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A Machine Learning-Based Approach for Antenna Design Using Class_Reg Algorithm Optimized Using Genetic Algorithm

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Abstract: Microstrip patch antennas are predominantly in use in mobile communication and healthcare. Their performances are even improved, using Split-Ring Resonator cells. But finding the ideal dimensions of the microstrip patch antenna and calculating the correct number and size of the split ring resonator cells consume a lot of time when we use Electromagnetic Simulation software to design first and then simulate. Using the pre-calculated results of certain sets of microstrip patch antennas with split ring resonators, a machine learning model can be trained and hence be used to predict the antenna metrics when the dimensions are specified. When the machine learning algorithms are combined with feature-optimization algorithms such as the Genetic Algorithm, the efficiency and performance can be improved further.
Keywords: Machine Learning, Micro-strip Patch Antenna, Genetic algorithm, Split Ring Resonator.

I. INTRODUCTION

The objective of this paper is to implement several machine learning algorithms to predict the Bandwidth, Gain, and Voltage Standing Wave Ratio (VSWR) of a Split Ring Resonator (SRR) based on an existing dataset and to identify the best machine-learning algorithm to find the above-mentioned parameters in a faster and efficient way with maximum accuracy and to study which features are best in the prediction of the Bandwidth, gain and VSWR of an SRR antenna to optimize the prediction.

The main goal of the paper is to develop a machine learning model which can predict Bandwidth, gain, and VSWR in a faster, efficient, and most accurate way possible when compared to conventional methods such as HFSS and CST simulations which are slow and resource heavy.

II. CLASS_REG ALGORITHM

A. Class_reg Algorithm

An algorithm (*Figure 1*) wherein both classification and regression are used in predicting the values. In the Class_Reg algorithm, after splitting into a training set and testing set, the dependent variables in the training set are segregated into a user-defined number of classes. In the same corresponding way, the independent features are also segregated based on the corresponding dependent variable value. A Regression algorithm is trained on each of these portions of the training set. Concurrently a Classification algorithm is also trained to predict which portion does the split part belongs to in the entire dataset.

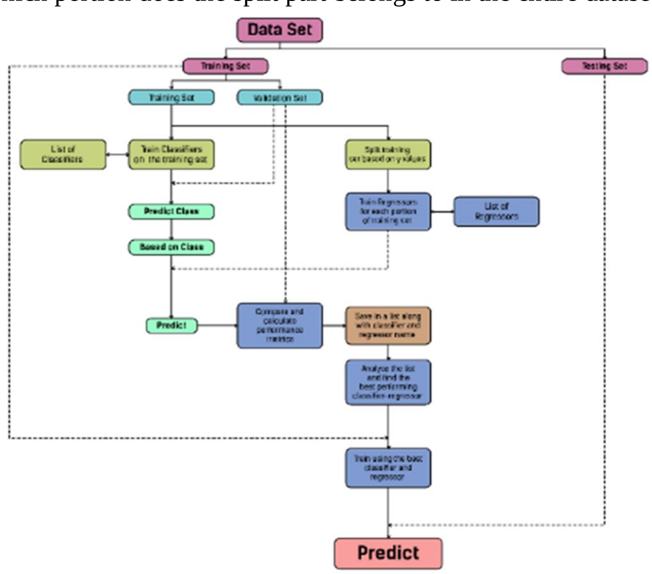


Figure 1: Flowchart of Class_Reg algorithm

For Example, let the dataset be split into a training set and testing set. Then, the training set is split into, say, Class A, B, C, D, and E. Now, we have five different portions of the training set. On each of these different portions, we train a regression algorithm. On the whole training set, we train a classification algorithm to predict if the set of independent features corresponds to Class A, B, C, D, or E. On applying the Class_Reg algorithm on the testing set, we supply the independent features to the algorithm on which we apply the trained classification algorithm to predict the class it belongs.
There is no straightforward way to know which kind of classification or regression algorithm would be suitable in the prediction of our parameters. So, we train on different classifier-regressor combinations and use the prediction accuracy on the test set as a metric to find out which classifier-regressor combination works best in prediction.

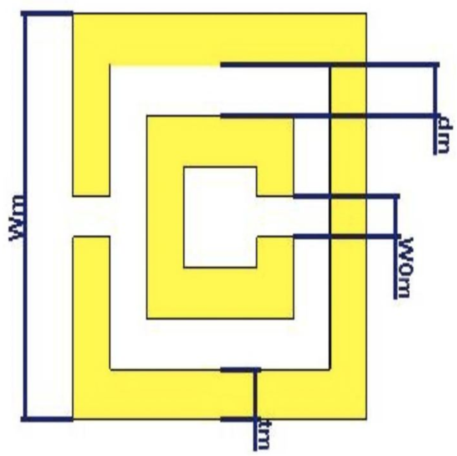
The metric we have used to evaluate the performance is weighted mean absolute percentage error.

$$WMAPE = \frac{\sum_{t=1}^{n}|A_t - F_t|}{\sum_{t=1}^{n}|A_t|}$$

The above-stated method can find us the best classifier-regressor combination, but there is a possibility that the combination only works best for a particular train-test split. So, to find the actual performance metric for all the classifier-regressor combinations, we consider five different train-test splits and average the performance metric of all of them for a particular classifier-regression combination to determine the best classifier-regressor.

This method has helped in achieving a better accuracy compared to a conventional regression algorithm, despite a larger training time.

Figure 2: Split Ring Resonator [4]



The features (*Figure 2*) on which the machine learning models are trained are:

- *Wm:* SRR Cell height
- *W0m:* Gap of rings
- *dm:* Distance between rings
- *tm:* Thickness of the rings
- *rows:* Number of cells in an array
- *Xa:* Distance between array and patch on X-axis
- *Ya:* Distance between array and patch on Y-axis

B. Genetic Algorithm in conjunction with Class_reg Algorithm

A Genetic Algorithm [3] is a feature optimization algorithm based on the theory of Evolution which helps in finding the best attributes on evaluating a function using a particular metric. We supplied the Class_reg function as the function to the genetic algorithm to find the best attributes to predict the required parameters (*Figure 3*).
For the fitness function in the genetic algorithm, we have used five different metrics, namely, weighted mean absolute percentage error [6], mean squared error [6], r2 score [6], weighted mean absolute percentage error multiplied with mean squared error, and weighted mean absolute percentage error added with mean squared error.

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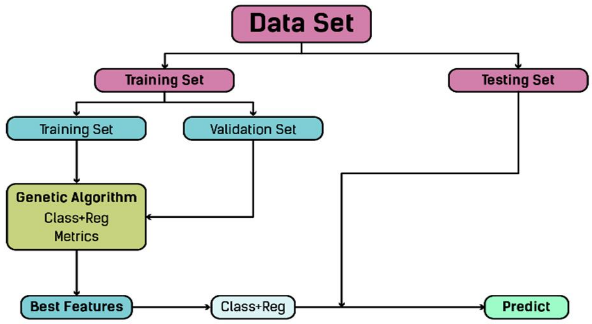
Figure 3: Flow Chart of Genetic algorithm applied in conjunction with Class_Reg algorithm.



III. RESULTS AND DISCUSSION

A. Class_Reg Algorithm applied with Genetic Algorithm

The metrics for each of the dependent parameters after applying class_reg algorithm on the genetic algorithm are:

- *Bandwidth:* Mean Squared Error
- *Gain:* Weighted Mean Absolute Percentage Error
- *VSWR:* Weighted Mean Absolute Percentage Error added with Mean Squared Error

The best features for each of the dependent parameters after applying class_reg algorithm on the genetic algorithm are:

- *Bandwidth:* Wm, dm, tm, Rows, Xa and Ya
- *Gain:* Wm, dm, Rows, Xa and Ya
- *VSWR:* Wm, dm, tm, Rows, Xa and Ya

The best classifiers and regressors for each of the dependent parameters after applying class_reg algorithm on the genetic algorithm are:

- *Bandwidth:* Extra Trees Classifier and Extra Trees Regressor
- *Gain:* Label Spreading Classifier and Extra Trees Regressor
- *VSWR:* Quadratic Discriminant Analysis Classifier and Decision Tree Regressor

B. Designing the Antenna based on the results of Genetic Algorithm optimized Class_Reg Algorithm

The range of the dimensions of the antenna:

- $0.025*\lambda \leq Wm \leq \lambda/4$
- $0.0019*\lambda \leq W0m \leq 0.0076*\lambda$
- $0.0009*\lambda \leq dm \leq 0.0057*\lambda$
- $tm \approx 0.1*Wm$
- rows $\in$ [3, 5, 7]
- $0 \leq Xa \leq W/2 - Wm/2$
- $Wm \leq Ya \leq 4*L/(\min(rows) - 1) - Wm$

$$W = \frac{c}{2f_r}\sqrt{\frac{2}{\varepsilon_r + 1}}$$

$$\varepsilon_{reff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left(1 + 12\frac{h}{W}\right)^{-\frac{1}{2}}$$

$$\Delta L = 0.412h\frac{(\varepsilon_{reff} + 0.3)\left(\frac{W}{h} + 0.264\right)}{(\varepsilon_{reff} - 0.258)\left(\frac{W}{h} + 0.8\right)}$$

$$L = \frac{c}{2f_r\sqrt{\varepsilon_{reff}}} - 2$$

After learning the best features from the genetic algorithm, we trained the class_reg algorithm on the dataset and saved the model weights. Based on the range of values specified above, we input these sets of values for each of the independent features and predict the corresponding bandwidth, gain, and VSWR values using the class_reg model weights. After predicting the set of feature values, we identify the best possible set of independent features, such that it results in high bandwidth, high gain, and low VSWR values, because such characteristics are considered good in a microstrip patch antenna.

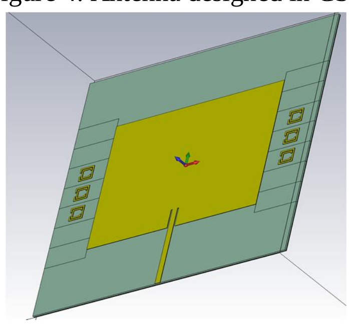
Table 1: The resultant values from the prediction using Class_Reg algorithm

Wm	W0m	dm	tm	Rows	Xa	Ya
2141.137 µm	650.78 µm	77.089 µm	214.1317 µm	3	1200 µm	2141.137 µm

After determining the dimensions of the microstrip antenna. We used the emtalk website [5] to determine the length and width of the antenna patch, where we used FR-4 as the dielectric (*dielectric constant = 4.3*), 0.2 mm as the thickness of the substrate, operating frequency as 3.5 GHz (5G Band). We get, Length of the Patch as 20.65 mm, Width of the Patch as 26.32 mm.

The antenna designed (Figure 4) on CST based on the values from Table 1.

Figure 4: Antenna designed in CST



On evaluating the performance of the Class_Reg algorithm on different predicted antenna dimensions and their corresponding dependent parameter values by comparing with resultant parameter values on simulating the antenna designed on CST, we are getting an average accuracy of:

- *Bandwidth:* 95.18%
- *Gain:* 93.02%
- *VSWR:* 83.29%

IV. CONCLUSION AND FUTURE SCOPE

A. Conclusion

The Class_Reg algorithm has shown promising results in predicting Bandwidth, Gain, and VSWR of a Microstrip Patch Antenna with SRR cells. The integration of the Genetic Algorithm with the Class_Reg has improved the performance even further, as we are only training using the features chosen to be best by the Genetic Algorithm.

Table 2: Time taken for the operations.

Operation	Training	Prediction	Simulation
Time Taken ^	600 s *	0.02 s #	180 s #

* Training time is the time taken for training all data points.
\# Prediction and Simulation time are for one data point
^ All the times mentioned above are for the operation on one parameter

It can be seen from Table 2 that the time taken to predict the Bandwidth, Gain, and VSWR of an antenna after training is nearly 9000 times faster than the time taken to simulate the designed antenna.

B. Future Scope

Even as we have trained on a relatively smaller dataset, we have achieved a reasonably good accuracy, so if the algorithm is trained on a larger dataset, the accuracy can be improved further.

REFERENCES

[1] H. M. E. Misilmani and T. Naous, "Machine Learning in Antenna Design: An Overview on Machine Learning Concept and Algorithms," 2019 International Conference on High Performance Computing & Simulation (HPCS), Jul. 2019, Accessed: May 27, 2021. [Online]. Available: http://dx.doi.org/10.1109/hpcs48598.2019.9188224.

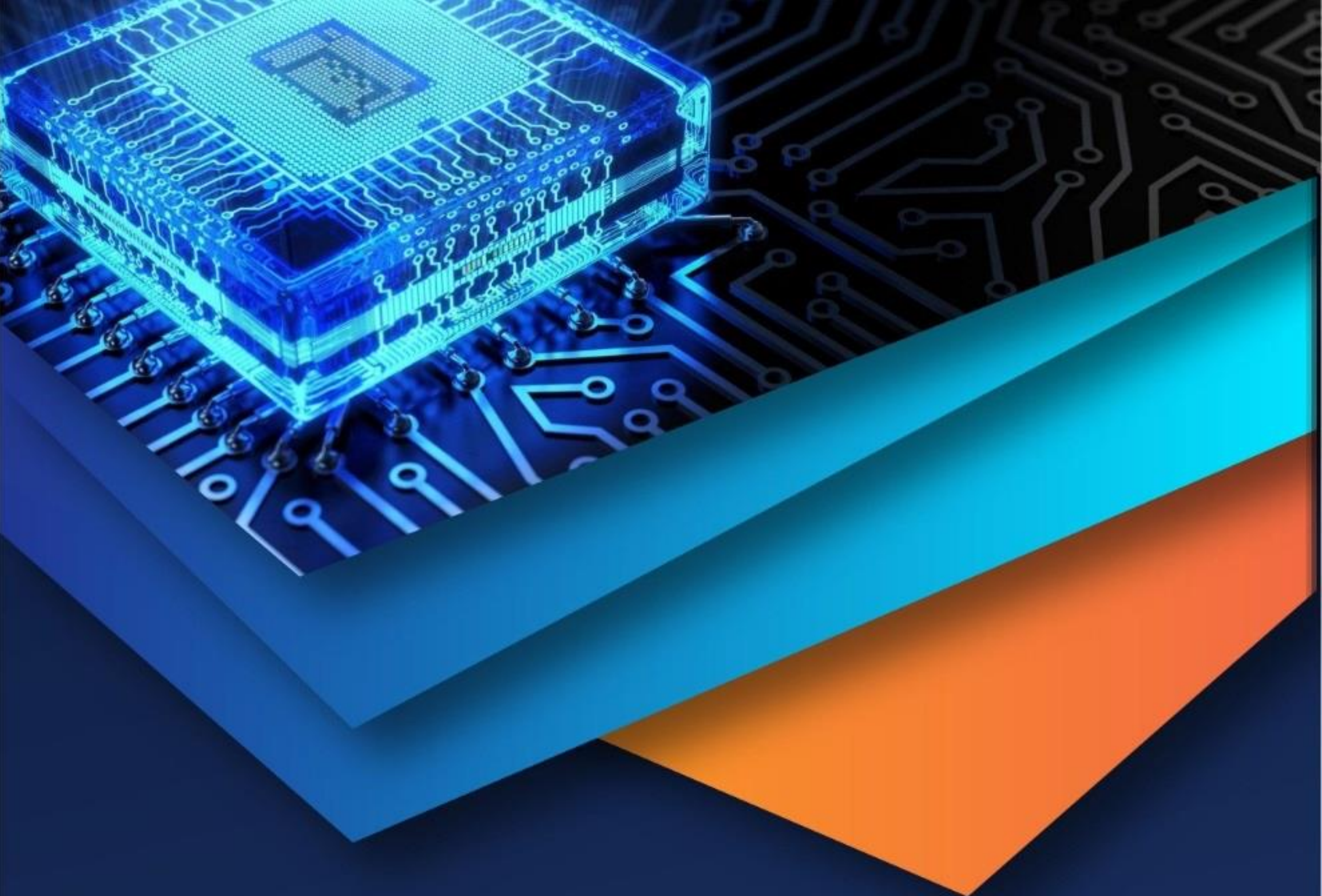
[2] B. Liu, H. Aliakbarian, Z. Ma, G. A. E. Vandenbosch, G. Gielen, and P. Excell, "An Efficient Method for Antenna Design Optimization Based on Evolutionary Computation and Machine Learning Techniques," IEEE Transactions on Antennas and Propagation, vol. 62, no. 1, pp. 7–18, Jan. 2014, doi: 10.1109/tap.2013.2283605.

[3] C. Kang et al., "A genetic algorithm-based boolean delay model of intracellular signal transduction in inflammation," BMC Bioinformatics, vol. 12, no. Suppl 1, p. S17, 2011, doi: 10.1186/1471-2105-12-s1-s17.

[4] R. M. Alves Vaz, "Simulation of SRR Metamaterial Cells with Machine Learning," 2019.

[5] "em: talk - Microstrip Patch Antenna Calculator." https://www.emtalk.com/mpacalc.php (accessed May 27, 2021).

[6] "scikit-learn machine learning in Python — scikit-learn 0.24.2 documentation." https://scikit-learn.org/stable/ (accessed May 27, 2021).



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