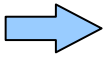
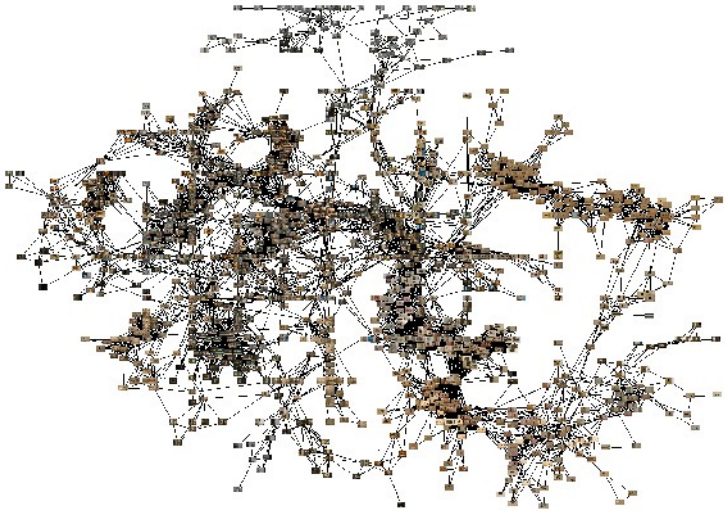
Image Webs

Computing and Exploiting Connectivity in Image Collections





Kyle Heath, Zixuan Wang – Stanford University

Challenges and opportunities in large image collections

- **Challenges**
  - Understanding what large collections contains
  - Finding the image or information you want

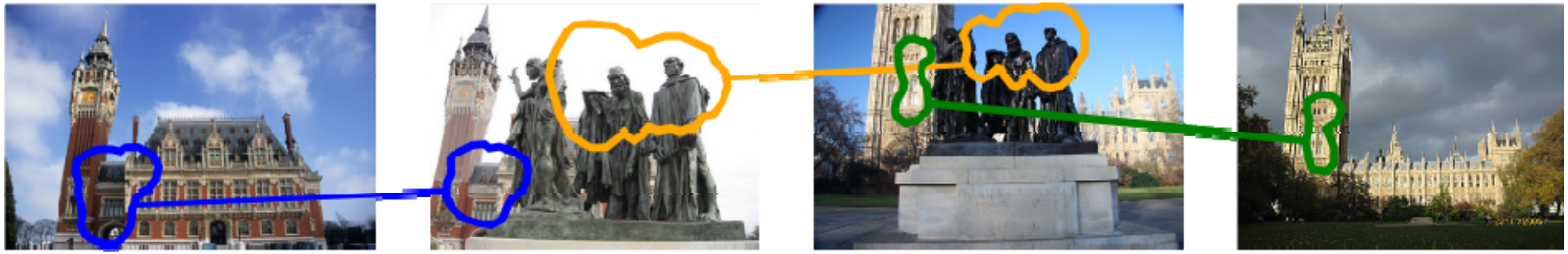
- **Opportunities**
  - Lots of visual information not searchable
  - Data-driven approach to hard problems

Goal: Link images together like web documents

- Discover "**visual hyperlinks**" between images in the collection induced by shared objects

- Exploit these links to search, visualize, and mine data from large image collections

Goal: Link images together like web documents

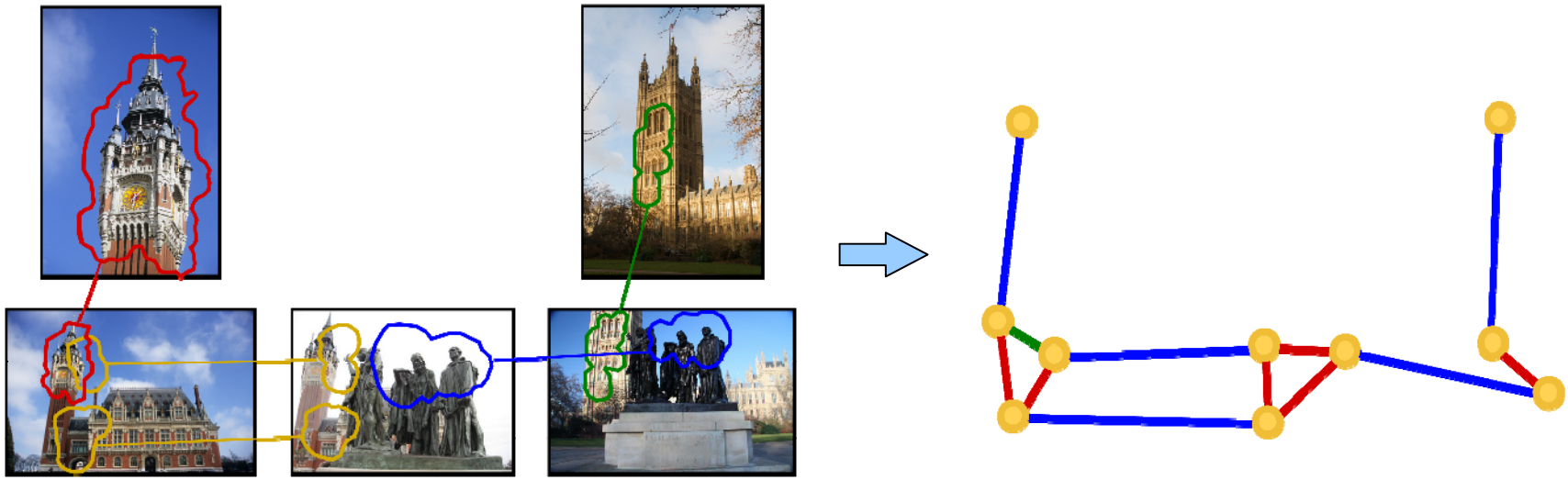


Overview

- What is an Image Web?
- Efficient construction
- Applications
  - Explore photo collections
  - Auto-annotate Flickr images
  - Mobile collaborative annotation

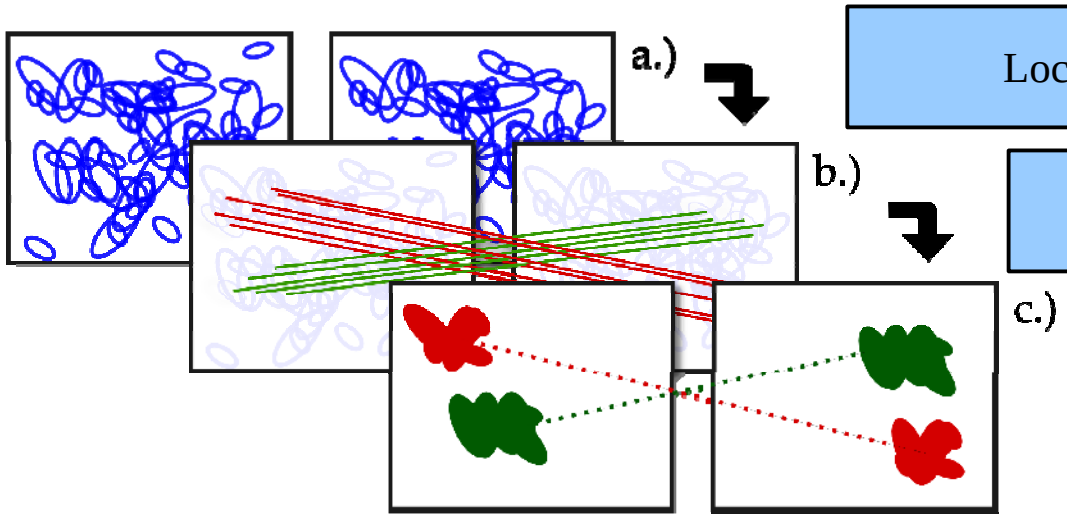
What is an Image Web?

- An **Image Web** is a graph generated by
  - Detecting corresponding regions in pairs of images
  - Forming links between these regions



Affine cosegmentation

Goal: Detect the shared region between a pair of images

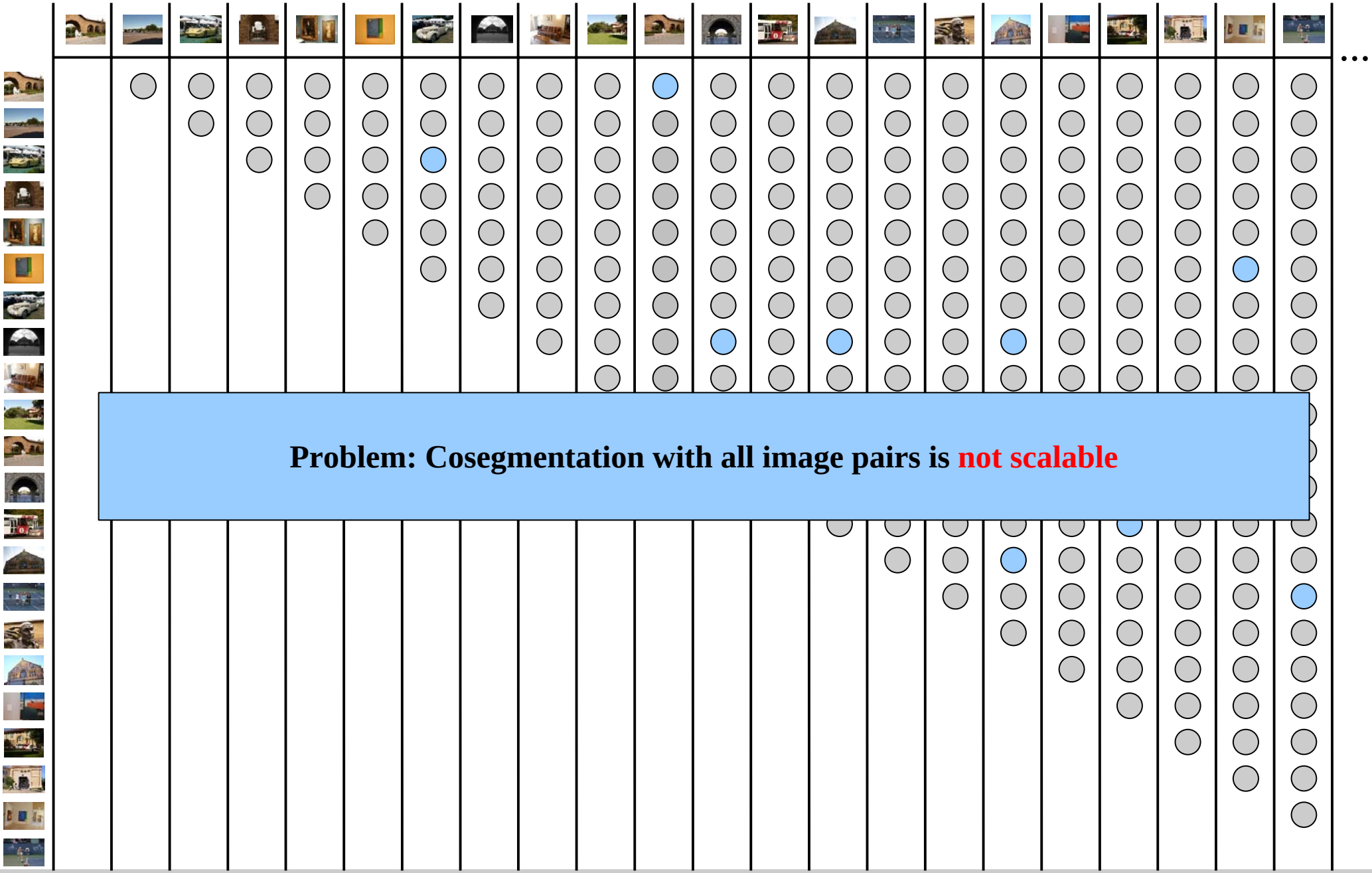


Local Feature Extraction

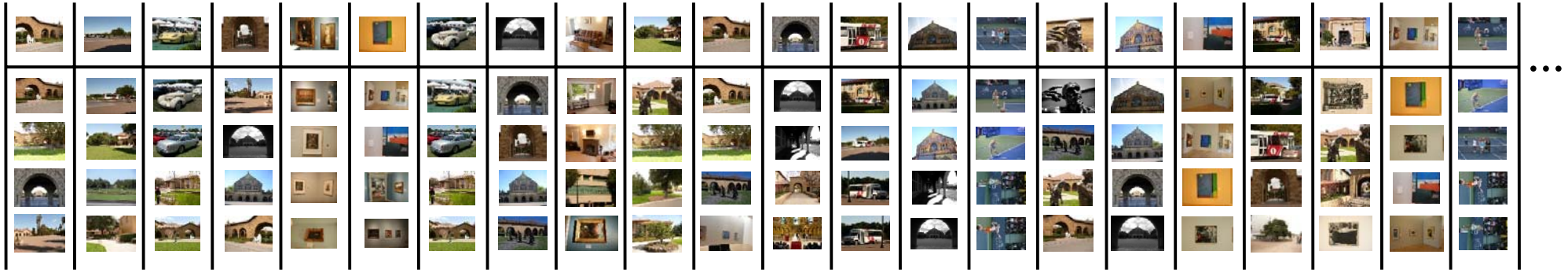
Feature Matching & Verification

Shared Region Segmentation

Ideal Image Web construction



Phase 1: Discover connected components



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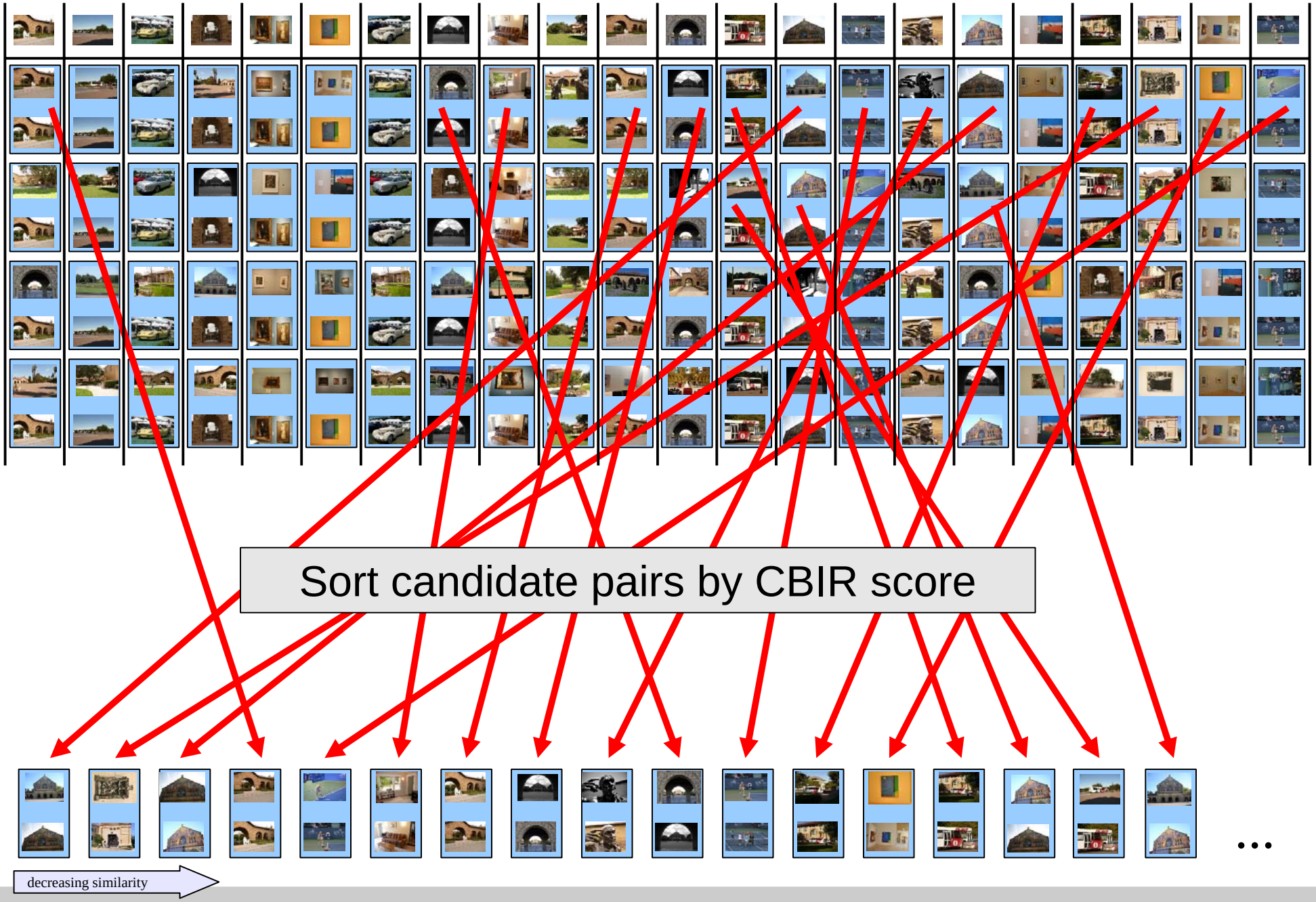

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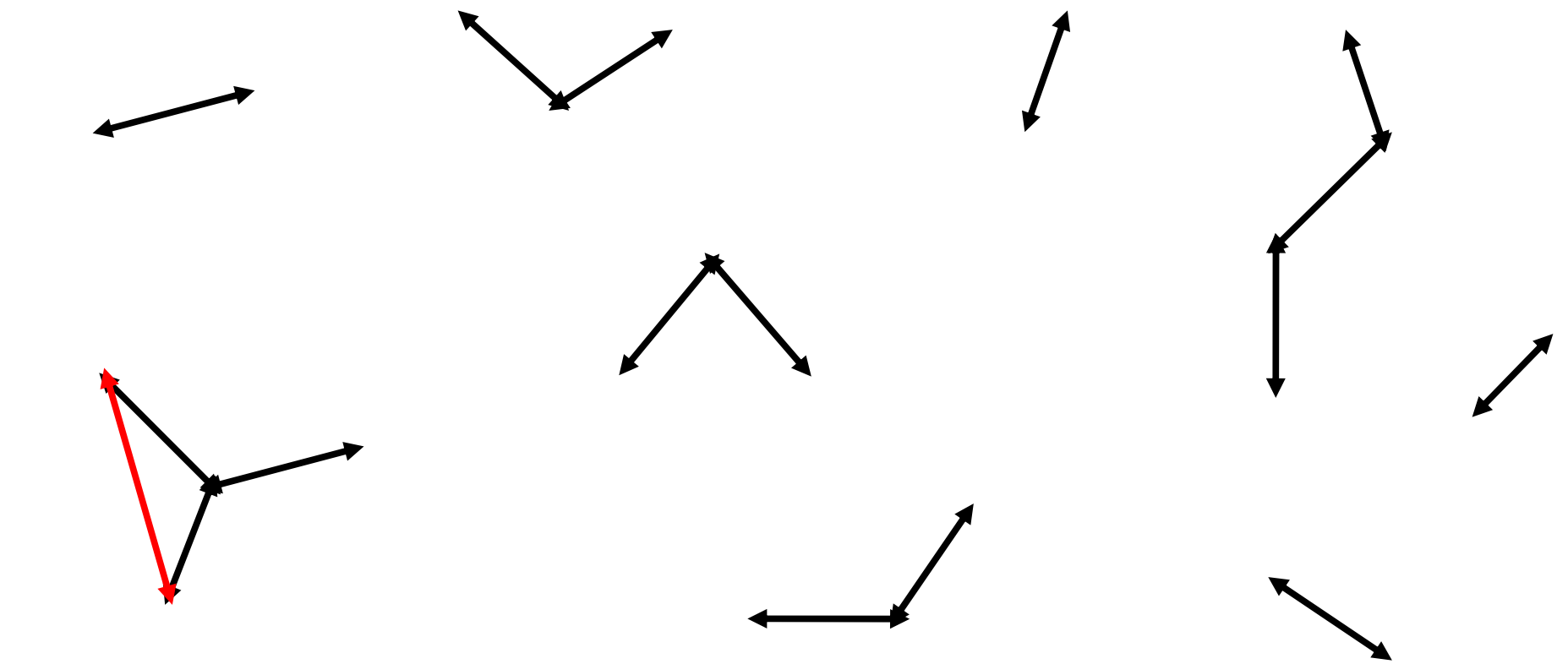
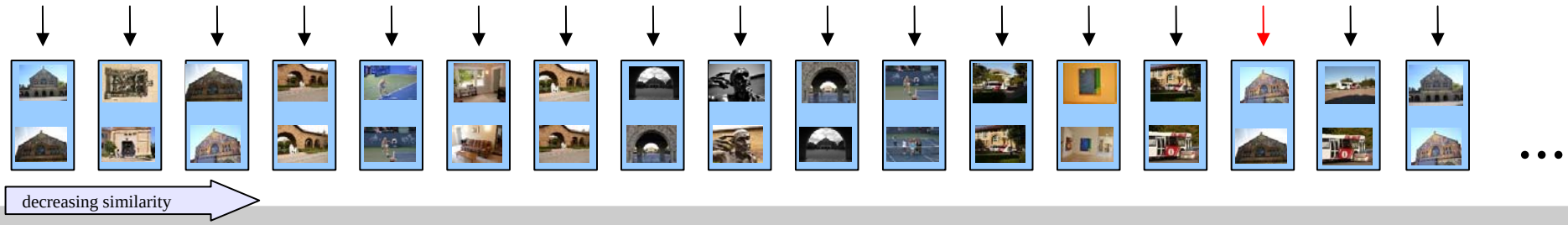
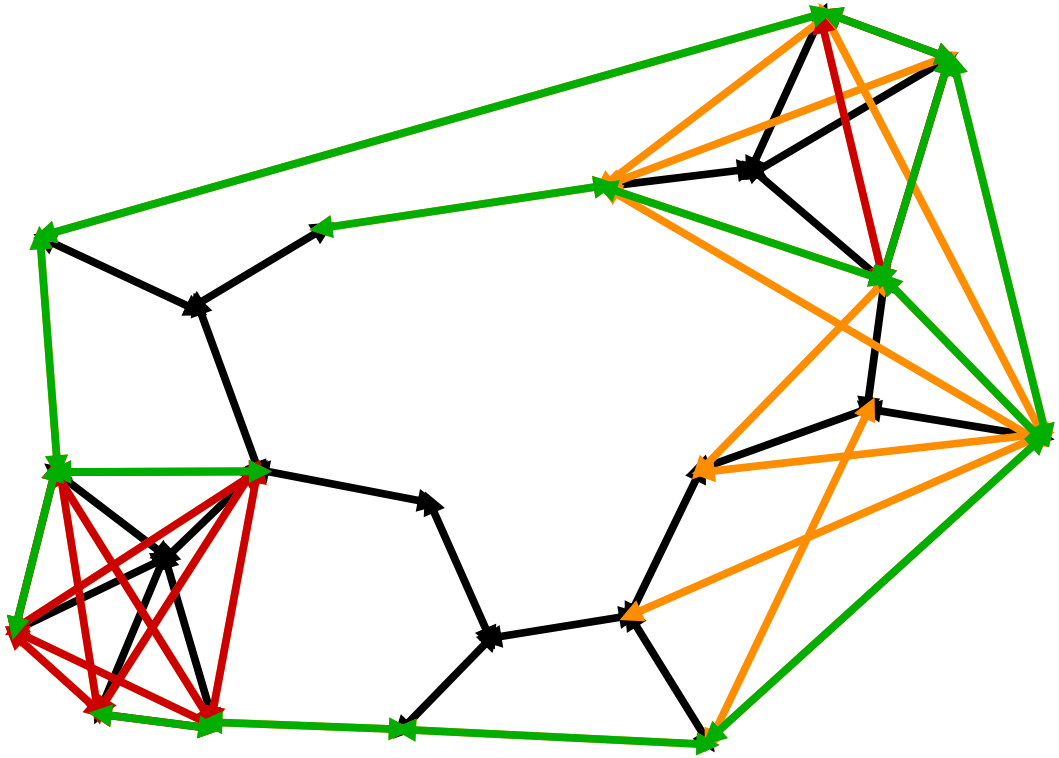




Phase 2: Recover component structure

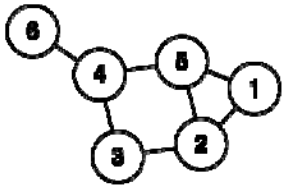


Phase 2: Boost component connectivity

- Use a notion of connectivity from spectral graph theory called ***algebraic connectivity***
  - *Defined as the second smallest eigenvalue (λ_2) of the graph Laplacian matrix L*

$$L_{i,j} = \begin{cases} d(i) & \text{if } i = j \\ -1 & \text{if } (i,j) \in E \\ 0 & \text{otherwise} \end{cases}$$

Example*



$$\begin{pmatrix} 2 & -1 & 0 & 0 & -1 & 0 \\ -1 & 3 & -1 & 0 & -1 & 0 \\ 0 & -1 & 2 & -1 & 0 & 0 \\ 0 & 0 & -1 & 3 & -1 & -1 \\ -1 & -1 & 0 & -1 & 3 & 0 \\ 0 & 0 & 0 & -1 & 0 & 1 \end{pmatrix}$$

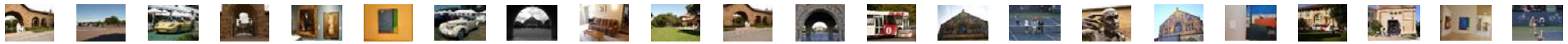
$d(i)$ is the degree of vertex i

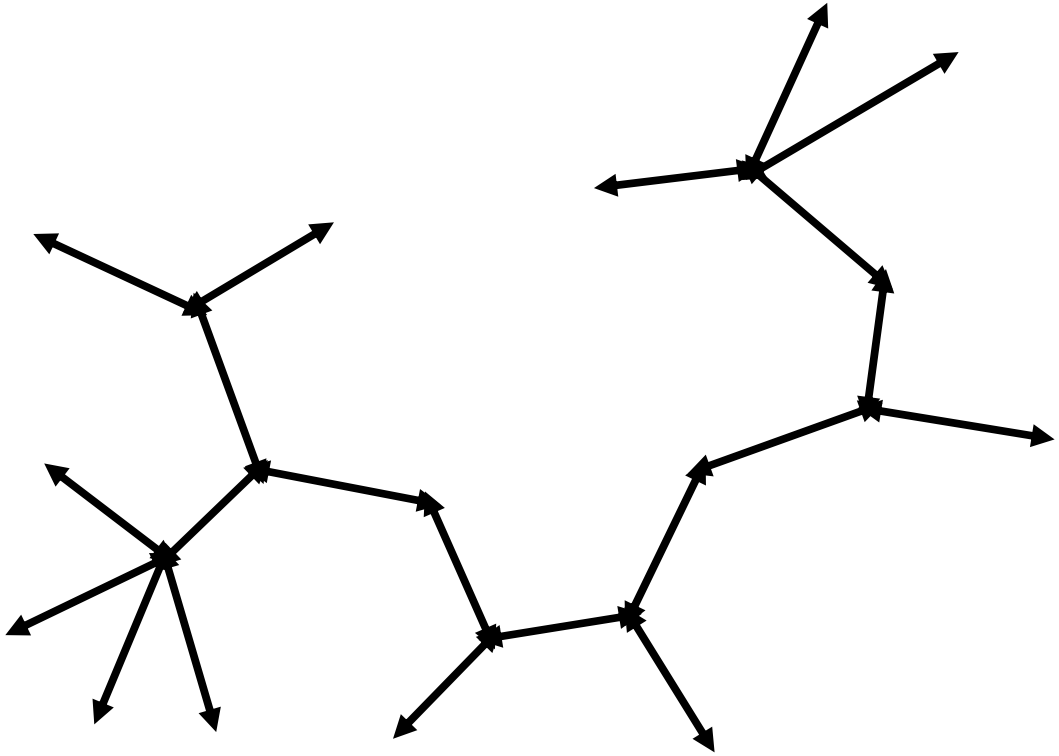
  - *Eigenvector of L corresponding to λ_2 is v_2, called the Fiedler vector*

$$e = (s,t) \qquad c_e = |v_2(s) - v_2(t)|$$

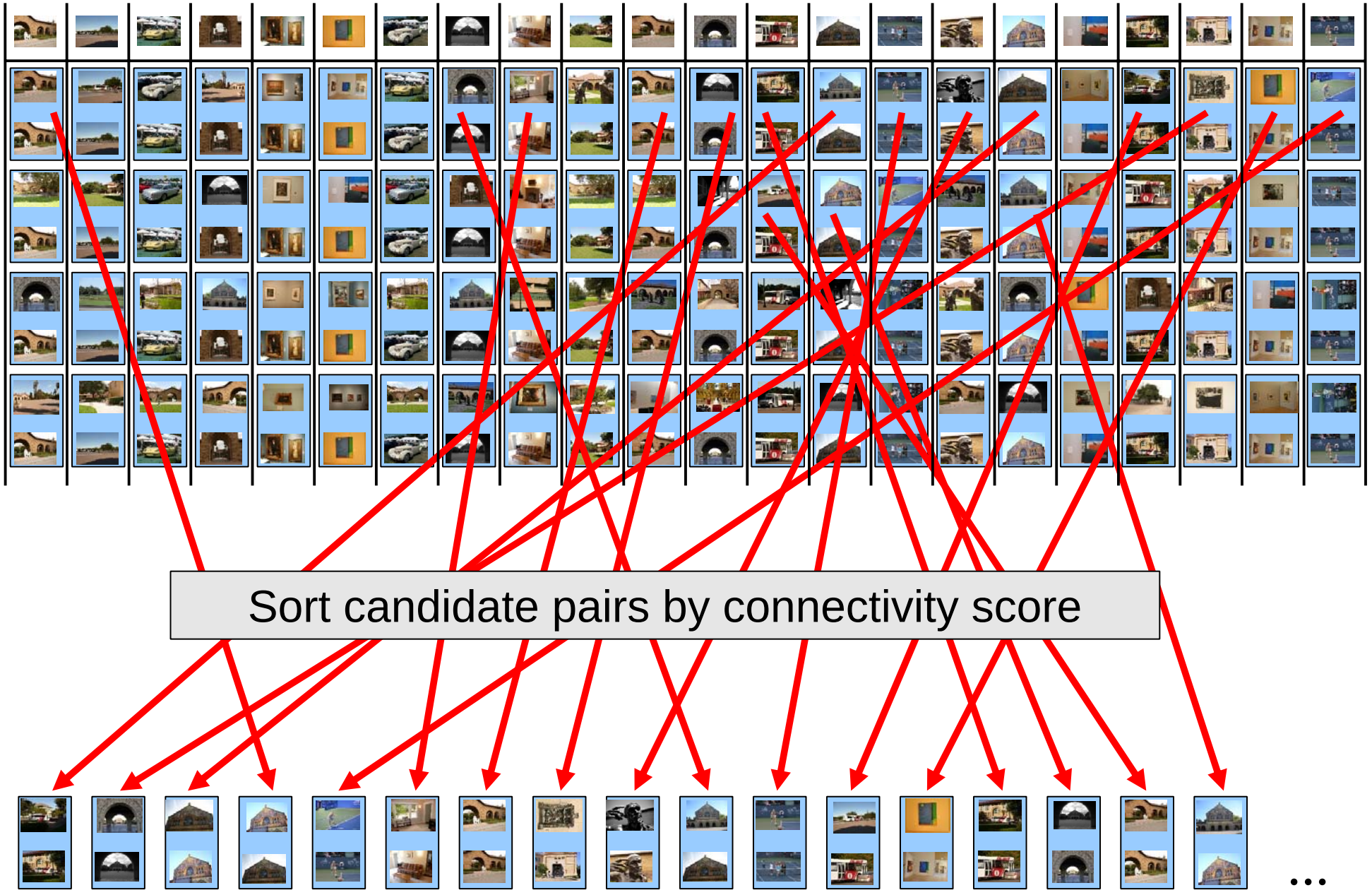
* shamelessly lifted from Wikipedia

Phase 2: Recover component structure





Phase 2: Boost component connectivity



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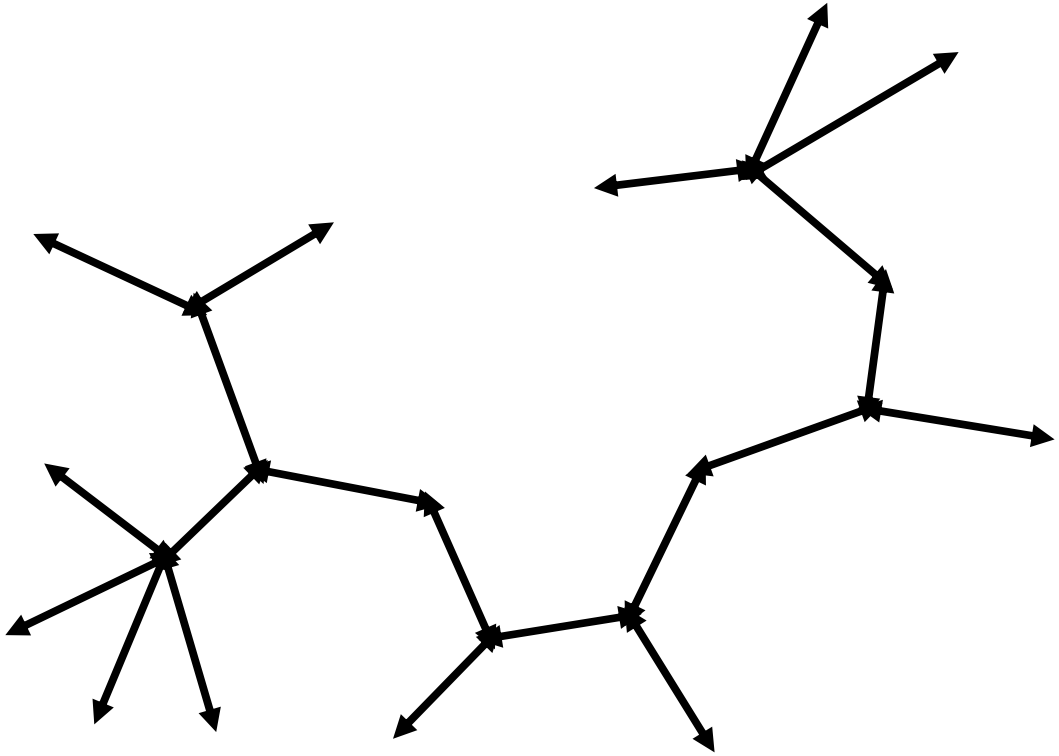
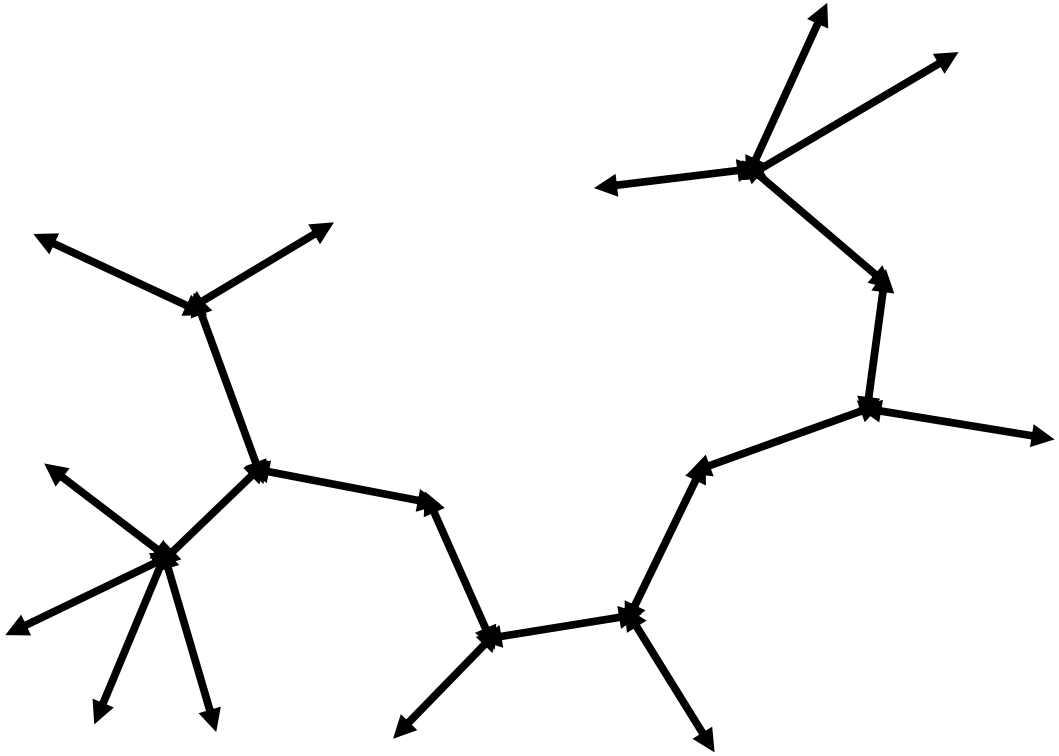
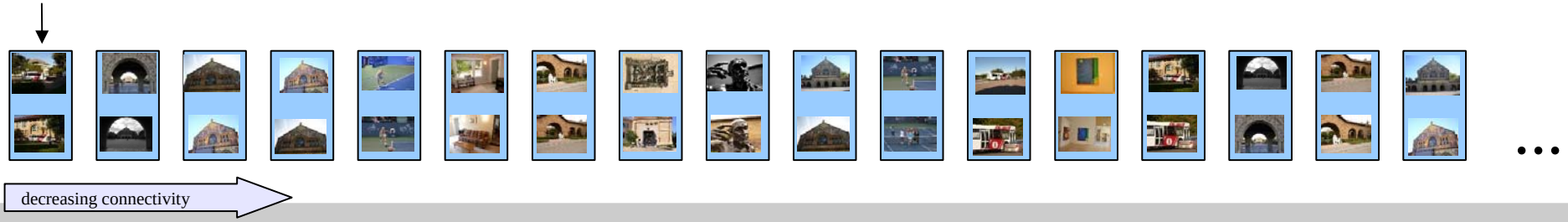


decreasing connectivity

Phase 2: Boost component connectivity





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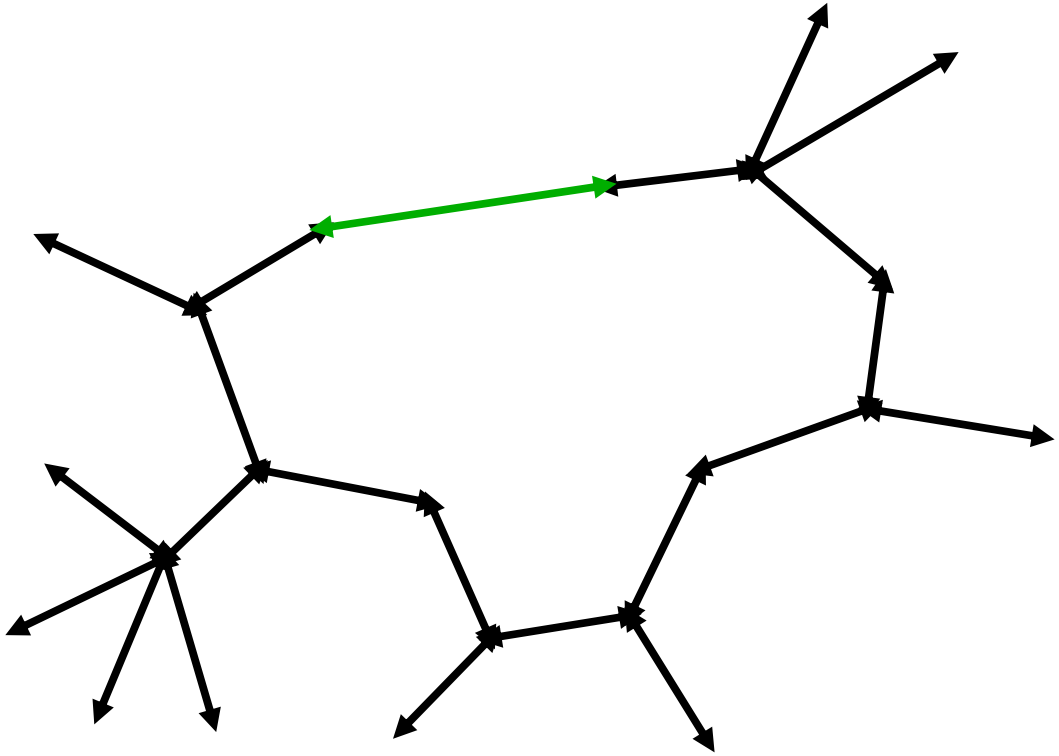

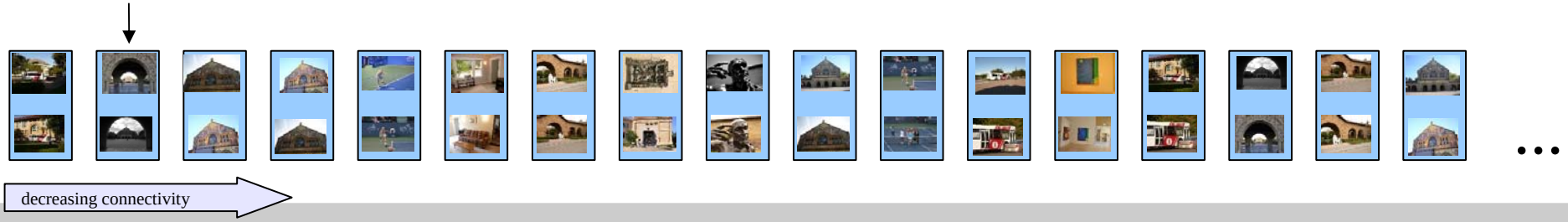

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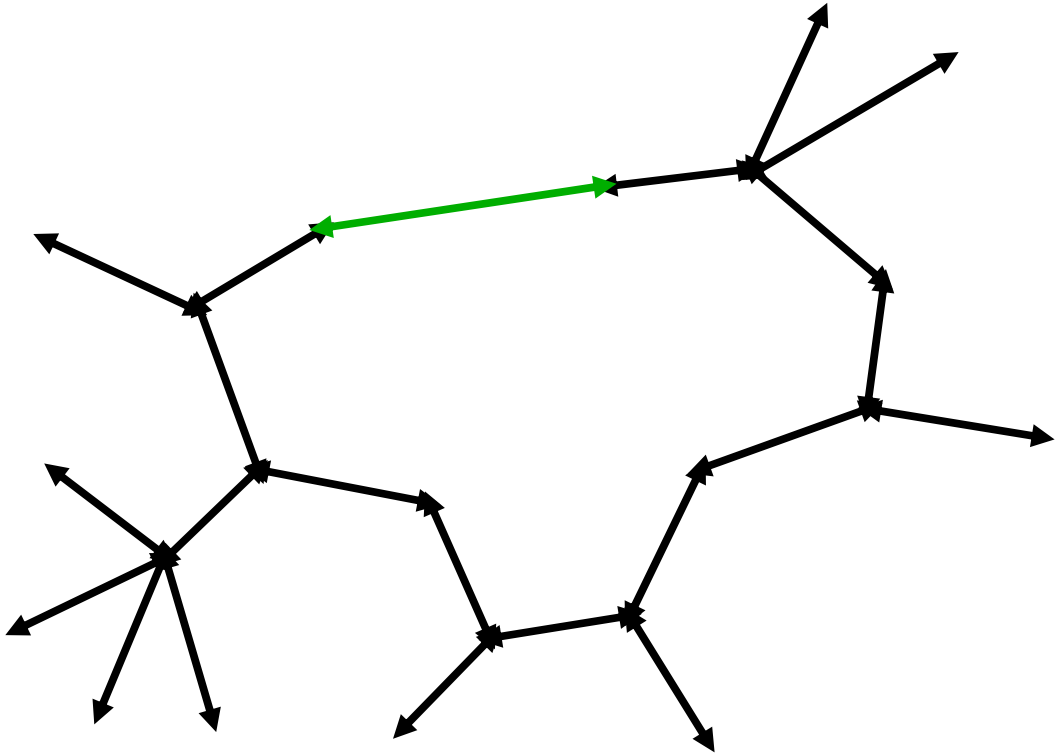

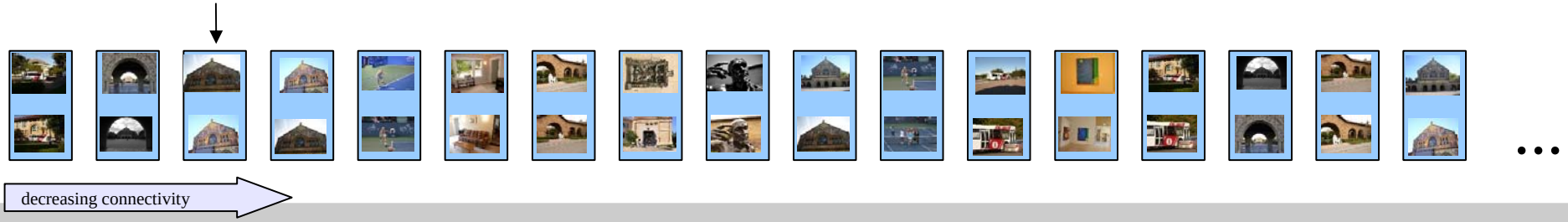

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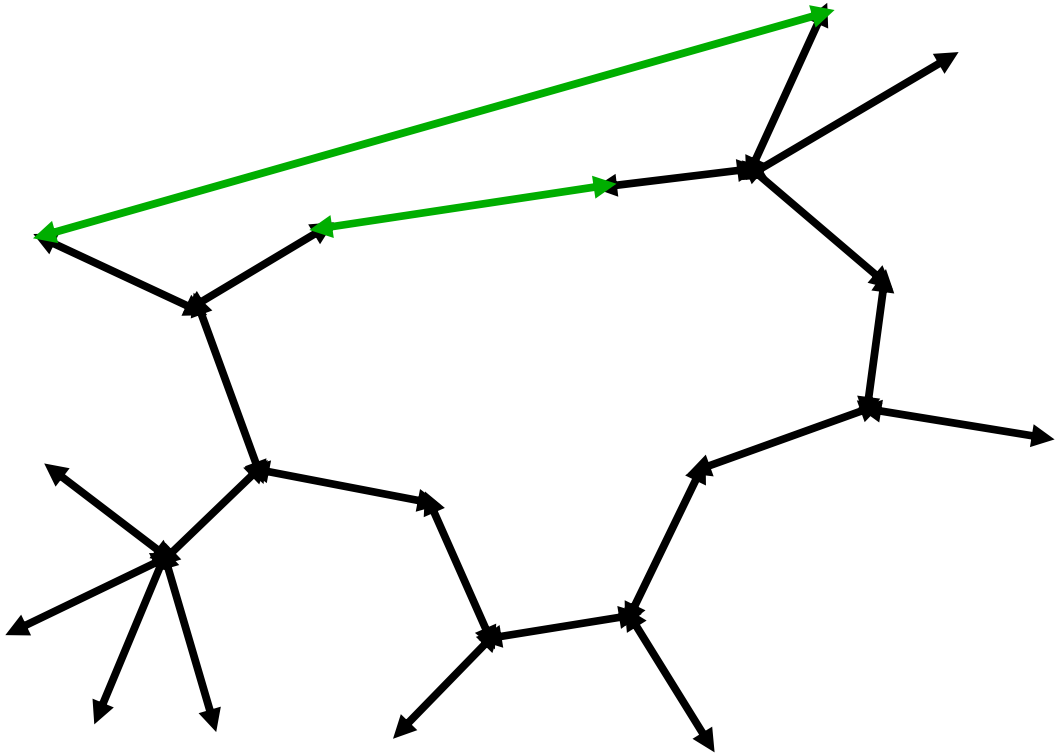

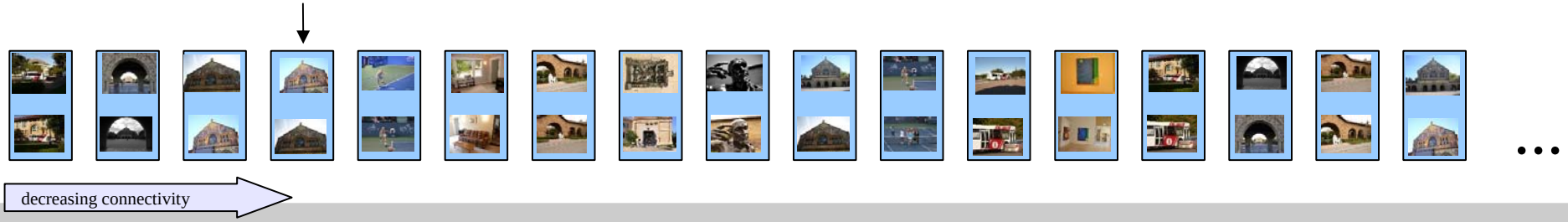

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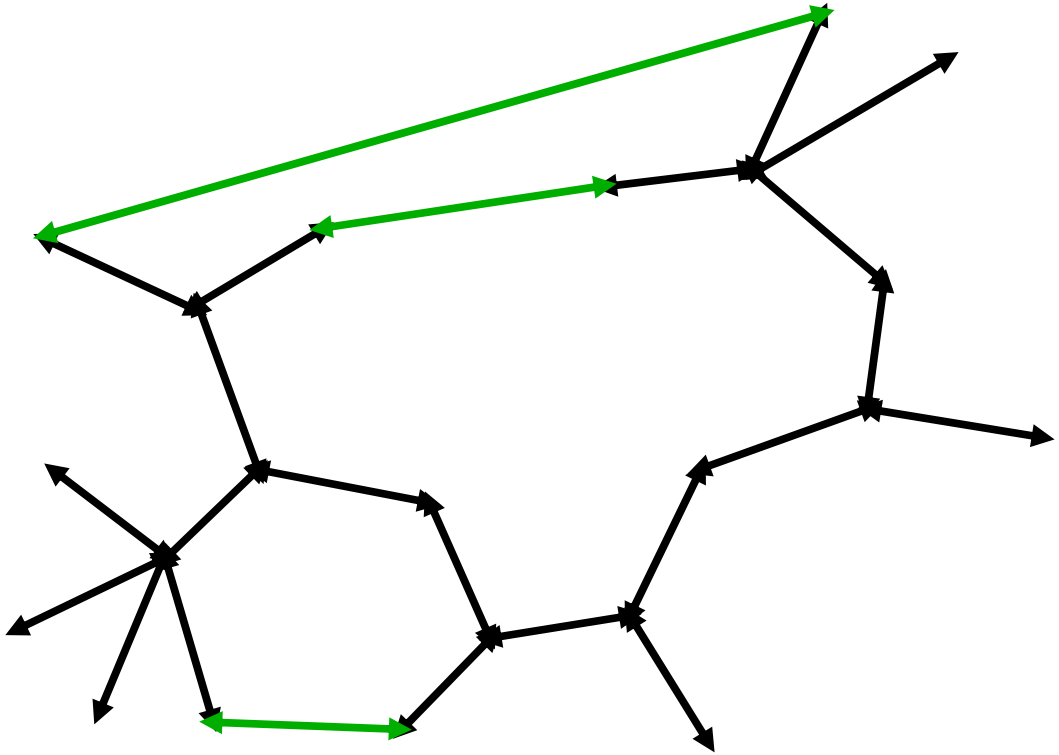

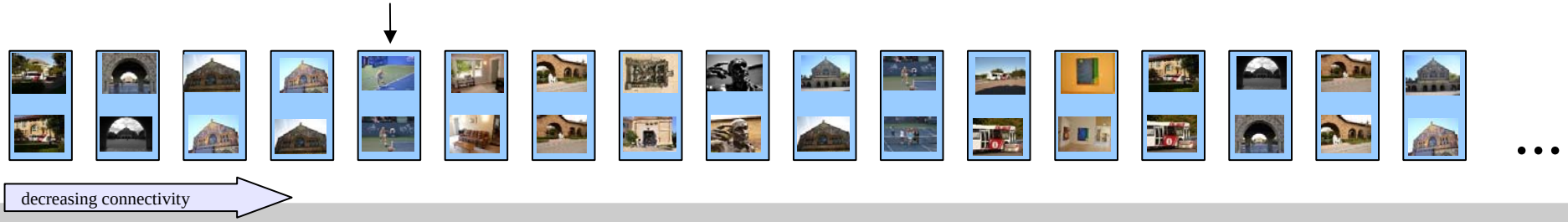

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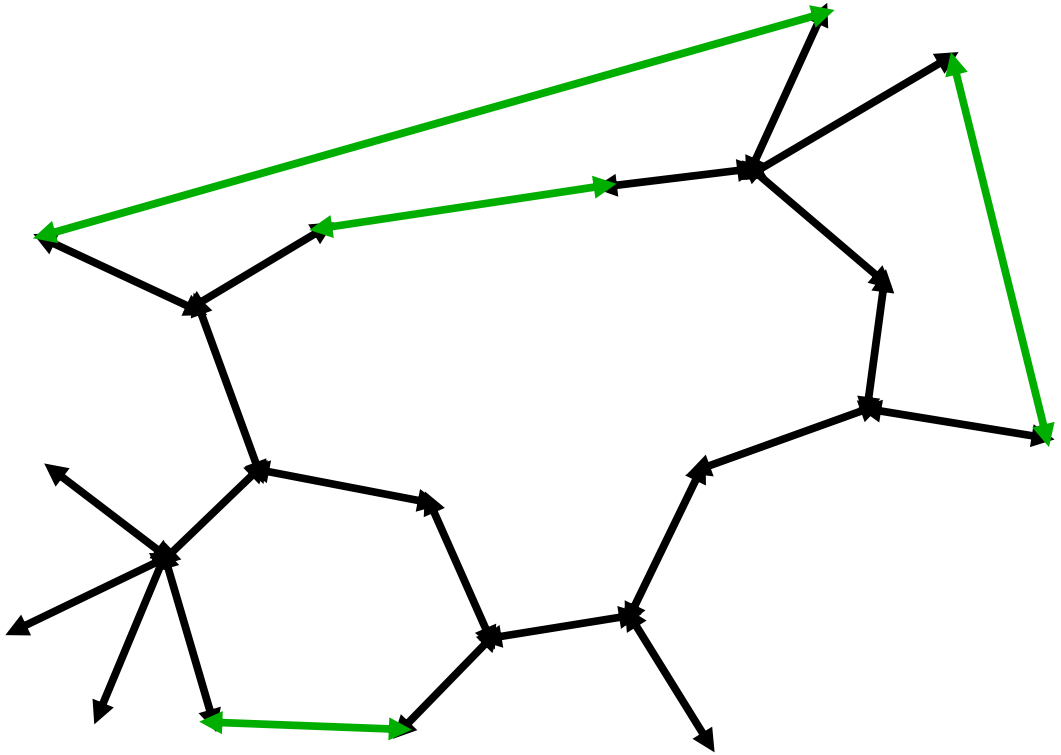

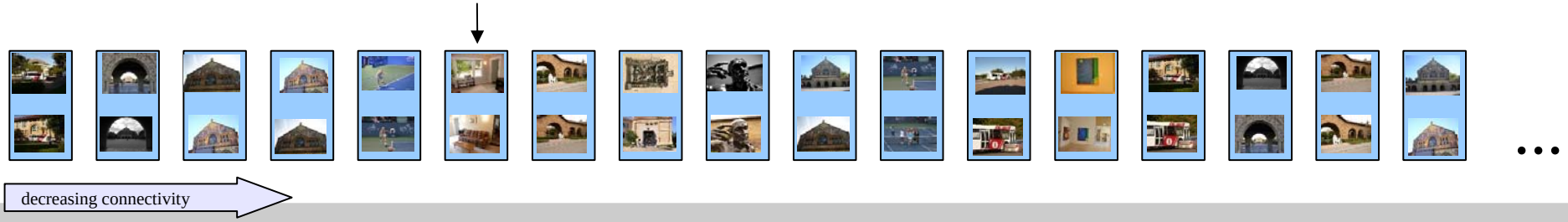

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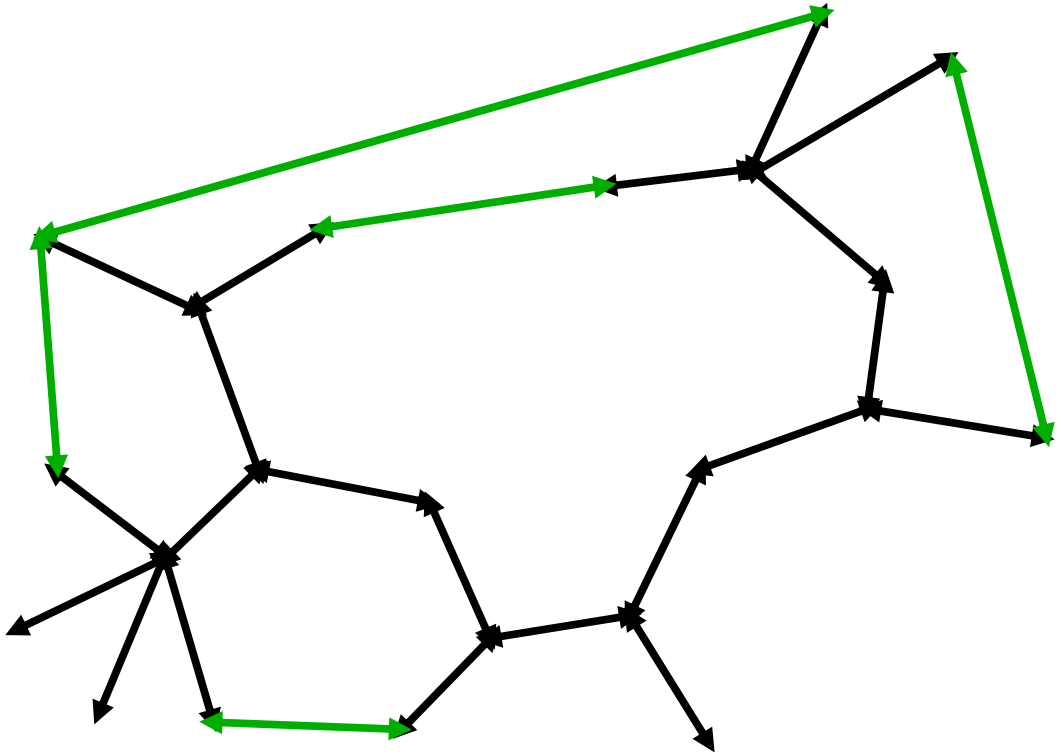

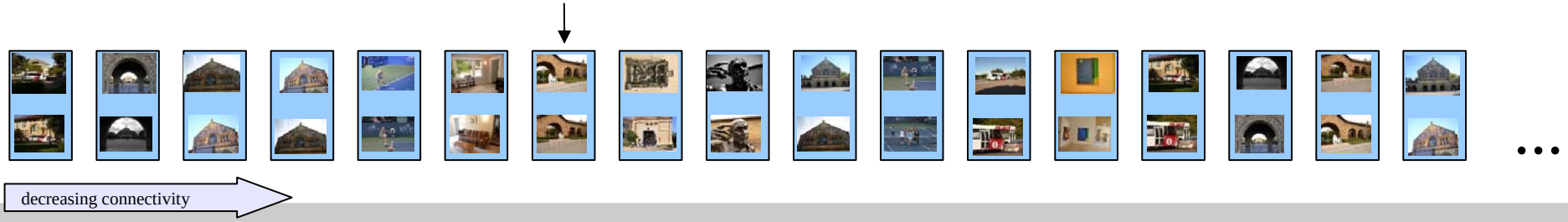

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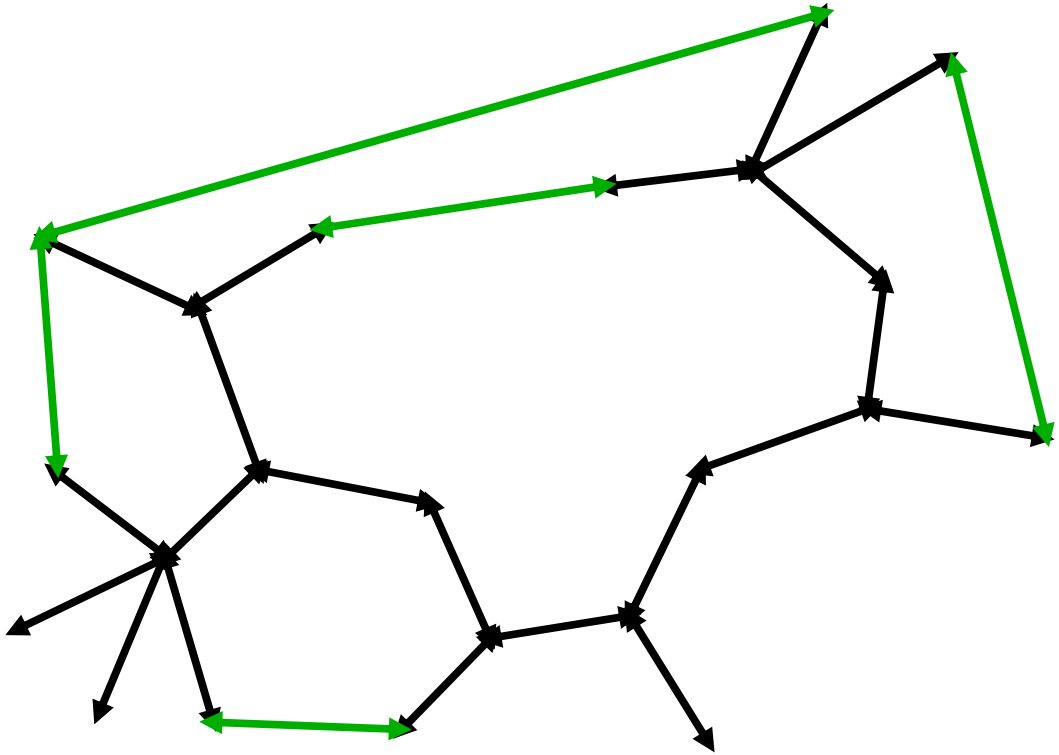

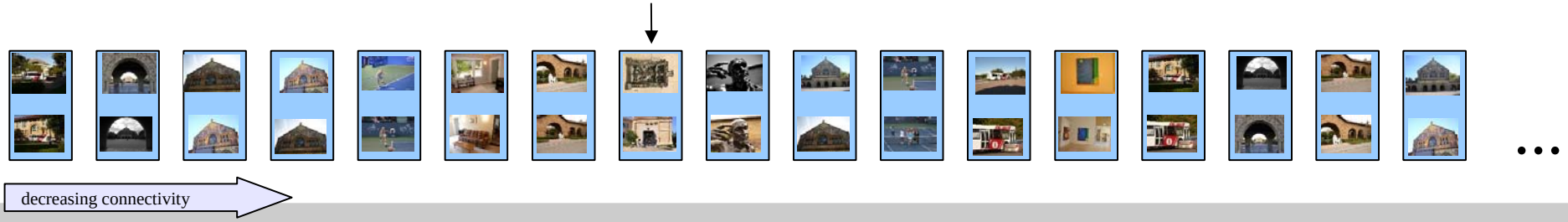

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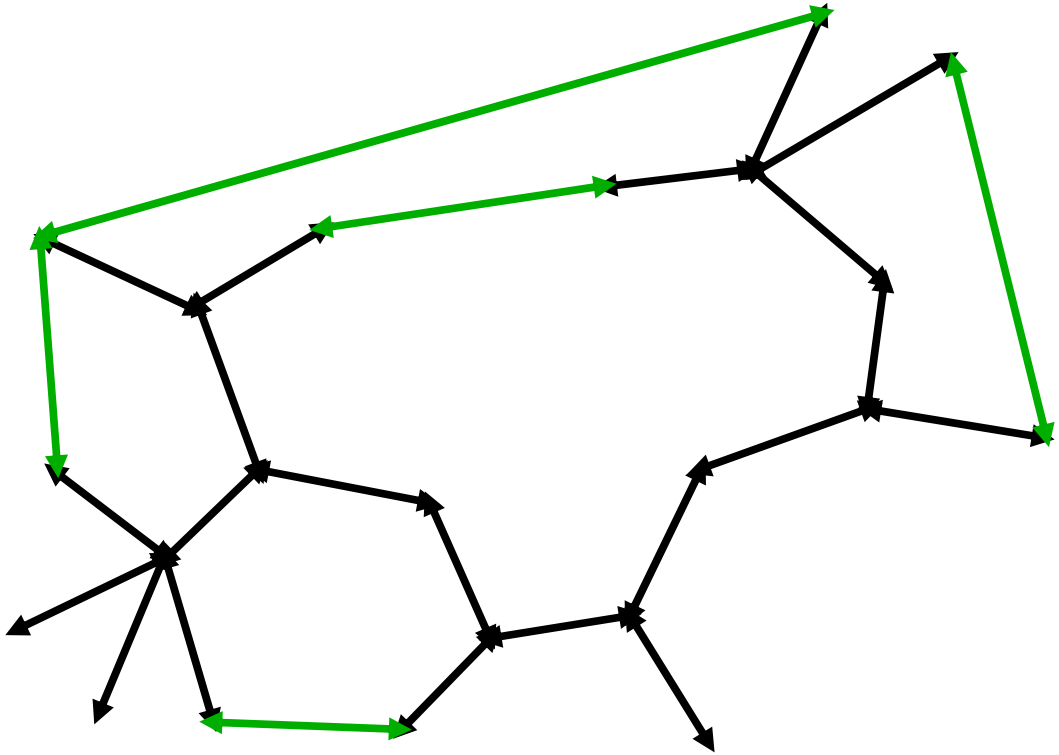

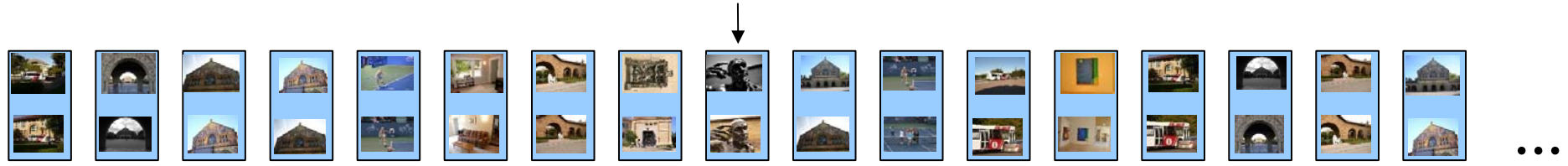

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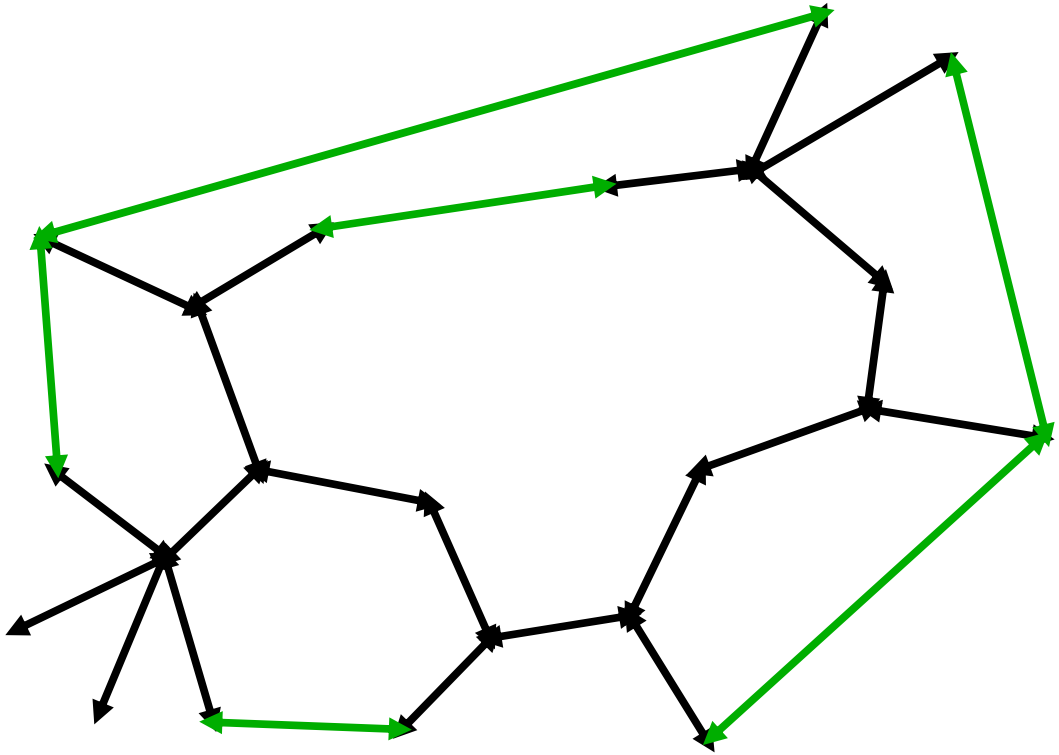

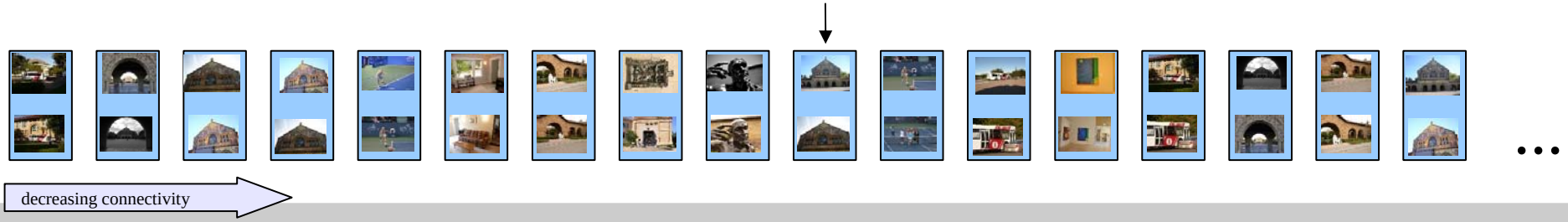

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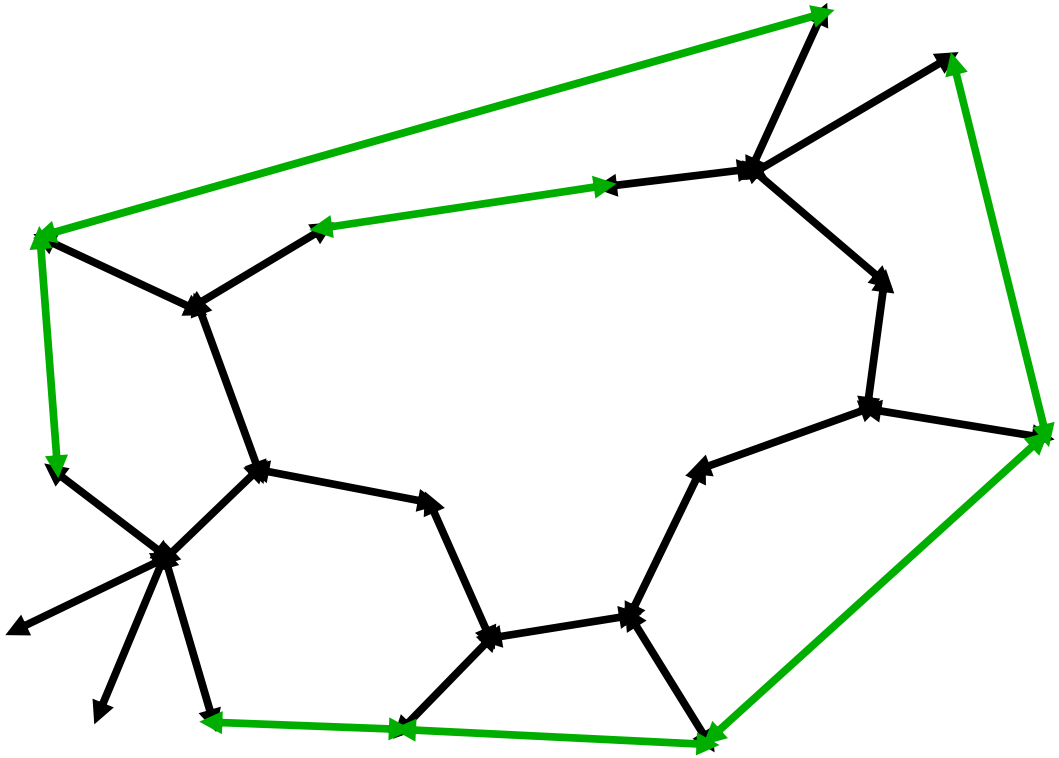
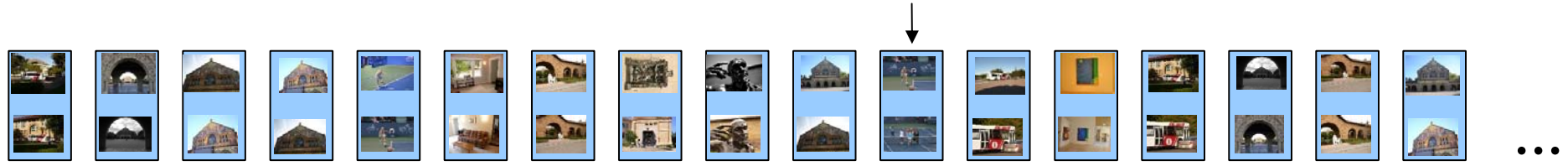
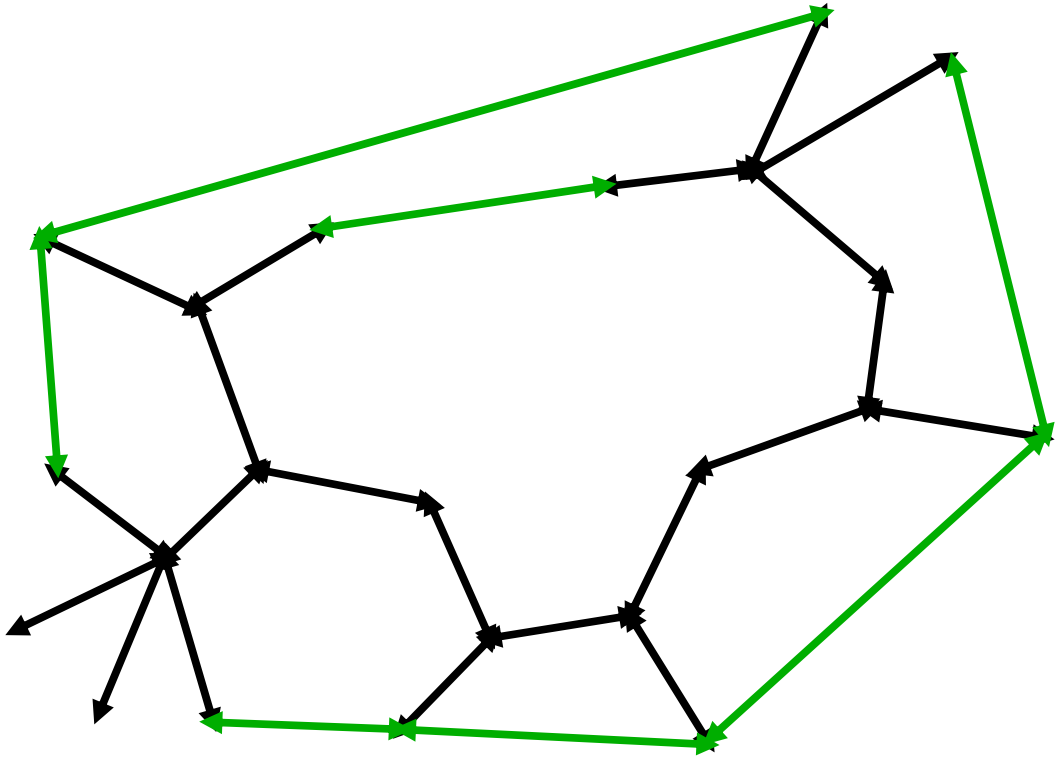
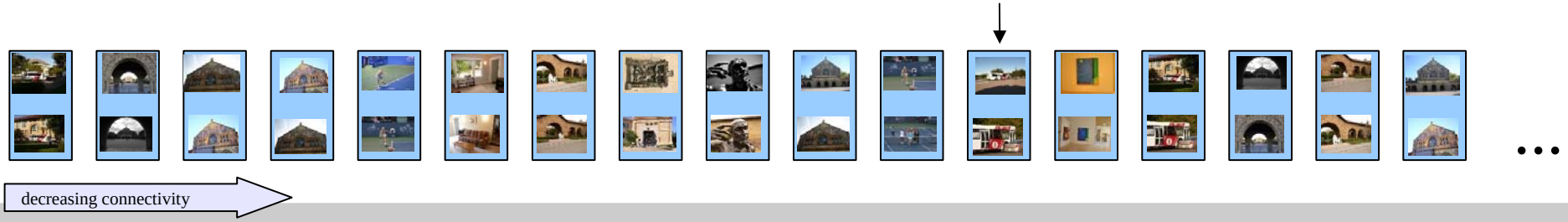




decreasing connectivity

Phase 2: Boost component connectivity





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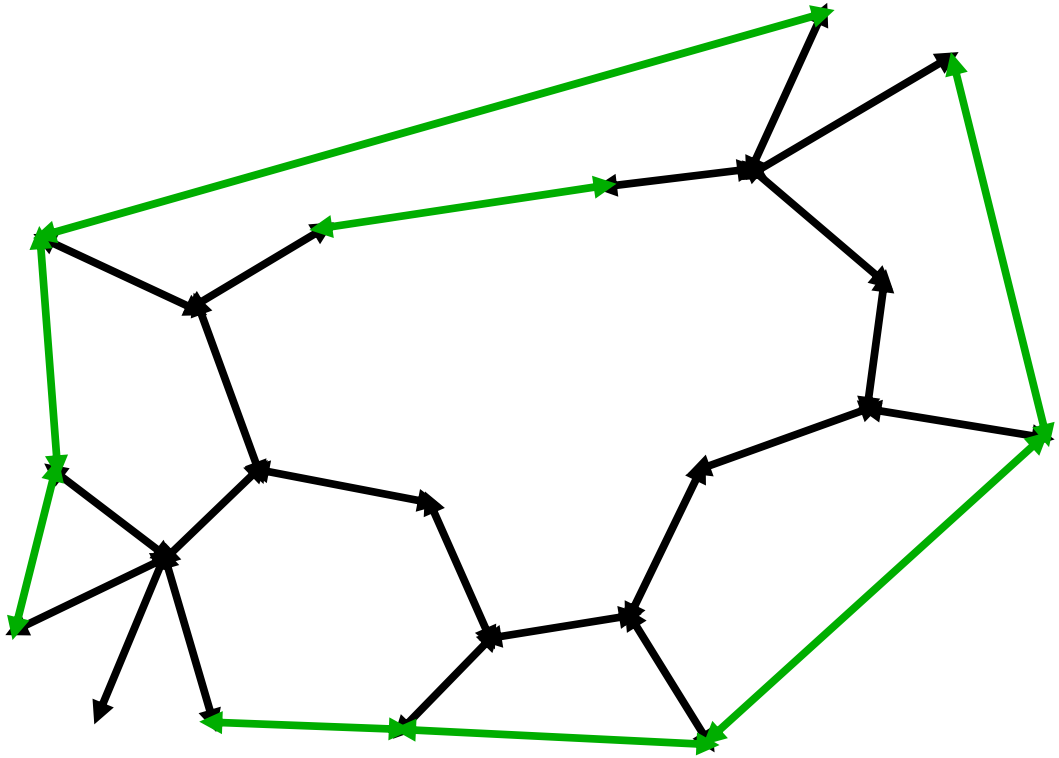

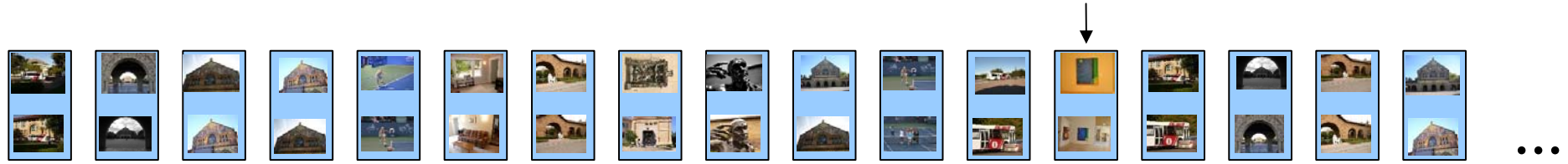

decreasing connectivity

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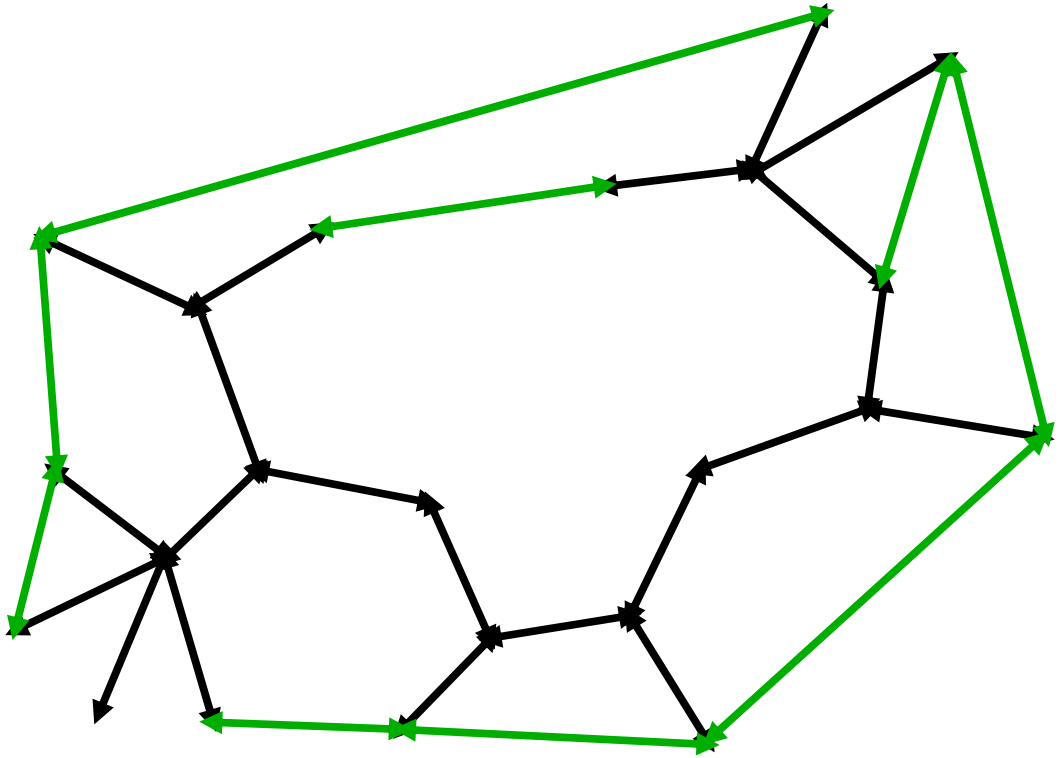

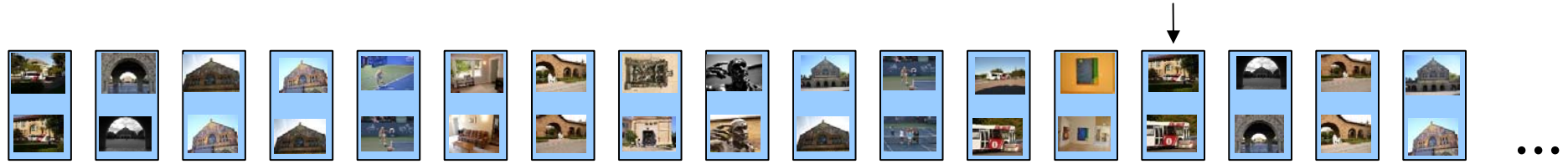

decreasing connectivity

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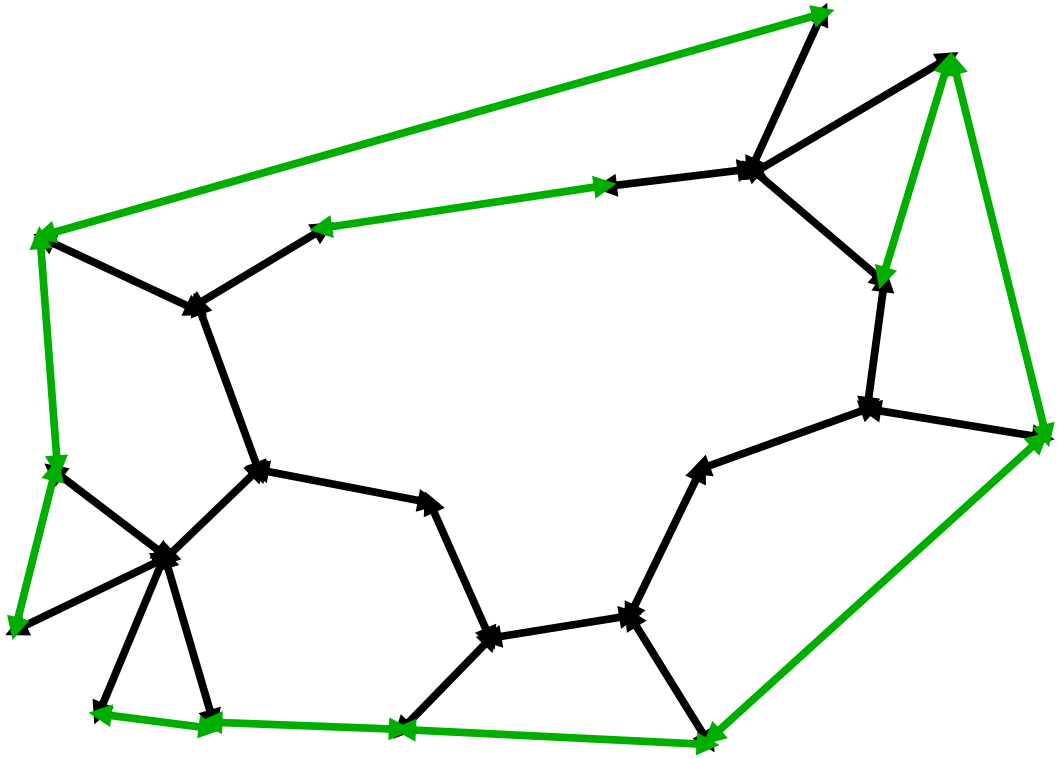

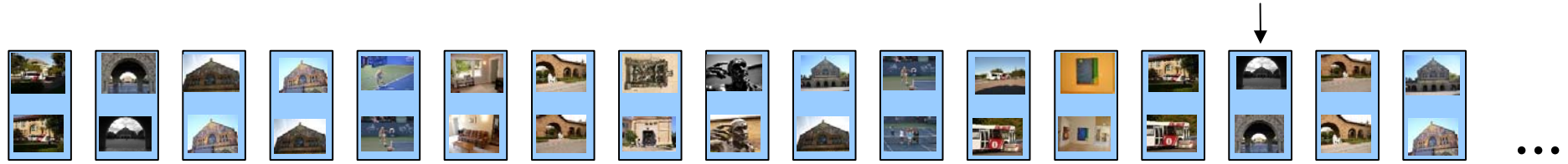

decreasing connectivity

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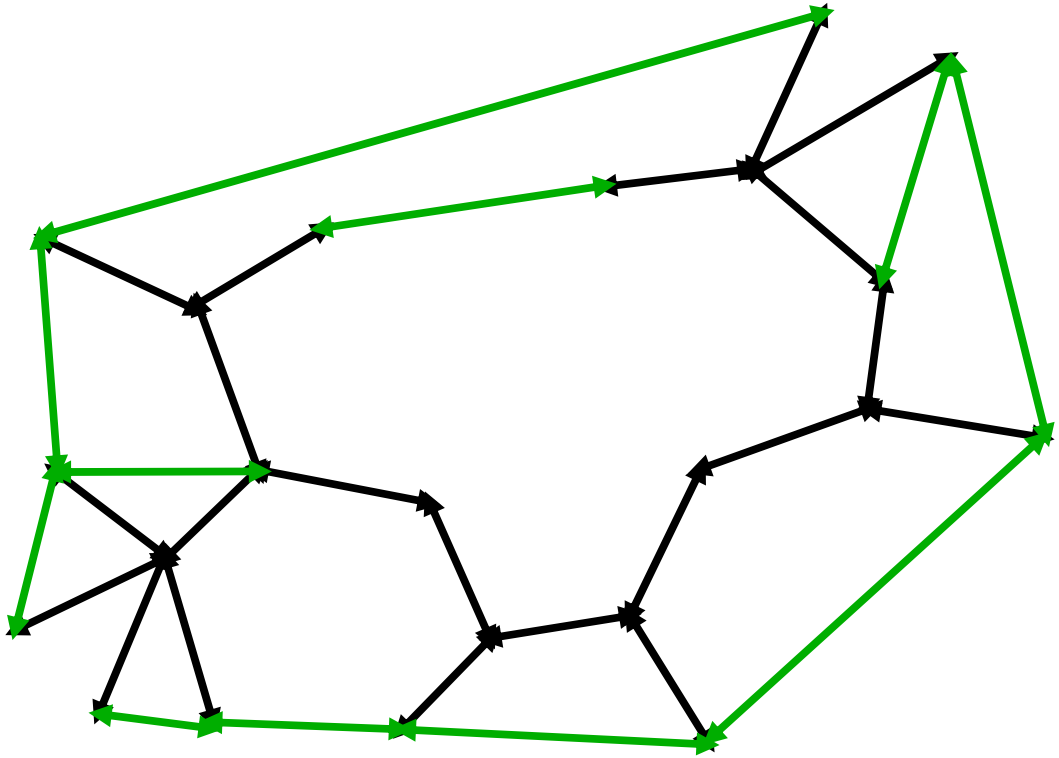

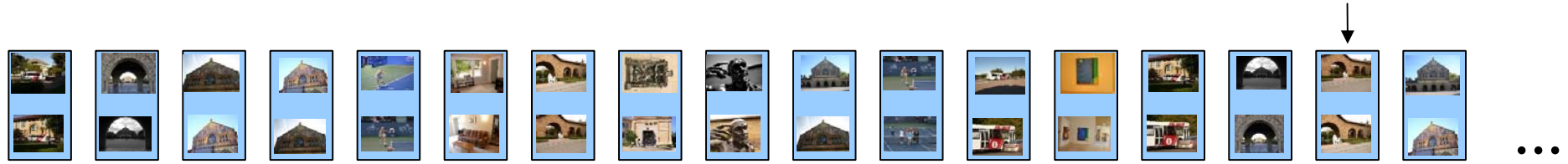

decreasing connectivity

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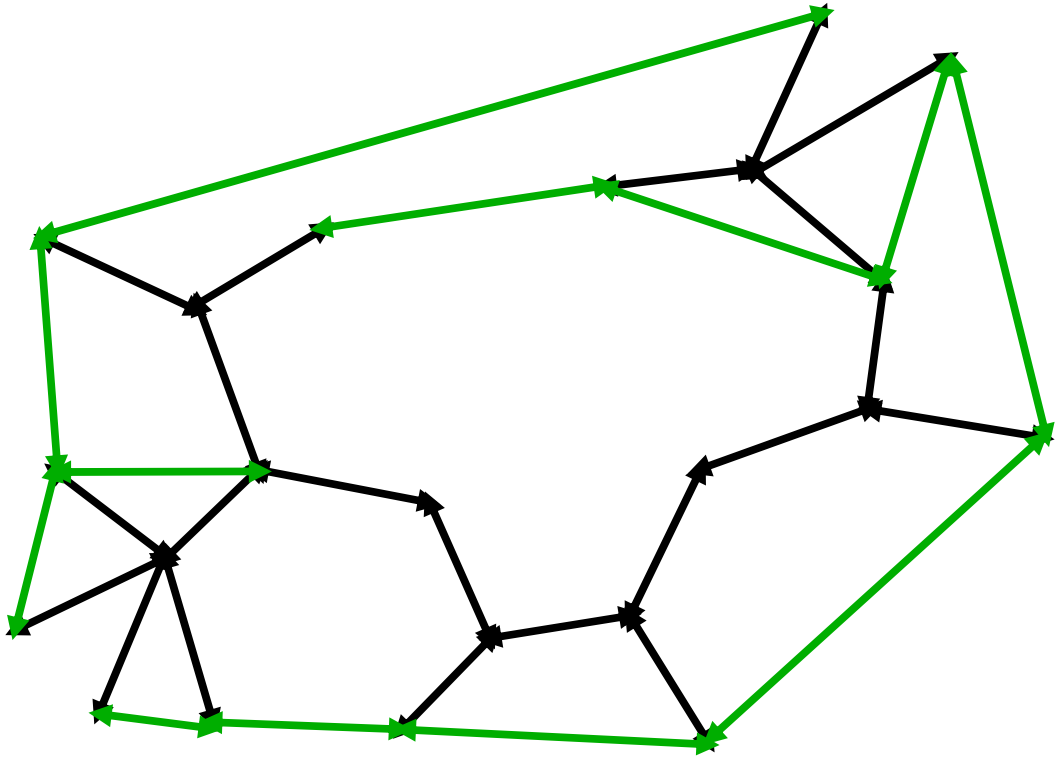

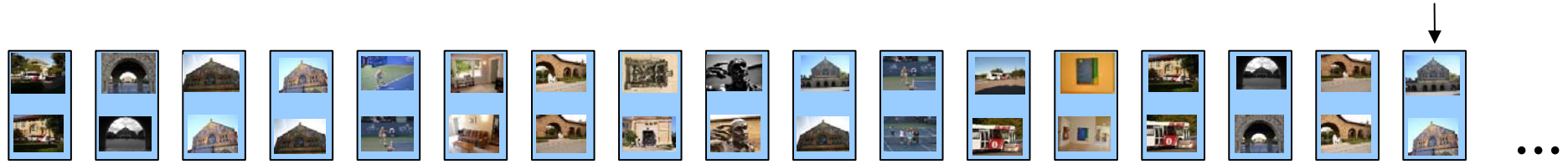

decreasing connectivity

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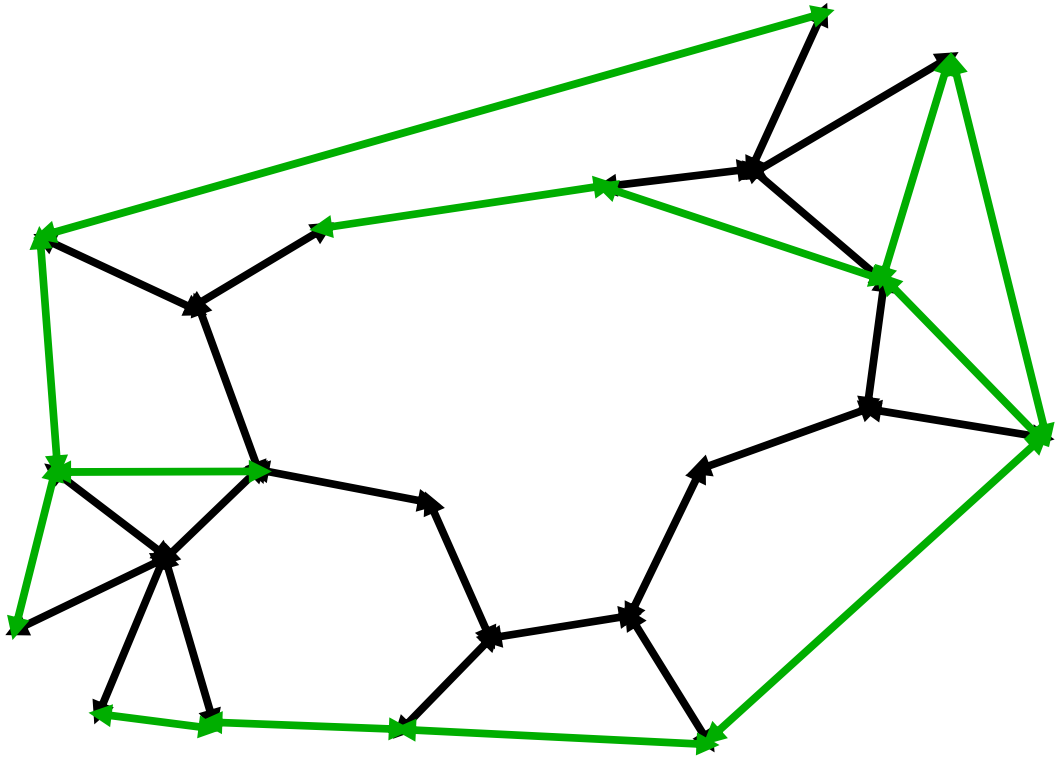

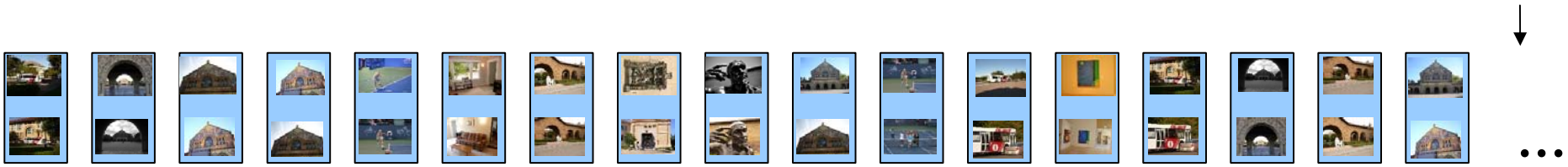

decreasing connectivity

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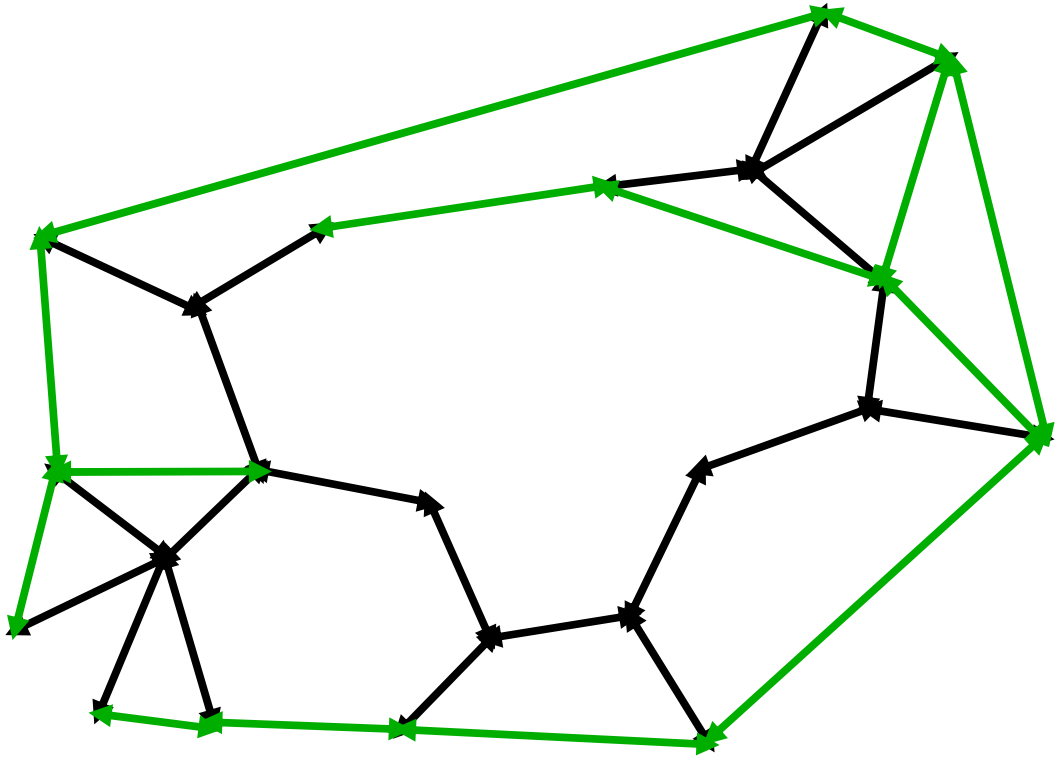
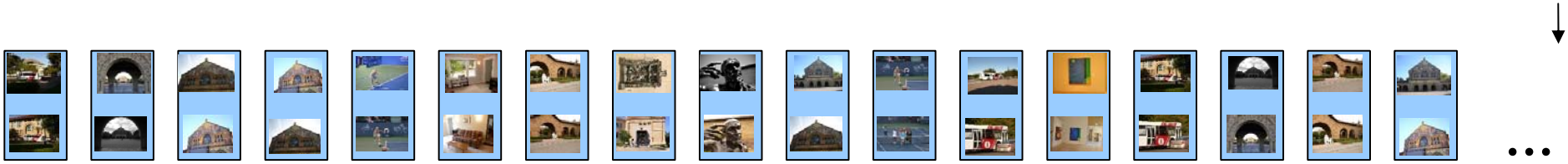




decreasing connectivity

Distributed computation

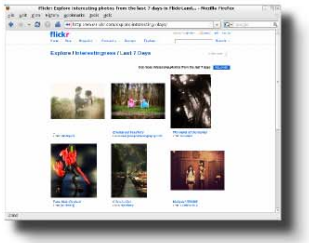
- Construction pipeline easily distributed on a computer cluster

Image Web Construction Timings on Cluster with 500 Nodes

Collection Name (Source)	Images	Components (size > 1)	Largest Component	Construction Time (min)		
				Phase 1	Phase 2	Total
Stanford (Flickr)	193,277	12,505	11,240	173	96	269
Pittsburgh (StreetView)	50,224	23	49,907	7.9	70	78
London (Panoramio)	17,925	902	4,617	7.7	5.9	14
Art Museum (created)	1,257	5	1,217	0.06	0.74	0.8

Applications

Auto-tagging Flickr Images



Flickr ~ 3.6 billion images
(2009)

~~stanford vacation~~
~~zurowskifamily~~
goldengatebridge

~~amerika catlovers city~~
goldengatebridge ~~harbor may~~
~~monterey~~ sanfrancisco
~~santacruz stanforduniversity usa~~

~~andreilinde dslr sony sonya700~~
memorialchurch stanford

Tag cleaning by simulated ESP game

10 architecture california **clarkcenter** delete delete2 fav10 fav25 jameshclarkcenter paloalto photowalking photowalking100107 photowalking 10012007 photowalking stanford save save10 save2 save3 save4 save5 save6 save7 save8 save9 southbay stanford **stanforduniversity** superfave unitedstates unitedstatesofamerica usa

clarkcenter lights night **stanforduniversity**

Clean Tags:
clarkcenter stanforduniversity

Lyndon Kennedy, Malcolm Slaney, Kilian Weinberger "Reliable Tags Using Image Similarity: Mining Specificity and Expertise from Large-Scale Multimedia Databases" In WSMC '09: Proceedings of the 1st workshop on Web-scale multimedia corpus (2009).

Auto-tagging experiment

- Dataset
  - Flickr search for “Stanford” ⇨ 195,268 images
  - Image Web ⇨ 1,132,406 regions
  - Tag cleaning ⇨ 525 tags

Auto-tagging experiment

- Results

	Provided Tags	Cleaned Tags	Suggested Tags
Number of Images	168,171	13,613	21,179
Percent of Dataset	86%	7.0%	11%

Successes

Image	Provided	Cleaned	Suggested
	church, stanford	stanford	stanford (1.01) stainedglass (0.04) university (0.03)
	<none>	<none>	stanford (0.189) california (0.173) university (0.073), stanforduniversity (0.041), hoovertower (0.001)
	stanford	stanford	stanford (1.05), university (0.15), tower (0.14), hoover (0.14), california (0.14), usa (0.13), 2009 (0.13)

Failures

Image	Provided	Cleaned	Suggested
	berkeley, stanford	berkeley, stanford	stanford (1.0357) berkeley (1.0298) university (0.1962) ca (0.1765)
	alcatraz, ghirardeli, goldengate, kipp, pier39, sandiego, sanfrancisco, stanford, streetsofsanfrancisco, students	alcatraz, goldengate, pier39, sanfrancisco, stanford	alcatraz (1.0019) goldengate (1.0019) pier39 (1.0019) sanfrancisco (1.0019) stanford (1.0019)

Mobile collaborative annotation

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- Questions?