Hubble Constant Estimation from Cosmic Chronometers(CC) using Artificial Neural Network

Diganta Samanta(21PH40020)
Indian Institute of Technology Kharagpur

Cosmology
Friday 24^{th} March, 2023

Contents

References

- Gómez-Vargas, Isidro, et al. **Cosmological Reconstructions with Artificial Neural Networks**; arXiv preprint arXiv:2104.00595 (2021).
- Li, En-Kun, et al. **"Testing the effect of H 0 on f 8 tension using a Gaussian process method."** Monthly Notices of the Royal Astronomical Society 501.3 (2021): 4452-4463.
- Zhang, Cong, et al. **"Four new observational H (z) data from luminous red galaxies in the Sloan Digital Sky Survey data release seven."** Research in Astronomy and Astrophysics 14.10 (2014): 1221.

Introduction

- **H(z)** calculation from differential age method.
- H(z) vs z data.
- From the data of H(z) vs z, calculation of Hubble constant using **Artificial Neural Network(ANN)**

Differential Age Method

- We know

$$H(z) = \frac{\dot{a}}{a}$$

where a is the cosmic scale factor and $\dot{a}$ is the rate of change with respect to the cosmic time.

- We know

$$\frac{a(t)}{a(t_0)} = \frac{1}{1+z}$$

where z is redshift and t_0 is current cosmic time.

- From these relations, we get

$$H(z) = -\frac{1}{1+z}\frac{dz}{dt}$$

Differential Age Method

- Jhang(2014) and Stern at al(2010) have used this method directly.
- Moresco(2015) and Moresco et al(2012 & 2016) have used 4000 Å break. There is a linear relation between D4000 feature and age(t)

$$D_n4000 = A(SFH, Z/Z_{\odot}).t + B$$

where A(SFH,$Z/Z_{\odot}$) is the slope of the D_n4000-age relation and B its normalization.Now the Hubble parameter expression is

$$H(z) = -\frac{1}{1+z}A(SFH, Z/Z_{\odot})\frac{dz}{dD_n4000}$$

H(z)($kms^{-1}Mpc^{-1}$) at red-shift z

z	H(z)	σ_H	Ref.
0.07	69.0	19.6	Zhang et al. (2014)
0.12	68.6	26.2	
0.2	72.9	29.6	
0.28	88.8	36.6	
0.1	69	12	Stern et al. (2010)
0.17	83	8	
0.27	77	14	
0.4	95	17	
0.48	97	60	
0.88	90	40	
0.9	117	23	
1.3	168	17	
1.43	177	18	
1.53	140	14	
1.75	202	40	

z	H(z)	σ_H	Ref.
0.1797	75	4	Moresco et al. (2012)
0.1993	75	5	
0.3519	83	14	
0.5929	104	13	
0.6797	92	8	
0.7812	105	12	
0.8754	125	17	
1.0370	154	20	
0.3802	83	13.5	Moresco et al. (2016)
0.4004	77	10.2	
0.4247	87.1	11.2	
0.4497	92.8	12.9	
0.4783	80.9	9.0	
1.363	160	33.6	Moresco (2015)
1.965	186.5	50.4	

Artificial Neural Network

- The primary component of an ANN is **'stylized neurons'**.
- A neuron consists of a **linear transformation** followed by a **non-linear activation function**. There are different types of Non -linear activation functions like Perceptrons, Sigmoid, Tanh, ReLU, ELU, etc.
- ANN consists of such neurons stacked in layers. A deep Neural Network(DNN) has more than two hidden layers.

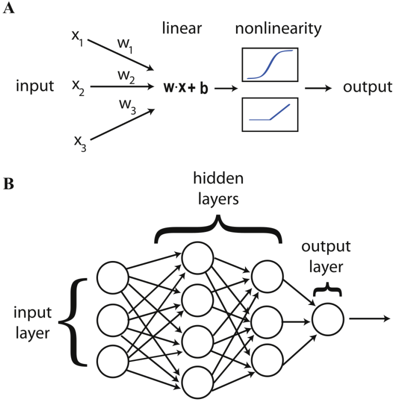

Figure: structure of Neural Network (Source: P. Mehta, M. Bukov, C.-H. Wang et al. / Physics Reports 810 (2019) 1–124)

Artificial Neural Network

- **Universal Approximation Theorem:** A neural network with single hidden layer can approximate any continuous, multi-input/multi-output function with arbitrary accuracy.

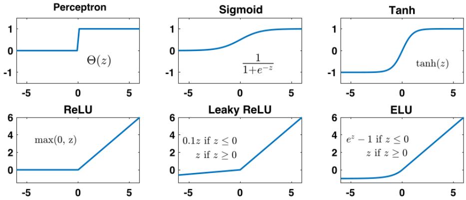

Figure: Some Non-linear Activation Functions (Source: P. Mehta, M. Bukov, C.-H. Wang et al. / Physics Reports 810 (2019) 1–124)

Neural Network for H_0 prediction

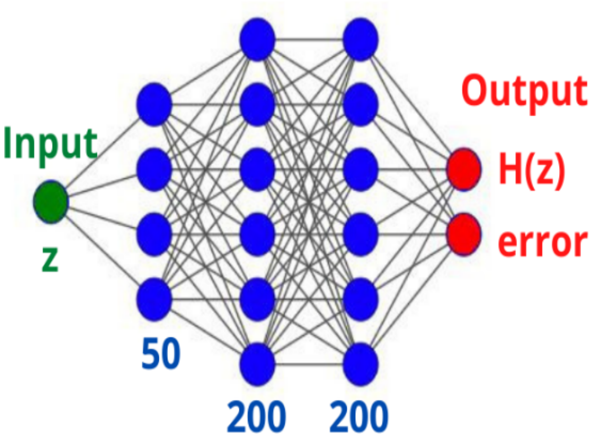

Figure: Neural network for H_0 prediction (Source: Gómez-Vargas, Isidro, et al. Cosmological Reconstructions with Artificial Neural Networks; arXiv preprint arXiv:2104.00595 (2021).

Fitted result

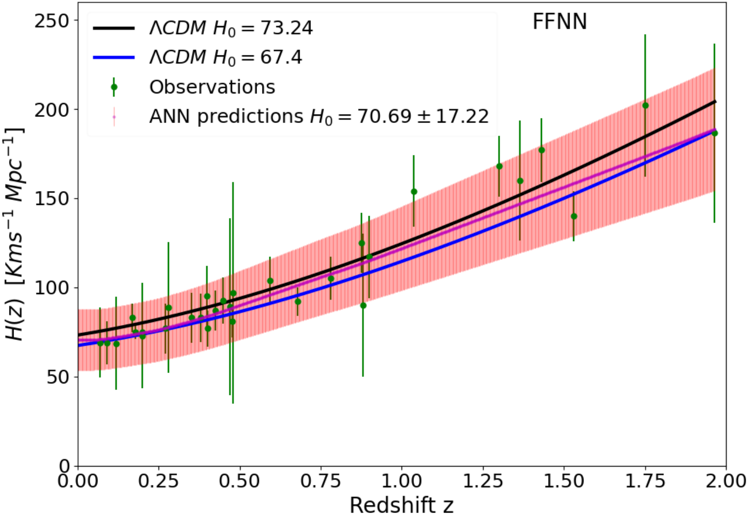

Figure: The result for cc data fitting after 100 epochs training of Neural Network

Behaviour of loss function

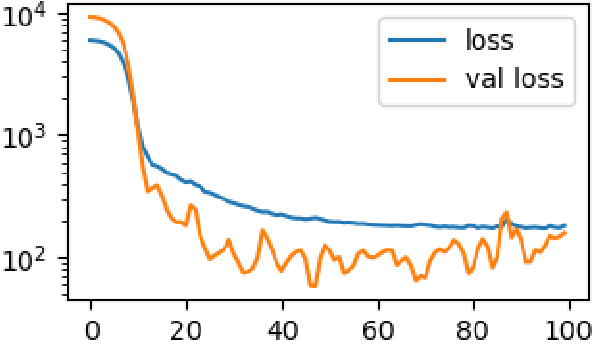

Figure: Behaviour of Mean Squared Error

More on Results

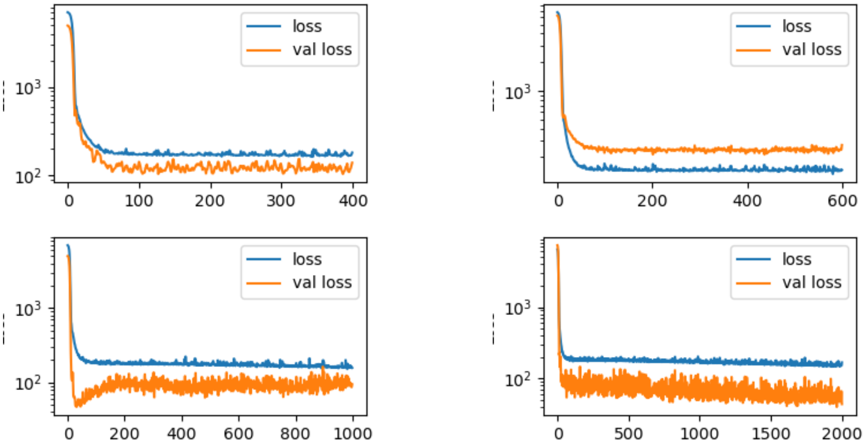

Figure: Behaviour of Mean Squared Error loss function for epochs 400, 600, 1000, and 2000

More on Results

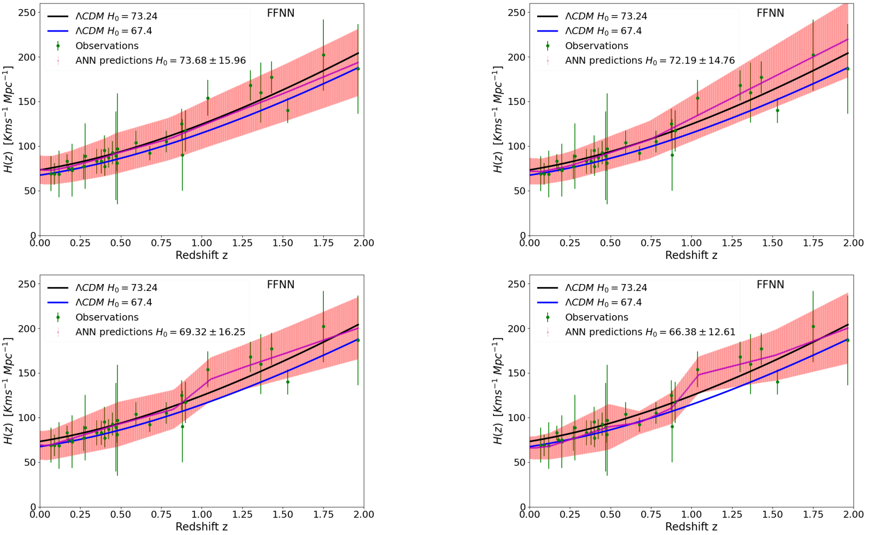

Figure: Results for epochs 400, 600, 1000, and 2000

Result from paper

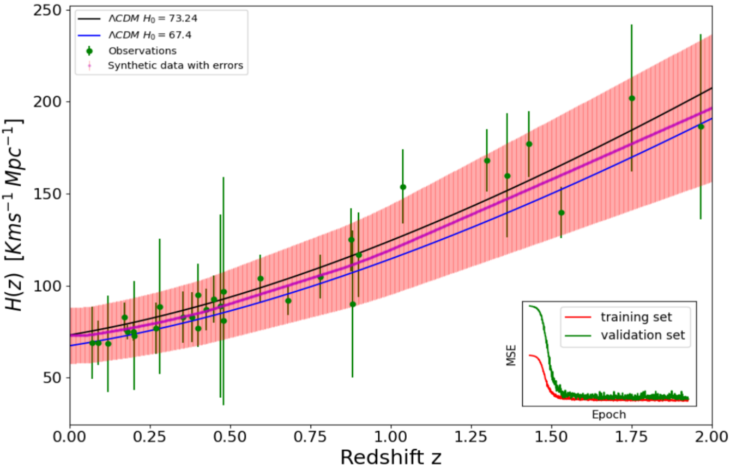

Figure: The results from paper **Gómez-Vargas, Isidro, et al. Cosmological Reconstructions with Artificial Neural Networks; arXiv preprint arXiv:2104.00595 (2021).** They predicted $H_0 = 75.09 \pm 15.49 Kms^{-1} Mpc^{-1}$

Further References

- Stern, Daniel, et al. **"Cosmic chronometers: constraining the equation of state of dark energy. I: H (z) measurements."** Journal of Cosmology and Astroparticle Physics 2010.02 (2010): 008.
- Moresco, Michele, et al. **"Improved constraints on the expansion rate of the Universe up to z 1.1 from the spectroscopic evolution of cosmic chronometers."** Journal of Cosmology and Astroparticle Physics 2012.08 (2012): 006.

Thank You

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