Fault Detection in Antenna Receiver System: Machine Learning Approach

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Antenna Subsystems

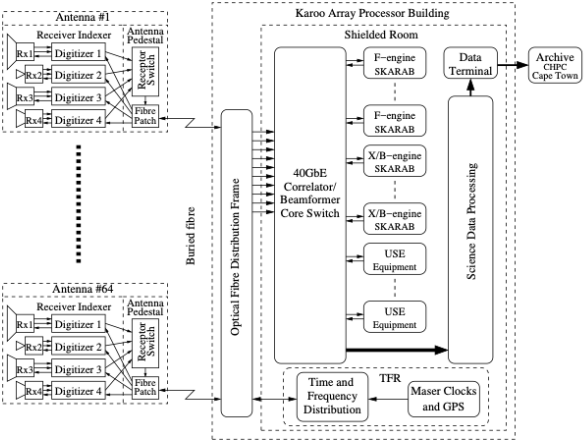


Figure 1: A block diagram showing the overall MeerKAT signal transport and data processing architecture. *Credit*: Justin L. Jonas paper

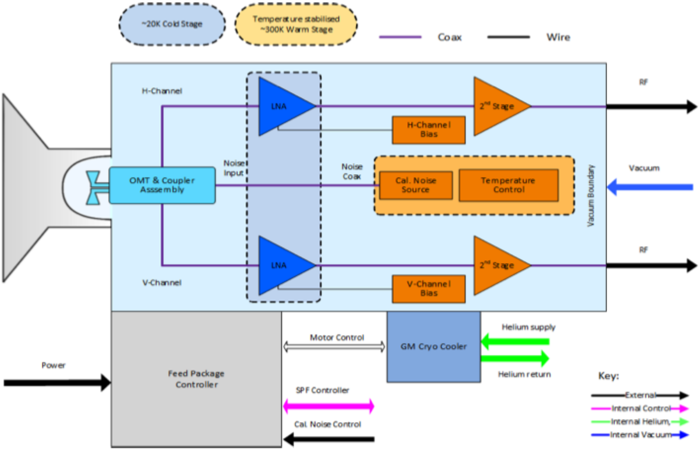


Figure 2: The main components of MeerKAT L-Band (950 – 1760 MHz) receiver system. *Credit*: Tan, Gie Han, et al. 2016

Machine Learning Approach

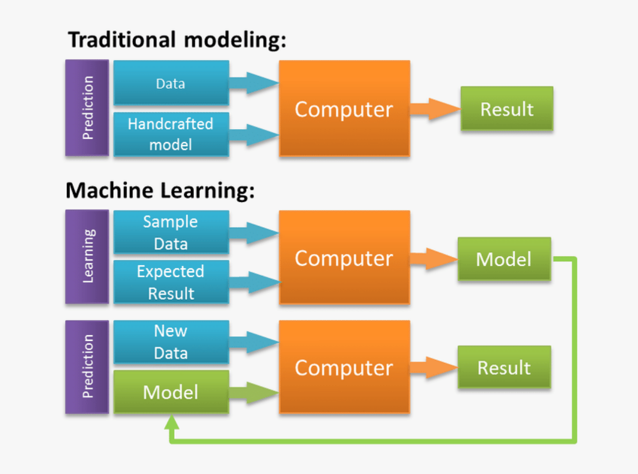


Figure 3: Traditional modelling Vs Machine learning

Machine Learning Approach

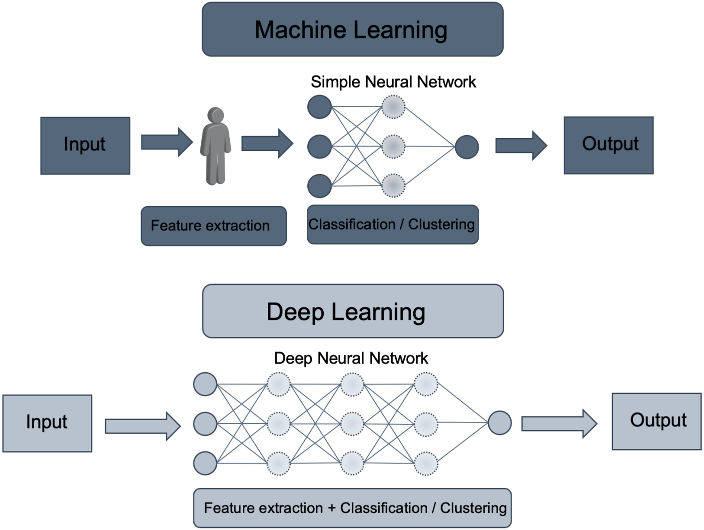


Figure 4: ML Vs DL

CNN application in Radio astronomy

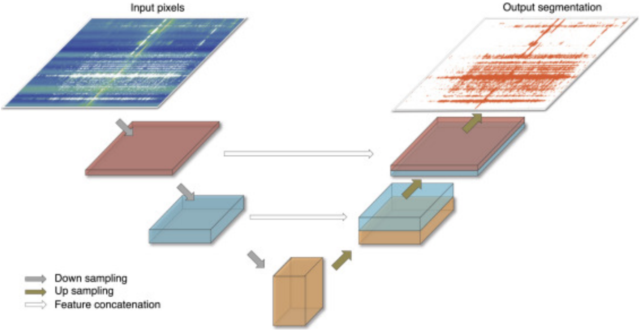


Figure 5: U-Net network design. *Credit*: J. Akeret et al., 2017

Problem with Feed Forward Neural Network

- Not designed for sequences/ time series data, hence the results with time series data are bad.
- Does not model memory.
- Examples of sequential data: Sentences, Stock prices, Video Stream, **Sensor data**, etc.

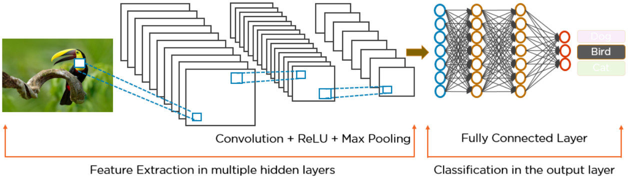


Figure 6: Convolutional Neural Network design. *Credit*: Simplilearn site

Recurrent Neural Networks (RNNs)

- RNNs are types of neural networks designed to record information from time series data.
- RNN has a recursive/ periodic formula: $S_t = R_w(S_{t-1}, X_t)$
  - X_t – Input at time t
  - S_t – Current state at time t
  - S_{t-1} – Initial state at time $t-1$
  - R_w – Periodic function
- Simple case: $S_t = \tanh(W_s S_{t-1} + W_x X_t)$
- Output becomes: $Y_t = W_y S_t$

- Use the outputs (Y_t) to calculate the **loss**.
- Update the weights in each state by multiplying the gradients.
- Update in each weight $= 0.01^{100} \approx 0$.

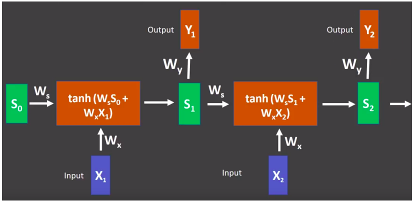


Figure 7: Basic RNN (unfolded). *Credit*: The Semicolon RNN lecture, 2018.

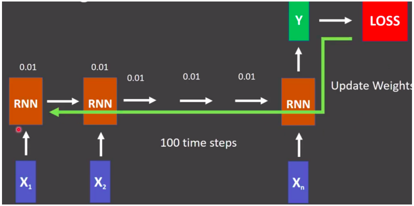
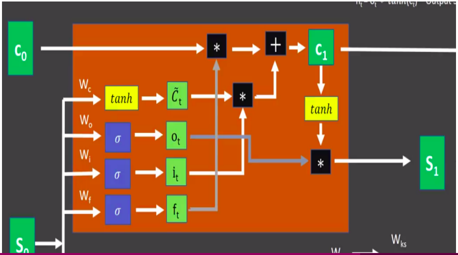


Figure 8: Problem of vanishing gradient. *Credit*: The Semicolon RNN lecture, 2018.

LSTM

- Input Gate:
  $i_t = \sigma(W_i S_{t-1} + W_i X_i)$
- Forget Gate:
  $f_t = \sigma(W_f S_{t-1} + W_f X_f)$
- Output Gate:
  $o_t = \sigma(W_o S_{t-1} + W_o X_o)$
- Cell State:
  $c_t = (i_t * \tilde{C}_t) + (f_t * c_{t-1})$
  - Intermediate cell state:
    $\tilde{C}_t = \tanh(W_c S_{t-1} + W_c X_c)$



Anomaly detection test


That's all Folks!