Empirical Guidance on Integral and Separable Marker Substrate for Large-Magnitude-Range Vector Field Visualization

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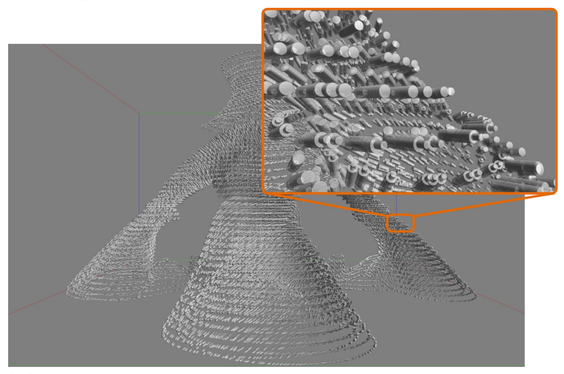
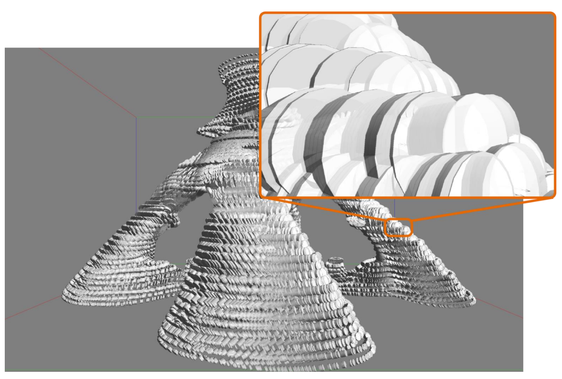
Which integral and separable dimension is better on bi-variate encoding for spatial large-magnitude-range vector fields?

Why?
To study the effectiveness and efficiency of visual encodings on bi-variate encoding in our SplitVectors approach, by comparing two theoretical foundations: *integral and separable variables* and *visual ranking ordering*.

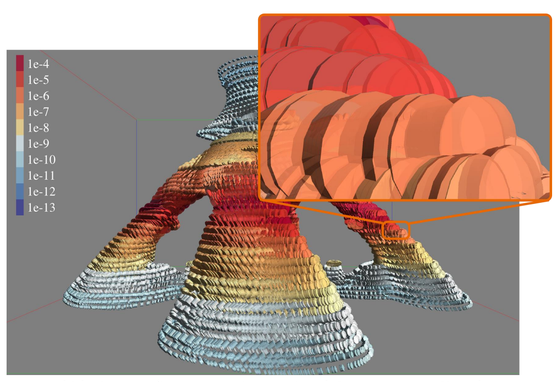
How?
An empirical study to compare five encodings (three separable, one integral, and one dual-encoding methods) on four tasks.



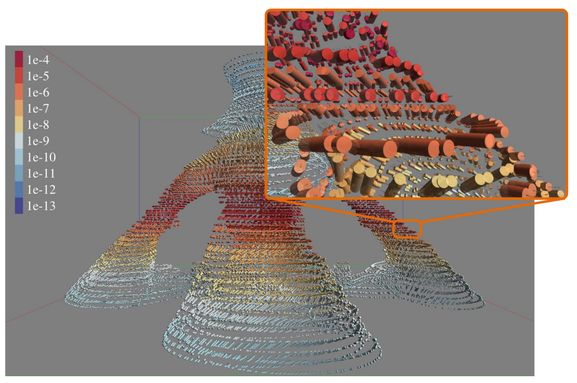
(1) Our previous SplitVectors: $Length_y$-$length_y$ (separable)



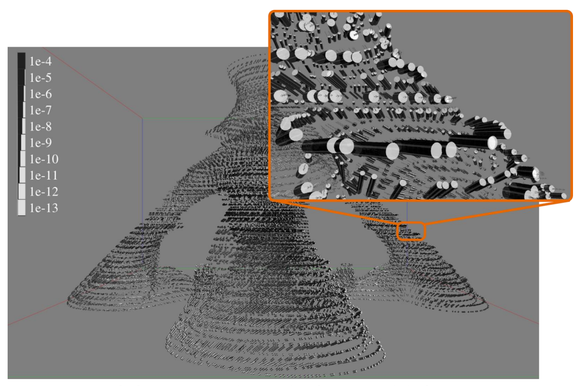
(2) $Length_x$-$length_y$ (integral)



(3) Color/$length_x$-$length_y$ (dual encoding)



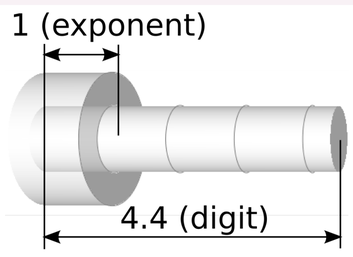
(4) Color-$length_y$ (separable)



(5) Texture-$length_y$ (separable)

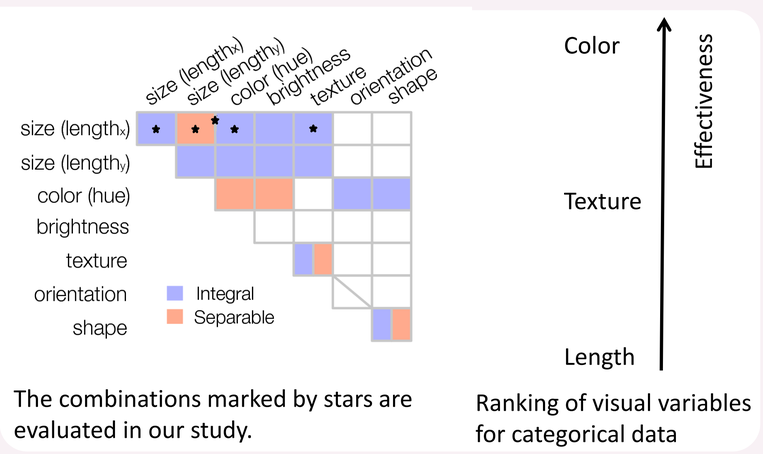
Motivations

Our previous SplitVectors approach [1] has improved accuracy by 10 times on *local* discrimination tasks for the large-magnitude-range vector fields, but failed for *global* pattern recognition tasks.



44 (4.4e1) is represented by SplitVectors approach.

We use integral and separable dimension theory [2] and Mackinlay's ranking theory [3] to allow both *local* and *global* visual discriminations by studying visual channel combinations.
If two dimensions are psychologically difficult to analyze and viewed holistically, they are integral; otherwise, the two dimensions are separable.



The combinations marked by stars are evaluated in our study.

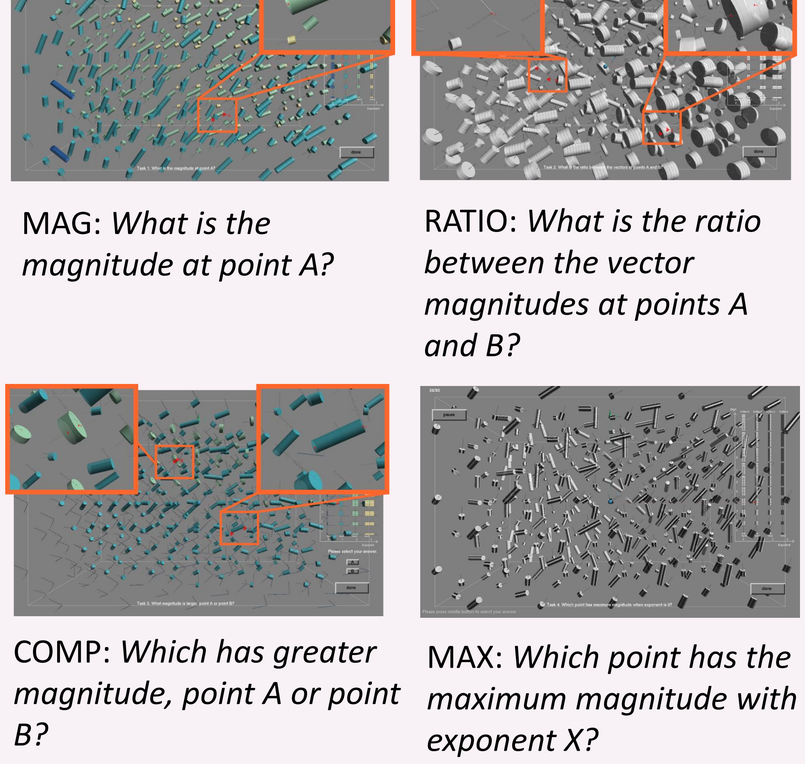
Ranking of visual variables for categorical data

Hypotheses

1) Color-$length_y$ may lead to the greatest speed and accuracy than $length_y$-$length_y$ and texture-$length_y$. [**supported**]
2) Color/$length_x$-$length_y$ may reduce time and improve accuracy than $length_x$-$length_y$. [**supported**]
3) On task MAG, RATIO and MAX, the ranking is color-$length_y$ > texture-$length_y$ > $length_y$-$length_y$, where ">" means better in terms of accuracy. [**not supported**]
4) On task COMP, color-$length_y$, texture-$length_y$ and color/$length_x$-$length_y$ may lead to less completion time than $length_y$-$length_y$ and $length_x$-$length_y$. [**supported**]

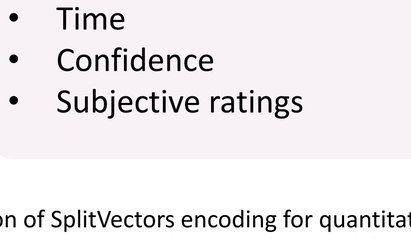
Empirical study

Independent variables:
(1) Five encodings

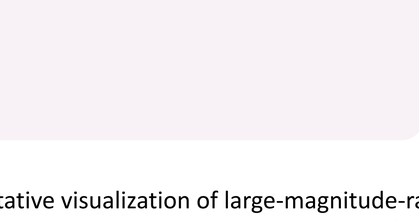


440 (4.4e2) is represented using (a) $length_y$-$length_y$ (b) $length_x$-$length_y$ (c) color/$length_x$-$length_y$ (d) color-$length_y$ (e) texture-$length_y$.

(2) Four Tasks



MAG: *What is the magnitude at point A?*



RATIO: *What is the ratio between the vector magnitudes at points A and B?*

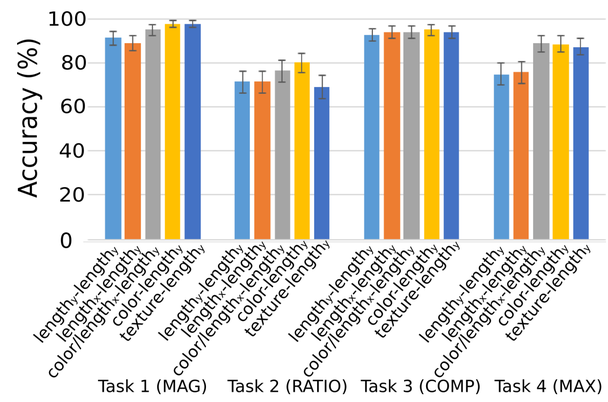
COMP: *Which has greater magnitude, point A or point B?*

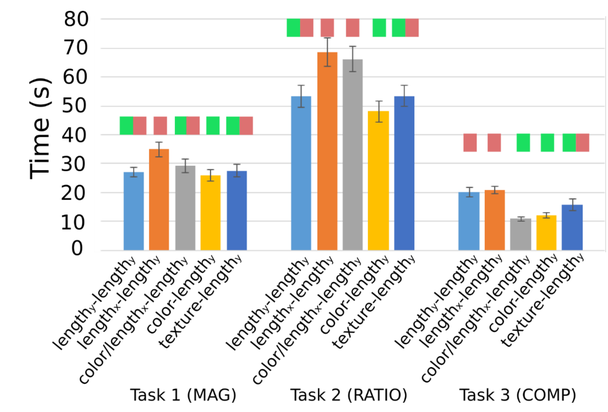
MAX: *Which point has the maximum magnitude with exponent X?*

Dependent variables:
- Error and accuracy
- Time
- Confidence
- Subjective ratings

Results

In the general trend, color-$length_y$ improved the accuracy better on task MAG,RATIO and COMP; color/$length_x$-$length_y$ improved the accuracy and speed better than $length_x$-$length_y$.





Conclusions

- Use color-$length_y$ if possible to encode SplitVectors;
- Use color-$length_y$ for MAG and RATIO tasks;
- Use color/$length_x$-$length_y$ or color-$length_y$ for COMP task;
- Use color/$length_x$-$length_y$, color-$length_y$, and texture-$length_y$ for MAX task.

Contributions

- Guidelines on selection of visual variables for large-magnitude-range vector fields.
- Statistical analysis on effectiveness and efficiency of five encoding approaches.
- Exploration of the use of integral and separable dimensions on spatial scientific data.

References: [1] H. Zhao, G. W. Bryant, W. Griffin, J. E. Terrill, and J. Chen. Validation of SplitVectors encoding for quantitative visualization of large-magnitude-range vector fields. IEEE Transactions on Visualization and Computer Graphics. 2016 (to appear). [2] W. R. Garner. The processing of information and structure. Psychology Press, 1974. [3] J. Mackinlay. Automating the design of graphical presentations of relational information. ACM Transactions on Graphics, 5(2):110–141, 1986.

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