Mining Historical Documents for Near-Duplicate Figures

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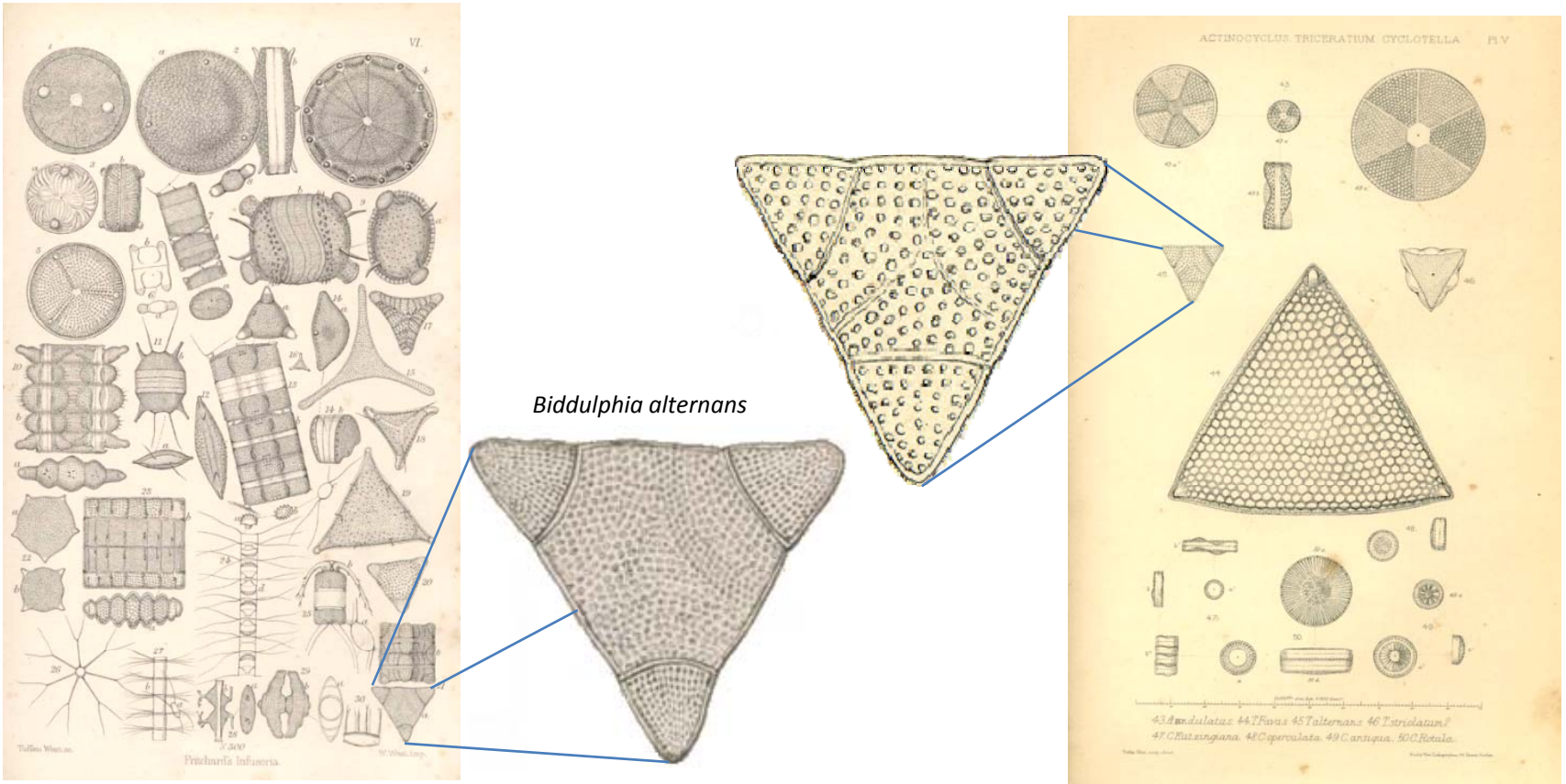
What is a near-duplicate pattern?

Same Species of diatoms in different books



A History of Infusoria, including Desmidiaceae and Diatomaceae, 1861.

A Synopsis of the British Diatomaceae, 1853.

Motivation

- There are about 130 million books in the world (according to Google 2010).
- Many are now digitized.
- Finding repeated patterns can ..
  - allow us to trace the evolution of cultural ideas
  - allow us to discover plagiarism
  - allow us to combine information from two different sources

Problem Statement

- Given 2 books and user defined parameters (i.e. size of motifs), find similar pattern/figures between these books in reasonable amount of time.

What is a “reasonable amount of time”?

- It can take minutes to hours for scanning a book.
- We would like to be able to discover similar figures in minutes or tens of minutes.
- This could be done offline (a ‘screensaver’ could work on you personal library at night).

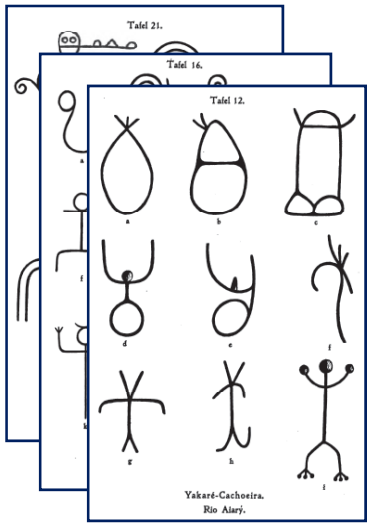
Objectives

- We propose an algorithm to discover similar patterns inside a manuscript or across 2 books.
- Our scalable method consider only *shape* so input documents can be b/w or color documents.
- Our method will return approximately repeated shape patterns in small amount of time.

Example Results (1)

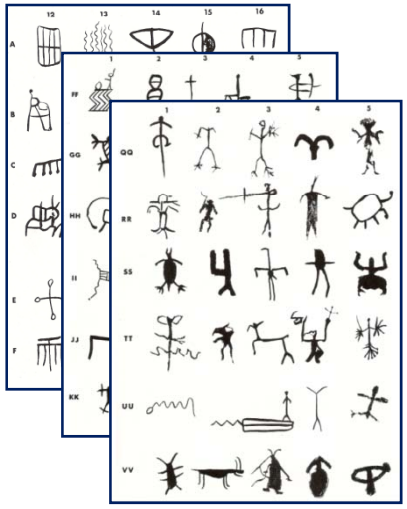
- Two Petroglyph Books

1st book



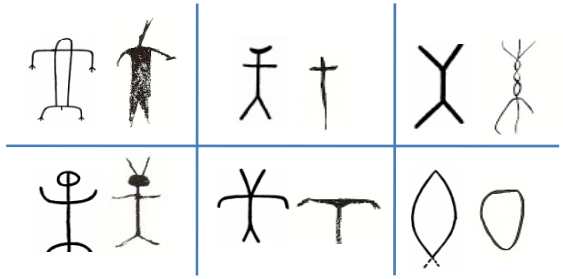
[1]

2nd book



[2]

Similar Figures

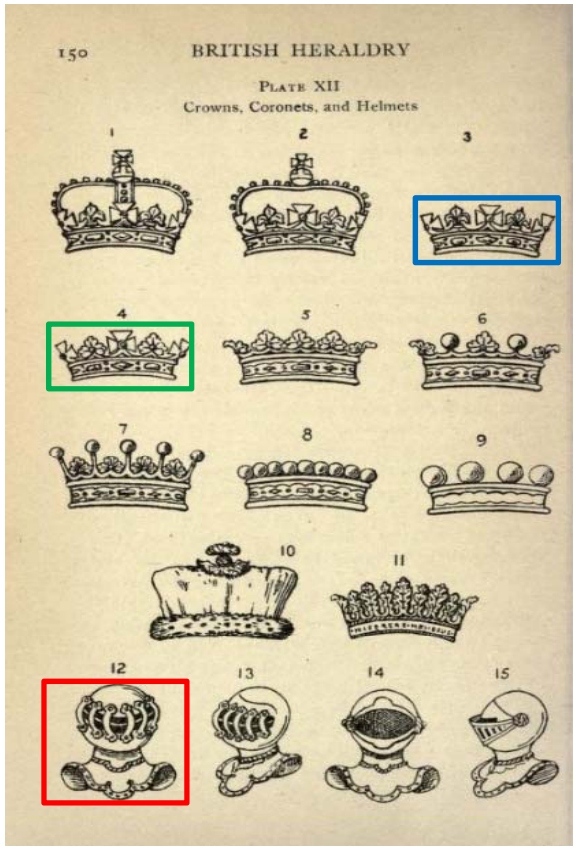


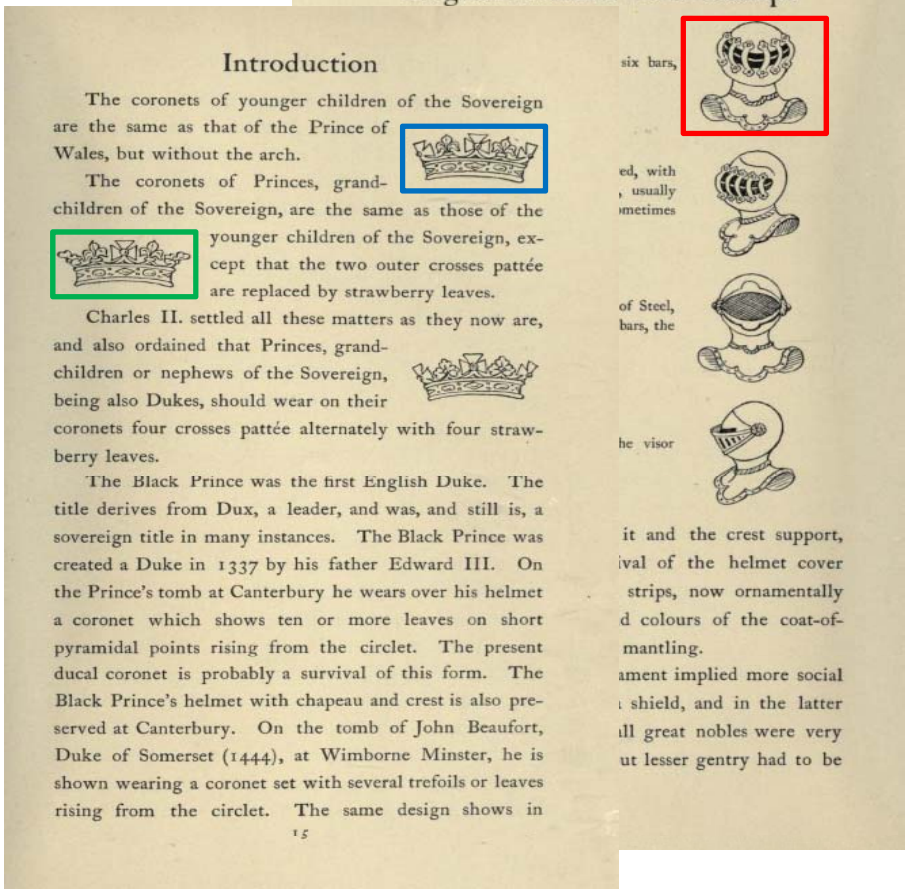
[1] Indian Rock Art of Southern California with Selected Petroglyph Catalog, 1975.

[2] Südamerikanische Felszeichnungen (South American Petroglyphs), Berlin, 1907.

Example Results (2)

- 25 seconds to find motifs across 2 books of size 478 pages and 252 pages.





Example Results (3)

- Similar figures from 4 different books are discovered.

Book1 [3]: Scottish Heraldry (243 pages)

Book2 [4]: Peeps at Heraldry (110 pages)

Book3 [5]: British Heraldry (252 pages)

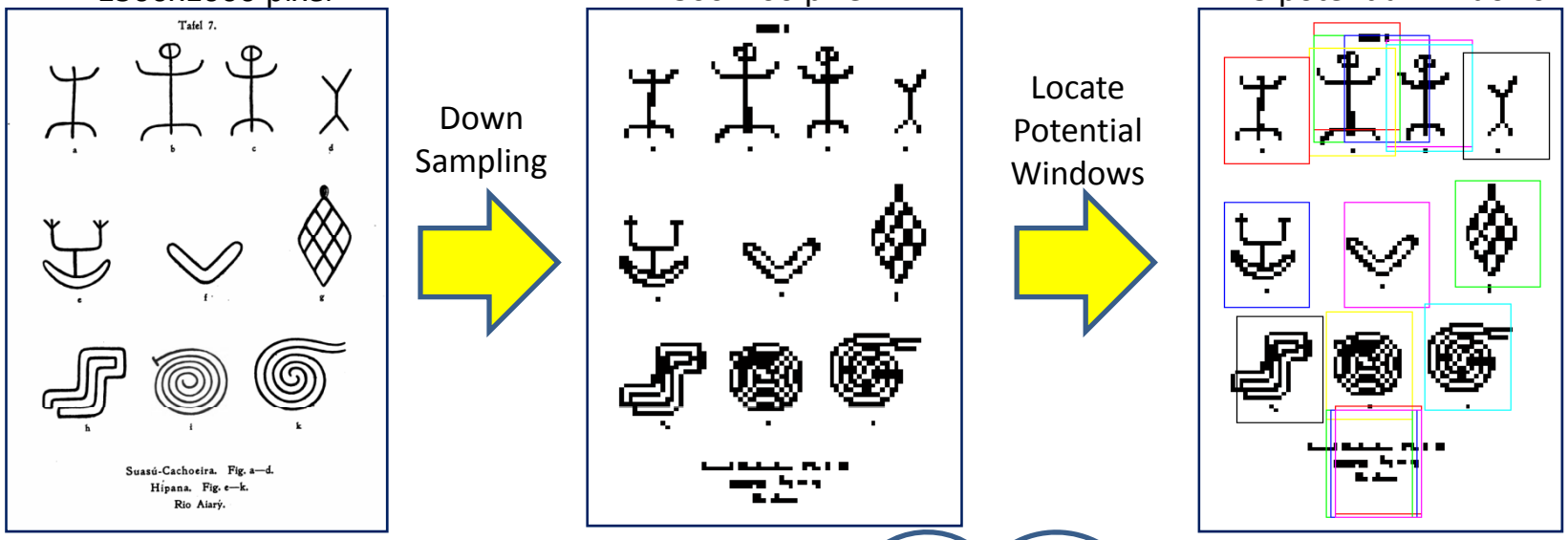
Book4 [6]: English Heraldry (487page)

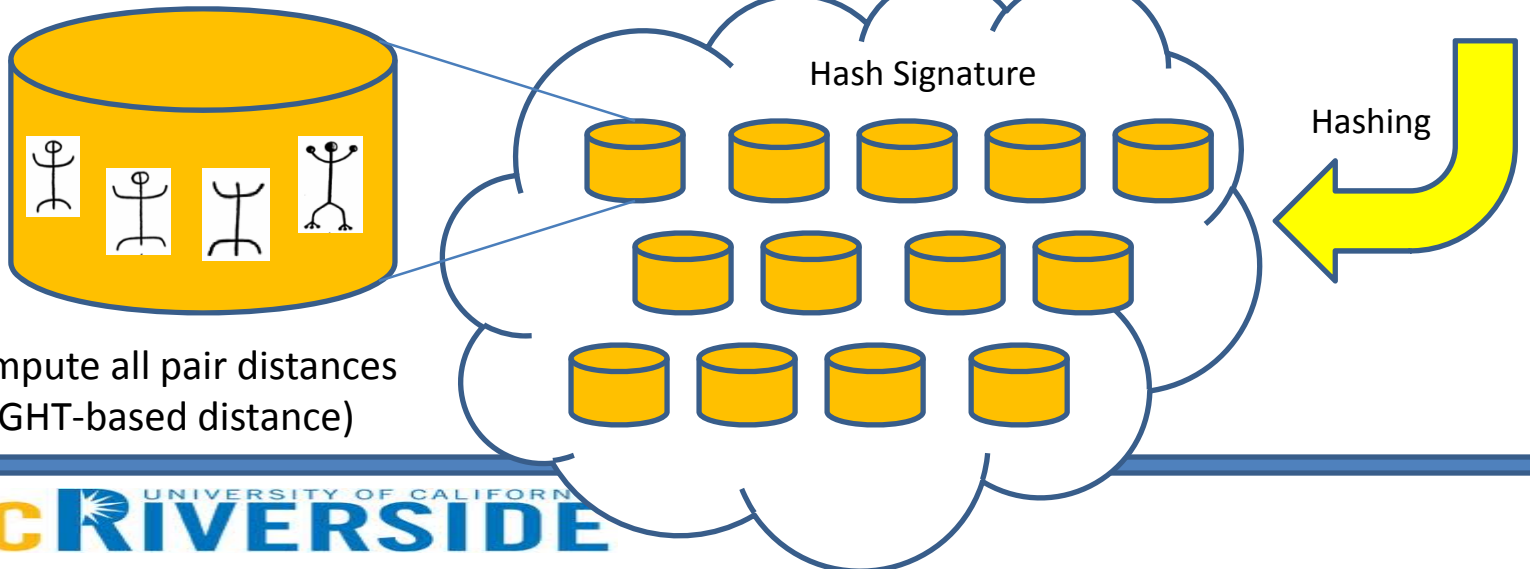
Example Results (4)

- Also works well for handwritten documents.

IAM dataset from Research Group on Computer Vision and Artificial Intelligence, University of Bern

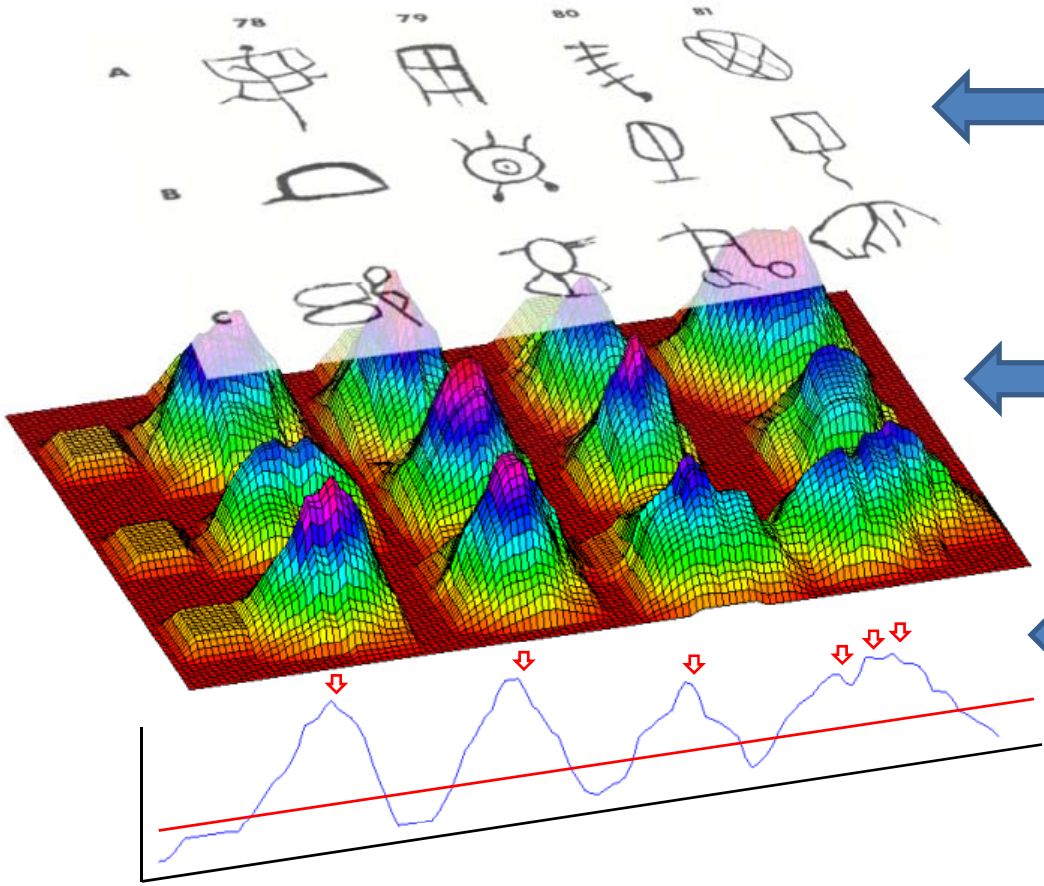
Overview of Our Algorithm





Locating Potential Windows

- Humans easily locate the figures. How?



Our observations ...

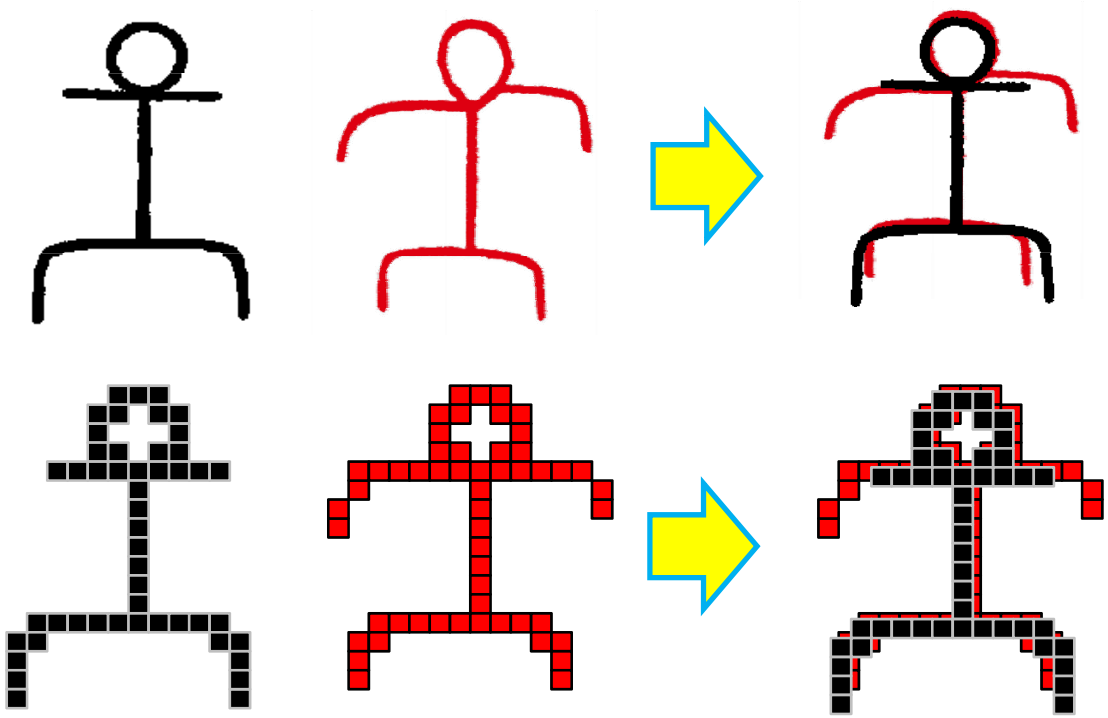
Document contain black and white pixels.

Count the number of black pixels around a fix pixel.

Locate figures by the peaks. Remove noise by threshold.

50,000 windows reduce to 20 potential windows.

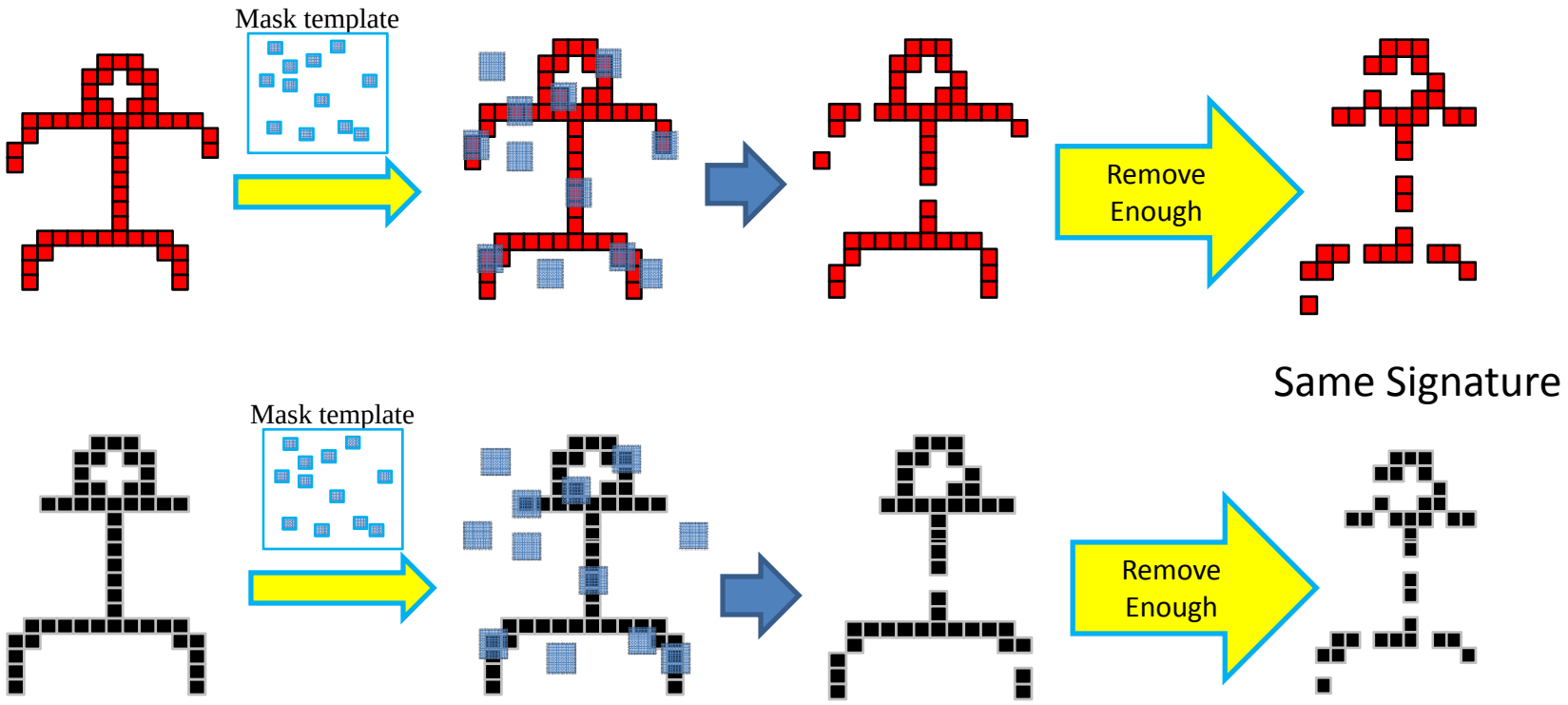
Down Sampling



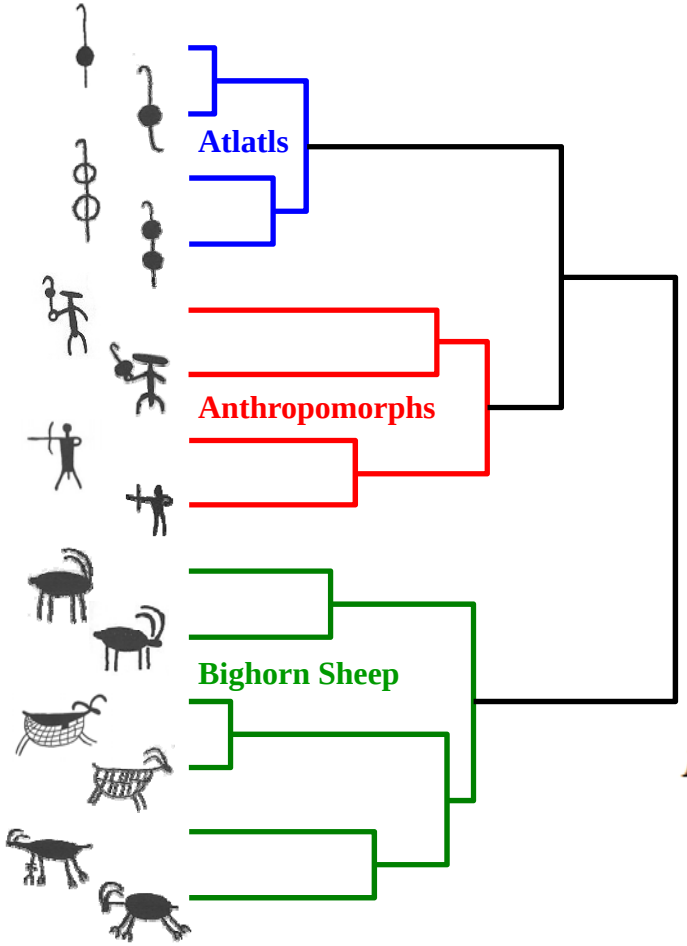
- Reduce search space.
- Increase the quality of matching.

Random Projection

- Hashing is an efficient way to reduce the number of expensive real distance calculations.



GHT-based Distance Calculation



GHT = Generalized Hough Transform

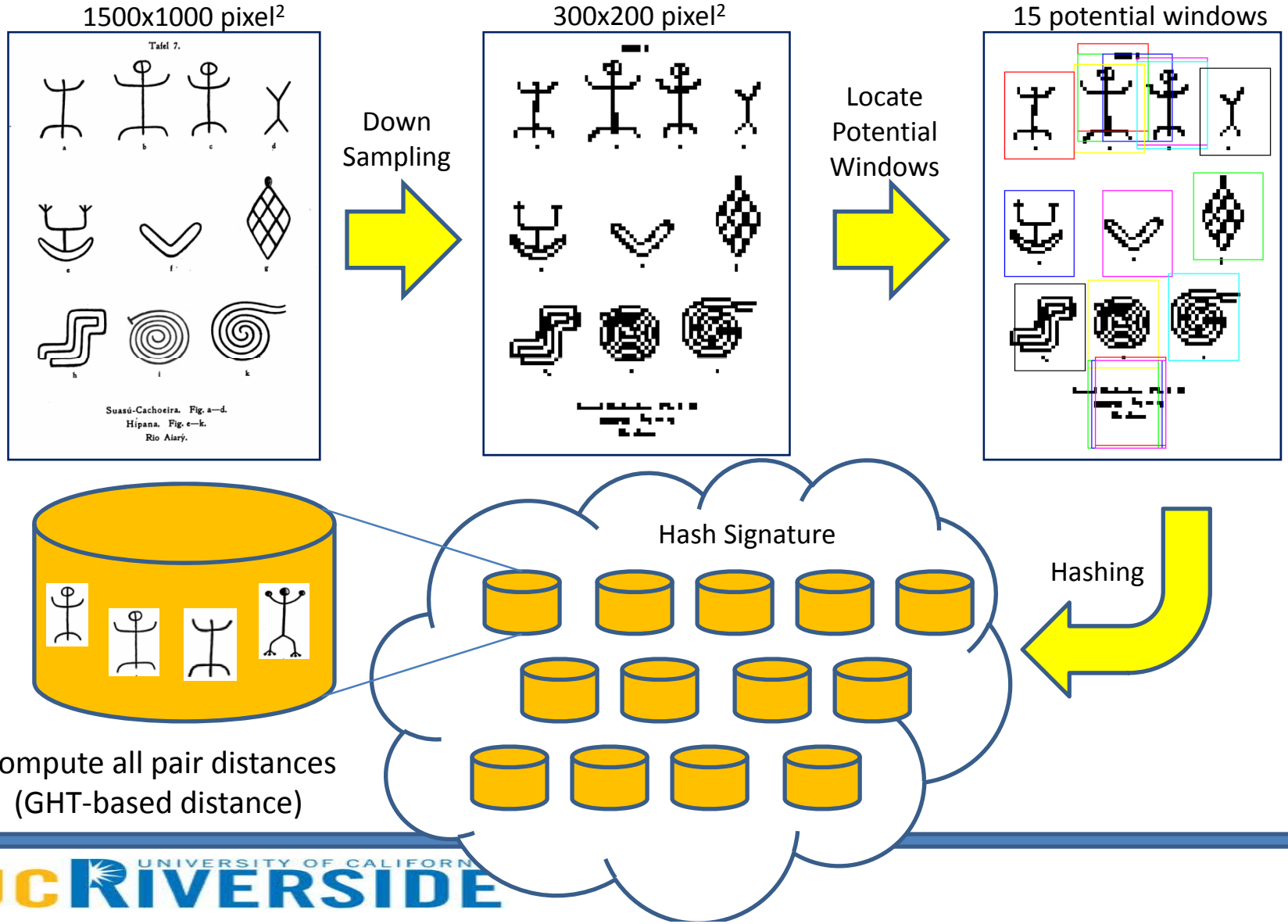
(1) GHT-based distance measure correctly groups all seven pairs.

(2) The higher level structure of the dendrogram also correctly groups similar petroglyphs.

$$Dnn(Q,C) = \begin{cases} \dfrac{1}{N_Q - MUE(Q,C)} \sqrt{N_C / N_Q} & \text{if } N_C > N_Q \\ \dfrac{1}{N_Q - MUE(Q,C)} & \text{otherwise} \end{cases}$$

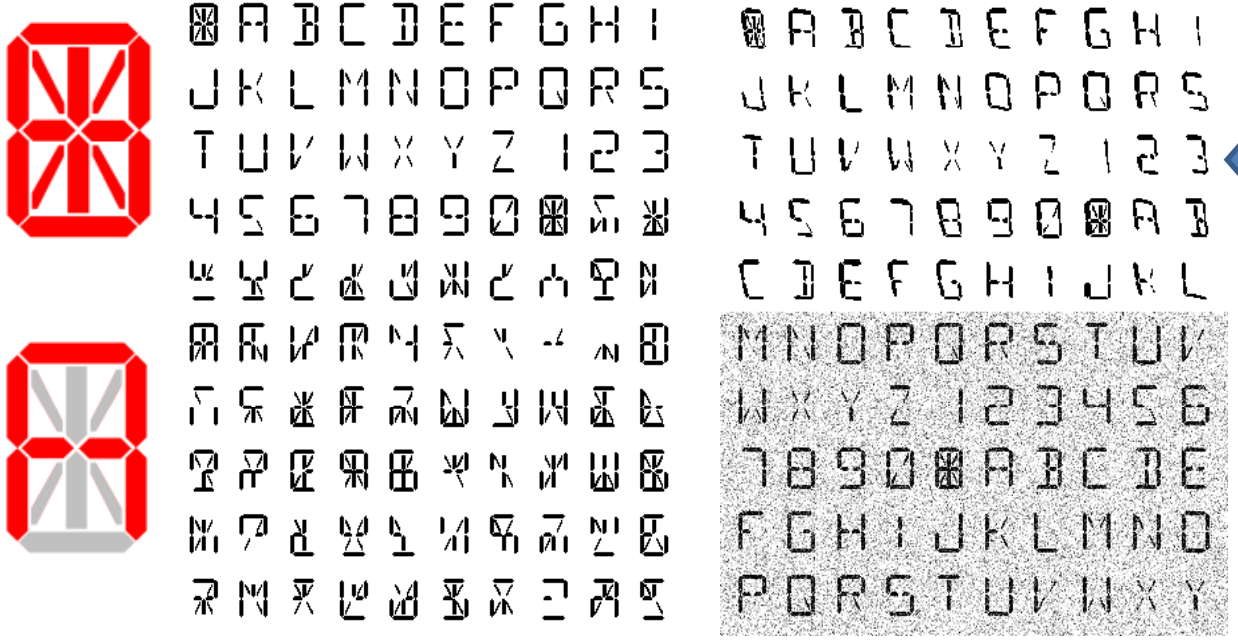
Figure and Equation from [14] Q. Zhu, X. Wang, E. Keogh and S.H. Lee, "Augmenting the Generalized Hough Transform to Enable the Mining of Petroglyphs," SIGKDD, 2009

Overview of Our Algorithm



Experimental Results

- The performance of our algorithm depends on dataset.
- We created artificial “books” to test on.
- Each page of book contains 100 random characters.
- Each characters contains 14 segments.

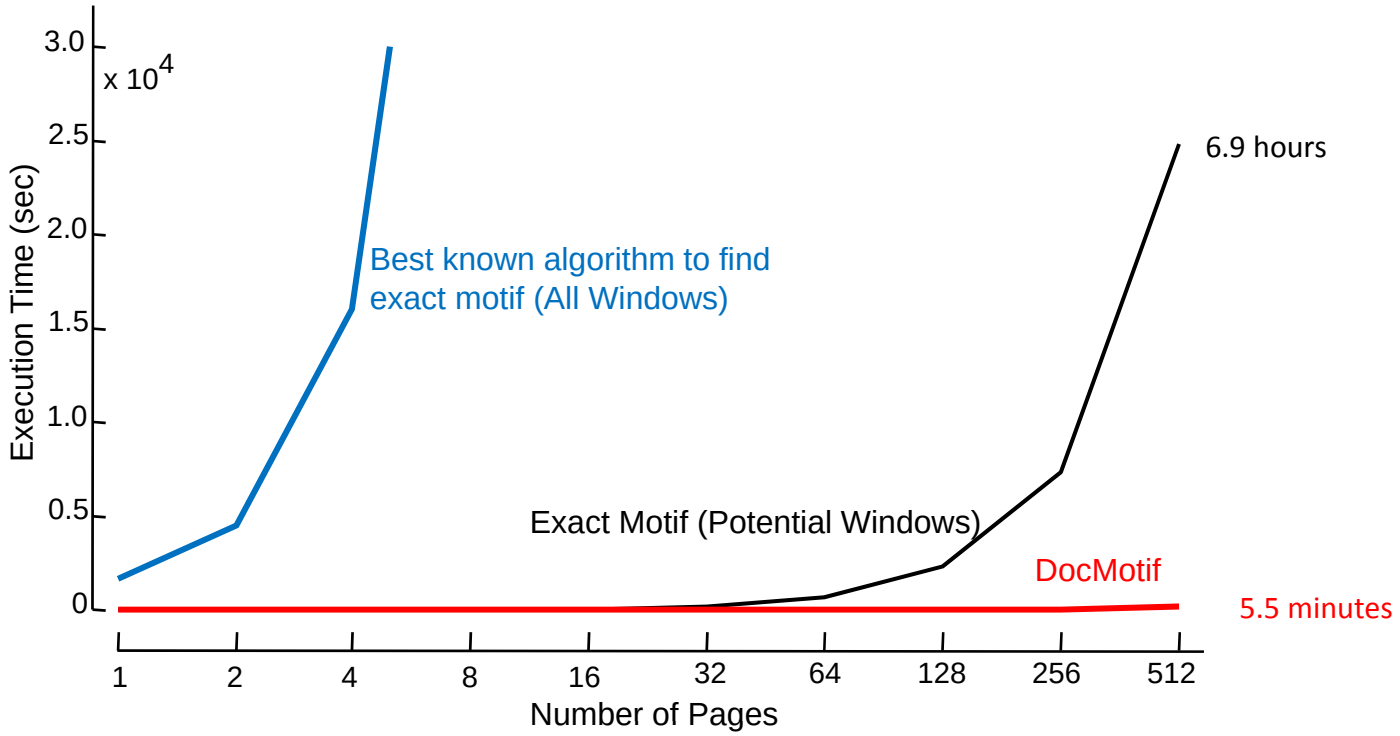


Polynomial Distortion

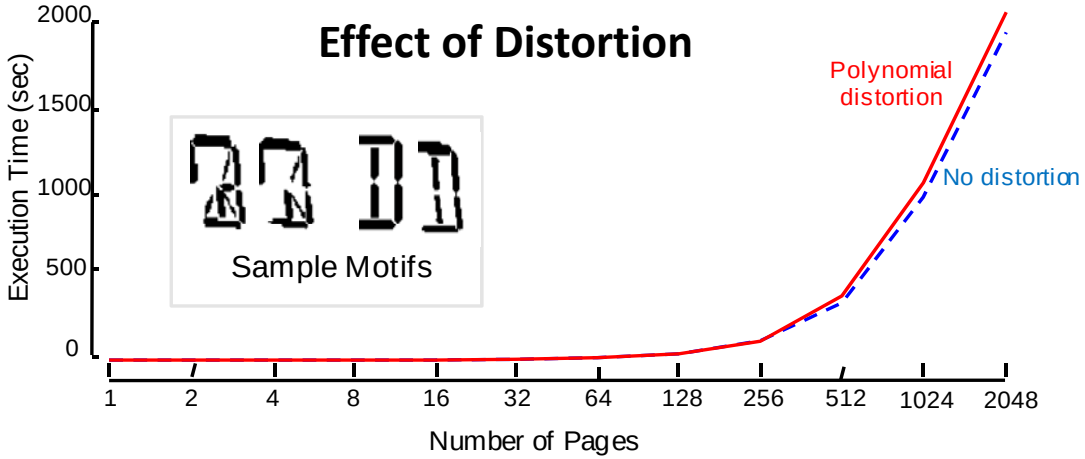
Gaussian Noise

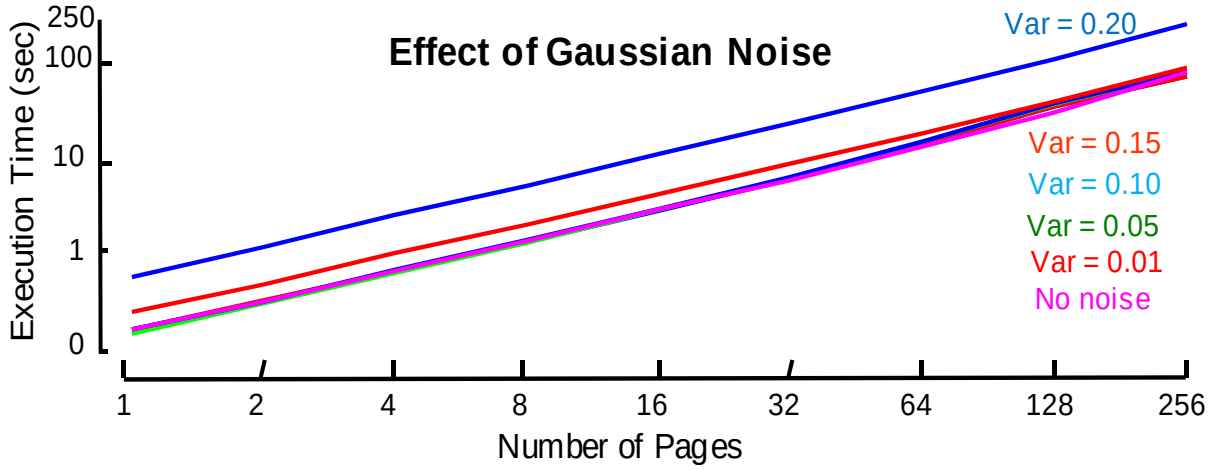
Experimental Results

- Our algorithm can find similar figures (motifs) from 100-page book in less than a minute.



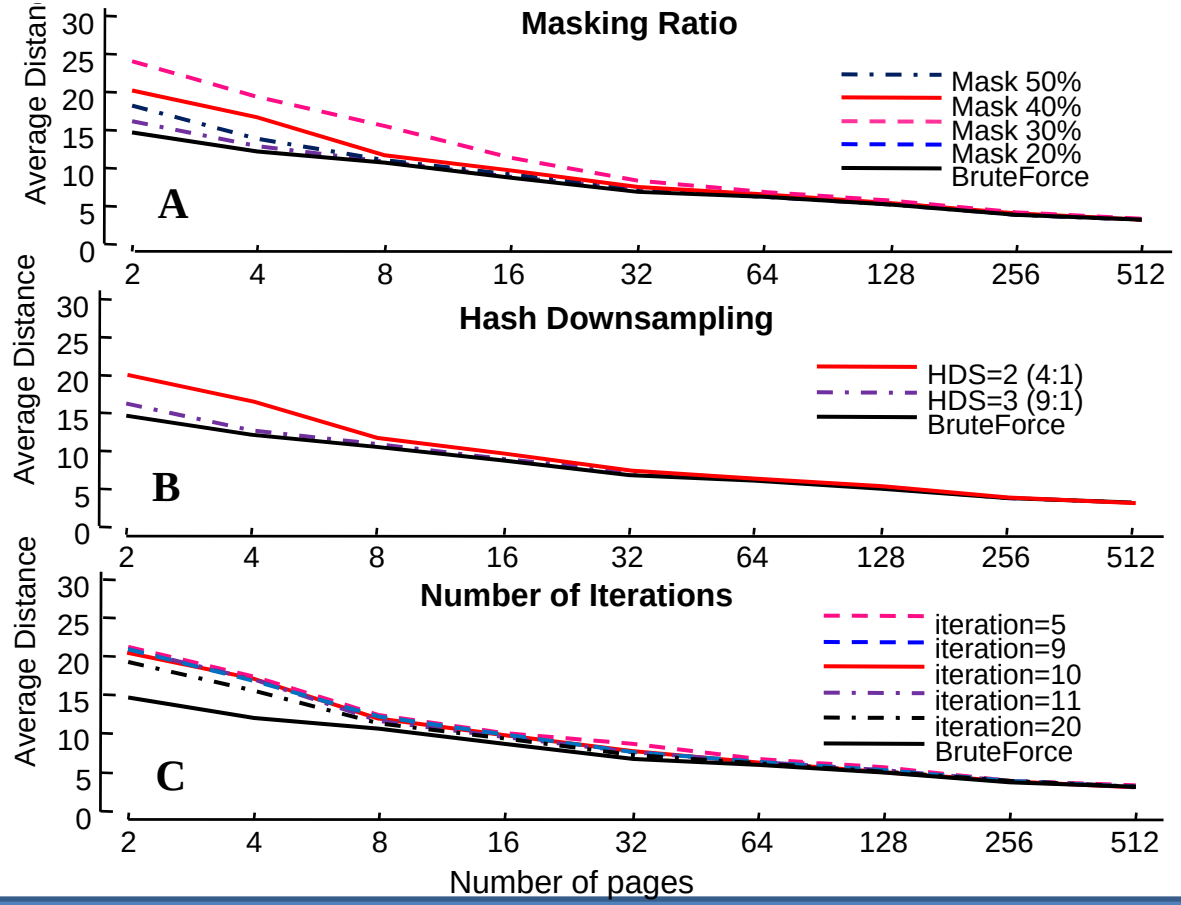
Scalability



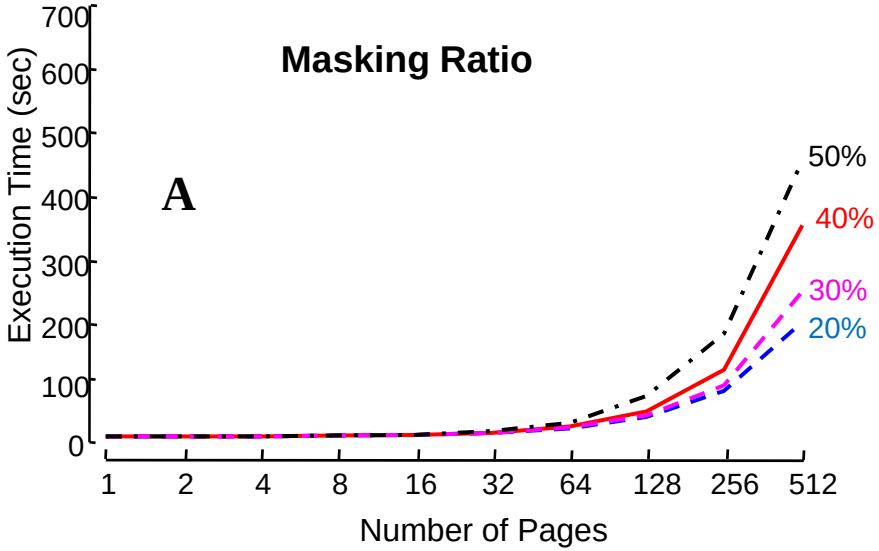


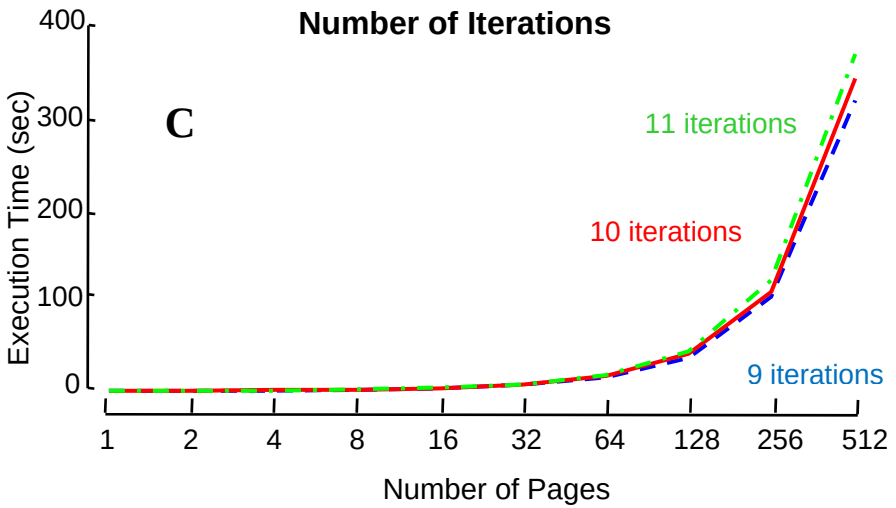
How Good of the Results?

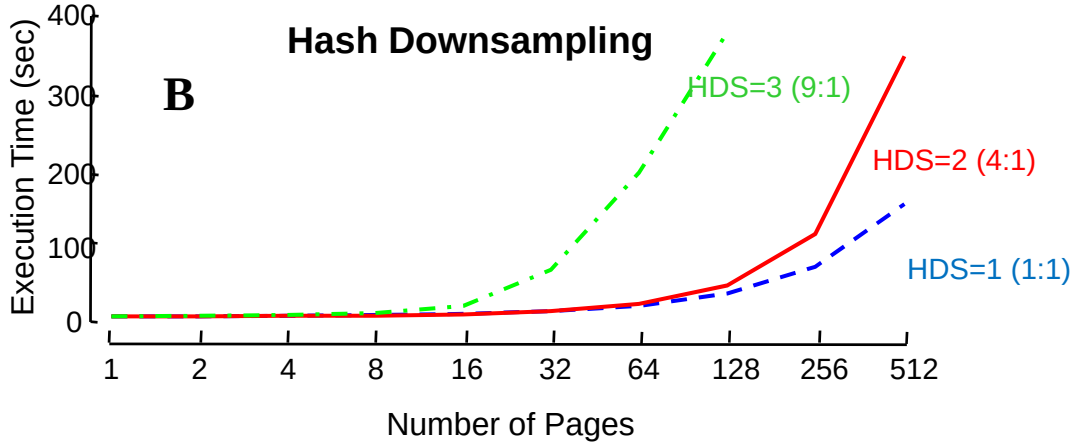
- The average distances from top 20 motifs are not much different among different parameter choices.



Parameter Effects







Conclusion

- An algorithm to find similar figures across two manuscripts.
  - Approximation algorithm
  - Work pretty well on both figures and text
  - Practical: very fast and very similar
- Key Ideas
  - Locating potential windows
  - Down Sampling
  - Random Projection
  - GHT-based Distance
- Drawbacks
  - Not support rotation invariance
  - Many parameters but not much sensitive

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Thank you for your attention

QUESTION?

Supplementary