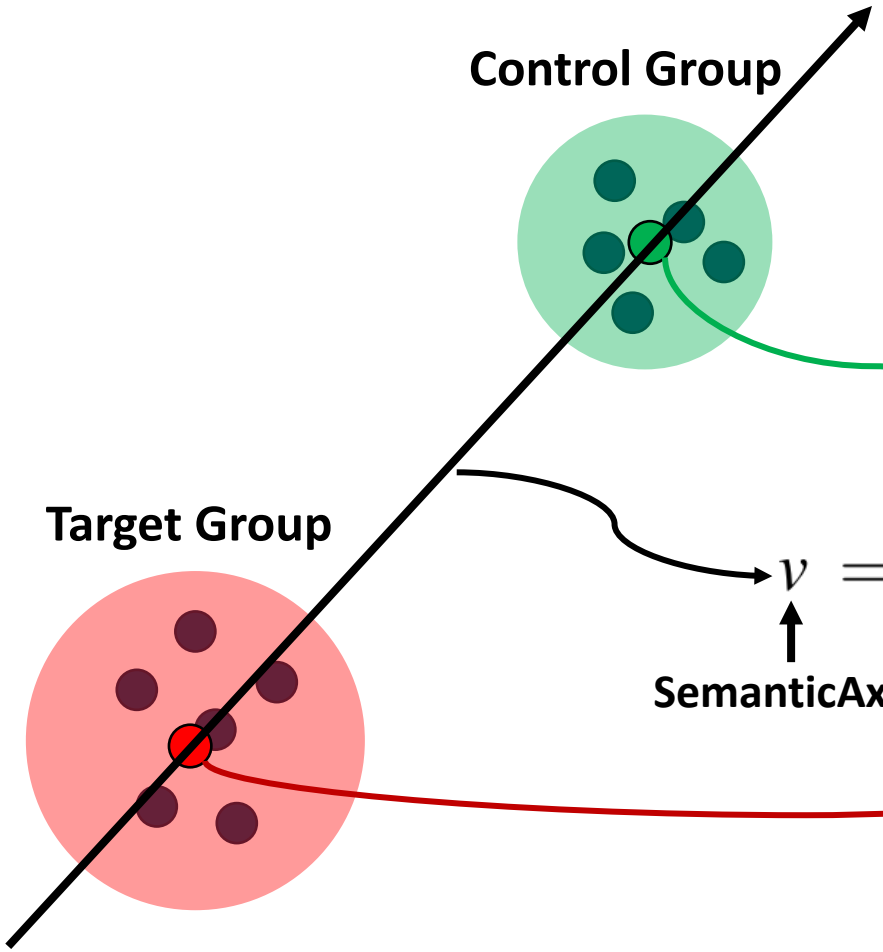
Multi-attribute rankings

Attribute weights

Ranking metrics

Ranking semantics

Creation of SemanticAxis



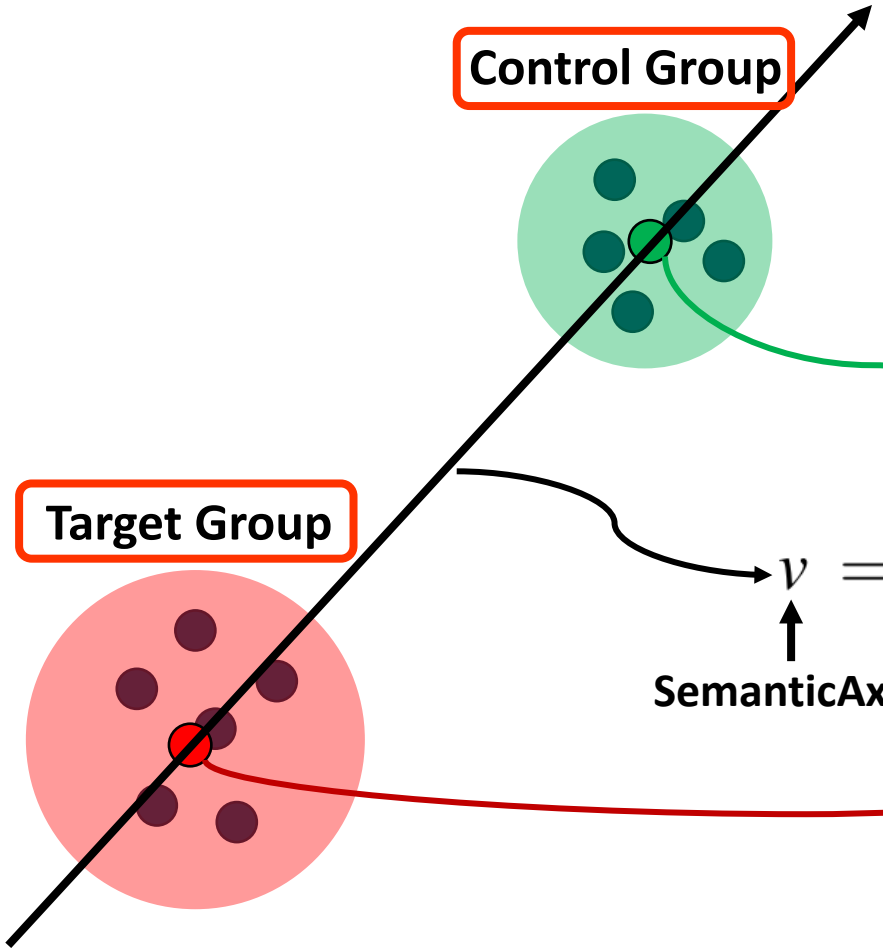
$$v = \left(\frac{1}{C} \sum_{i=1}^{C} p_i - \frac{1}{T} \sum_{j=1}^{T} p_j \right) \odot \omega \qquad p_i^l,\ p_j^r, \omega \in R^{1 \times N}$$

SemanticAxis

element-wise product

attribute weights

Creation of SemanticAxis



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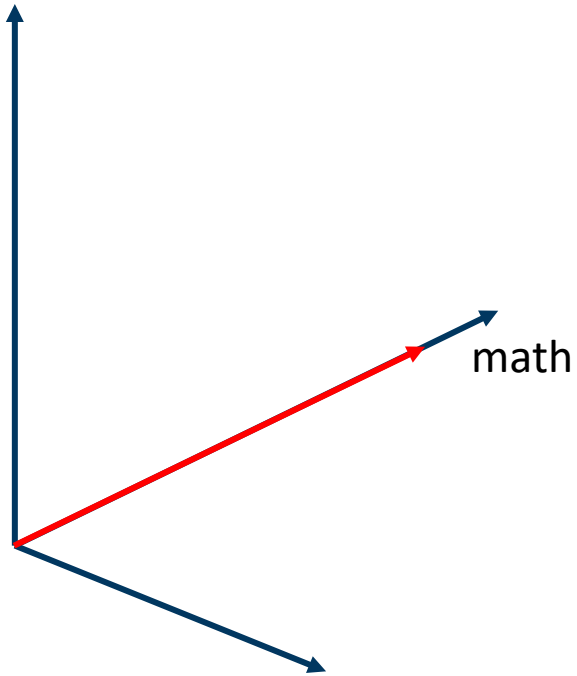
SemanticAxis

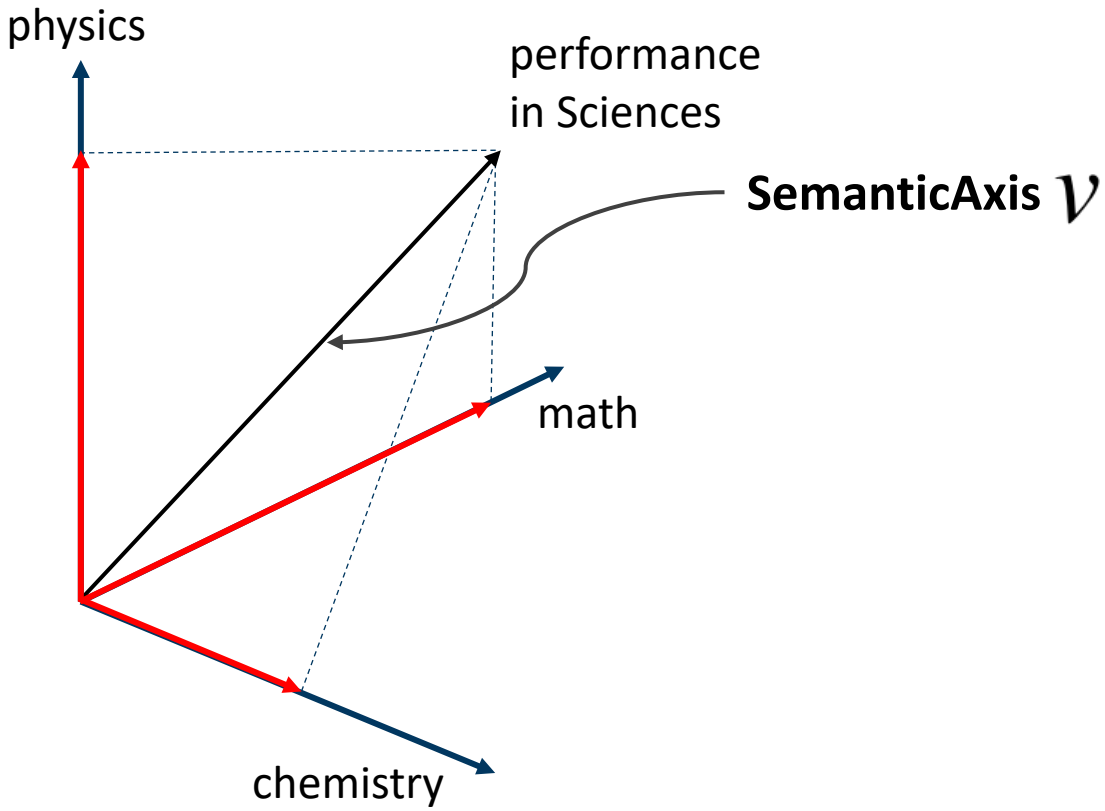
element-wise product

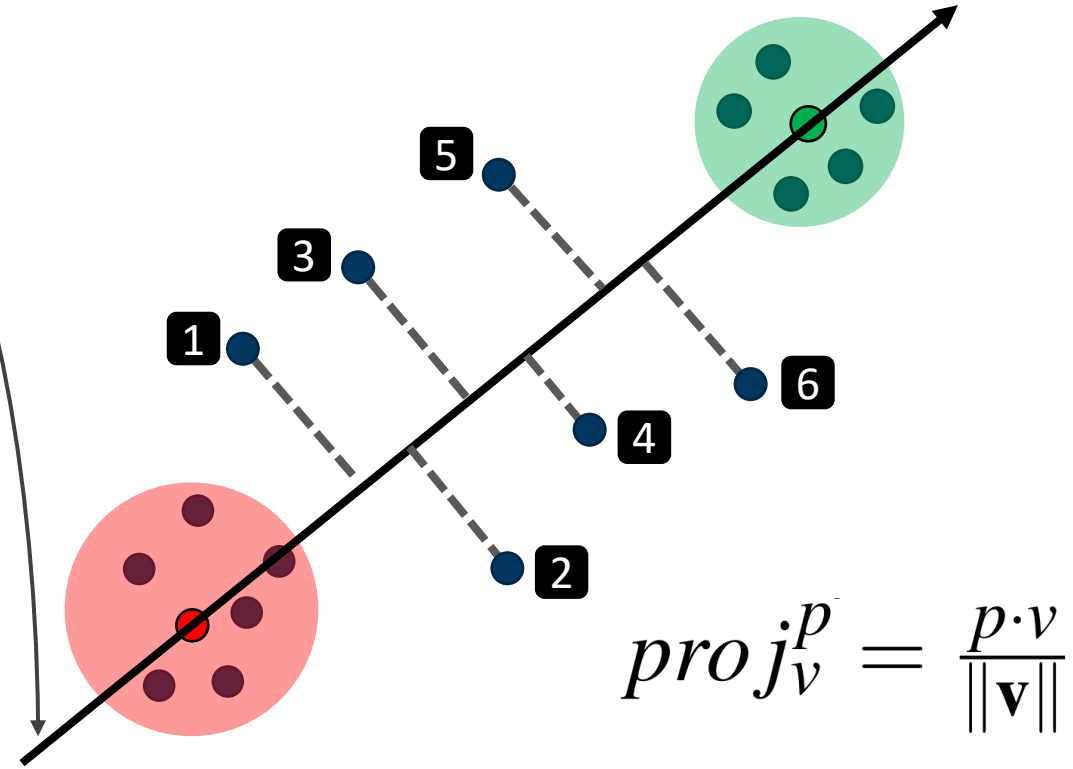
attribute weights

Supporting multi-attribute rankings



Supporting multi-attribute rankings



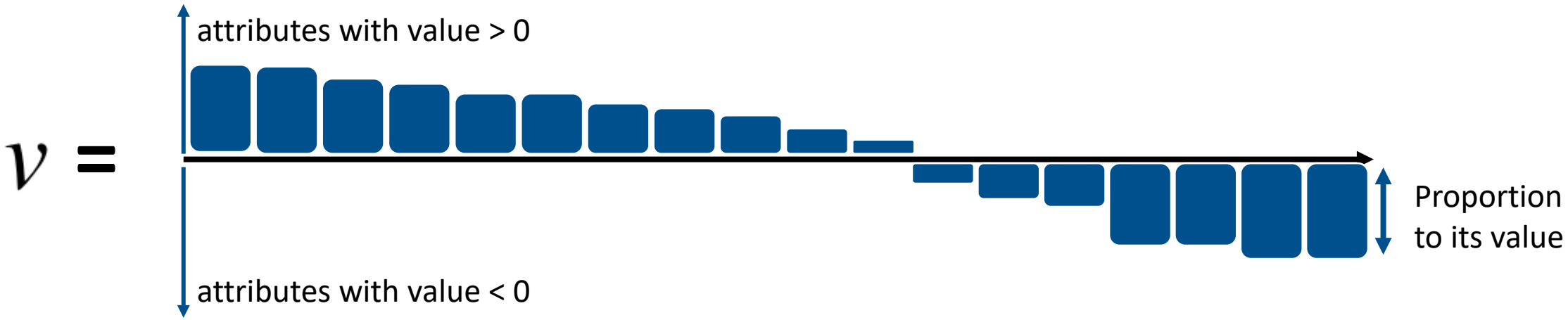


$$proj_v^p = \frac{p \cdot v}{\|\mathbf{v}\|}$$

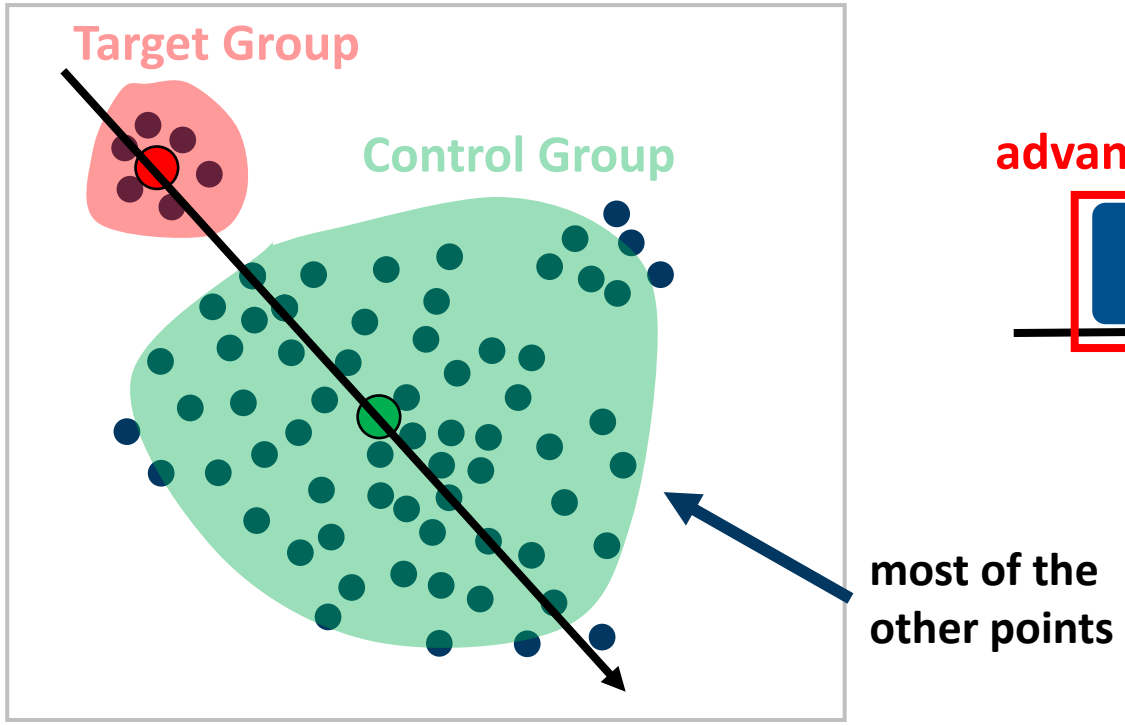
Interpreting the semantics uncovered by a semantic axis

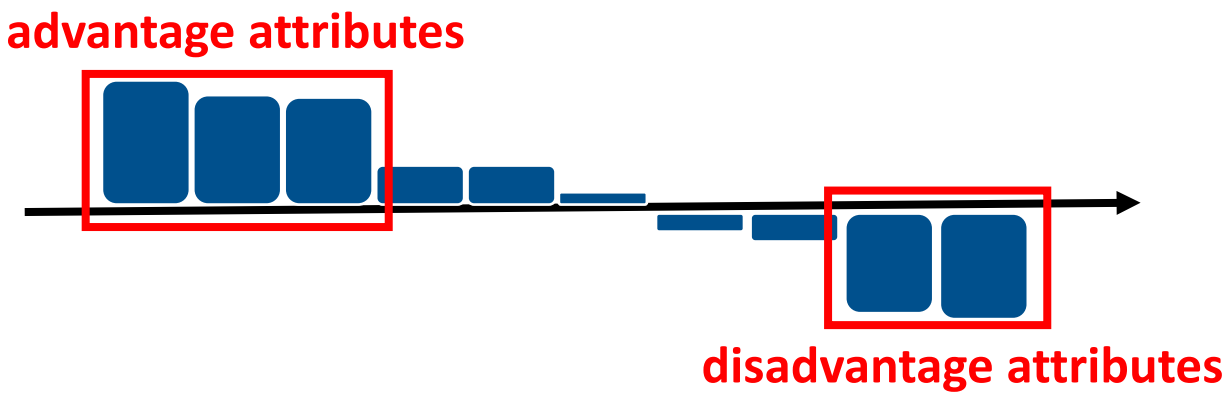
$v =$

Interpreting the semantics uncovered by a semantic axis

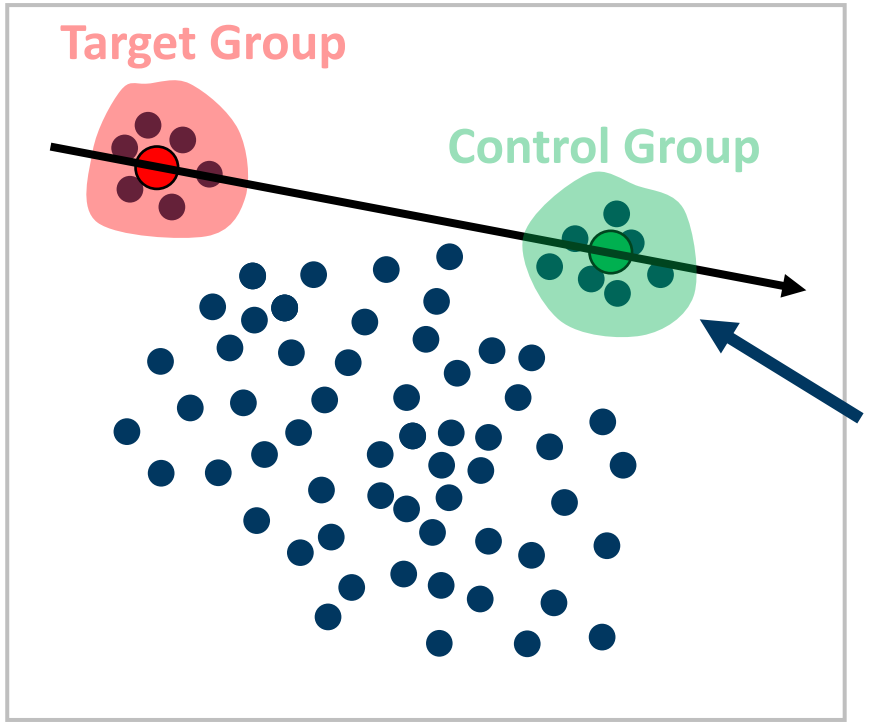


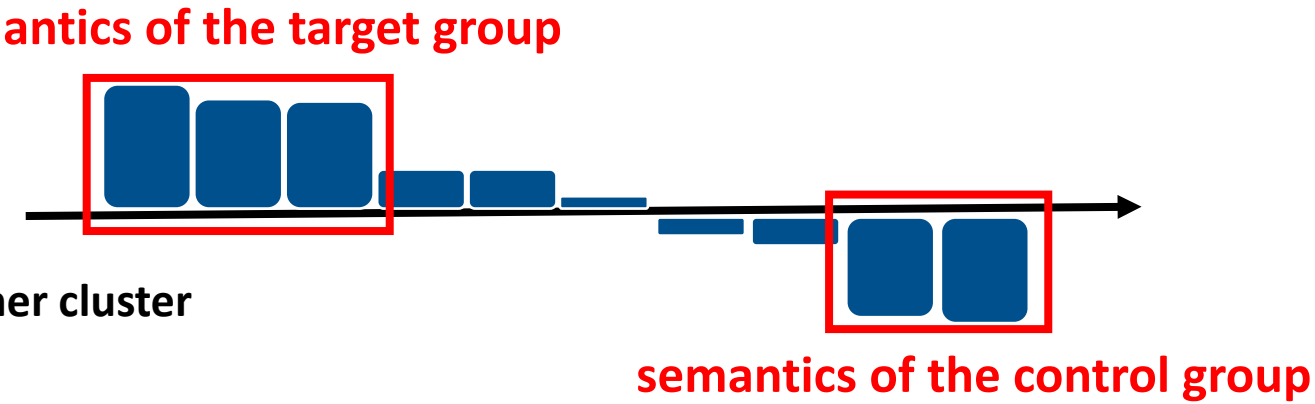
Unipolar semantic axis

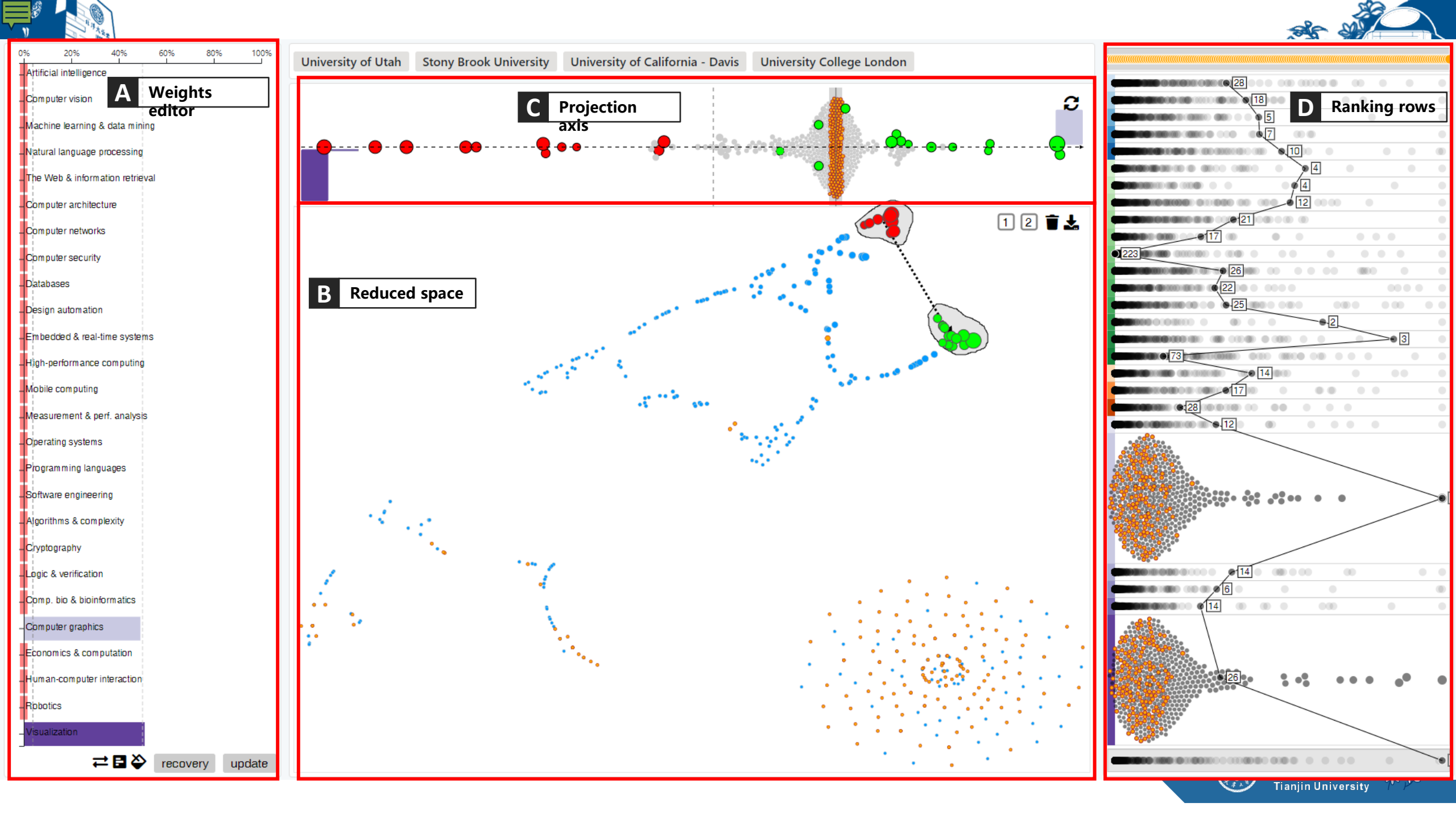




Bipolar semantic axis



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University of California - Davis
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C Projection axis
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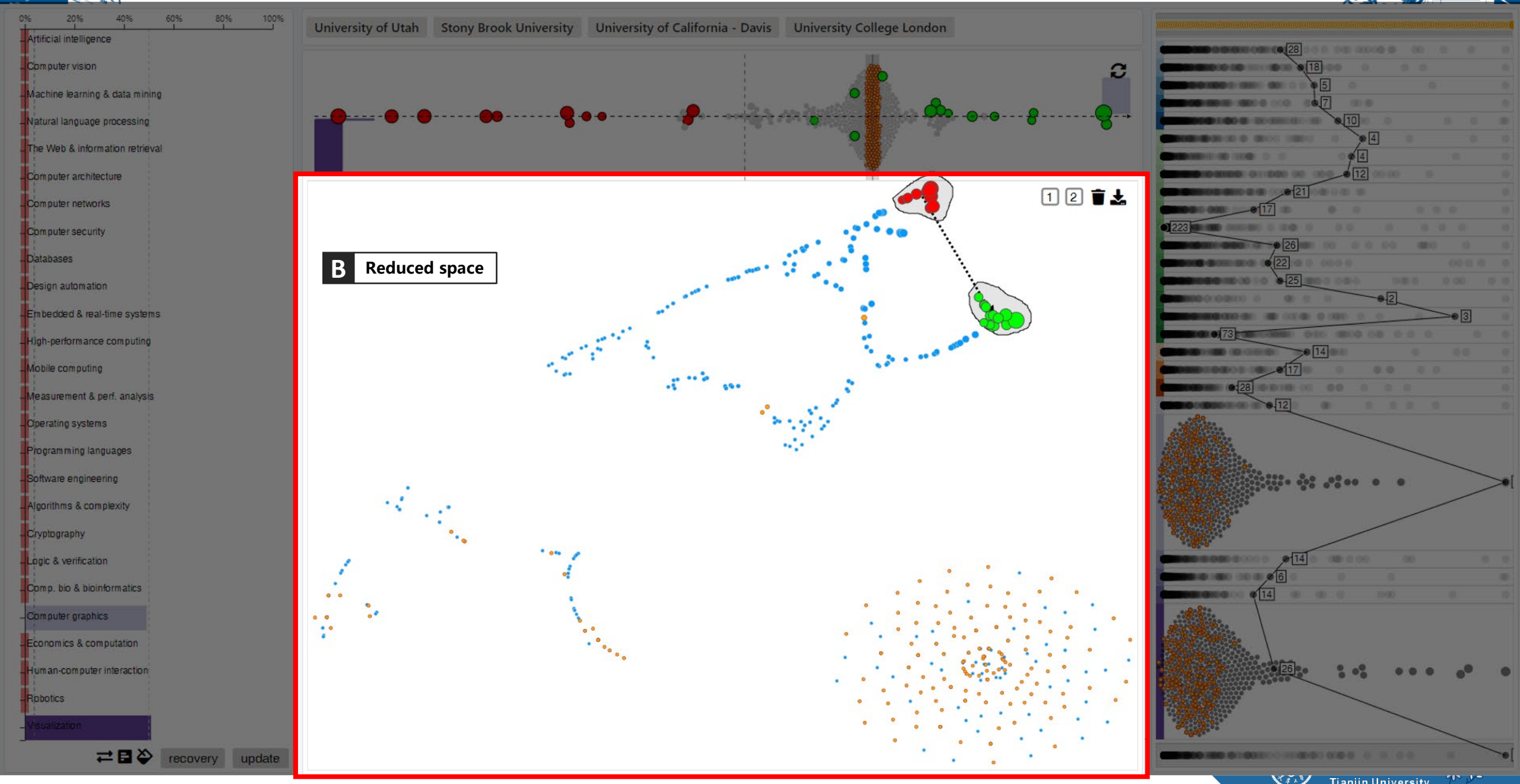
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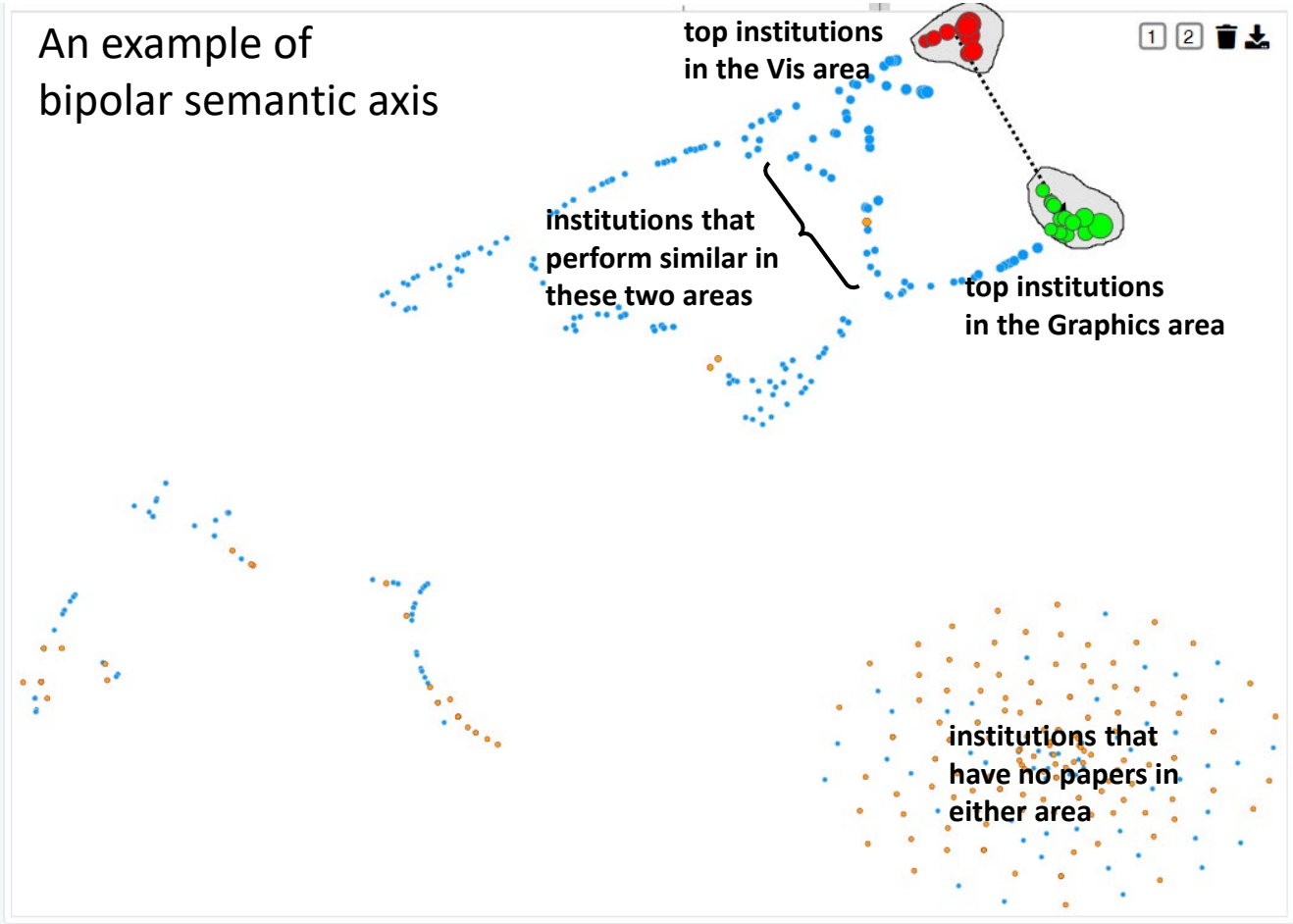
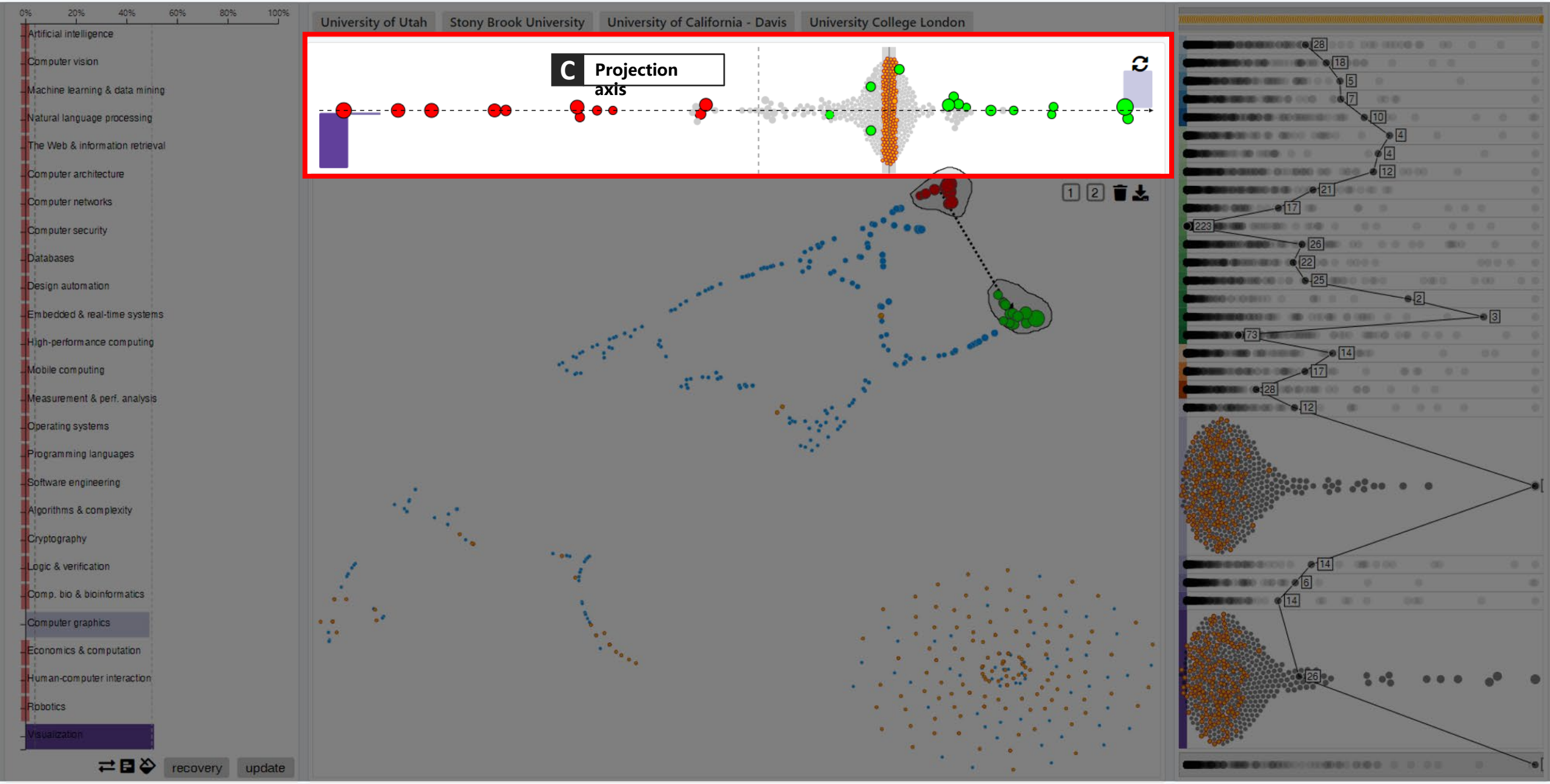
Reduced space



DR algorithm: t-SNE

Radius of points: weighted scores $\sum_{i=1}^{N} \bar{p} \cdot \omega$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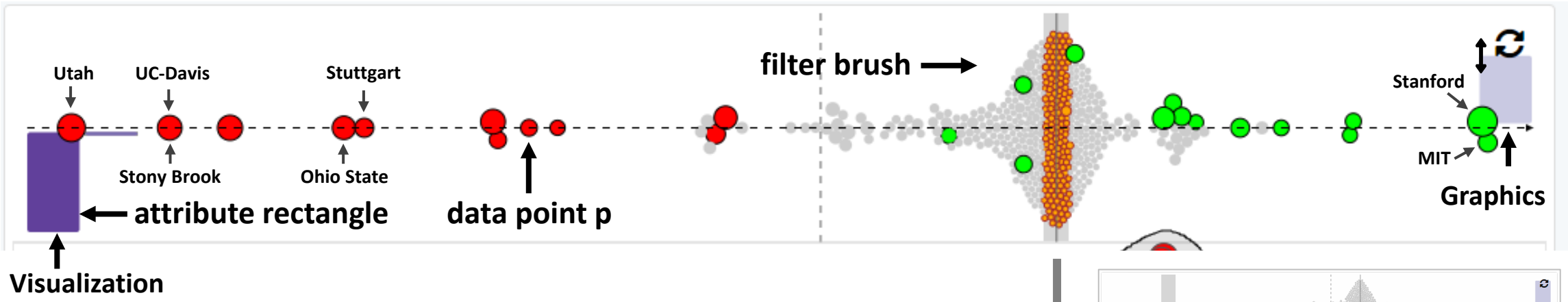
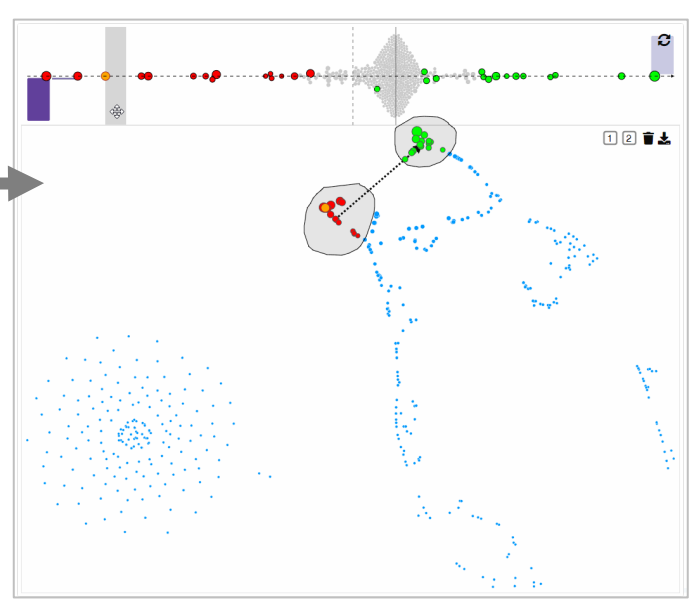
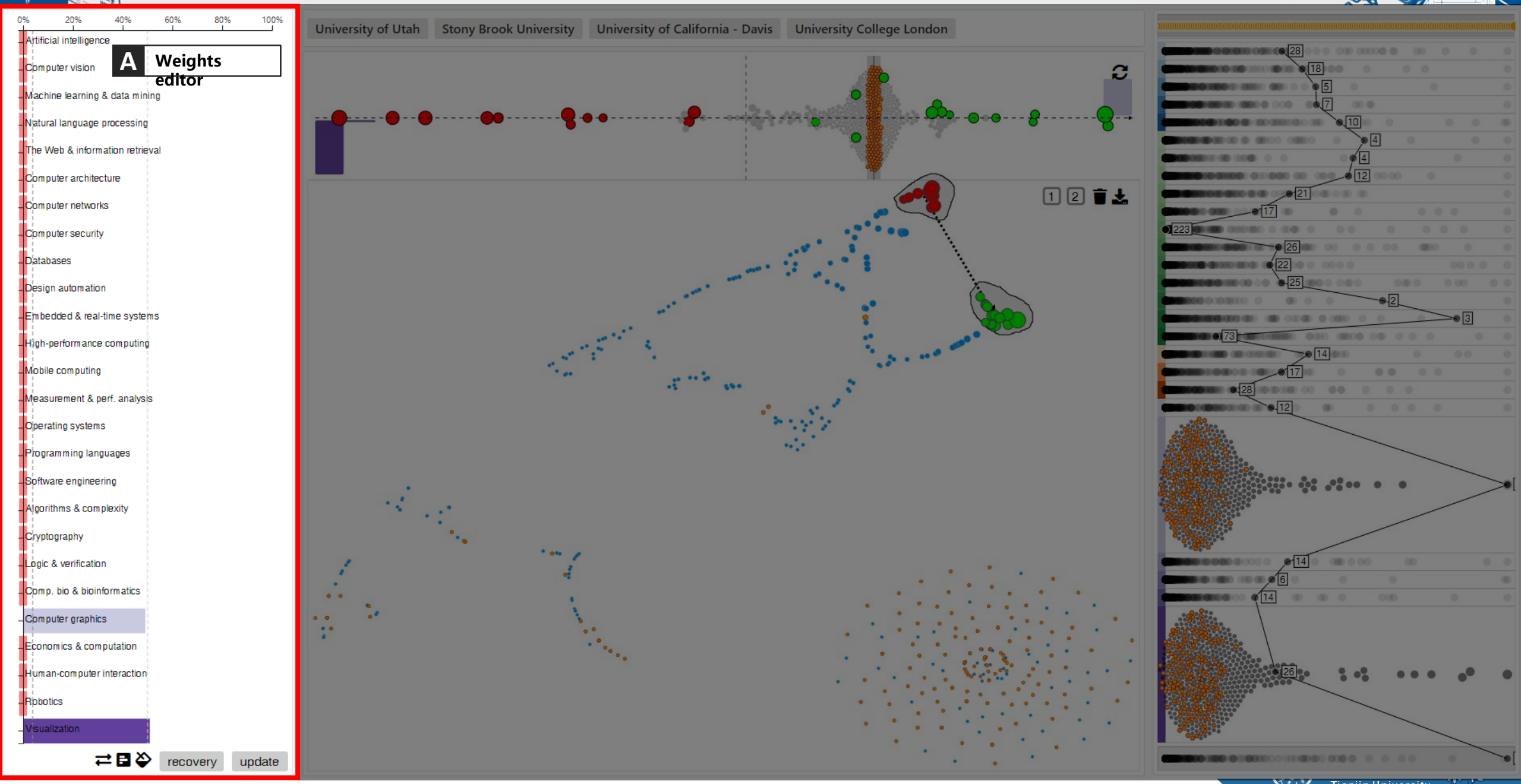
Projection axis



Radius of points: weighted score $\sum_{i=1}^{N} p \cdot \omega$

X-position of points: projection position $proj_v^p = \frac{p \cdot v}{\|\mathbf{v}\|}$

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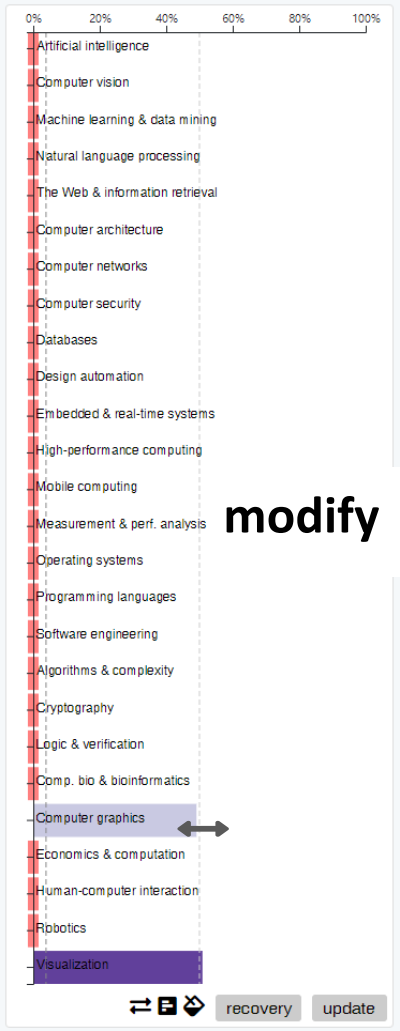
Weight editor

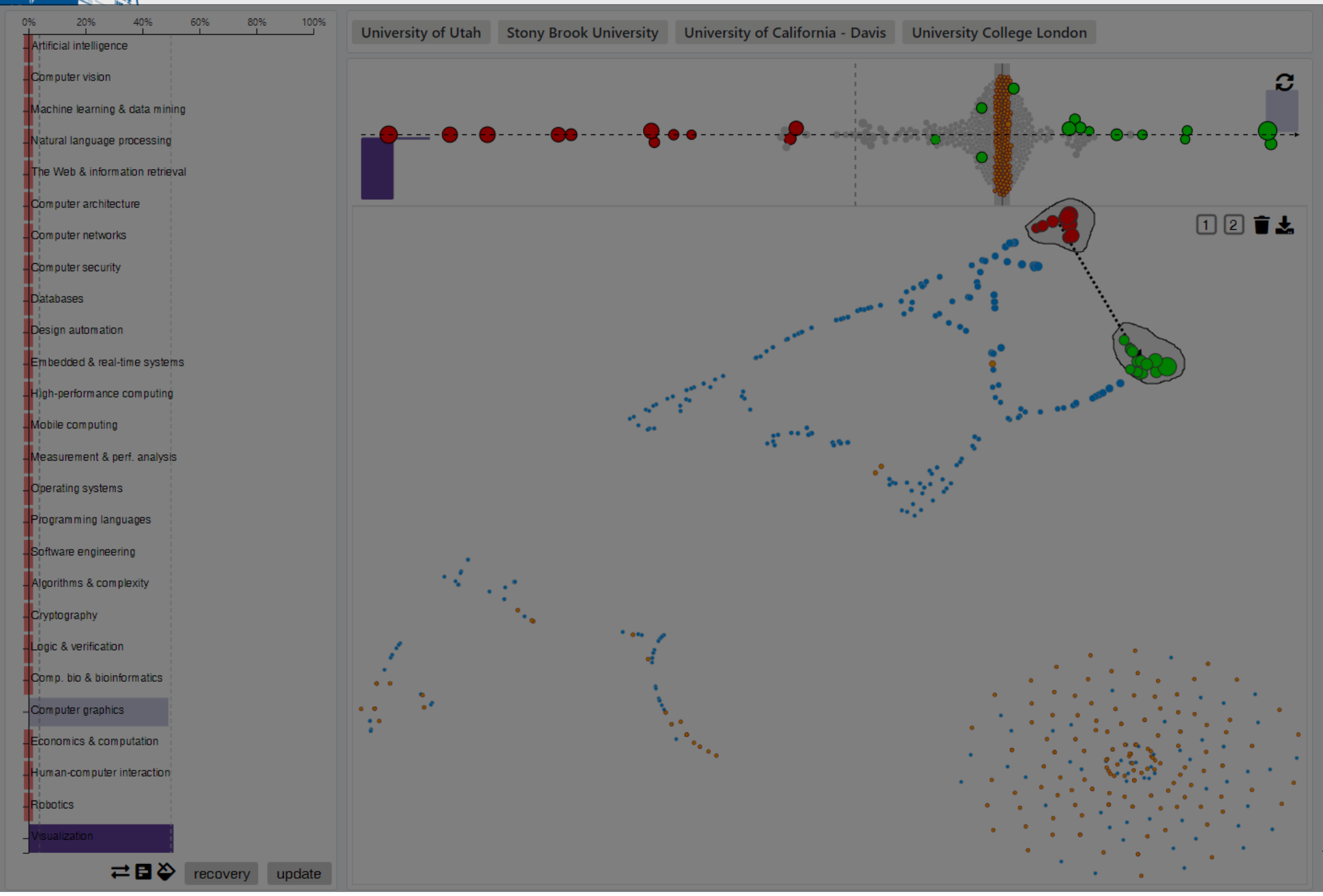


modify ω

Purpose:

1. Support interactive refinement in multi-attribute rankings, allow shaping ranking criteria according to preferences

2. Rebuild reduced space, in order to gather data points that conform to the target semantics in close proximity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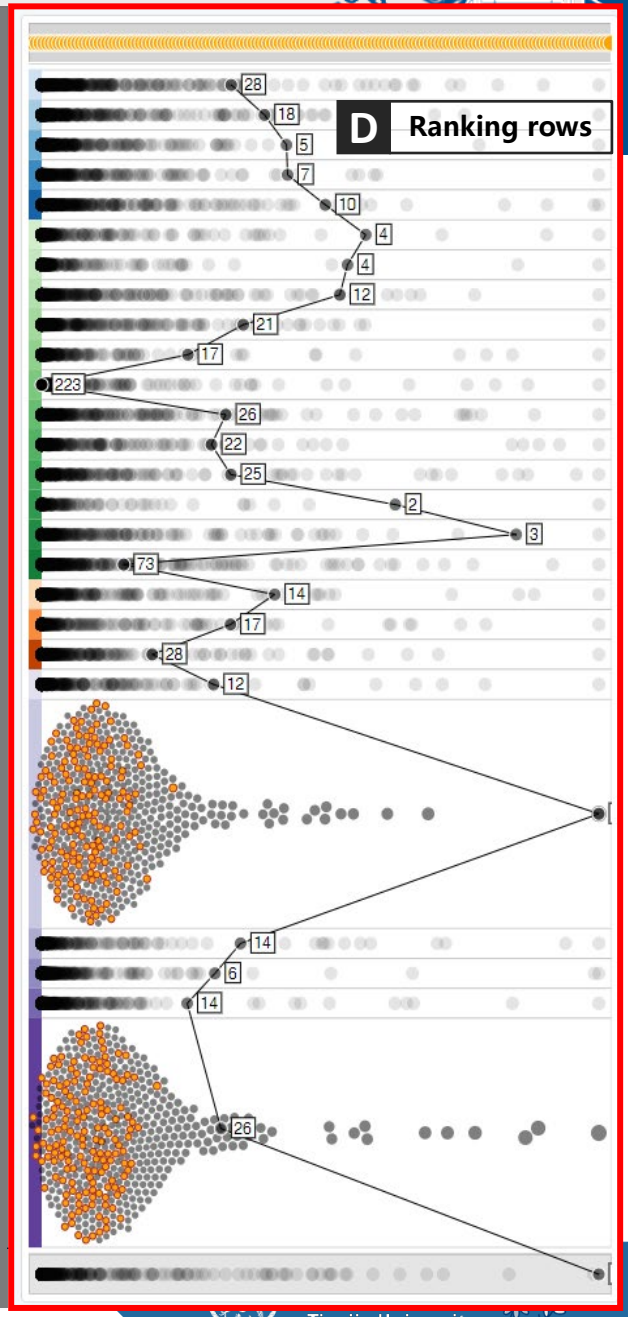
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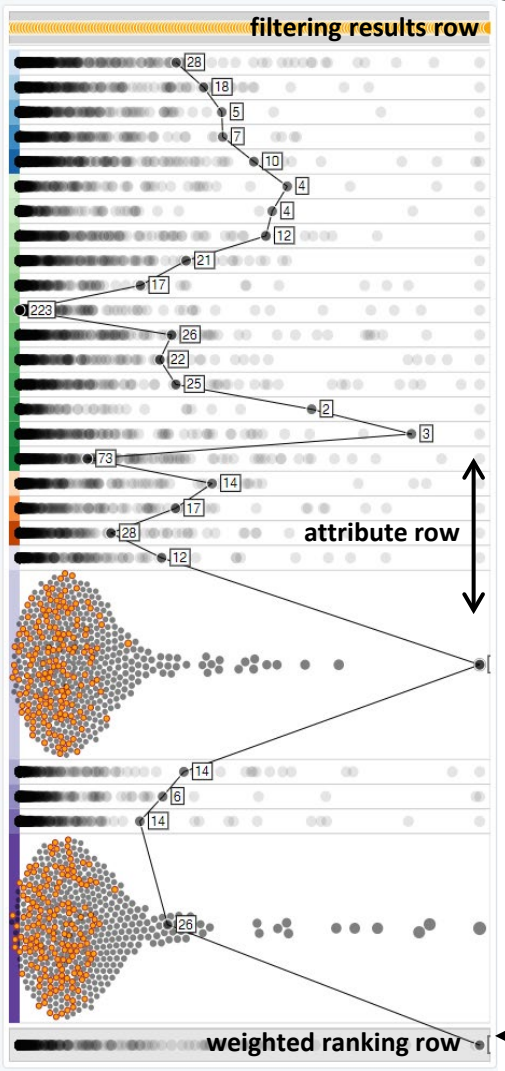
Ranking rows

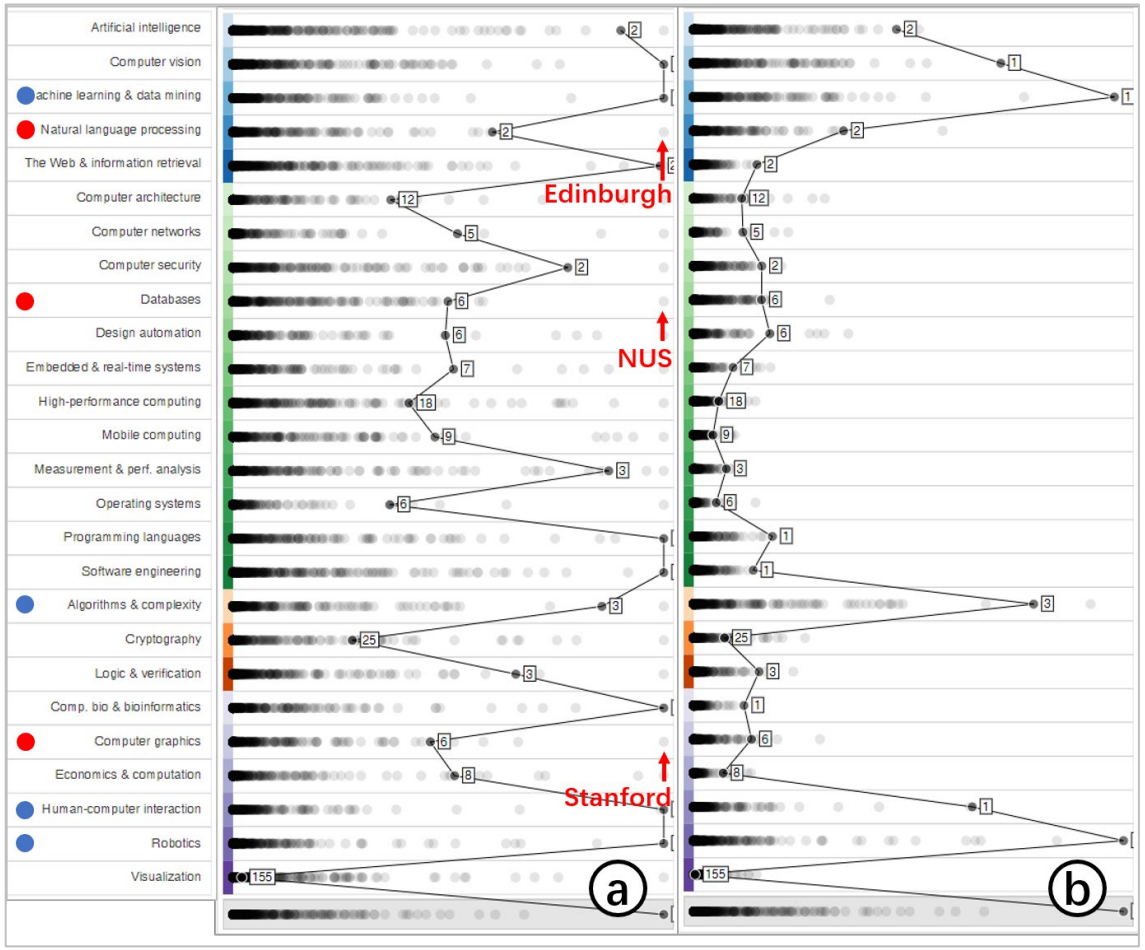


parallel coordinate axis

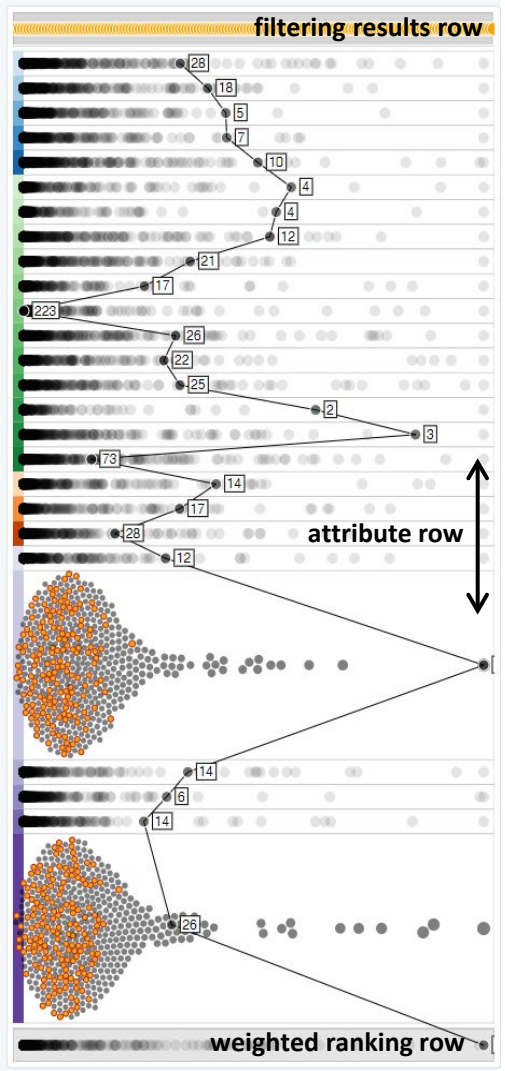
Sorted by weight scores

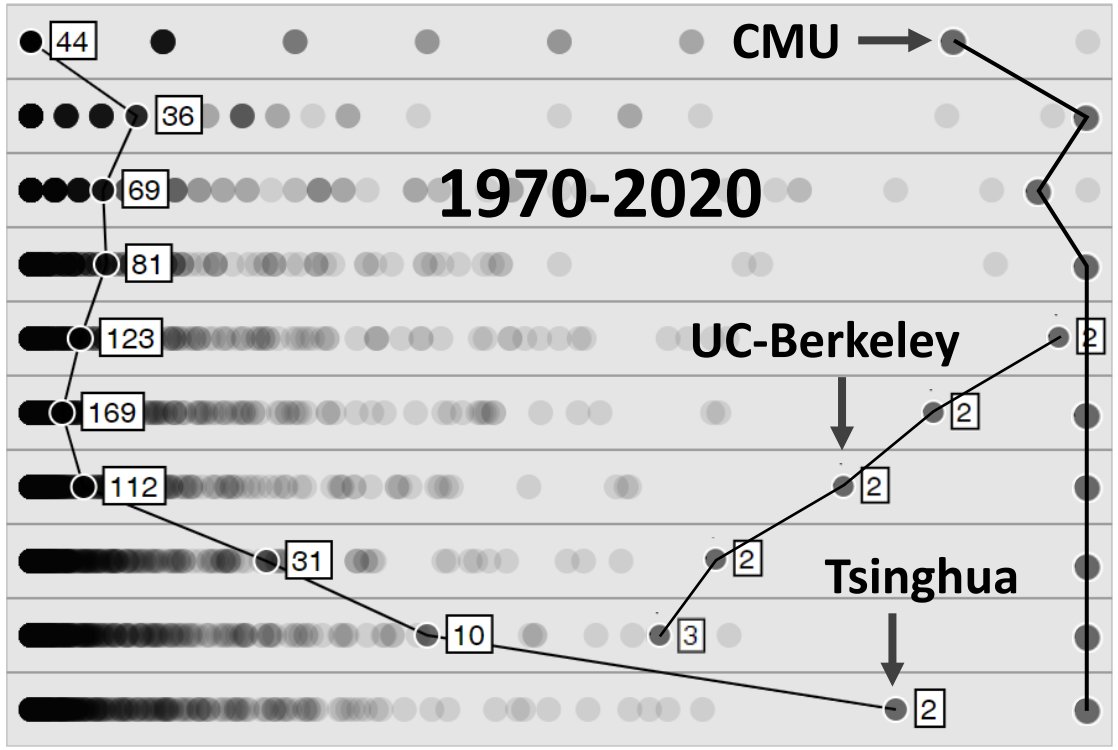
local scale

global scale

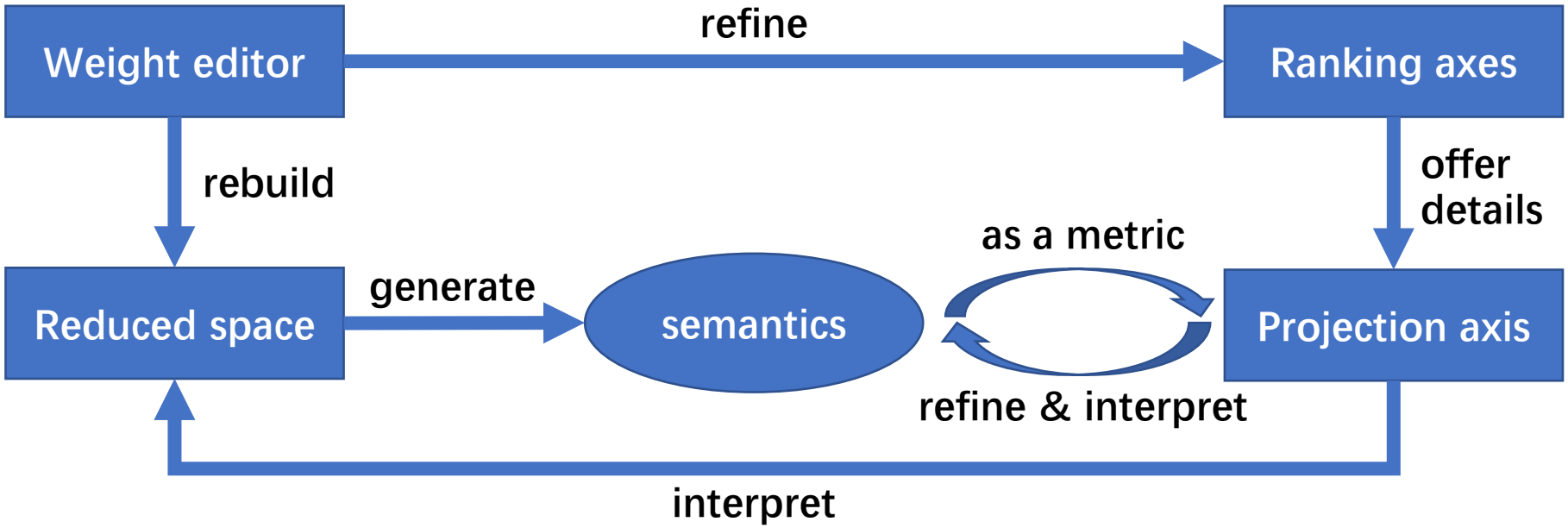


Ranking rows



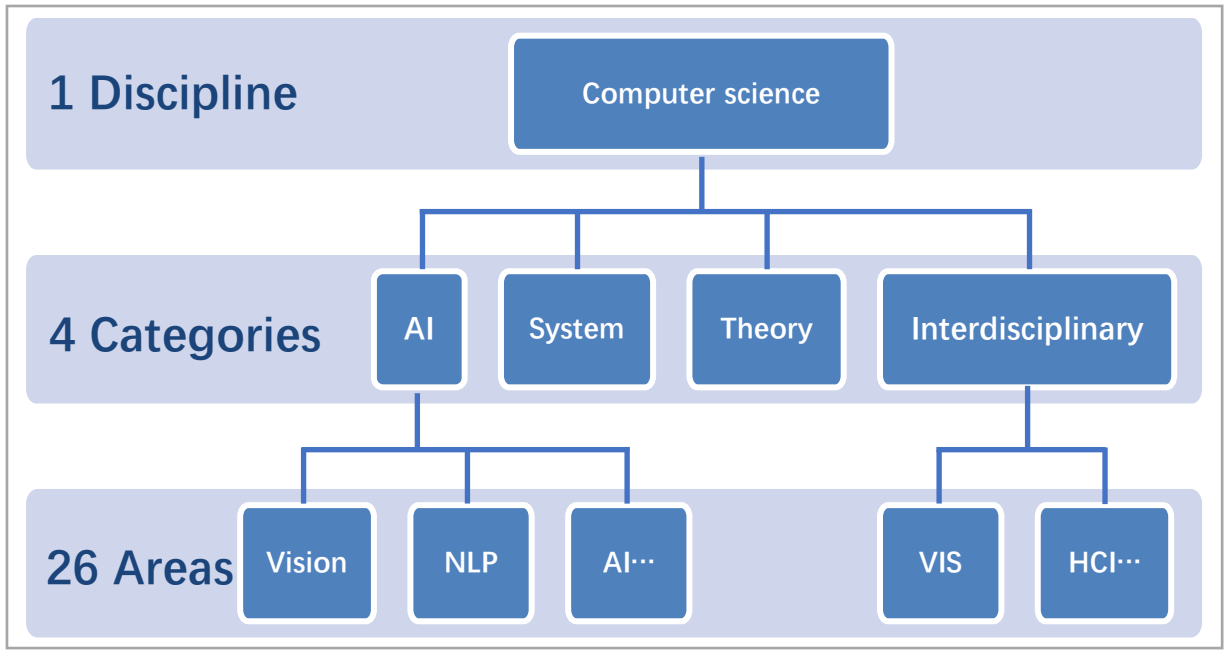


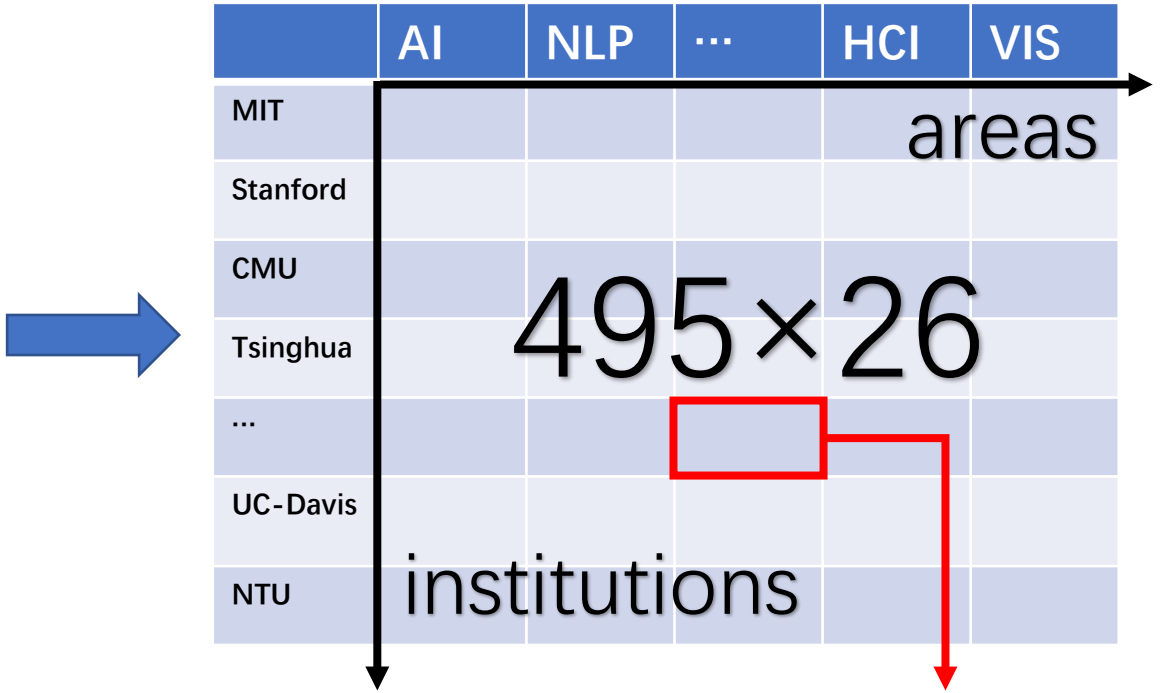
Relationships between the four main components of our system



Case: explore the academic performance and rankings of the institutions in computer science

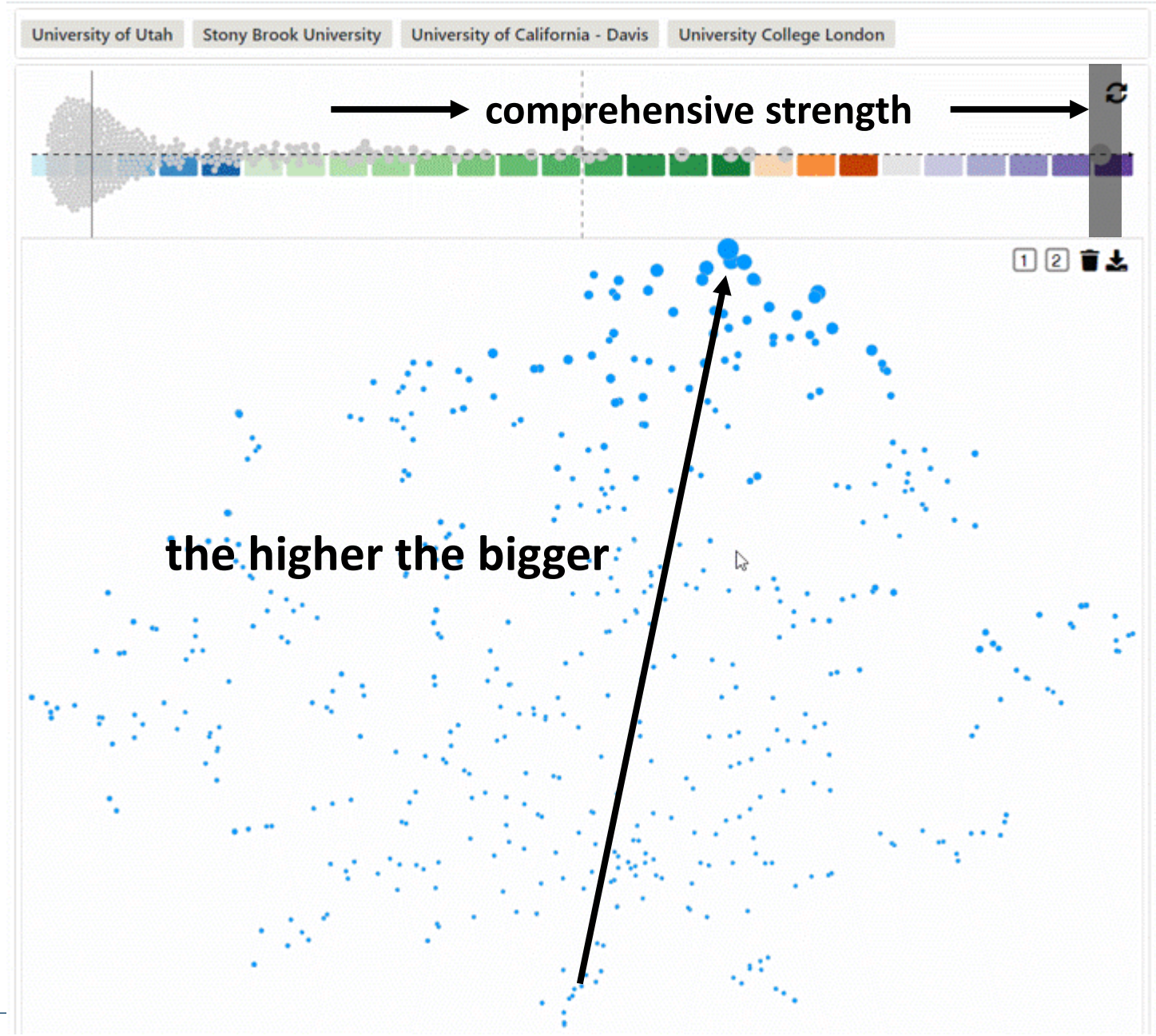
Data description





Source: CSRankings

 # published paper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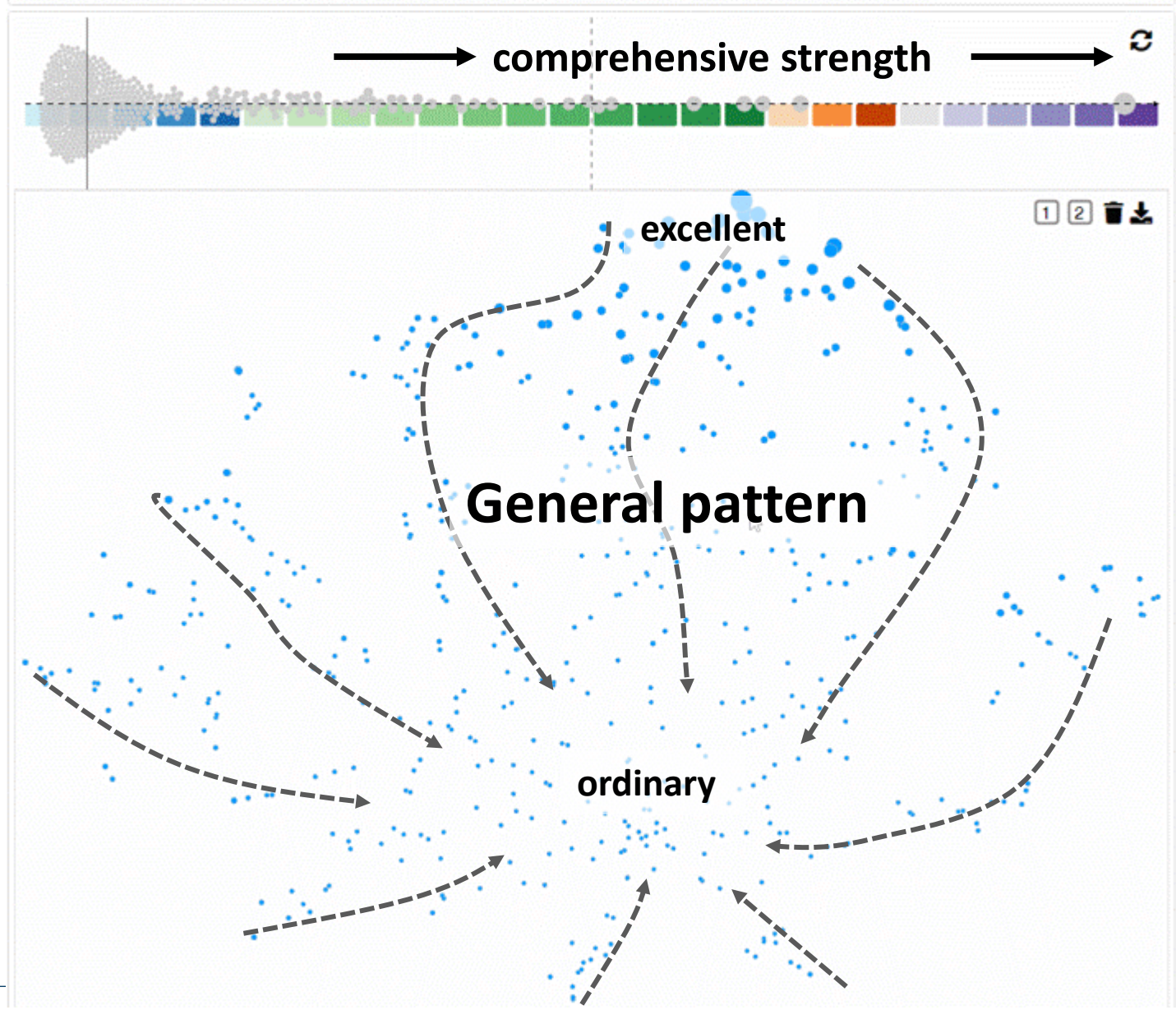
Stony Brook University
University of California - Davis
University College London
comprehensive strength
the higher the bigger


comprehensive strength
excellent
General pattern
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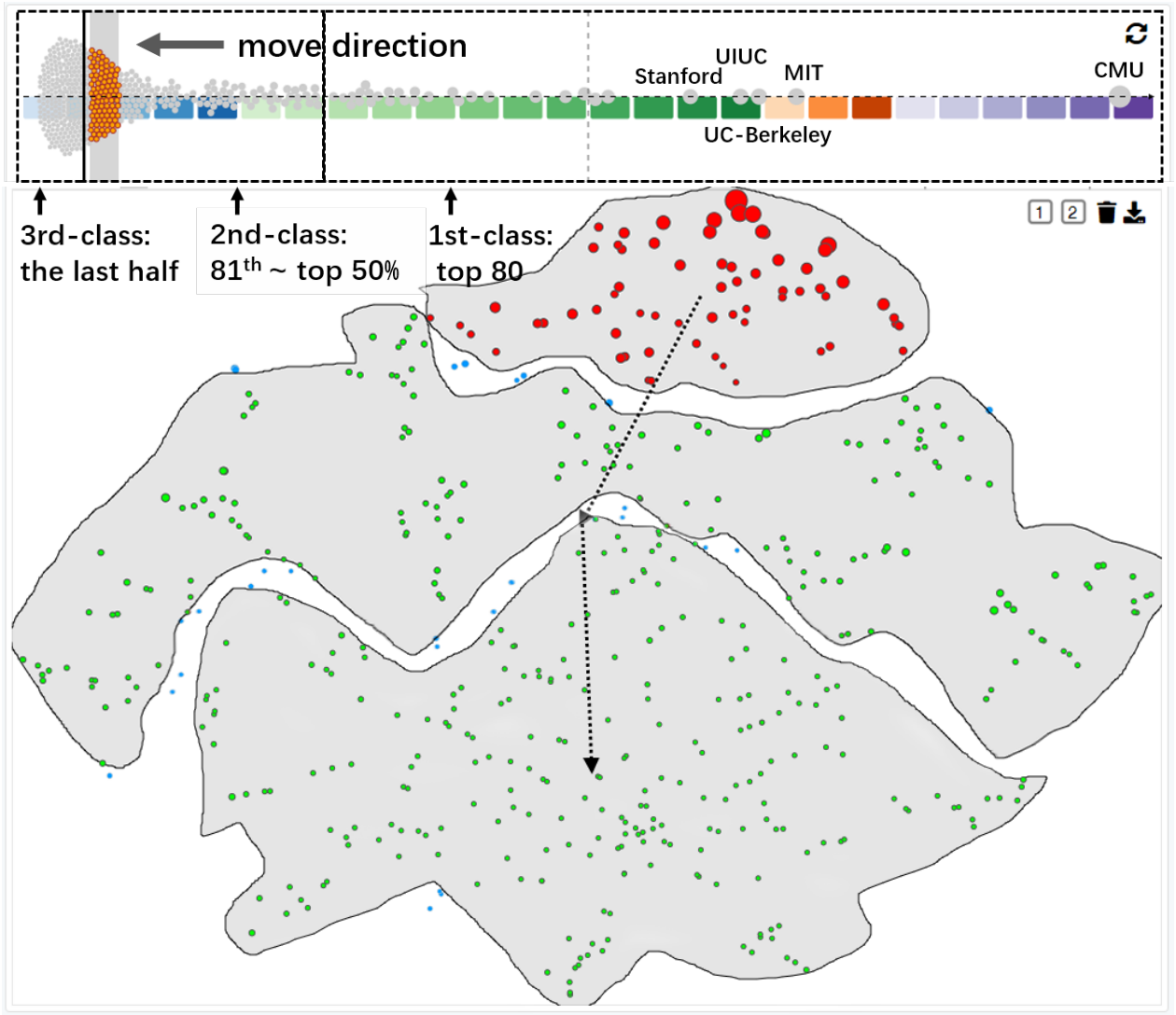
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3rd-class:
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2nd-class:
81th ~ top 50%
1st-class:
top 80


System category
AI category
High-performance computing
Databases
Measurement & perf. analysis
Computer security
Mobile computing
Programming languages
First class
Second class
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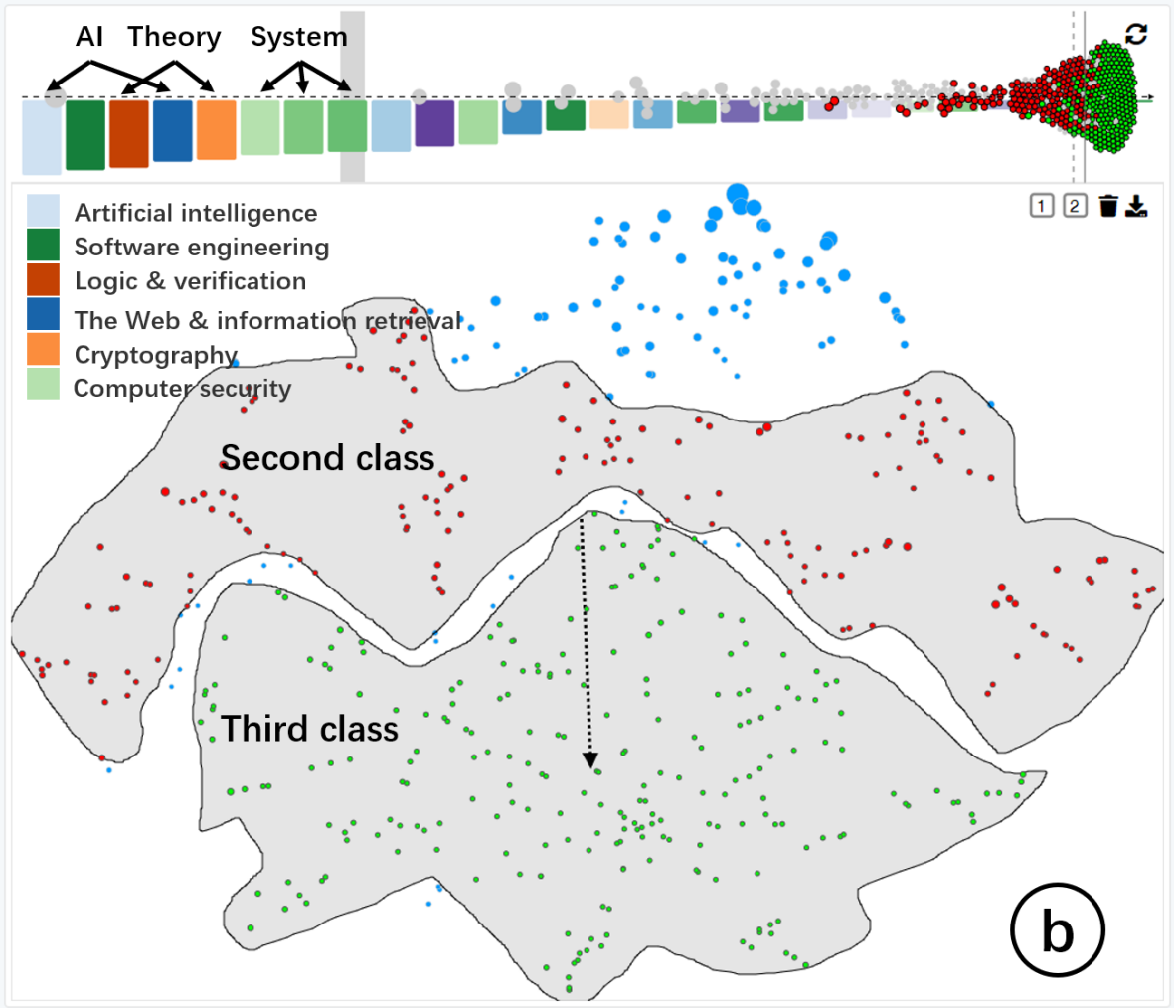
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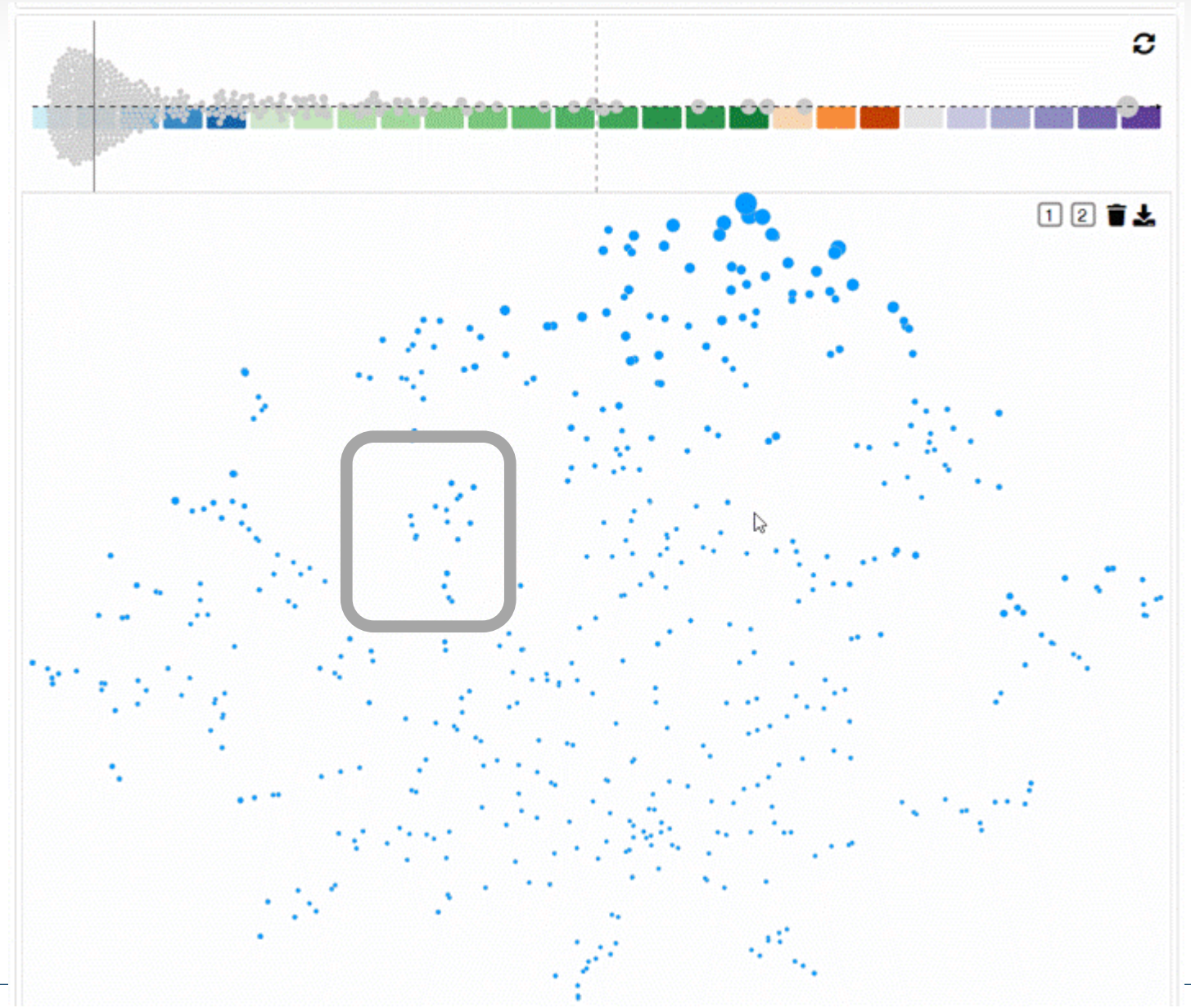
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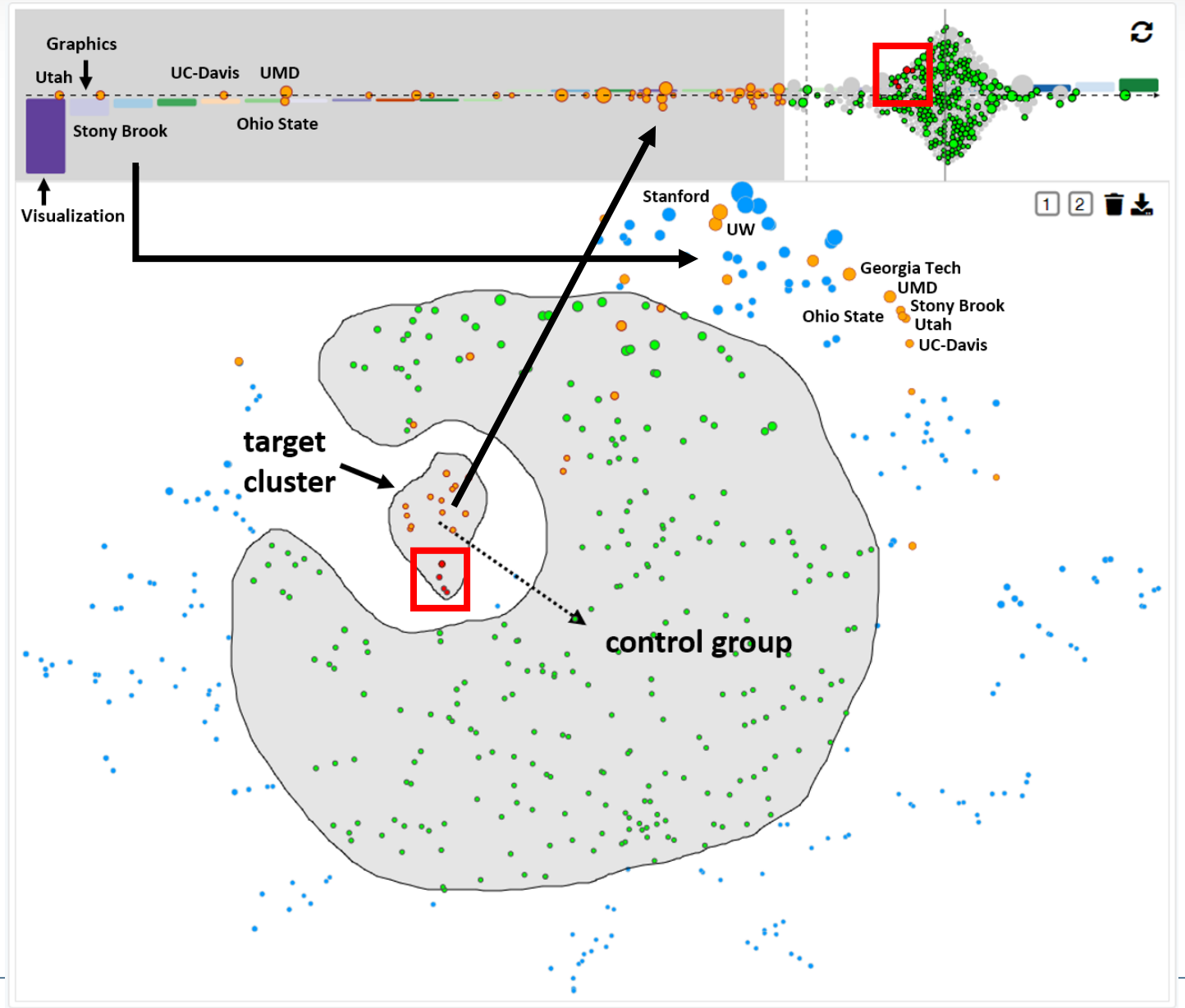
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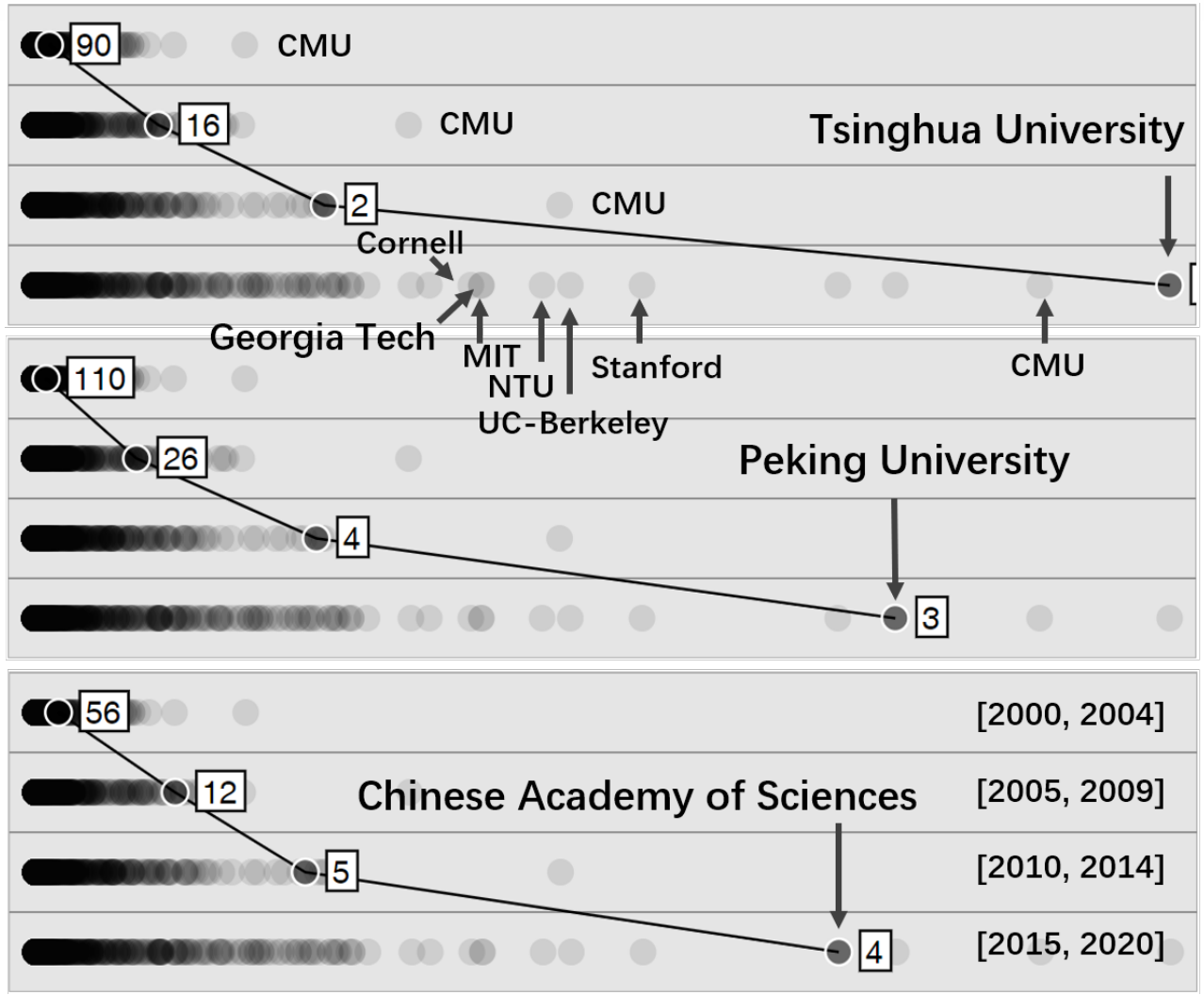
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Discussion

Non-linear semantics

The linearity of the our semantic axis makes it impossible to accurately describe the nonlinear semantics. But it gives a linear approximation of the nonlinear semantics, which tells the analyst what attributes are associated with the target semantics.

The choice of DR algorithm

Any DR algorithm can be used in the reduced space.
For linear DR algorithms, such as PCA, …
For nonlinear DR algorithms, such as t-SNE and UMAP, …

Conclusion

We present **semanticAxis**, a multi-attribute data analysis technique based on the idea of comparative analysis, which combines dimensionality reduction result understanding and multi-attribute data rankings into a unified exploration context.

We also designed a **visual analysis system** with semanticAxis as the core, which demonstrated the effectiveness of semanticAxis, and the rich components and interactions extended its analytical capabilities in complex analysis scenarios.

Due to its linear nature, semanticAxis does not precisely measure and interpret **nonlinear semantics**. But information provided by other components can alleviate this problem.