A Spatial-Color Layout Feature for Representing Galaxy Images

Yin Cui[+] Yongzhou Xiang[+] Kun Rong[+] Rogerio S. Feris[*] Liangliang Cao[*]

[+]Columbia University [*]IBM T. J. Watson Research Center

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1. Background and Motivation

Hubble Ultra-Deep Field (HUDF)

- 1/13,000,000 of the entire sky.
- 12-day of total exposure time.
- ~10,000 galaxies in the image.
- Over 100 billion galaxies in the entire universe.

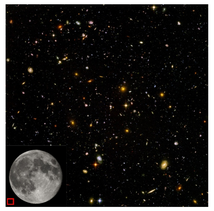


Image credit: NASA

Sloan Digital Sky Survey (SDSS) Dataset

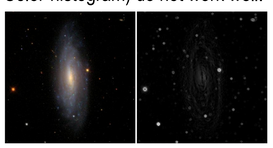
- Aiming at exploring the tremendous number of galaxies in the universe.
- Has collected almost 1 million galaxies images to date.
- More than 50 million galaxy images in the near future.

➢Need an automatic way to deal with galaxy images.

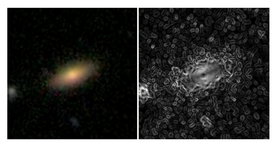
Astronomical Galaxy Images

- Very noisy (dark-current noises) and contain a large area of dark background.

- Commonly used Computer Vision features (e.g., HOG, LBP, Gist, Color-histogram) do not work well.



(a) Spiral galaxy image and corresponding gradient magnitude



(b) Elliptical galaxy image and corresponding gradient magnitude

➢Need a new feature specially designed for galaxies.

The Hubble Sequence and Galaxy Evolution

- The most widely used galaxy representation scheme in Astronomy developed by Edwin Hubble in 1926.

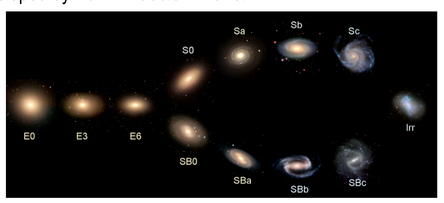


Image credit: University of Oregon

- Galaxy evolves from the right side to the left side.
- Young and active stars are bluer, old stars are redder.
- As the stars become old and inactive, the galaxy they formed evolves from irregular to spiral to elliptical.

➢An important cue: Local Color Distribution.

2. Spatial-Color Layout Feature (SCLF)

SCL Galaxy Detector

✓Scale and rotation invariant for the galaxy.

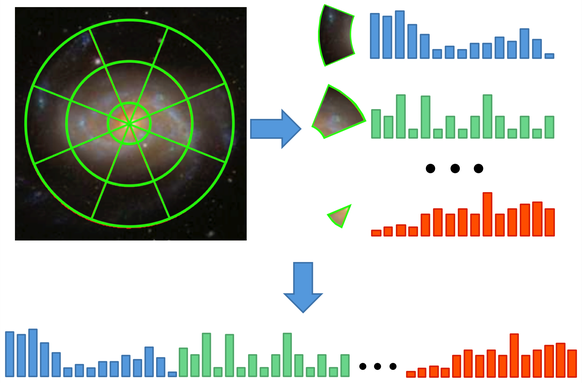
✓Robust to noise and changing of background.

- Step I: Convert to gray-scale and do edge-preserving bilateral filtering.
- Step II: Binary segmentation using Otsu's method.
- Step III: Fill holes based on morphological operations.
- Step IV: Find the center and orientation of the biggest connected component.
- Step V: Align the galaxy by its center and orientation.

SCL Galaxy Descriptor

- Dark background → color distributions infer shape.
- Concatenated local color-histograms on spatial layout.

✓Capture local and global galaxy shape information.



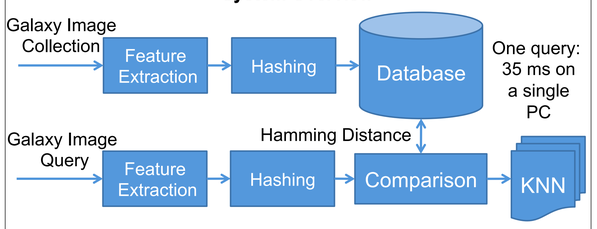
- 3 layers and 8 directions: 24 sections
- 48 dim color-histogram on each section: 1152 dim

Comparison with other features

	Global shape	Local Shape	Color	Robust to noise
Color-Hist	×	×	✔	✔
LBP	✔	✔	×	×
Gist	✔	×	×	✔
HOG	✔	✔	×	×
Ours	✔	✔	✔	✔

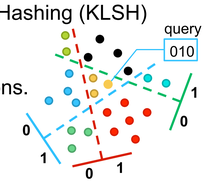
3. Galaxy Retrieval System

System Overview



Hashing

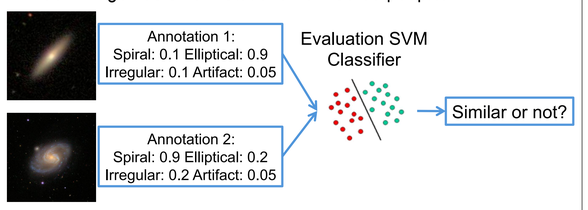
- Use Kernelized Locality Sensitive Hashing (KLSH) (B. Kulis and K. Grauman, 2009)
- ✓ Locality-sensitive for kernel functions.
- ✓ Sub-linear time in approximation.
- Test on three kernel functions: *Chi-Square Kernel*, ***Histogram Intersection Kernel***, *Jenson-Shannon Divergence Kernel*



4. Experiments

Evaluation by Galaxy Zoo Annotations

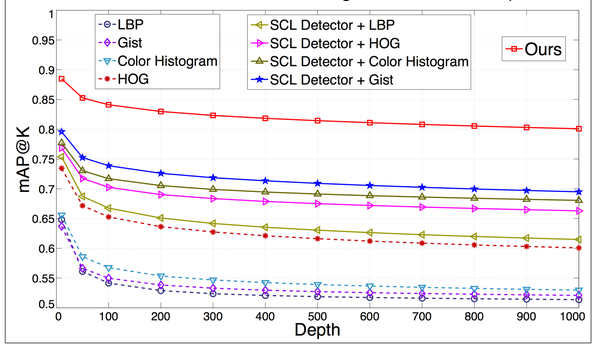
- Galaxy Zoo is a crowdsourcing project to collect annotations for galaxy images from SDSS dataset.
- Each image has 37 annotations from 30-50 people.



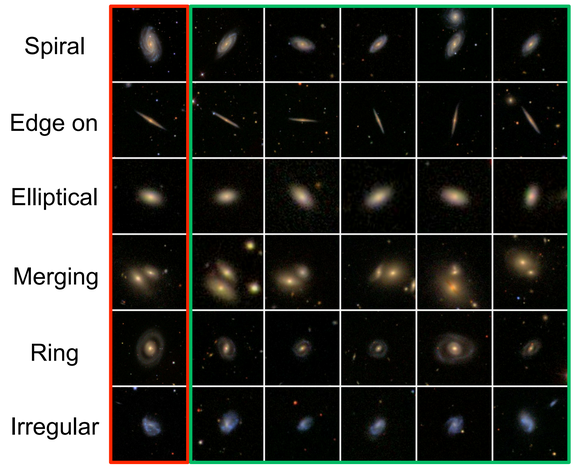
- Train a evaluation SVM from labeled training pairs.

Performance Comparison

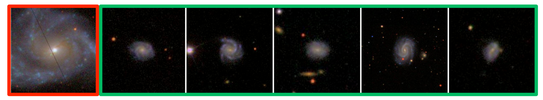
- 283,971 galaxy images with annotations from SDSS.
- Top K retrieved images are judged by evaluation SVM.
- Evaluation metric: mean Average Precision at depth K.



Top 5 Retrieved Examples



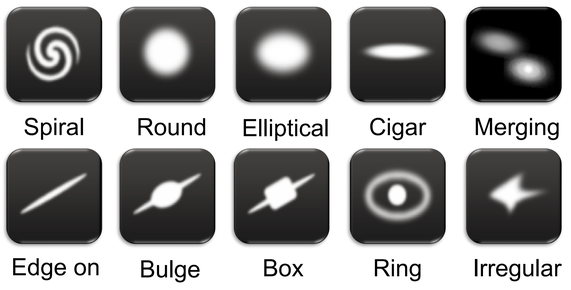
- Scale and rotation invariant



5. Future Work

Representing Galaxy by Attributes

- Build attribute detectors for Galaxies based on the proposed feature and GalaxyZoo labels.



6. Summary

- ✓ **A new feature designed for representing galaxy.**
- ✓ **An efficient large-scale galaxy retrieval system.**
- ✓ **An evaluation method based on crowdsourcing data.**

7. Acknowledgement

- **Thanks to Dr. Rogerio Feris and Dr. Liangliang Cao (last two authors). This work came from our course project in a class taught by them:**

http://rogerioferis.com/VisualRecognitionAndSearch2013/