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Comparative Study of Path-Loss Minimization Using Rao-Type Metaphor less Optimization Approaches

Collins Iyaminapu Iyoloma[1], Tamunotonye Sotonye Ibanibo[2], Minah-Eeba Winner[3].
[1, 2 &3] Dept. of Electrical Engineering, Rivers State University, Port Harcourt, Nigeria

Abstract
Existing statistical and Artificial Intelligence (AI) models for the path-loss studies in GSM communication systems are quite large and it becomes a problem identifying suitable ones for solving the PLMP. In this research, an alternative purely mathematical and very simple approach to solving the PLMP based on three Rao-type algorithms is proposed. The approach is applied to modeling a case study dataset with the integration of Cost-232 Hata model in an error-loss minimization objective. The results agree with those reported in similar studies and using available case data. The results further show that Rao-1 and Rao-2 techniques have better fitness error response than the Rao-1 and should be considered for future path-loss problems.
Key words: *Dynamic Programming, GSM, Path loss, Optimization*

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I. Introduction

Path loss minimization is an important aspect of communication systems as the need to properly fine-tune the base station parameters for a given satiation is paramount to ensuring a sustainable information transfer process. However, there are a plethora of techniques and modeling approach to choose from considering both classical and nature-inspired optimization techniques. For instance, in (Anireh & Osegi, 2019), the nature inspired swarm intelligence and evolutionary techniques such as the Artificial Bee Colony (ABC), the Particle Swarm Optimization (PSO) and the Genetic Algorithm Optimizer (GAO) have been comparatively studied to examine which model does best for solving the Path Loss Minimization (PLMP).Al Salameh et al (2015), reported up to 37 dB improvement using PSO for optimizing GSM path-loss fitting model.Nadir & Suwailam (2014)developed path loss predictions for the Okumura-Hata model and applied to the semi-urban and urban environments; however, their model was not designed to operate optimally. Jadhav and Kale (2014)implemented an optimized path loss model for the Maharashtra city in India considering several path loss models. And using a sum-of-deviation squares function as objective.Akinwole and Biebuma (2013)investigated the suitability of three path-loss models considering a real world base station path-loss data; they found out that the Cost-231 Hata model was well suited for the South-South zone of the Nigerian state.

In this research study, an entirely different but dynamic programming approach that does not require the use of metaphors (natural phenomena)or the use of classical programming is employed for solving the PLMP.The proposed metaphorless optimization approaches are based on Rao-Type algorithms (Rao, 2020). Though these algorithms are purely mathematical operators, they equally adopt population based search procedures just as is found in nature-inspired (metaphor-based) techniques in solving optimization problems.

II. Methodology

The method employed in this research study follows a data-driven dynamic programming approach comprising of actual measured path-loss data for performing model-fitting simulations, the Cost-231 Hata model and the Rao-type optimizer.

The data for the model-fitting simulations are obtained from the research study in (Marderni &Priya, 2010) which is based on the urban environment. Rao-type optimizers employed include three different updation logic for improving speed and accuracy of model fitting process.

Generally, the Rao-Type model describes a Best-Worst case scenario for solving optimization processes (Rao, 2020; Jagun et al., 2020).

The solution update points are described mathematically as:

$$X_{j,k,i}^{new} = X_{j,k,i}^{old} + r_{1,j,i}\left(X_{j,best,i} - X_{j,worst,i}\right). \tag{1}$$

where,

$X_{j,k,i}^{old}$ = the initial or past candidate value of *j-th* variable for *k-th* candidate at *i-th* iteration

$r_{1,j,i}$ = a random perturbation factor of *j-th* variable at *i-th* iteration

$X_{j,best,i}$ = the best (minimum) candidate value of *j-th* variable at *i-th* iteration

$X_{j,worst,i}$ = the worst (maximum) candidate value of *j-th* variable at *i-th* iteration

The model process requires only two tuning parameters: the population size, and the number of generations (iterations).
Considering the PLMP the objective function is sated as:

Minimize:

$$f_{obj} = \sum \left| P_{l(measured)} - P_{(\cos t-231)} \right| \quad (2)$$

s.t. constraints:

$$h_{cpe}^{\min} \leq h_{cpe} \leq h_{cpe}^{\max} \quad (3)$$

$$h_{base}^{\min} \leq h_{base} \leq h_{base}^{\max} \quad (4)$$

$$f_{base}^{\min} \leq f_{base} \leq f_{base}^{\max} \quad (5)$$

where,

$P_{l(measured)}$ = measured path-loss, dB

$P_{(\cos t-231)}$ = estimated path-loss based on Cost-231 Hata, dB

h_{cpe} = customer premise equipment height, m

h_{base} = height of base station (BS), m

f_{base} = base station transmitting frequency, MHz

III. Results and Discussion

3.1 Simulation Details

The simulations were performed with an Intel i-core-5 PC and using the MATLAB R2007b software which is a legacy but very light and fast IDE version for performing simulation studies.
The data range considered for optimization studies has been taken from the research study conducted in (Marderni & Priya, 2010) with the frequency range set between 1500MHz and 2500MHz.The initial parameters for the Rao techniques were also set to 5 and 100 for the population size and the number of iterations respectively.

3.2 Default Simulation Results

The results showing the optimal performance of the three Rao-type optimizers (Rao-1, Rao-2 and Rao-3) considering fitness response at first trial run are as shown in Figure 1.

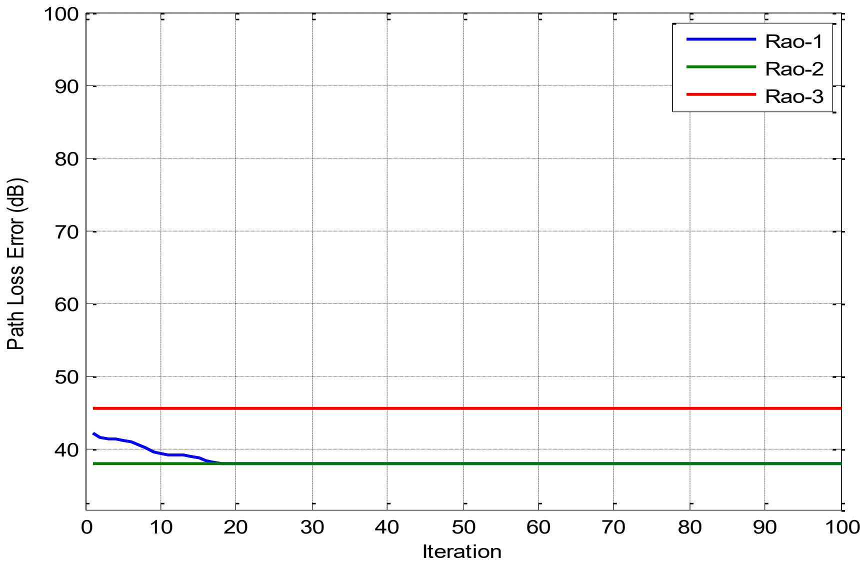

Figure 1: Predicted Path-loss for three types of Rao techniques

As can be seen from Figure 1, the Rao-1 and Rao-2 techniques gave better path-loss of < 40dB. So these techniques should be considered in future fitting studies. Also, the Rao-2 and Rao-3 techniques exhibited a flat response. This may be attributed to their updating procedure.
Considering the decision variables (DV's), the optimal settings are as provided in Table 1.

Table 1: Optimized Results Using Default Parameters

Technique	h_{cpe}	h_{base}	f_{base}
Rao-1	10	40	1500
Rao-2	10	40	1500
Rao-3	10	40	2488

As can be clearly seen, it is preferable to work with the Rao-1 and Rao-2 algorithms as there is no significant difference in the estimated optimal states.

3.3 Sensitivity Studies

In order to validate the influence of some crucial Rao-type parameters, the simulations performed earlier with a different set of values are used for estimating path loss.
For this study, the population size parameter is increased from the default value of 5units to values from 10 to 50 units and at intervals of 10units. The results are as provided in Table 2.

Table 2: Optimized Path Loss Estimates

Pop size	PL_{Rao-1} (dB)	PL_{Rao-2} (dB)	PL_{Rao-3} (dB)
10	45.81	37.99	37.99
20	47.94	44.53	44.40
30	47.94	37.99	43.46
40	42.31	44.42	37.99
50	38.92	37.99	44.33

From the results in Table 2, it can be observed that the worst and best path loss estimates for Rao-1 algorithm are 47.94dB and 38.92dB respectively. The best estimate was obtained at a population size of 50units. Similarly, for Rao-2 and Rao-3 algorithms, the worst and best estimates are 44.53dB and 37.99dB respectively for Rao-2 and 44.40 and 37.99 respectively for Rao-3. The best path loss estimates are obtained at Rao-2 and

Rao-3 solution algorithms. The best estimates for Rao-2 are obtained at population size of 10, 30 and 50 units while that of Rao-3 occurred at 10 and 40 units.
In general, it may be inferred that since the frequency of occurrence of best path loss is greater (no.3) at the Rao-2, then it should be preferred choice for the PLMP. In Table 3 is shown the comparative path loss estimates with previous research studies.

Table 3 Reported optimized path-loss estimates using different techniques compared with proposed.

Technique	Best Possible Path-loss (dB)	Reference
Standard Deviation/RMSE	18.67	Mardeni and Priya (2010)
Mean Error/RMSE	130.00	Tahcfulloh and Riskayadi (2015)
Hybrid Swarming/RMSE	29.89	Anireh & Osegi (2019)
RMSE	5.89	Proposed: Rao-1
RMSE	6.16	Proposed: Rao-2
RMSE	6.16	Proposed: Rao-3

As seen in Table 3, it is best to employ Rao-type algorithms for wireless communication path loss studies as they perform far better than other approaches.

IV. Conclusions and Future Work

The research has shown the performance of using a new kind of dynamic programming approach for solving the PLMP. The approach based on three types of Rao optimizer algorithms showed that it is possible to attain comparative path-loss model with that reported in the literature.
In future, it will be desirable to compare with other kinds of methaporless techniques for the solution of PLMP. Also, other wireless models apart from the Cost-231 Hata should be studied.

References

[1]. Akinwole, B. O. H., Biebuma, J. J. Comparative Analysis Of Empirical Path Loss Model For Cellular Transmission In Rivers State, *Jurnal Ilmiah Electrical/Electronic Engineering* 2 (2013) 24-31.

[2]. Anireh, V. I. E., &Osegi, E. N. (2019). ABC-PLOSS: a software tool for path-loss minimisation in GSM telecom networks using artificial bee colony algorithm. *International Journal of Swarm Intelligence*, *4*(1), 20-37.

[3]. Al Salameh, M. S. H., Al-Zu'bi, M. M. Swarm Intelligence Optimization of Lee Radio-wave Propagation Model for GSM Networks in Irbid, In *The International Conference on Circuits, Systems, Signal Processing, Communications and Computers (CSSCC 2015), Vienna, Austria* 2015.

[4]. Jadhav, A.N., Kale, S.S.*International Journal of Advanced Research in Computer and Communication Engineering***3** (2014) 5004-5008.

[5]. Jagun, Z. O., Okandeji, A. A., Olajide, M. B., Osegi, N. E., & Wokoma, B. A. (2020). Adaptive Hybrid PSO-RAO-Type for Predictive Economic Load Dispatch. *Equity Journal of Science and Technology*, *7*(1), 131-131.

[6]. Marderni, R. &Priya, T.S. (2010). Optimised COST-231 Hata Models for WiMAX Path Loss Prediction in Suburban and Open Urban Environments. *Modern Applied Science*, *4*(9), 75-89.

[7]. Rao, R. (2020). Rao algorithms: Three metaphor-less simple algorithms for solving optimization problems. *International Journal of Industrial Engineering Computations*, *11*(1), 107-130.

[8]. Nadir, Z.,&Suwailam, M. Pathloss Analysis at 900 MHz for Outdoor Environment, In *Proceedings of the 2014 International Conference on Communications, Signal Processing and Computers,(EUROPMENT 2014)*, (2014) pp. 182-186.