Unsupervised Machine Learning For Identifying Signatures Of Past Mergers In Galaxy Light Profiles

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Background

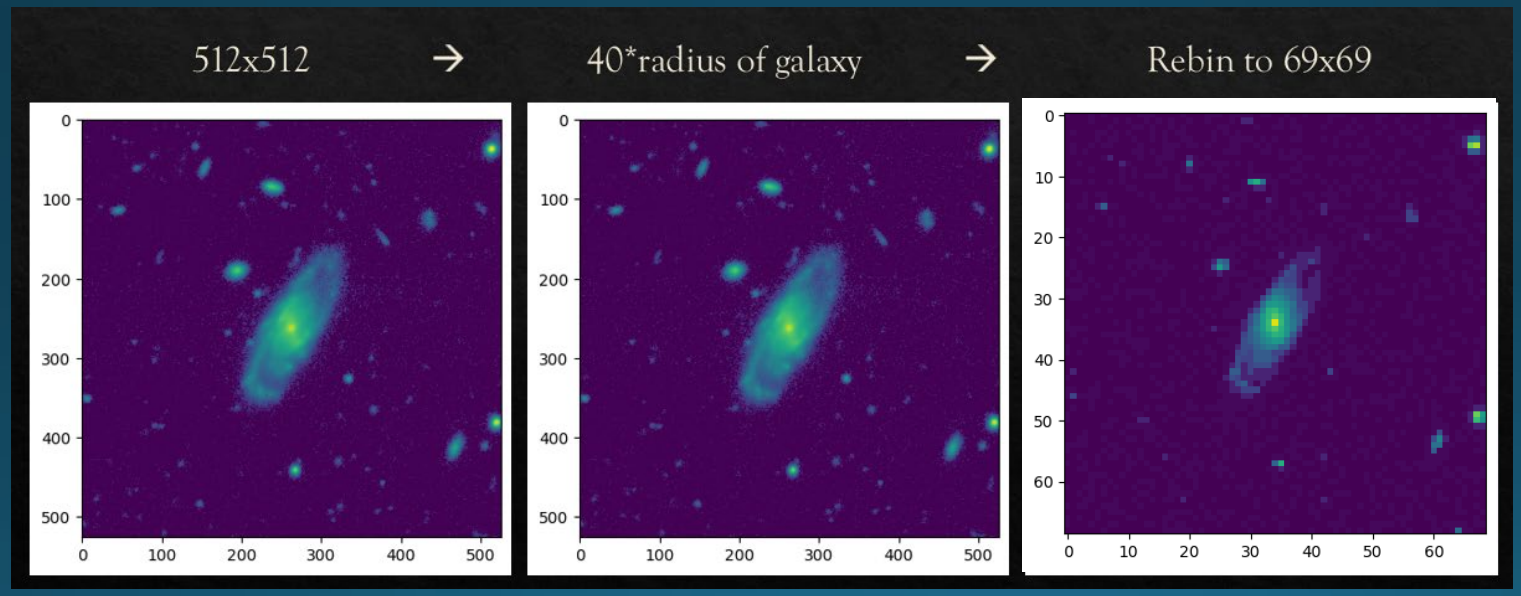
- Galaxy interactions → stars and gas being pulled into different shapes (tidal features)
  - Streams & shells
- Difficult to detect by eye
- Solution: Machine learning!
  - Previous research: not enough labels for supervised → try unsupervised

Fig. 1. Two galaxies interacting, producing tidal streams. Photo credit: HSC-SSP

Methodology

1. Scale images

Image Dataset: Hyper Suprime-Cam Subaru Strategic Program PDR-3 512x512 pixels in g,r,i bands with labels for tidal features (for method testing)



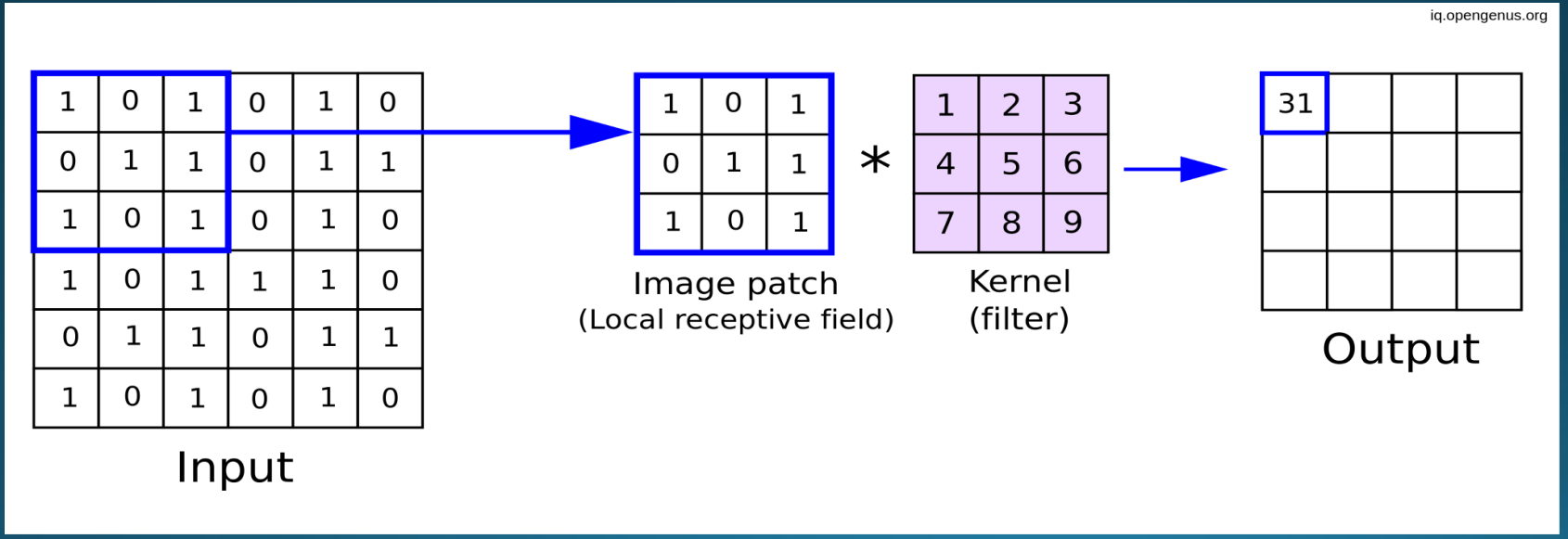
*https://hsc-release.mtk.nao.ac.jp/doc/

Methodology

2. Augmentations of scaled images

- Maintain tidal features
- Result: image pair
  - one image scaled and augmented, one scaled and non-augmented

3. Convolution Step



Methodology

3. Compute similarity (loss)

- Between augmented and non-augmented image pair

$$\text{Cosine Similarity} = \frac{\sum_{i=1}^{n} x_i y_i}{\sqrt{\sum_{i=1}^{n} x_i^2}\sqrt{\sum_{i=1}^{n} y_i^2}}$$

Methodology

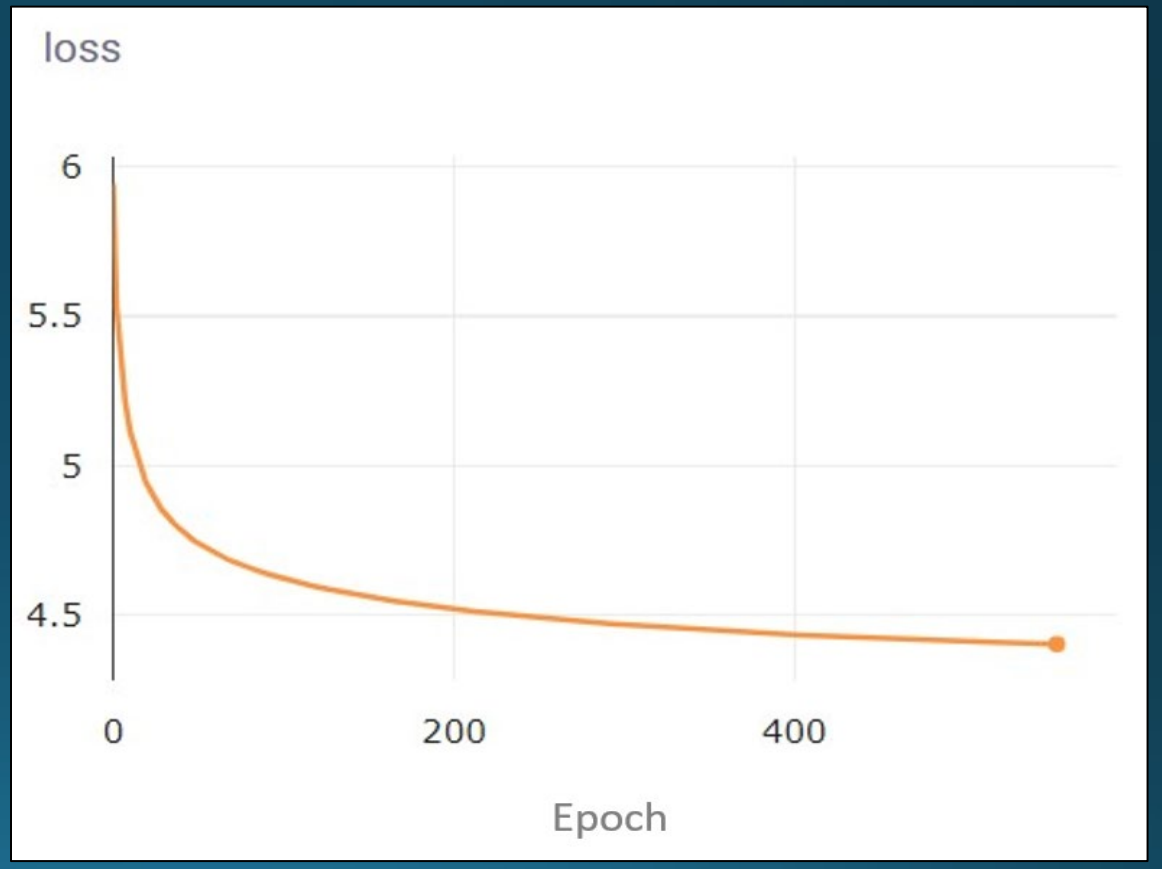
5. Adjust weights through iteration

Goal: minimize loss function between images within pairs and maximize it between different pairs

Output

multidimensional representation of dataset

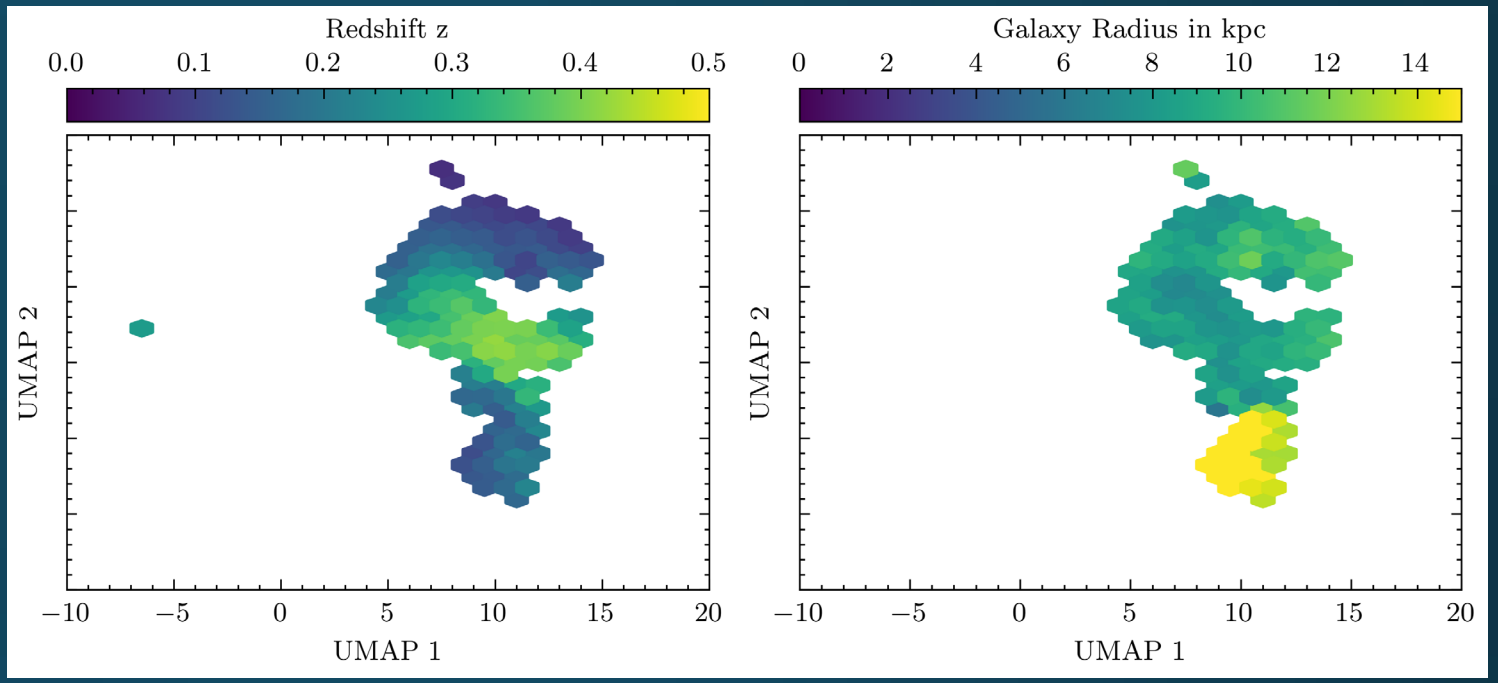
- Similar images grouped
- Scale to 2D
- Plot parameters

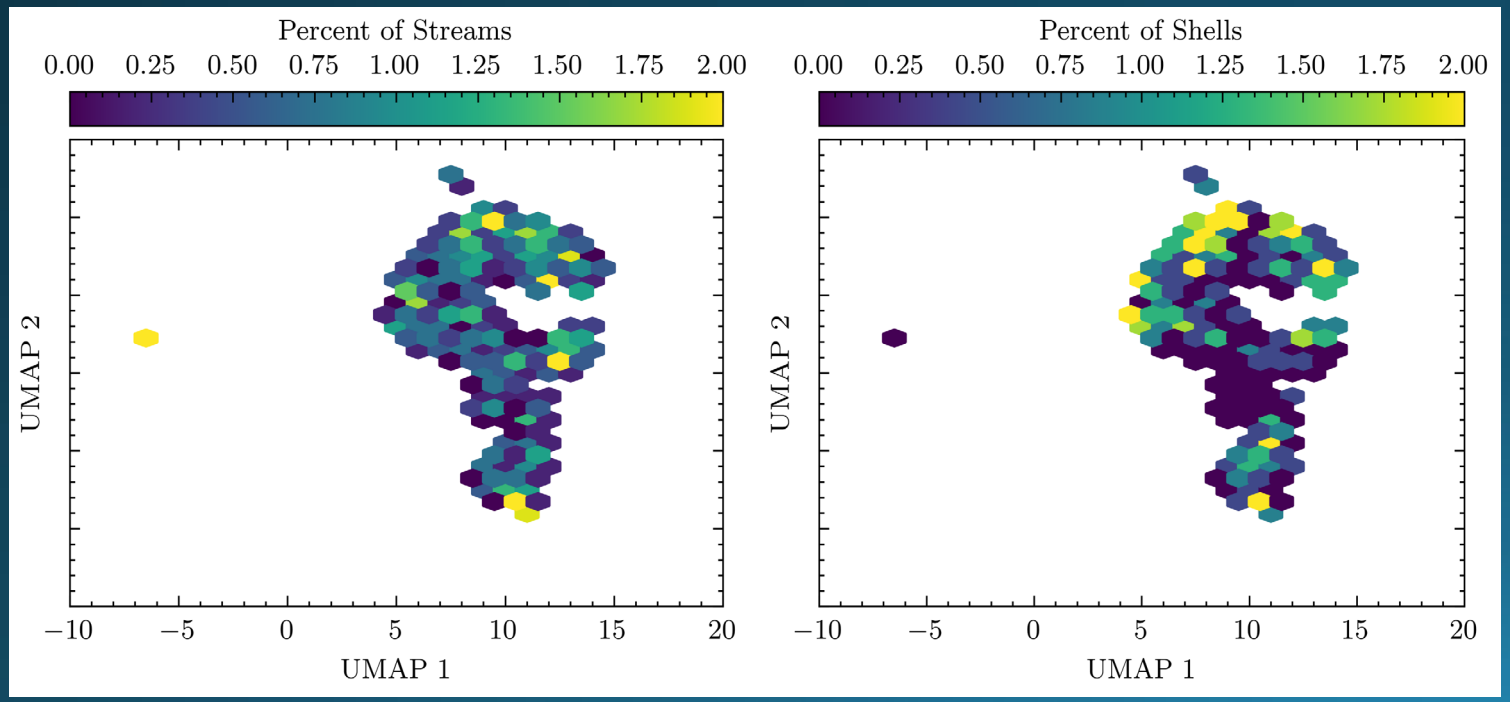


Results

Top Plots

- Clear trends in galaxy redshift and galaxy size





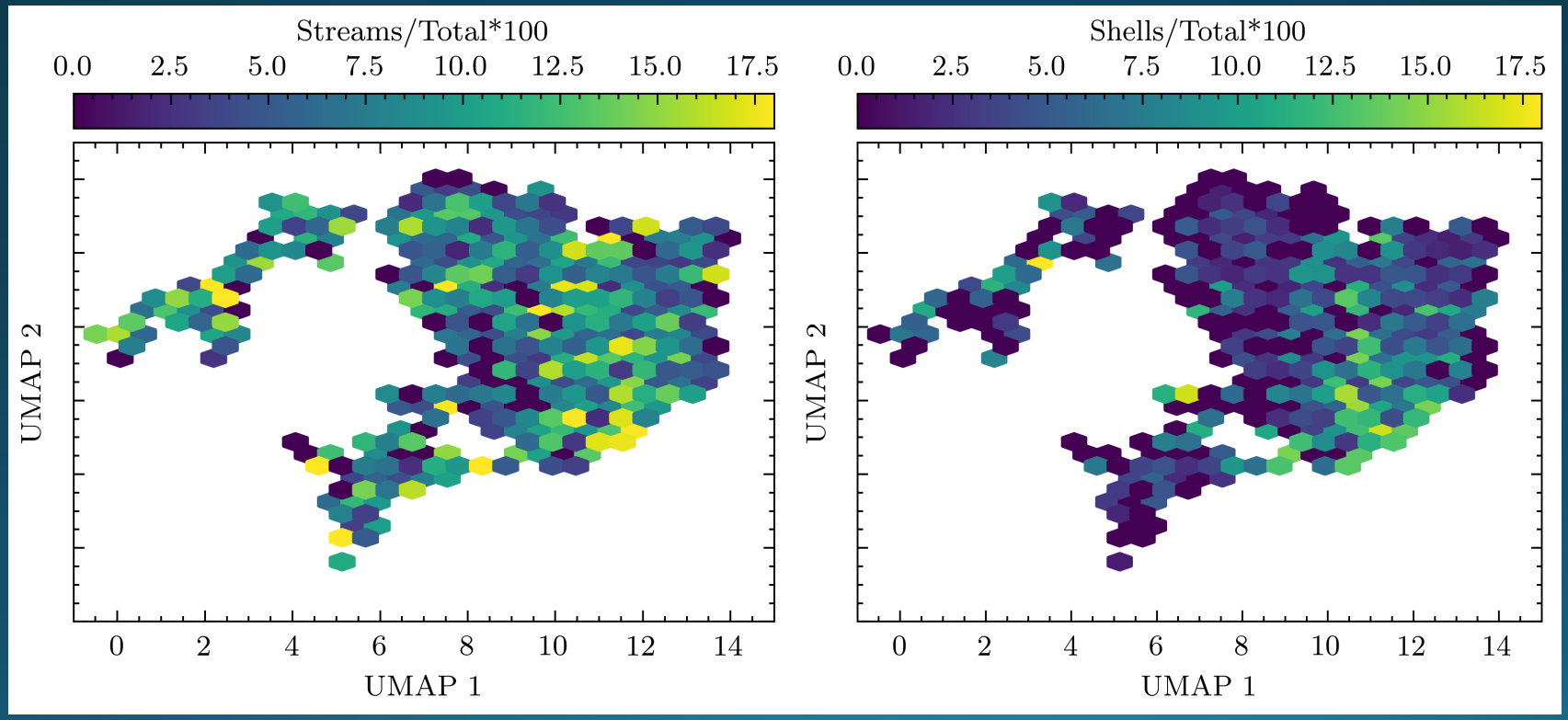
Bottom plots

- Faint trend in tidal shell plot
- No trend in tidal streams

Results

Run again

- Each image has its reflection subtracted
- Emphasis on asymmetric data like tidal features
- Improved results



Conclusion

- Unsupervised machine learning does separate galaxies based on their parameters, but not the parameters we want
- To continue improving the model, we need a larger set of galaxy images and to experiment with augmentations.

NTCO

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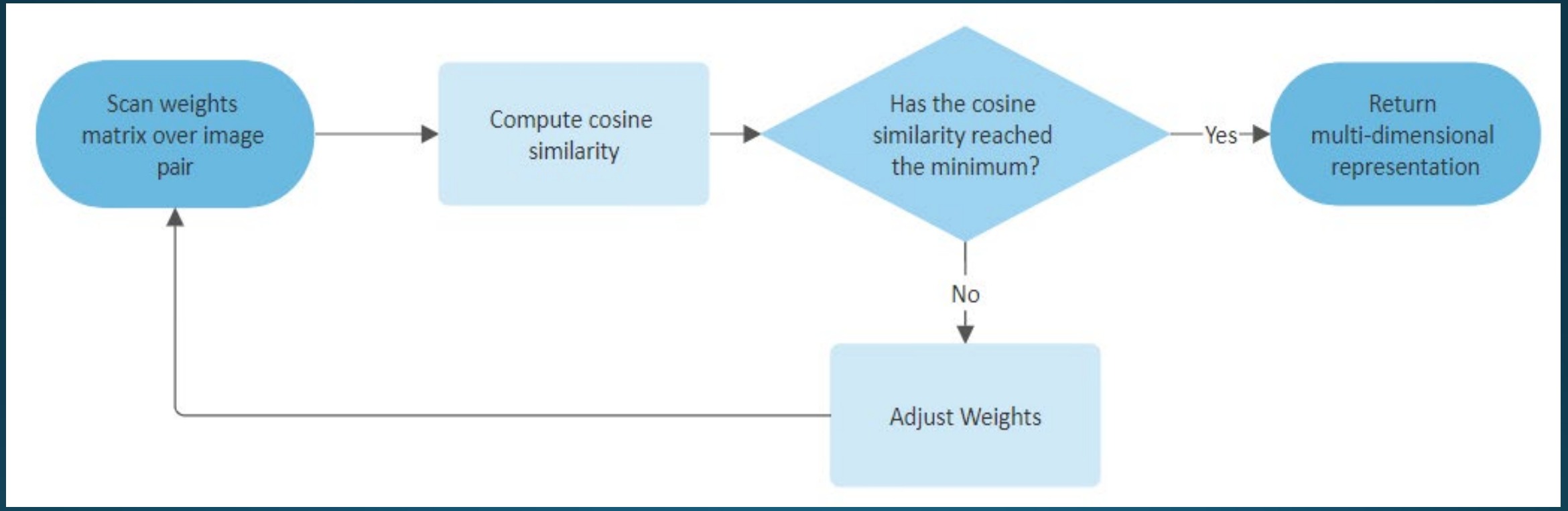
Thank you!

Universidad de Valladolid


Scan weights matrix over image pair
Compute cosine similarity
Has the cosine similarity reached the minimum?
Yes
Return multi-dimensional representation
No
Adjust Weights

Streams

Shells