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MORE_LOC: MULTI-OUTPUT REGRESSION BASED LOCALIZATION FOR INDOOR APPLICATIONS

Sukhvir Singh
University Institute of Engineering and Technology Panjab University
Chandigarh, India sukhvirpu@gmail.com

Krishan Kumar
University Institute of Engineering and Technology Panjab University
Chandigarh, India k.salujauiet@gmail.com

Savita Gupta
University Institute of Engineering and Technology Panjab University
Chandigarh, India savita2k8@yahoo.com

Abstract— Many indoor applications are developed and being used in the industry and homes. One of the key requirement in these applications is knowing the position of the target. In this paper a novel multi-output regression based localization (MORE_LOC) technique is proposed, which can estimate the location of target node by utilizing the received signal strength (RSS) from multiple anchor nodes. These anchor nodes are deployed in the same room or hall where target node is roaming. MORE_LOC utilizes machine learning algorithms for generation of prediction models. These models are helpful in estimation of current location of mobile target moving in the indoor environment. In this paper, datasets collected from different scenarios are also discussed. Experiments are conducted using real as well as synthetic dataset. The performance analysis of the proposed techniques is done by calculating mean absolute error (MAE), root mean square error (RMSE) and Mean Localization Error (MLE). It is observed that MORE_LOC gives best results when Decision Tree (DT) algorithm is utilized. Values of performance metrics in this case are: MAE 0.23m, RMSE 0.44m and MLE 0.36m. Experiments are also conducted by using MORE_LOC with kalman filter. In this case also proposed technique performs better with DT algorithm. And the values of performance metrics are: MAE 0.24m, RMSE 0.43m and MLE 0.38m.
Keywords-Localization; Indoor Applications; Machine Learning.

I. INTRODUCTION

In the past decade, sensors technology got advanced and are being used for smart indoor applications. These application vary from case to case but one of the key requirement is knowing the location of the target so as to deliver related services deliberately. Actually, global positioning system (GPS) does not provide accurate results in the indoor environment. It is because of non-line of sight conditions, signal fluctuations, noise etc. Estimation of position of a wireless node in indoor environments is called indoor localization. Indoor localization is essential for various smart applications. It is useful in developing smart cities and smart buildings. Basically, there are two categories of localization techniques: a) Range-based b) Range-free. Here, range-based localization deals with time, distance and angle. Using

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these features several localization techniques are developed. And range-free localization techniques deal with features like hop count, etc. Under range-free localization there comes another category of localization techniques called machine learning (ML) based localization techniques. Number of such techniques are proposed in the past but finding positions accurately in mobile environment is a complex task [1]-[4]. In literature following technologies are found which are used in localization related work: Bluetooth, RFID, Vision, XBee, WiFi, Ultrasound, Infrared [5]-[8]. Moreover, there is scarcity of related benchmark datasets for research studies in this area.

In this paper, a new MORE_LOC technique is proposed that finds the target with good accuracy. The main idea is to collect the RSS fingerprint data from multiple anchors so as to generate a regression model using relevant machine learning approach. The detailed analysis of the proposed technique is also done.

Key contributions of this research are:

a) Study of existing localization techniques for indoor applications.
b) Generation of a dataset for localization.
c) Development of a new localization technique using Multi-output regression modeling.
d) Experimentation in different scenarios.
e) Analysis of performance of localization technique.

The organization of this paper is as follows: Section I outlines the basics of problem of localization. It also covers the key contributions of this research work. Section II listed the different applications depicting necessity of localization. And then section III discusses about the existing localization related work. Next, section IV deals with the architecture of the proposed technique. Then section V covers the experimental results and discussion. Finally, section VI concludes the paper.

II. APPLICATIONS OF LOCALIZATION

There are several indoor applications of localization techniques. A lot of research work is going on in this area. Some key applications are listed below:

a) Indoor navigation and related services.
b) Localization fire fighters inside the building.
c) Coal Miners' tracking.
d) Automated parking system.
e) Robot tracking
f) Monitoring of patients or elderly at home.

Localization is essential in many applications e.g. a blind person can navigate with the help of an application which will provide audio support based on his current location. In a museum audio/visuals can be updated on mobile app based on position of visitor. Exact location of a firefighter can be tracked inside the building. GPS is not appropriate for indoor applications. Similarly, a coal miner can be tracked. In smart cities, automated smart parking system are proposed where location of current car parking can be traced. These days, robots and artificial

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intelligence based application are being used by big organizations. Exact information about location of robots is necessary for these applications. In another case one can monitor the patients or elderly by smart applications which need precise current location of object [9]-[12].

III. EXISTING RESEARCH WORK

Many researchers worked on the localization problem and proposed many different approaches. As mentioned in section I there are generally two broad categories of localization techniques: a) Range-based and b) Range-free. ML based localization techniques are new and broadly comes under range-free localization. Further ML based localization

Recently, lot of work is done on techniques based on machine learning algorithms. One of such approach is proposed in [13] which is uses support vector machine (SVM), K-k-nearest neighbors (KNN) and deep neural network (DNN). Mean square error of DNN and KNN has been minimum and similar. In another approach SVM based technique is proposed using RSS [14]. It is a classification based approach where authors compared the proposed technique with artificial neural network (ANN) and observed higher accuracy.

Support vector regression (SVR) has been used in [15]for localization. IEEE802.11 based technologies are utilized in the study. Proposed technique has shown good localization results. Location based services are evaluated in [16] where KNN is integrated with ANN-back propagation. RMSE obtained for the proposed method is 0.56m. In [17] authors presented a comparative study by performing experiments on deterministic, probabilistic and ensemble learning algorithms. UJIIndoorLoc database has been used for experiments [18].

Another research work is done using XBee devices where DT, KNN, RF and linear regression algorithms are used in the experiments [19]. RSS fingerprints are collected and utilized for generation of model. KNN model performs better than others with localization error of 1.4m. Author of [20] proposed three methods for localization which are based on feature standardization. Authors name them Scaling-SVR, Zero-SVR and Range-SVR. From results they concludes that Range-SVR performs better than other two methods.

IV. PROPOSED TECHNIQUE

After surveying existing related work, it is observed that problem of localization has not been formulated as multi-output regression problem. Moreover, RSS is inversely proportional to Euclidean distance between two coordinates. So in the present research work MORE_LOC technique is proposed which utilizes multi- output regression. In this section proposed technique is explained.

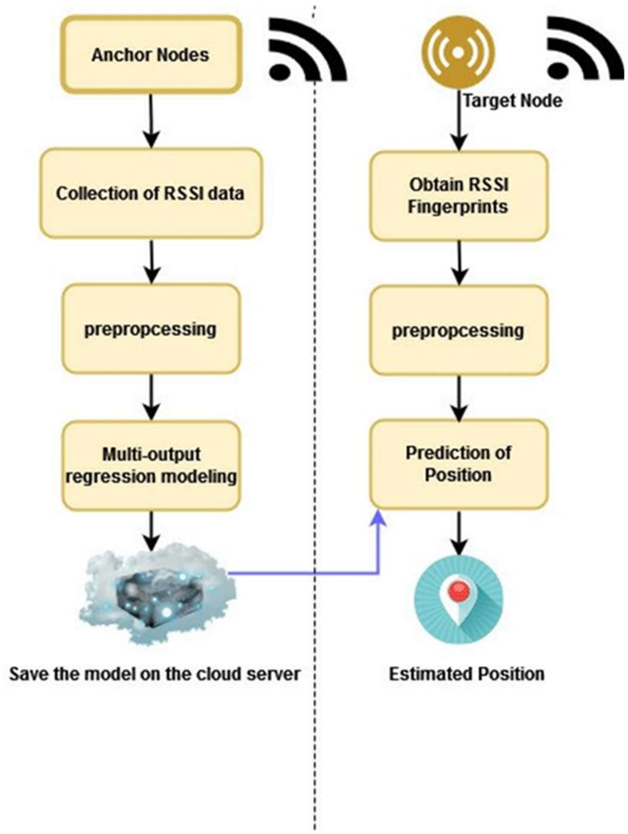

Figure 1. An architecture of proposed technique

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Proposed localization technique i.e. MORE_LOC works in following three phases:

1. Data sensing: First, RSS data is collected form anchors at different test points.
2. Model Generation: Dataset obtained in previous phase is utilized for multi-output regression modeling.
3. Prediction: Finally, data sensed at current location of the target node is used as input to model generated and it returns coordinates (position) of target node.

Figure 1 shows the architecture of proposed technique for localization. A step by step description is provided with the help of an algorithm below.

ALGORITHM 1. AN ALGORITHM FOR MULTI-OUTPUT REGRESSIONBASED LOCALIZATION

1. FOR TP = 1 to TP = N: # TP is test point
    a. FOR A= 1 to A = M # A is anchor node
        i. REPEAT: Collect RSS- D_{rss}
2. GENERATE Muti-Output Regression model - f(D_{rss}).
3. SEND f(D_{rss}) to Mobile Target Node.
4. FOR A= 1 to A = M:
    a. REPEAT: Mobile Node will Collect RSS- D^{1}_{rss}
5. PREDICT Location (x,y) using f(D^{1}_{rss}) and return.

Algorithm 1 clearly explained the steps of proposed localization technique for indoor applications.

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V. EXPERIMENTAL RESULTS AND DISCUSSION

In this section, details of all the experiments and observed results are outlined and discussed. Different test cases are explained in which experiments are conducted. The performance of proposed localization techniques, i.e. MORE_LOC and MORE_LOC_Kalman is analyzed in this section. Different datasets are utilized during experimentation. This chapter is concluded with a brief discussion of the performance of the aforementioned techniques. Own dataset is collected using XBee and Arduino devices. Total 6 devices are deployed as anchors and data is collected at 16 test points in the lab. Channel frequency of XBee devices is 5GHz. Total 36307 observations are made using this setup.

The proposed techniques are evaluated for three given trajectories traversed by a target node in the testbed. Experiments are performed for proposed techniques using these trajectories. Statistical analysis of the performance is conducted. The MLE is calculated, which is equivalent to the euclidean distance between the predicted and actual positions divided by the total number of positions. The MAE and the RMSE are also calculated for given trajectories. Different test cases used in this research study are explained below:

Case1: Using Test Trajectory-1

In this case, target node follows a trajectory shown in figure 2 for which RSS fingerprint data from the anchors are obtained. Proposed technique generates a model which predicts location coordinates using RSS inputs of given trajectory. DT, RF and KNN algorithms are utilized for modeling. The predicted positions are compared with original positions. The results of the localization in terms of MAE, RMSE and MLE of proposed technique for trajectory-1 are shown in table I-III. As observed from the tables, the minimum value of MAE is 0.23m, RMSE is 0.44m and MLE is 0.36m.

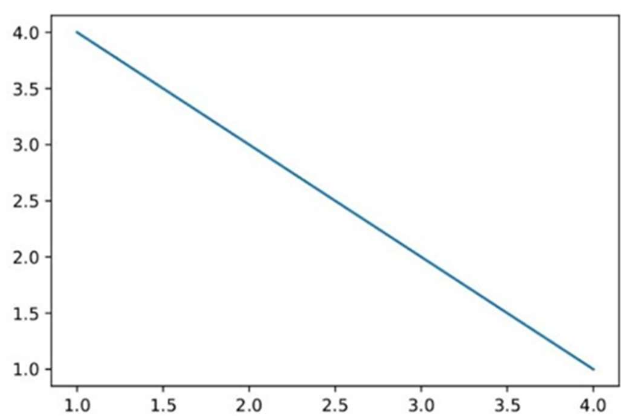

Figure 2. Test trajectory-1.

Similar experiments are conducted by utilizing Kalman filter and results are given in table IV-VI. It is observed from the results that minimum value of MAE is 0.24m, RMSE is 0.43m and MLE is 0.36m.

Case 2: Using Test Trajectory-2

Similar experiments are conducted with second trajectory traversed by target node. The minimum

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values of the MAE and RMSE values in this case are 0.49m and 0.72m respectively. And minimum value of MLE obtained is 0.73m. Please refer figure 3 for trajectory used. And experimental results of the proposed localization technique for trajectory-2 can be seen in table I-III.

Similar experiments are conducted by utilizing kalman filter and it is observed from the results that minimum value of MAE is 0.50m, RMSE is 0.78m and MLE is 0.73m. These results are presented in table IV- VI.

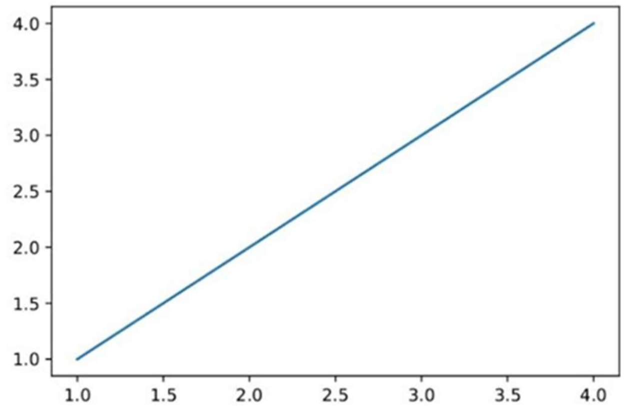

Figure 3. Test trajectory-2.

Case 3: Using Test Trajectory-3

Trajectory used in this case is shown in figure 4. Positioning results of the proposed technique are shown in table I-III. Minimum observed value of MLE, MAE and MLE is 0.32m, 0.53m and 0.48m respectively. And in second phase of experiments minimum value of MAE obtained is 0.32, RMSE observed is 0.51m and MLE occurred is 0.48m. Please refer table IV–VI for results.

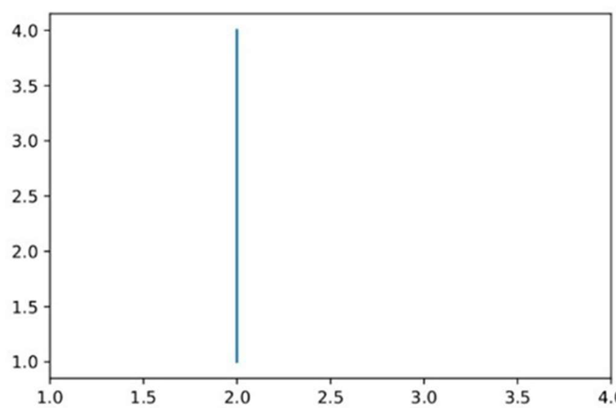

Figure 4. Test trajectory-3.

TABLE I. A COMPARISON TABLE OF MAE IN EXPERIMENTAL RESULTS FOR MORE_LOC_TECHNIQUE.

Localization Technique	Mean Absolute Error (m)		
	Trajectory - 1	Trajectory-2	Trajectory-3
MORE_LOC_DT	0.23	0.49	0.32
MORE_LOC_KNN	0.28	0.57	0.37

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MORE_LOC_RF	0.23	0.49	0.32

TABLE II. A COMPARISON TABLE OF RMSE IN EXPERIMENTAL RESULTS FOR MORE_LOC_TECHNIQUE.

Localization Technique	Root Mean Square Error (m)		
	Trajectory - 1	Trajectory-2	Trajectory-3
MORE_LOC_DT	0.44	0.72	0.53
MORE_LOC_KNN	0.58	0.91	0.74
MORE_LOC_RF	0.44	0.72	0.53

TABLE III. A COMPARISON TABLE OF MLE IN EXPERIMENTAL RESULTS FOR MORE_LOC_TECHNIQUE.

Localization Technique	Mean Localization Error (m)		
	Trajectory - 1	Trajectory-2	Trajectory-3
MORE_LOC_DT	0.36	0.73	0.48
MORE_LOC_KNN	0.46	0.89	0.60
MORE_LOC_RF	0.36	0.73	0.48

In second phase of experiments proposed technique is evaluated using kalman filter. Experimental localization results of second phase are given below:

TABLE IV. A COMPARISON TABLE OF MAE IN EXPERIMENTAL RESULTS FOR MORE_LOC_KALMAN TECHNIQUE.

Localization Technique	Mean Absolute Error (m)		
	Trajectory - 1	Trajectory-2	Trajectory-3
MORE_LOC_DT _KALMAN	0.24	0.50	0.32
MORE_LOC_KNN _KALMAN	0.30	0.59	0.39
MORE_LOC_RF _KALMAN	0.24	0.51	0.32

TABLE V. A COMPARISON TABLE OF RMSE IN EXPERIMENTAL RESULTS FOR MORE_LOC_KALMAN TECHNIQUE.

Localization Technique	Mean Absolute Error (m)		
	Trajectory - 1	Trajectory-2	Trajectory-3
MORE_LOC_DT _KALMAN	0.24	0.50	0.32
MORE_LOC_KNN _KALMAN	0.30	0.59	0.39
MORE_LOC_RF _KALMAN	0.24	0.51	0.32

TABLE VI. A COMPARISON TABLE OF MLE IN EXPERIMENTAL RESULTS FOR MORE_LOC_KALMAN TECHNIQUE.

Localization Technique	Mean Localization Error (m)		
	Trajectory - 1	Trajectory-2	Trajectory-3
MORE_LOC_DT _KALMAN	0.36	0.73	0.48
MORE_LOC_KNN _KALMAN	0.46	0.89	0.60

MORE_LOC_RF _KALMAN	0.36	0.73	0.48

From experimental results it is observed that overall performance of MORE_LOC_DT technique is best as compare to others and therefore recommended for indoor applications.

VI. CONCLUSION AND FUTURE DIRECTIONS

A novel localization technique named MORE_LOC is proposed in this paper. Different test cases are designed in which performance of proposed technique is judged with different test trajectories. DT, KNN and RF algorithms are utilized which supports multi-output regression. MORE_LOC_DT gives the best localization in terms of MAE, RMSE and MLE.

As many smart indoor applications are being developed, there is a need to address the future challenges. In future, research work can be performed with optimization techniques and deep learning methods for better research findings in the future. Moreover, more real testbed experiments should be conducted in future.

REFERENCES

[1] Al-Ammar, Mai A., Suheer Alhadhrami, Abdulmalik Al- Salman, Abdulrahman Alarifi, Hend S. Al-Khalifa, Ahmad Alnafessah, and Mansour Alsaleh. "Comparative survey of indoor positioning technologies, techniques, and algorithms." In 2014 International Conference on Cyberworlds, pp. 245-252. IEEE, 2014.

[2] Kunhoth, Jayakanth, AbdelGhani Karkar, Somaya Al- Maadeed, and Abdulla Al-Ali. "Indoor positioning and wayfinding systems: a survey." Human-centric Computing and Information Sciences 10, no. 1 (2020): 1-41.

[3] Sesyuk, Andrey, Stelios Ioannou, and Marios Raspopoulos. "A survey of 3D indoor localization systems and technologies." Sensors 22, no. 23 (2022): 9380.

[4] Mainetti, Luca, Luigi Patrono, and Ilaria Sergi. "A survey on indoor positioning systems." In 2014 22nd international conference on software, telecommunications and computer networks (SoftCOM), pp. 111-120. IEEE, 2014.

[5] Zafari, Faheem, Athanasios Gkelias, and Kin K. Leung. "A survey of indoor localization systems and technologies." IEEE Communications Surveys & Tutorials 21, no. 3 (2019): 2568-2599.

[6] Zhu, Lingling, Aolei Yang, Dingbing Wu, and Li Liu. "Survey of indoor positioning technologies and systems." In International Conference on Intelligent Computing for Sustainable Energy and Environment, pp. 400-409. Berlin, Heidelberg: Springer Berlin Heidelberg, 2014.

[7] Billa, Arlind, Ibraheem Shayea, Abdulraqeb Alhammadi, Qazwan Abdullah, and Mardeni Roslee. "An overview of indoor localization technologies: Toward IoT navigation services." In 2020 IEEE 5th International Symposium on Telecommunication Technologies (ISTT), pp. 76-81. IEEE, 2020.

[8] Hayward, S. J., Kate van Lopik, Christopher Hinde, and A. A. West. "A survey of indoor location technologies, techniques and applications in industry." Internet of Things (2022): 100608.

[9] Cheng, Long, Chengdong Wu, Yunzhou Zhang, Hao Wu, Mengxin Li, and Carsten Maple. "A survey of localization in wireless sensor network." International Journal of Distributed

Sensor Networks 8, no. 12 (2012): 962523.
[10] Mohar, Satinder Singh, Sonia Goyal, and Ranjit Kaur. "A survey of localization in wireless sensor network using optimization techniques." In 2018 4th International Conference on Computing Communication and Automation (ICCCA), pp. 1-6. IEEE, 2018.
[11] Kuriakose, Jeril, V. Amruth, and N. Swathy Nandhini. "A survey on localization of wireless sensor nodes." In International Conference on Information Communication and Embedded Systems (ICICES2014), pp. 1-6. IEEE, 2014.
[12] Farid, Zahid, Rosdiadee Nordin, and Mahamod Ismail. "Recent advances in wireless indoor localization techniques and system." Journal of Computer Networks and Communications 2013 (2013).
[13] Abidin, Dodo Zaenal, Siti Nurmaini, Erwin, Errissya Rasywir, and Yovi Pratama. "Indoor positioning system in learning approach experiments." Journal of Electrical and Computer Engineering 2021 (2021): 1- 16.
[14] Chriki, Amira, Haifa Touati, and Hichem Snoussi. "SVM
-based indoor localization in wireless sensor networks." 2017 13th international wireless communications and mobile computing conference (IWCMC). IEEE, 2017.
[15] Shi, Ke, Zhenjie Ma, Rentong Zhang, Wenbiao Hu, and Hongsheng Chen. "Support vector regression based indoor location in IEEE 802.11 environments." Mobile Information Systems 2015 (2015).
[16] Adege, Abebe Belay, Yirga Yayeh, Getaneh Berie, Hsin- piao Lin, Lei Yen, and Yun Ruei Li. "Indoor localization using K-nearest neighbor and artificial neural network back propagation algorithms." In 2018 27th Wireless and Optical Communication Conference (WOCC), pp. 1
-2. IEEE, 2018.
[17] Bozkurt, Sinem, Gulin Elibol, Serkan Gunal, and Ugur Yayan. "A comparative study on machine learning algorithms for indoor positioning." In 2015 International Symposium on Innovations in Intelligent SysTems and Applications (INISTA), pp. 1-8. IEEE, 2015.
[18] UCI Machine Learning Repository, [online] Available: archive.ics.uci.edu/ml/..
[19] Alhmiedat, Tareq. "Fingerprint-Based Localization Approach for WSN Using Machine Learning Models." Applied Sciences 13, no. 5 (2023): 3037.
[20] Singh, Abhilash, Vaibhav Kotiyal, Sandeep Sharma, Jaiprakash Nagar, and Cheng-Chi Lee. "A machine learning approach to predict the average localization error with applications to wireless sensor networks." IEEE Access 8 (2020): 208253-208263.