Deep Learning based Photometric Redshifts of Galaxies in Kilo-Degree Survey

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Why Photometric Redshift?!

- Redshift is a key quantity to constrain the models of galaxy evolution and for cosmological analyses, as it is the basic proxy for galaxy distances.
- We can obtain redshift via spectroscopic and photometric ways.
- It is difficult to obtain spectroscopic redshifts of billions of galaxies.
- In modern wide-angle deep surveys, most of the redshifts are derived indirectly from photometry rather than spectroscopy.
- The redshifts from photometric quantities are called photometric redshifts (Photo-zs).

Photo-z Estimation Methods
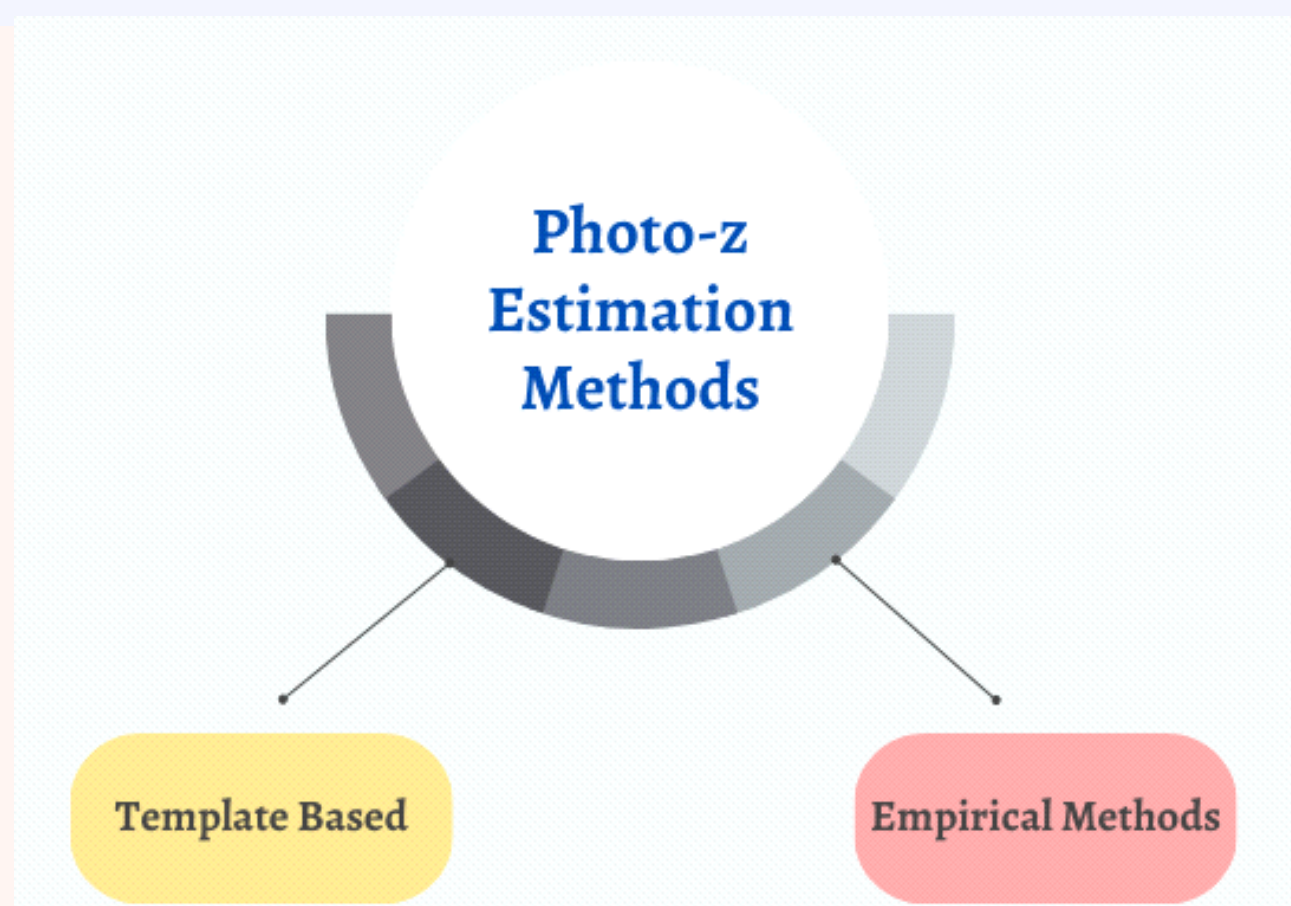
- Deep learning based estimation is an empirical method
- Here, Convolutional Neural Networks (CNN) are used for photo-z estimation of galaxies in Kilo-Degree Survey (KiDS)[2]

Input Data

- The input data to the CNN is the galaxy images from KiDS-DR4.KiDS is a wide-angle image campaign using broad-band optical filters (u,g,r, and i).
- The network is trained by galaxy images and the corresponding spectroscopic redshifts (spec-zs).
- Spec-zs are obtained from the Galaxy And Mass Assembly (GAMA) survey [3].
- 9-band Magnitude (a measure of brightness) of galaxies are also supplemented as additional information.

Example of Galaxy image (Image credit: Alex Tudorica, KiDS)

Combined Model

- Developed a deep learning model based on Inception [4].
- Inception is a deep CNN architecture.
- This model uses two inputs:
  - Galaxy images
  - Magnitudes of galaxies
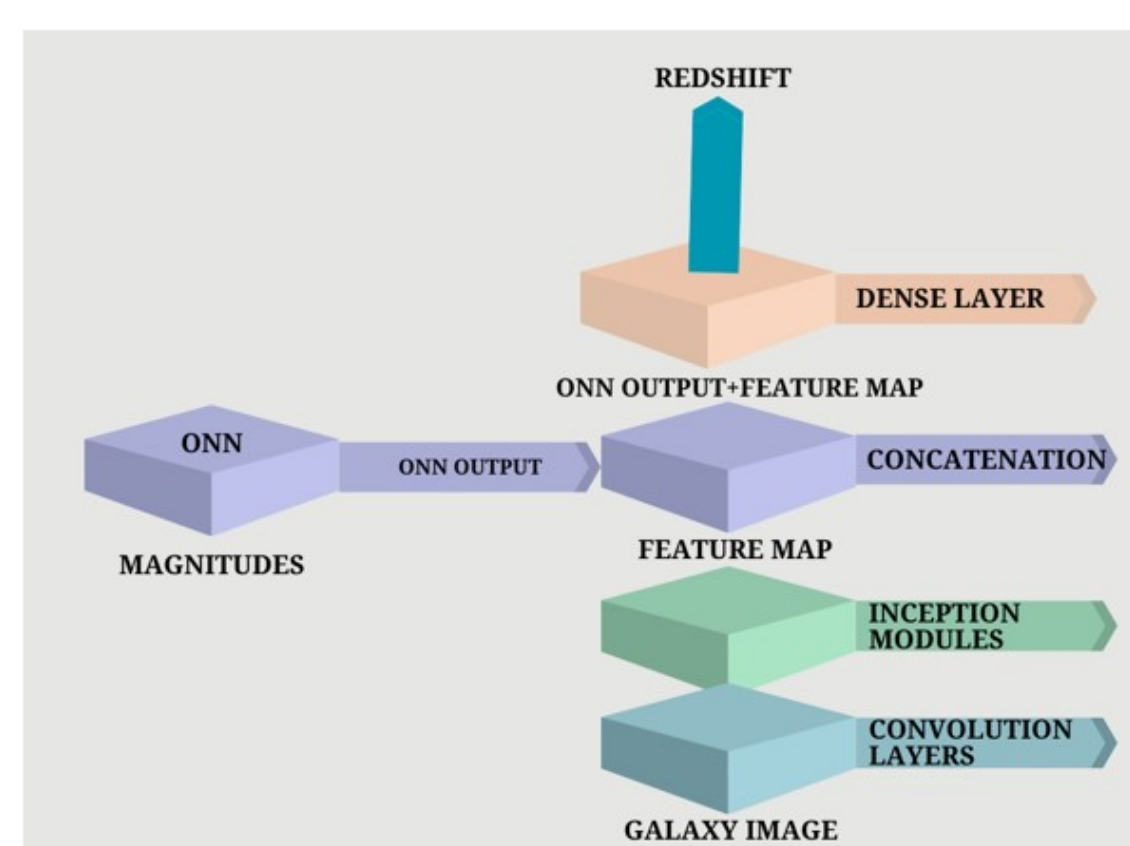
- ONN – Ordinary Neural Network
- Concatenation – Combines two outputs

References

1. Bilicki, M., Hoekstra, H., Brown, M. J. I., et al. 2018, AA, 616, A69

2. de Jong, J. T. A., et al. 2015, AA,582, A62

3. Driver, et al. 2011, Monthly Notices of the Royal Astronomical Society, 413, 971,

4. Szegedy, ., et al. 2015, Proceedings of the IEEE Conference on Computer Vision and Pattern Recognition (CVPR),

Training

- The network tries to minimize the loss function during training by adjusting the weights.

Here, Huber loss (L_h) function is used. It is the combination of mean squared error (MSE) and mean absolute value (MAE) functions.

$$L_h = \begin{cases} \frac{1}{2}(e)^2, |e| \leq \delta \\ \delta(|e| - \frac{1}{2}\delta, \text{otherwise} \end{cases} \tag{1}$$

where,
e= true redshift - predicted redshift
δ is a hyperparameter that determines the transition between MSE and MAE.

Statistics

The performance of the photo-zs is measured using the following statistics:

- Bias

$$dz= \text{Predicted redshift - True redshift} \tag{2}$$

- Normalised bias

$$normdz = \frac{dz}{1 + \text{True redshift}} \tag{3}$$

- standard deviation of normdz, SD(normdz)
- scale median absolute deviation of normdz, SMAD(normdz), where

$$SMAD(x) = 1.4826 \text{median}(|x\text{-median}(x)|) \tag{4}$$

dz	0.001
normdz	0.001
SD(normdz)	0.021
SMAD(normdz)	0.016

Results and Discussions

The total number of sources that have corresponding spec-zs in GAMA is 179,825 with the redshift range $0 < z \leq 0.8$. It is divided into training, validation, and testing samples.
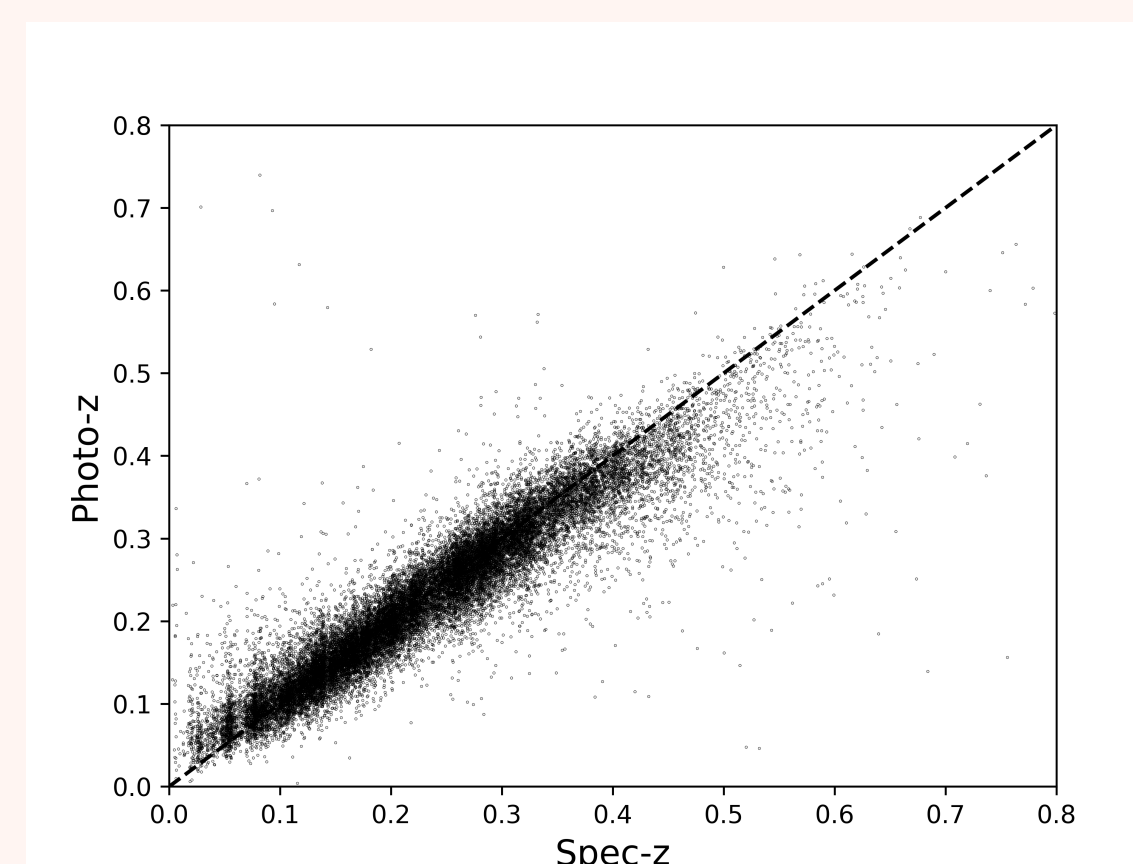
A comparison of true redshift and predicted redshift plot tells that the model is making better predictions compared to existing photo-zs[1].
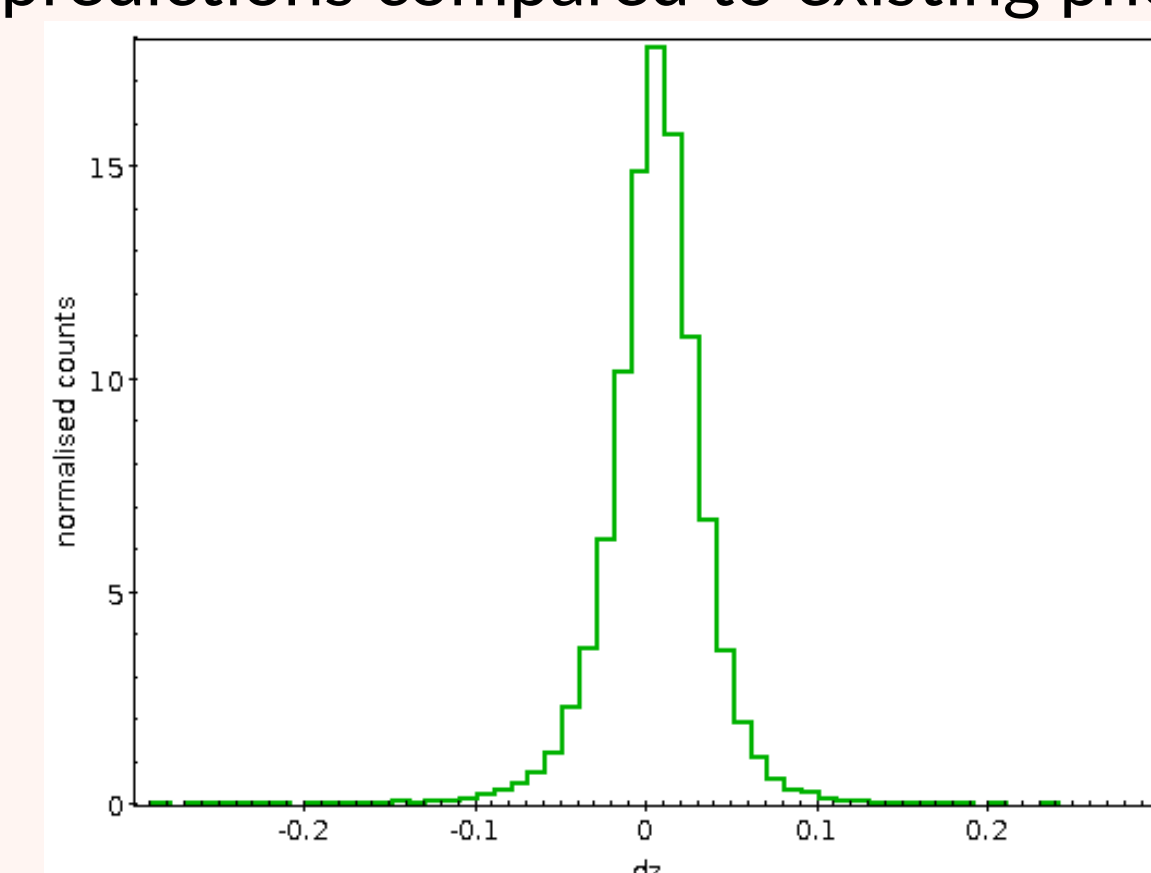

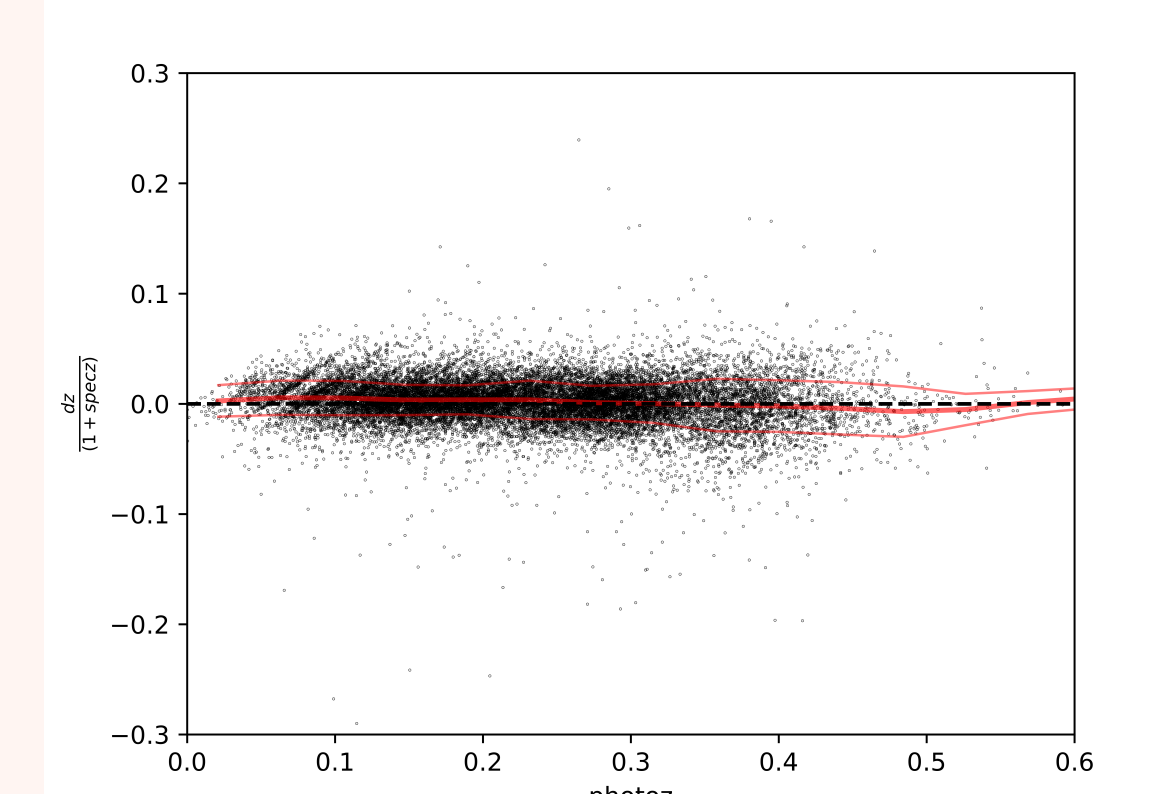Photo-z error almost peaks at zero.

Photo-z error as a function predicted redshift.

Acknowledgement

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