

**DEVELOPMENT AN ACCURATE AND  
STABLE RANGE-FREE LOCALIZATION  
SCHEME FOR ANISOTROPIC WIRELESS  
SENSOR NETWORKS**

**HAN FENGRONG**

**DOCTOR OF PHILOSOPHY**

**UNIVERSITI MALAYSIA PAHANG**



### **SUPERVISOR'S DECLARATION**

We hereby declare that We have checked this thesis and in our opinion, this thesis is adequate in terms of scope and quality for the award of the degree of Doctor of Philosophy.

A handwritten signature in blue ink, appearing to read 'Ibrahim' or a similar variation.

---

(Supervisor's Signature)

Full Name : DR. IZZELDIN IBRAHIM MOHAMED ABDELAZIZ

Position : SENIOR LECTURER

Date : 9/2/2022

A handwritten signature in black ink.

PROFESSOR IR. TS. DR. KAMARUL HAWARI BIN GHAZALI  
FAKULTI TEKNOLOGI KEjuruteraan Elektrik dan Elektronik  
UNIVERSITI MALAYSIA PAHANG  
26600 PEKAN, PAHANG

---

(Co-supervisor's Signature)

Full Name : IR. TS. DR. KAMARUL HAWARI BIN GHAZALI

Position : PROFESSOR

Date : 9/2/2022



### **STUDENT'S DECLARATION**

I hereby declare that the work in this thesis is based on my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at Universiti Malaysia Pahang or any other institutions.

韩凤荣

---

(Student's Signature)

Full Name : HAN FENG RONG

ID Number : PEG18005

Date : 9 FEBRUARY 2022

DEVELOPMENT AN ACCURATE AND STABLE RANGE-FREE  
LOCALIZATION SCHEME FOR ANISOTROPIC WIRELESS SENSOR  
NETWORKS

HAN FENGRONG

Thesis submitted in fulfillment of the requirements  
for the award of the degree of  
Doctor of Philosophy

College of Engineering  
UNIVERSITI MALAYSIA PAHANG

FEBRUARY 2022

## **ACKNOWLEDGEMENTS**

Time flies, suddenly looking back, my Ph.D. study journey has come to an end. Along the way, I have to thank so many people. First and foremost, I would like to express my sincere gratitude to my supervisor Dr. Izzeldin Ibrahim Mohamed Abdelaziz, and my co-supervisor Prof. Kamarul Hawari Ghazali for their continuous support of my Ph.D. study and related research, for their patience, assistance, and immense knowledge.

Besides my supervisor, I would like to thank the Universiti Pahang Malaysia for giving me the study opportunities and financial grant support, DRS and PGRS. Thank the Institute of Postgraduate for providing a convenient learning studio. In addition, I take this opportunity to express gratitude to all of the faculty members of College Engineering and Faculty of Electrical & Electronics Engineering Technology, for their hard work, help, and support. Thanks to all the lovely teachers who taught me knowledge. Thank the International Office for organizing the colorful activities.

I would also like to thank the experts who were involved in the validation survey for this research project. Thank all the international students of KK2, and thank all the classmates, friends who helped me, and those who I did not mention by name, thanks for your support and help all the way.

Last but not the least, nobody has been more important to me in the pursuit of this project than the members of my family. Special thanks go to my parents, thanks for their selfless, unrequited love giving to me over the years. My sincere thanks also go to my father mother-in-law and mother-in-law for their understanding, supporting, and helping me to take care of my kid. Without them, I would not be able to complete my Ph.D. studies.

Finally, I must express my profound gratitude to my beloved husband, Dr. Zhao Yue, thank for your silent company and support love over the years. Your understanding and support are the driving force for me to move forward. Most importantly, thank my lovely son, Zhao Sihan, for giving me infinite motivation. Your innocent smile, like a breeze in the sun, has eliminated my fatigue and gave me infinite power and inspiration.

## **ABSTRAK**

Dengan pengembangan teknologi radio tanpa wayar berkelajuan tinggi, banyak nod sensor disatukan ke dalam rangkaian sensor tanpa wayar, yang telah mempromosikan banyak aplikasi berasaskan lokasi yang berjaya diterapkan dalam pelbagai bidang, seperti memantau bencana alam dan penyelamatan pasca bencana. Maklumat lokasi adalah bahagian tidak terpisahkan dari rangkaian sensor tanpa wayar, tanpa maklumat lokasi, semua data yang diterima akan kehilangan makna. Walau bagaimanapun, skema penyetempatan semasa didasarkan pada GSP yang dilengkapi pada setiap nod, yang tidak menjimatkan kos dan tidak sesuai untuk rangkaian sensor tanpa wayar berskala besar dan persekitaran luar. Untuk mengatasi masalah ini, para sarjana penyelidikan telah mencadangkan skema penyetempatan bebas julat yang hanya bergantung pada kesambungan rangkaian. Walaupun demikian, sebagai skema penyetempatan bebas jangkauan yang mewakili, algoritma penyetempatan Distance Vector-Hop (DV-Hop) menunjukkan ketepatan penyetempatan yang sangat buruk di bawah rangkaian sensor tanpa wayar anisotropik. Karya-karya sebelumnya menganggap bahawa persekitaran rangkaian diedarkan secara merata dan seragam, mengabaikan faktor-faktor anisotropik dalam suasana yang sebenarnya. Selain itu, kebanyakan akademik penyelidikan meningkatkan ketepatan penyetempatan ke tahap tertentu, tetapi dengan mengorbankan overhead komunikasi tinggi dan kerumitan komputasi, yang tidak dapat memenuhi syarat aplikasi ketepatan tinggi untuk rangkaian sensor tanpa wayar anisotropik. Oleh itu, mencari jalan penyelesaian yang cepat, tepat, dan kuat untuk menyelesaikan masalah penyetempatan bebas jarak masih menjadi cabaran besar. Oleh itu, kajian ini berhasrat untuk merapatkan jurang penyelidikan dengan meneroka algoritma DV-Hop baru untuk membina skema penyetempatan cepat, cekap kos, bebas julat yang kuat. Kajian ini mencadangkan variasi algoritma penyetempatan DV-Hop yang dioptimumkan untuk rangkaian sensor tanpa wayar anisotropik. Untuk mengatasi masalah ketepatan penyetempatan yang lemah dalam topologi rangkaian berbentuk C yang tidak teratur, kajian ini mengadopsi Pengoptimum Grew Wolf yang efisien dan bukan kaedah kuasa dua. Jangkauan komunikasi dinamik diperkenalkan untuk memperbaiki hop antara node anchor, dan parameter baru disarankan untuk mengoptimumkan protokol rangkaian untuk mengimbangkan kos tenaga pada langkah awal. Selain itu, algoritma pekali berwajaran dan centroid digunakan untuk mengurangkan ralat kumulatif dengan kiraan hop dan mengurangkan kerumitan komputasi. Kerangka penyetempatan yang dicadangkan secara berasingan disahkan dan dinilai setiap langkah yang dioptimumkan di bawah pelbagai kriteria penilaian, dari segi ketepatan, kestabilan, dan kos, dll. Hasil EGWO-DV-Hop menunjukkan ketepatan penyetempatan yang unggul di bawah kedua-dua topologi, rata-rata kesalahan penyetempatan menurun sehingga 87.79% berbanding dengan DV-Hop asas di bawah topologi berbentuk C. Algoritma penyetempatan DWGWO-DV-Hop yang dicadangkan menunjukkan hasil yang baik dengan ketepatan tinggi dan kestabilan yang kuat. Kesalahan penyetempatan keseluruhan adalah sekitar 1.5m di bawah topologi berbentuk C, sementara algoritma tradisional DV-Hop lebih besar daripada 20m. Secara amnya, ralat penyetempatan rata-rata turun hingga 93.35%, berbanding dengan DV-Hop. Ketepatan lokalisasi dan ketahanan perbandingan menunjukkan bahawa algoritma DWGWO-DV-Hop yang dicadangkan super mengatasi kaedah bebas julat klasik yang lain. Ini berpotensi penting untuk dipandu dan diterapkan dalam aplikasi berasaskan lokasi praktikal untuk rangkaian sensor tanpa wayar anisotropic.

## ABSTRACT

With the high-speed development of wireless radio technology, numerous sensor nodes are integrated into wireless sensor networks, which has promoted plentiful location-based applications that are successfully applied in various fields, such as monitoring natural disasters and post-disaster rescue. Location information is an integral part of wireless sensor networks, without location information, all received data will lose meaning. However, the current localization scheme is based on equipped GPS on every node, which is not cost-efficient and not suitable for large-scale wireless sensor networks and outdoor environments. To address this problem, research scholars have proposed a range-free localization scheme which only depends on network connectivity. Nevertheless, as the representative range-free localization scheme, Distance Vector-Hop (DV-Hop) localization algorithm demonstrates extremely poor localization accuracy under anisotropic wireless sensor networks. The previous works assumed that the network environment is evenly and uniformly distributed, ignored anisotropic factors in a real setting. Besides, most research academics improved the localization accuracy to a certain degree, but at expense of high communication overhead and computational complexity, which cannot meet the requirements of high-precision applications for anisotropic wireless sensor networks. Hence, finding a fast, accurate, and strong solution to solve the range-free localization problem is still a big challenge. Accordingly, this study aspires to bridge the research gap by exploring a new DV-Hop algorithm to build a fast, cost-efficient, strong range-free localization scheme. This study developed an optimized variation of the DV-Hop localization algorithm for anisotropic wireless sensor networks. To address the poor localization accuracy problem in irregular C-shaped network topology, it adopts an efficient Grew Wolf Optimizer instead of the least-squares method. The dynamic communication range is introduced to refine hop between anchor nodes, and new parameters are recommended to optimize network protocol to balance energy cost in the initial step. Besides, the weighted coefficient and centroid algorithm is employed to reduce cumulative error by hop count and cut down computational complexity. The developed localization framework is separately validated and evaluated each optimized step under various evaluation criteria, in terms of accuracy, stability, and cost, etc. The results of EGWO-DV-Hop demonstrated superior localization accuracy under both topologies, the average localization error dropped up to 87.79% comparing with basic DV-Hop under C-shaped topology. The developed enhanced DWGWO-DV-Hop localization algorithm illustrated a favorable result with high accuracy and strong stability. The overall localization error is around 1.5m under C-shaped topology, while the traditional DV-Hop algorithm is large than 20m. Generally, the average localization error went down up to 93.35%, compared with DV-Hop. The localization accuracy and robustness of comparison indicated that the developed DWGWO-DV-Hop algorithm super outperforms the other classical range-free methods. It has the potential significance to be guided and applied in practical location-based applications for anisotropic wireless sensor networks.

## **TABLE OF CONTENT**

### **DECLARATION**

### **TITLE PAGE**

|                         |    |
|-------------------------|----|
| <b>ACKNOWLEDGEMENTS</b> | ii |
|-------------------------|----|

|                |     |
|----------------|-----|
| <b>ABSTRAK</b> | iii |
|----------------|-----|

|                 |    |
|-----------------|----|
| <b>ABSTRACT</b> | iv |
|-----------------|----|

|                         |   |
|-------------------------|---|
| <b>TABLE OF CONTENT</b> | v |
|-------------------------|---|

|                       |    |
|-----------------------|----|
| <b>LIST OF TABLES</b> | ix |
|-----------------------|----|

|                        |   |
|------------------------|---|
| <b>LIST OF FIGURES</b> | x |
|------------------------|---|

|                        |     |
|------------------------|-----|
| <b>LIST OF SYMBOLS</b> | xii |
|------------------------|-----|

|                              |      |
|------------------------------|------|
| <b>LIST OF ABBREVIATIONS</b> | xiii |
|------------------------------|------|

|                           |    |
|---------------------------|----|
| <b>LIST OF APPENDICES</b> | xv |
|---------------------------|----|

|                               |   |
|-------------------------------|---|
| <b>CHAPTER 1 INTRODUCTION</b> | 1 |
|-------------------------------|---|

|                  |   |
|------------------|---|
| 1.1 Introduction | 1 |
|------------------|---|

|                         |   |
|-------------------------|---|
| 1.2 Research Motivation | 5 |
|-------------------------|---|

|                       |   |
|-----------------------|---|
| 1.3 Problem Statement | 7 |
|-----------------------|---|

|                        |   |
|------------------------|---|
| 1.4 Research Objective | 9 |
|------------------------|---|

|                     |    |
|---------------------|----|
| 1.5 Research Scopes | 10 |
|---------------------|----|

|                           |    |
|---------------------------|----|
| 1.6 Research Significance | 10 |
|---------------------------|----|

|                                 |    |
|---------------------------------|----|
| 1.7 The Structure of the Thesis | 10 |
|---------------------------------|----|

|                                    |    |
|------------------------------------|----|
| <b>CHAPTER 2 LITERATURE REVIEW</b> | 12 |
|------------------------------------|----|

|                  |    |
|------------------|----|
| 2.1 Introduction | 12 |
|------------------|----|

|                              |    |
|------------------------------|----|
| 2.2 Wireless Sensor Networks | 12 |
|------------------------------|----|

|  |    |
|--|----|
| 2.2.1 Isotropic Wireless Sensor Networks | 12 |
|--|----|

|  |    |
|--|----|
| 2.2.2 Anisotropic Wireless Sensor Networks | 13 |
|--|----|

|       |  |    |
|-------|--|----|
| 2.3   | Range-free Localization Scheme                   | 15 |
| 2.3.1 | Centroid   | 16 |
| 2.3.2 | Bounding Box                                     | 17 |
| 2.3.3 | Approximate Point-in Triangulation Test (APIT)   | 18 |
| 2.3.4 | Amorphous  | 19 |
| 2.3.5 | Distance-Vector Hop (DV-Hop)                     | 20 |
| 2.3.6 | Summary of Range-free Localization Scheme        | 22 |
| 2.4   | Error Analysis of DV-Hop                         | 23 |
| 2.4.1 | Error Caused by Hop Count                        | 23 |
| 2.4.2 | Accumulated Estimated Error by Average Hop Size  | 24 |
| 2.4.3 | Error Caused by Least Squares                    | 26 |
| 2.4.4 | Summary of Error Analysis of DV-Hop              | 27 |
| 2.5   | Weighted Optimization-based Algorithm in DV-Hop  | 27 |
| 2.5.1 | Optimize Flood Protocol                          | 28 |
| 2.5.2 | Optimize Minimum Hop Count and Hop Size          | 28 |
| 2.5.3 | Optimize Estimated Distance of Unknown Nodes     | 30 |
| 2.5.4 | Optimize Obtained Coordinate of Unknown Nodes    | 30 |
| 2.5.5 | Summary of Weighted Optimization-based Algorithm | 31 |
| 2.6   | Metaheuristic-based Algorithm in DV-Hop          | 36 |
| 2.6.1 | Applied Swarm-based Technology                   | 37 |
| 2.6.2 | Applied Evolutionary-based Technology            | 46 |
| 2.6.3 | Applied Human-based Technology                   | 48 |
| 2.6.4 | Summary of Metaheuristic-based Algorithm         | 49 |
| 2.7   | Hybrid Scheme-Based Algorithm in DV-Hop          | 64 |
| 2.7.1 | Applied Range-based Technique                    | 64 |
| 2.7.2 | Applied Range-free Technique                     | 65 |

|   |   |           |
|---|---|-----------|
| 2.7.3                                   | Summary of Hybrid Scheme-based Algorithm          | 67        |
| 2.8                                     | Summary of the Chapter and Research Gap           | 71        |
| <b>CHAPTER 3 METHODOLOGY</b>            |   | <b>73</b> |
| 3.1                                     | Introduction                                      | 73        |
| 3.2                                     | Overall Approach of the Research Methodology      | 75        |
| 3.3                                     | Network Model                                     | 75        |
| 3.3.1                                   | Parameter Setting                                 | 75        |
| 3.3.2                                   | Data Collection                                   | 76        |
| 3.4                                     | DWGWO-DV-Hop Range-free Localization Algorithm    | 78        |
| 3.4.1                                   | DDV-Hop by Dynamic Communication Range            | 78        |
| 3.4.2                                   | WDV-Hop by Weighted Coefficient                   | 79        |
| 3.4.3                                   | EGWO-DV-Hop by Efficient Grew Wolf Optimizer      | 81        |
| 3.4.4                                   | Summary of DWGWO-DV-Hop Algorithm                 | 90        |
| 3.5                                     | Evaluation Metrics                                | 91        |
| 3.5.1                                   | Localization Accuracy Metric                      | 91        |
| 3.5.2                                   | Localization Stability Metric                     | 93        |
| 3.5.3                                   | Localization Coverage Metric                      | 93        |
| 3.5.4                                   | Cost Metric                                       | 94        |
| 3.6                                     | Summary of the Chapter                            | 95        |
| <b>CHAPTER 4 RESULTS AND DISCUSSION</b> |   | <b>96</b> |
| 4.1                                     | Introduction                                      | 96        |
| 4.2                                     | Verification based on Dynamic Communication Range | 96        |
| 4.3                                     | Verification based on Weighted Coefficient        | 99        |
| 4.3.1                                   | Verified Optimization Average Hop Size            | 99        |
| 4.3.2                                   | Verified Estimated Coordinate of Unknown Node     | 100       |

|                             |   |            |
|-----------------------------|---|------------|
| 4.4                         | Verification based on EGWO                  | 104        |
| 4.5                         | Experiment Results of DWGWO-DV-Hop          | 109        |
| 4.5.1                       | Parameters Initialization                   | 109        |
| 4.5.2                       | Localization Accuracy for Each Unknown Node | 110        |
| 4.5.3                       | Effect of Anchor Node Proportion            | 114        |
| 4.5.4                       | Effect of Communication Range               | 117        |
| 4.5.5                       | Localization Stability                      | 120        |
| 4.5.6                       | Cost Analysis                               | 122        |
| 4.6                         | Summary of the Chapter                      | 127        |
| <b>CHAPTER 5 CONCLUSION</b> |   | <b>129</b> |
| 5.1                         | Conclusion                                  | 129        |
| 5.2                         | Future Work                                 | 131        |
| <b>REFERENCES</b>           |   | <b>133</b> |
| <b>APPENDICES</b>           |   | <b>143</b> |

## REFERENCES

- A. Hammod, W., Abdullah Arshah, R., Mohamad Asmara, S., Al Halbusi, H., A. Hammod, O., & Abri, S. A. (2021). A systematic review on flood early warning and response system (FEWRS): a deep review and analysis. *Sustainability*, 13(1), 440. <https://doi.org/10.3390/su13010440>
- Alexander, D. (2012). Resilience against earthquakes: some practical suggestions for planners and managers. *Journal of Seismology and Earthquake Engineering*, 13(2), 109-115. Retrieved from <https://iranjournals.nlai.ir/bitstream/handle/123456789/775534/041170589A4B82796C3205F98028E048.pdf?sequence=-1&isAllowed=y>
- Bhat, S. J., & Santhosh, K. J. I. A. (2021). A Method for Fault Tolerant Localization of Heterogeneous Wireless Sensor Networks. *IEEE Access*, 9, 37054-37063. <https://doi.org/10.1109/ACCESS.2021.3063160>
- Bhat, S. J., & Santhosh, K. J. W. P. C. (2020). Is localization of wireless sensor networks in irregular fields a challenge? *Wireless Personal Communications*, 114, 2017-2042. <https://doi.org/10.1007/s11277-020-07460-6>
- Bulusu, N., Heidemann, J., & Estrin, D. J. I. p. c. (2000). GPS-less low-cost outdoor localization for very small devices. *IEEE personal communications*, 7(5), 28-34. <https://doi.org/10.1109/98.878533>
- Cai, X., Wang, P., Cui, Z., Zhang, W., & Chen, J. J. S. C. (2020). Weight convergence analysis of DV-hop localization algorithm with GA. *Soft Computing*, 24(23), 18249-18258. <https://doi.org/10.1007/s00500-020-05088-z>
- Cao, Y., & Wang, Z. J. I. A. (2019). Improved DV-hop localization algorithm based on dynamic anchor node set for wireless sensor networks. *IEEE Access*, 7, 124876-124890. <https://doi.org/10.1109/ACCESS.2019.2938558>
- Cheikhrouhou, O., M Bhatti, G., & Alroobaea, R. J. S. (2018). A hybrid DV-hop algorithm using RSSI for localization in large-scale wireless sensor networks. *Sensors*, 18(5), 1469. <https://doi.org/10.3390/s18051469>
- Chelouah, L., Semchedine, F., & Bouallouche-Medjkoune, L. (2018). Localization protocols for mobile wireless sensor networks: A survey. *Computers & Electrical Engineering*, 71, 733-751. <https://doi.org/10.1016/j.compeleceng.2017.03.024>
- Chen, J., Zhang, W., Liu, Z., Wang, R., & Zhang, S. J. I. A. (2020). CWDV-Hop: A hybrid localization algorithm with distance-weight DV-Hop and CSO for wireless sensor networks. *IEEE Access*, 9, 380-399. <https://doi.org/10.1109/ACCESS.2020.3045555>
- Chen, T., Sun, L., Wang, Z., Wang, Y., Zhao, Z., & Zhao, P. J. A. H. N. (2021). An enhanced nonlinear iterative localization algorithm for DV\_Hop with uniform calculation criterion. *Ad Hoc Networks*, 111, 102327. <https://doi.org/10.1016/j.adhoc.2020.102327>
- Chen, T., & Sun, L. J. J. o. S. (2019). A Connectivity Weighting DV\_Hop Localization Algorithm Using Modified Artificial Bee Colony Optimization. *Journal of Sensors*,

2019. <https://doi.org/10.1155/2019/1464513>

- Cheng, Y.-S., Yu, T.-T., & Son, N.-T. J. R. S. (2021). Random Forests for Landslide Prediction in Tsengwen River Watershed, Central Taiwan. *Remote Sensing*, 13(2), 199. <https://doi.org/10.3390/rs13020199>
- Cui, L., Xu, C., Li, G., Ming, Z., Feng, Y., & Lu, N. J. A. S. C. (2018). A high accurate localization algorithm with DV-Hop and differential evolution for wireless sensor network. *Applied Soft Computing*, 68, 39-52. <https://doi.org/10.1016/j.asoc.2018.03.036>
- Cui, Z., Sun, B., Wang, G., Xue, Y., Chen, J. J. J. o. P., & Computing, D. (2017). A novel oriented cuckoo search algorithm to improve DV-Hop performance for cyber–physical systems. *Journal of Parallel and Distributed Computing*, 103, 42-52. <https://doi.org/10.1016/j.jpdc.2016.10.011>
- Erdelj, M., Natalizio, E., Chowdhury, K. R., & Akyildiz, I. F. J. I. P. C. (2017). Help from the sky: Leveraging UAVs for disaster management. *IEEE Pervasive Computing*, 16(1), 24-32. <https://doi.org/10.1109/MPRV.2017.11>
- Girod, L., Bychkovskiy, V., Elson, J., & Estrin, D. (2002, September). Locating tiny sensors in time and space: A case study. In *Proceedings. IEEE International Conference on Computer Design: VLSI in Computers and Processors* (pp. 214-219). IEEE. <https://doi.org/10.1109/ICCD.2002.1106773>
- Gui, L., Huang, X., Xiao, F., Zhang, Y., Shu, F., Wei, J., & Val, T. J. I. T. o. V. T. (2018). DV-hop localization with protocol sequence based access. *IEEE Transactions on Vehicular Technology*, 67(10), 9972-9982. <https://doi.org/10.1109/TVT.2018.2864270>
- Gui, L., Val, T., Wei, A., & Dalce, R. J. A. H. N. (2015). Improvement of range-free localization technology by a novel DV-hop protocol in wireless sensor networks. *Ad Hoc Networks*, 24, 55-73. <https://doi.org/10.1016/j.adhoc.2014.07.025>
- Gui, L., Xiao, F., Zhou, Y., Shu, F., & Val, T. J. I. T. o. V. T. (2020). Connectivity based DV-hop localization for Internet of Things. *IEEE Transactions on Vehicular Technology*, 69(8), 8949-8958. <https://doi.org/10.1109/TVT.2020.2998093>
- Gupta, A., & Mahaur, B. J. W. P. C. (2021). An Improved DV-maxHop Localization Algorithm for Wireless Sensor Networks. *Wireless Personal Communications*, 117(3), 2341-2357. <https://doi.org/10.1007/s11277-020-07976-x>
- Han, D., Yu, Y., Li, K.-C., & de Mello, R. F. J. S. (2020). Enhancing the sensor node localization algorithm based on improved DV-hop and DE algorithms in wireless sensor networks. *Sensors*, 20(2), 343. <https://doi.org/10.3390/s20020343>
- Han, F., Abdelaziz, I. I. M., Liu, X., & Ghazali, K. H. (2020). A Hybrid Range-Free Algorithm Using Dynamic Communication Range for Wireless Sensor Networks. *International Journal of Online and Biomedical Engineering (iJOE)*, 16(8), 4–24. <https://doi.org/10.3991/ijoe.v16i08.14379>
- Han, G., Jiang, J., Zhang, C., Duong, T. Q., Guizani, M., Karagiannidis, G. K. J. I. C. S., & Tutorials. (2016). A survey on mobile anchor node assisted localization in wireless sensor networks. *IEEE Communications Surveys & Tutorials*, 18(3), 2220-2243. <https://doi.org/10.1109/COMST.2016.2544751>

- Harik, G. R., Lobo, F. G., & Goldberg, D. E. J. I. t. o. e. c. (1999). The compact genetic algorithm. *IEEE Transactions on Evolutionary Computation*, 3(4), 287-297. <https://doi.org/10.1109/4235.797971>
- Hassan Gillani, S. M. A., Raza, H., Qureshi, M. I., Khan, N. J. J. o. C. I. i. B., & Government. (2021). The effective use of technology and digitalization in Disaster Management in Malaysia. *Journal of Contemporary Issues in Business and Government*, 27(1), 71-87. <https://cibg.org.au/>
- He, T., Huang, C., Blum, B. M., Stankovic, J. A., & Abdelzaher, T. (2003, September). Range-free localization schemes for large scale sensor networks. In *Proceedings of the 9th annual international conference on Mobile computing and networking* (pp. 81-95). <https://doi.org/10.1145/938985.938995>
- Huang, X. J. C. C. (2020). Multi-node topology location model of smart city based on Internet of Things. *Computer Communications*, 152, 282-295. <https://doi.org/10.1016/j.comcom.2020.01.052>
- Intrieri, E., Gigli, G., Gracchi, T., Nocentini, M., Lombardi, L., Mugnai, F., . . . Favalli, M. J. E. G. (2018). Application of an ultra-wide band sensor-free wireless network for ground monitoring. *Engineering Geology*, 238, 1-14. <https://doi.org/10.1016/j.enggeo.2018.02.017>
- Jian Yin, L. J. M. I. S. (2019). A new distance vector-hop localization algorithm based on half-measure weighted centroid. *Mobile Information Systems*, 2019, 1-9. <https://doi.org/10.1155/2019/9892512>
- Jiang, B. J. P.-t.-P. N., & Applications. (2020). Research on wireless sensor location technology for biologic signal measuring based on intelligent bionic algorithm. *Peer-to-Peer Netw. Appl.*, 14, 2495–2500. <https://doi.org/10.1007/s12083-020-00932-3>
- Jiang, R., Wang, X., Cao, S., Zhao, J., & Li, X. J. I. A. (2019). Joint compressed sensing and enhanced whale optimization algorithm for pilot allocation in underwater acoustic OFDM systems. *IEEE Access*, 7, 95779-95796. <https://doi.org/10.1109/ACCESS.2019.2929305>
- Kanwar, V., & Kumar, A. J. I. J. o. C. S. (2020). Multiobjective optimization - based DV - hop localization using NSGA - II algorithm for wireless sensor networks. *International Journal of Communication Systems*, 33(11), e4431. <https://doi.org/10.1002/dac.4431>
- Kanwar, V., Kumar, A. J. J. o. A. I., & Computing, H. (2020). DV-Hop based localization methods for additionally deployed nodes in wireless sensor network using genetic algorithm. *Journal of Ambient Intelligence and Humanized Computing*, 11(11), 5513-5531. <https://doi.org/10.1007/s12652-020-01907-1>
- Kanwar, V., & Kumar, A. J. W. N. (2021). DV-Hop localization methods for displaced sensor nodes in wireless sensor network using PSO. *Wireless Networks*, 27(1), 91-102. <https://doi.org/10.1007/s11276-020-02446-5>
- Karaboga, D. (2005). *An idea based on honey bee swarm for numerical optimization*. (Vol. 200, pp. 1-10). Technical report-tr06, Erciyes university, engineering faculty, computer engineering department. Retrieved from [https://abc.erciyes.edu.tr/pub/tr06\\_2005.pdf](https://abc.erciyes.edu.tr/pub/tr06_2005.pdf)

- Kaur, A., Kumar, P., Gupta, G. P. J. J. o. K. S. U.-C., & Sciences, I. (2019). A weighted centroid localization algorithm for randomly deployed wireless sensor networks. *Journal of King Saud University-Computer and Information Sciences*, 31(1), 82-91. <https://doi.org/10.1016/j.jksuci.2017.01.007>
- Kaur, A., Kumar, P., & Gupta, G. P. J. W. P. C. (2018). Nature inspired algorithm-based improved variants of DV-Hop algorithm for randomly deployed 2D and 3D wireless sensor networks. *Wireless Personal Communications*, 101(1), 567-582. <https://doi.org/10.1007/s11277-018-5704-7>
- Kennedy, J., & Eberhart, R. (1995, November). Particle swarm optimization. In *Proceedings of ICNN'95-international conference on neural networks* (Vol. 4, pp. 1942-1948). IEEE. <https://doi.org/10.1109/ICNN.1995.488968>
- Khan, K. A., Zaman, K., Shoukry, A. M., Sharkawy, A., Gani, S., Ahmad, J., . . . Research, P. (2019). Natural disasters and economic losses: controlling external migration, energy and environmental resources, water demand, and financial development for global prosperity. *Environmental Science and Pollution Research*, 26(14), 14287-14299. <https://doi.org/10.1007/s11356-019-04755-5>
- Kumar, S., Kumar, S., & Batra, N. J. W. P. C. (2021). Optimized Distance Range Free Localization Algorithm for WSN. *Wireless Personal Communications*, 117(3), 1879-1907. <https://doi.org/10.1007/s11277-020-07950-7>
- Kumberg, T., Schneid, S., & Reindl, L. J. A. S. (2017). A wireless sensor network using GNSS receivers for a short-term assessment of the modal properties of the neckartal bridge. *Applied Sciences*, 7(6), 626. <https://doi.org/10.3390/app7060626>
- Laoudias, C., Moreira, A., Kim, S., Lee, S., Wirola, L., Fischione, C. J. I. C. S., & Tutorials. (2018). A survey of enabling technologies for network localization, tracking, and navigation. *IEEE Communications Surveys & Tutorials*, 20(4), 3607-3644. <https://doi.org/10.1109/COMST.2018.2855063>
- Li, T., Wang, C., Na, Q. J. E. J. o. W. C., & Networking. (2020). Research on DV-Hop improved algorithm based on dual communication radius. *EURASIP Journal on Wireless Communications and Networking*, 2020, 1-10. <https://doi.org/10.1186/s13638-020-01711-7>
- Li, X., Wang, K., Liu, B., Xiao, J., Han, S. J. E. J. o. W. C., & Networking. (2020). An improved range-free location algorithm for industrial wireless sensor networks. *EURASIP Journal on Wireless Communications and Networking*, 2020(1), 1-13. <https://doi.org/10.1186/s13638-020-01698-1>
- Liu, C., Liu, S., Zhang, W., Zhao, D. J. M. N., & Applications. (2016). The performance evaluation of hybrid localization algorithm in wireless sensor networks. *Mobile Networks and Applications*, 21(6), 994-1001. <https://doi.org/10.1007/s11036-016-0737-1>
- Liu, G., Qian, Z., & Wang, X. J. C. C. (2019). An improved DV-Hop localization algorithm based on hop distances correction. *China Communications*, 16(6), 200-214. <https://doi.org/10.23919/JCC.2019.06.016>
- Liu, W., Shi, C., Zhu, H., & Yu, H. J. J. o. W. E. (2021). Wireless Sensor Network Node

- Localization Algorithm Based on PSO-MA. *Journal of Web Engineering*, 20(4), 1075-1092. <https://doi.org/10.13052/jwe1540-9589.2048>
- Liu, Y., & Bao, Y. J. M. (2021). Review of electromagnetic waves-based distance measurement technologies for remote monitoring of civil engineering structures. *Measurement*, 176, 109193. <https://doi.org/10.1016/j.measurement.2021.109193>
- Liu, Y., Chen, J., Xu, Z. J. K. T. o. I., & Systems, I. (2017). Improved DV-hop localization algorithm based on bat algorithm in wireless sensor networks. *KSII Transactions on Internet and Information Systems (TIIS)*, 11(1), 215-236. <https://doi.org/10.3837/tiis.2017.01.011>
- Mass-Sanchez, J., Ruiz-Ibarra, E., Cortez-González, J., Espinoza-Ruiz, A., & Castro, L. A. J. W. P. C. (2017). Weighted hyperbolic DV-hop positioning node localization algorithm in WSNs. *Wireless Personal Communications*, 96(4), 5011-5033. <https://doi.org/10.1007/s11277-016-3727-5>
- Mehrabi, M., Taheri, H., & Taghdiri, P. J. T. S. (2017). An improved DV-Hop localization algorithm based on evolutionary algorithms. *Telecommunication Systems*, 64(4), 639-647. <https://doi.org/10.1007/s11235-016-0196-9>
- Meng, X., Liu, Y., Gao, X., & Zhang, H. (2014). A new bio-inspired algorithm: chicken swarm optimization. In *International conference in swarm intelligence* (pp. 86-94). Springer, Cham. [https://doi.org/10.1007/978-3-319-11857-4\\_10](https://doi.org/10.1007/978-3-319-11857-4_10)
- Messous, S., Liouane, H., & Liouane, N. J. T. S. (2020). Improvement of DV-Hop localization algorithm for randomly deployed wireless sensor networks. *Telecommunication Systems*, 73(1), 75-86. <https://doi.org/10.1007/s11235-019-00592-6>
- Messous, S., & Liouane, H. J. M. I. S. (2020). Online sequential DV-hop localization algorithm for wireless sensor networks. *Mobile Information Systems*, 2020. <https://doi.org/10.1155/2020/8195309>
- Mirjalili, S., Mirjalili, S. M., & Lewis, A. J. A. i. e. s. (2014). Grey wolf optimizer. *Advances in engineering software*, 69, 46-61. <https://doi.org/10.1016/j.advengsoft.2013.12.007>
- Mirjalili, S. J. A. i. e. s. (2015). The ant lion optimizer. *Advances in engineering software*, 83, 80-98. <https://doi.org/10.1016/j.advengsoft.2015.01.010>
- Mittal, N., Singh, U., Sohi, B. S. J. A. C. I., & Computing, S. (2016). Modified grey wolf optimizer for global engineering optimization. *Applied Computational Intelligence and Soft Computing*, 2016. <https://doi.org/10.1155/2016/7950348>
- Mohanta, T. K., & Das, D. K. J. W. P. C. (2021). Class Topper Optimization Based Improved Localization Algorithm in Wireless Sensor Network. *Wireless Personal Communications*, 119(4), 3319-3338. <https://doi.org/10.1007/s11277-021-08405-3>
- Munadhil, Z., Gharghan, S. K., Mutlag, A. H. J. A. J. f. S., & Engineering. (2021). Distance Estimation-Based PSO Between Patient with Alzheimer's Disease and Beacon Node in Wireless Sensor Networks. *Arabian Journal for Science and Engineering*, 46(10), 9345-9362. <https://doi.org/10.1007/s13369-020-05283-y>
- Munoz, D., Bouchereau, F., Vargas, C., & Enriquez, R. (2009). Signal parameter estimation for

- the localization problem. In *Position Location Techniques and Applications* (pp. 23-29): Elsevier Inc. <https://doi.org/10.1016/B978-0-12-374353-4.00008-9>
- Nadimi-Shahraki, M. H., Taghian, S., & Mirjalili, S. J. E. S. w. A. (2021). An improved grey wolf optimizer for solving engineering problems. *Expert Systems with Applications*, 166, 113917. <https://doi.org/10.1016/j.eswa.2020.113917>
- Nagpal, R., Shroba, H., & Bachrach, J. (2003, April). Organizing a global coordinate system from local information on an ad hoc sensor network. In *Information processing in sensor networks* (pp. 333-348). Springer, Berlin, Heidelberg. [https://doi.org/10.1007/3-540-36978-3\\_22](https://doi.org/10.1007/3-540-36978-3_22)
- Najeh, T., Sassi, H., & Liouane, N. J. I. J. o. W. I. N. (2018). A novel range free localization algorithm in wireless sensor networks based on connectivity and genetic algorithms. *International Journal of Wireless Information Networks*, 25(1), 88-97. <https://doi.org/10.1007/s10776-017-0375-y>
- Navidi, N., & Landry, R. J. S. (2021). A new perspective on low-cost mems-based AHRS determination. *Sensors*, 21(4), 1383. <https://doi.org/10.3390/s21041383>
- Nemer, I., Sheltami, T., Shakshuki, E., Elkhail, A. A., Adam, M. J. P., & Computing, U. (2021). Performance evaluation of range-free localization algorithms for wireless sensor networks. *Personal and Ubiquitous Computing*, 25(1), 177-203. <https://doi.org/10.1007/s00779-020-01370-x>
- Niculescu, D., & Nath, B. J. T. S. (2003). DV based positioning in ad hoc networks. *Telecommunication Systems*, 22(1), 267-280. <https://doi.org/10.1023/A:1023403323460>
- Passino, K. M. J. I. c. s. m. (2002). Biomimicry of bacterial foraging for distributed optimization and control. *IEEE control systems magazine*, 22(3), 52-67. <https://doi.org/10.1109/MCS.2002.1004010>
- Paul, A. K., Sato, T. J. J. o. s., & networks, a. (2017). Localization in wireless sensor networks: A survey on algorithms, measurement techniques, applications and challenges. *Journal of sensor and actuator networks*, 6(4), 24. <https://doi.org/10.3390/jsan6040024>
- Peng, B., & Li, L. J. C. N. (2015). An improved localization algorithm based on genetic algorithm in wireless sensor networks. *Cognitive Neurodynamics*, 9(2), 249-256. <https://doi.org/10.1007/s11571-014-9324-y>
- Phoemphon, S., So-In, C., & Leelathakul, N. J. I. A. (2018). Optimized hop angle relativity for DV-Hop localization in wireless sensor networks. *IEEE Access*, 6, 78149-78172. <https://doi.org/10.1109/ACCESS.2018.2884837>
- Phoemphon, S., So-In, C., & Niyato, D. T. J. A. S. C. (2018). A hybrid model using fuzzy logic and an extreme learning machine with vector particle swarm optimization for wireless sensor network localization. *Applied Soft Computing*, 65, 101-120. <https://doi.org/10.1016/j.asoc.2018.01.004>
- Prashar, D., Jyoti, K., & Kumar, D. J. T. o. E. T. T. (2018). Design and analysis of distance error correction-based localization algorithm for wireless sensor networks. *Transactions on Emerging Telecommunications Technologies*, 29(12), e3547. <https://doi.org/10.1002/ett.3547>

- Prashar, D., & Jyoti, K. J. W. P. C. (2019). Distance error correction based hop localization algorithm for wireless sensor network. *Wireless Personal Communications*, 106(3), 1465-1488. <https://doi.org/10.1007/s11277-019-06225-0>
- Rajakumar, R., Amudhavel, J., Dhavachelvan, P., & Vengattaraman, T. (2017). GWO-LPWSN: Grey wolf optimization algorithm for node localization problem in wireless sensor networks. *Journal of computer networks and communications*, 2017. <https://doi.org/10.1155/2017/7348141>
- Rao, R. V., Savsani, V. J., & Vakharia, D. J. C.-A. D. (2011). Teaching–learning-based optimization: a novel method for constrained mechanical design optimization problems. *Computer-aided design*, 43(3), 303-315. <https://doi.org/10.1016/j.cad.2010.12.015>
- Ren, K., & Wu, M. J. J. o. H. S. N. (2019). DV-Hop algorithm for adaptive hop-count improvement and average hop distance optimization. *Journal of High Speed Networks*, 25(2), 127-137. <https://doi.org/10.3233/JHS-190607>
- Shahra, E. Q., Sheltami, T. R., & Shakshuki, E. M. (2020). A comparative study of range-free and range-based localization protocols for wireless sensor network: Using cooja simulator. In *Sensor Technology: Concepts, Methodologies, Tools, and Applications* (pp. 1522-1537): IGI Global. <https://doi.org/10.4018/978-1-7998-2454-1.ch071>
- Shahzad, F., Sheltami, T. R., & Shakshuki, E. M. J. I. T. o. M. C. (2016). DV-maxHop: A fast and accurate range-free localization algorithm for anisotropic wireless networks. *IEEE Transactions on Mobile Computing*, 16(9), 2494-2505. <https://doi.org/10.1109/TMC.2016.2632715>
- Shahzad, F., Sheltami, T. R., Shakshuki, E. M. J. J. o. A. I., & Computing, H. (2016). Effect of network topology on localization algorithm's performance. *Journal of Ambient Intelligence and Humanized Computing*, 7(3), 445-454. <https://doi.org/10.1007/s12652-016-0349-4>
- Sharma, G., & Kumar, A. J. I. J. o. R. (2018). Modified energy-efficient range-free localization using teaching–learning-based optimization for wireless sensor networks. *IETE Journal of Research*, 64(1), 124-138. <https://doi.org/10.1080/03772063.2017.1333467>
- Sharma, G., & Kumar, A. J. T. S. (2018). Improved DV-Hop localization algorithm using teaching learning based optimization for wireless sensor networks. *Telecommunication Systems*, 67(2), 163-178. <https://doi.org/10.1007/s11235-017-0328-x>
- Shen, G., Hwang, S. N. J. G., Natural Hazards, & Risk. (2019). Spatial–Temporal snapshots of global natural disaster impacts Revealed from EM-DAT for 1900-2015. *Geomatics, Natural Hazards and Risk*. <https://doi.org/10.1080/19475705.2018.1552630>
- Shi, Q., Wu, C., Xu, Q., & Zhang, J. J. T. J. o. S. (2021). Optimization for DV-Hop type of localization scheme in wireless sensor networks. *The Journal of Supercomputing*, 77(12), 13629-13652. <https://doi.org/10.1007/s11227-021-03818-0>
- Shi, Q., Xu, Q., & Zhang, J. J. E. L. (2020). Amended DV - hop scheme based on N - gram model and weighed LM algorithm. *Electronics Letters*, 56(5), 247-250. <https://doi.org/10.1049/el.2019.2957>
- Shi, Q., Xu, Q., & Zhang, J. J. W. P. C. (2019). An improved DV-Hop scheme based on path

- matching and particle swarm optimization algorithm. *Wireless Personal Communications*, 104(4), 1301-1320. <https://doi.org/10.1007/s11277-018-6084-8>
- Shit, R. C., Sharma, S., Puthal, D., & Zomaya, A. Y. (2018). Location of Things (LoT): A review and taxonomy of sensors localization in IoT infrastructure. *IEEE Communications Surveys & Tutorials*, 20(3), 2028-2061. <https://doi.org/10.1109/COMST.2018.2798591>
- Simic, S. N., & Sastry, S. (2002). *Distributed localization in wireless ad hoc networks* (Vol. 2, pp. 1-13). Technical Report UCB/ERL.
- Singh, S. P., & Sharma, S. C. J. I. J. o. R. (2019). Implementation of a PSO based improved localization algorithm for wireless sensor networks. *IETE Journal of Research*, 65(4), 502-514. <https://doi.org/10.1080/03772063.2018.1436472>
- Singh, S. P., & Sharma, S. J. W. P. C. (2018). A PSO based improved localization algorithm for wireless sensor network. *Wireless Personal Communications*, 98(1), 487-503. <https://doi.org/10.1007/s11277-017-4880-1>
- So-In, C., & Katekaew, W. J. I. J. o. D. S. N. (2015). Hybrid fuzzy centroid with MDV-Hop BAT localization algorithms in wireless sensor networks. *International Journal of Distributed Sensor Networks*, 11(10), 894560. <https://doi.org/10.1155/2015/894560>
- Song, G., & Tam, D. J. I. J. o. D. S. N. (2015). Two novel DV-Hop localization algorithms for randomly deployed wireless sensor networks. *International Journal of Distributed Sensor Networks*, 11(7), 187670. <https://doi.org/10.1155/2015/187670>
- Song, L., Zhao, L., & Ye, J. J. J. o. S. (2019). DV-hop node location algorithm based on GSO in wireless sensor networks. *Journal of Sensors*, 2019. <https://doi.org/10.1155/2019/2986954>
- Storn, R., & Price, K. J. J. o. g. o. (1997). Differential evolution—a simple and efficient heuristic for global optimization over continuous spaces. *Journal of global optimization*, 11(4), 341-359. <https://doi.org/10.1023/A:1008202821328>
- Sun, Y., Yuan, Y., Xu, Q., Hua, C., & Guan, X. J. S. (2019). A mobile anchor node assisted RSSI localization scheme in underwater wireless sensor networks. *Sensors*, 19(20), 4369. <https://doi.org/10.3390/s19204369>
- Tomic, S., & Mezei, I. J. T. S. (2016). Improvements of DV-Hop localization algorithm for wireless sensor networks. *Telecommunication Systems*, 61(1), 93-106. <https://doi.org/10.1007/s11235-015-0014-9>
- Tseng, C.-L., Liu, F.-Y., Lin, C.-H., Lee, C.-Y. J. S., & Materials. (2017). Boundary-improved distance vector-hop localization method with multipower correction for wireless sensor networks. *Sensors and Materials*, 29(6), 675-687. <https://doi.org/10.18494/SAM.2017.1489>
- Tu, Q., Liu, Y., Han, F., Liu, X., & Xie, Y. J. A. H. N. (2021). Range-free localization using Reliable Anchor Pair Selection and Quantum-behaved Salp Swarm Algorithm for anisotropic Wireless Sensor Networks. *Ad Hoc Networks*, 113, 102406. <https://doi.org/10.1016/j.adhoc.2020.102406>

- Wang, F., Wang, C., Wang, Z., & Zhang, X.-y. J. I. J. o. D. S. N. (2015). A hybrid algorithm of GA+ simplex method in the WSN localization. *International Journal of Distributed Sensor Networks*, 11(7), 731894. <https://doi.org/10.1155/2015/731894>
- Wang, P., Xue, F., Li, H., Cui, Z., Xie, L., & Chen, J. J. M. (2019). A multi-objective DV-Hop localization algorithm based on NSGA-II in internet of things. *Mathematics*, 7(2), 184. <https://doi.org/10.3390/math7020184>
- Wongkhan, M., & Chantaraskul, S. J. E. J. (2015). Selected RSSI-based DV-hop localization for wireless sensor networks. *Engineering Journal*, 19(5), 199-212. <https://doi.org/10.4186/ej.2015.19.5.199>
- Xu, Y., Luo, X., Wang, W., & Zhao, W. J. S. (2017). Efficient dv-hop localization for wireless cyber-physical social sensing system: A correntropy-based neural network learning scheme. *Sensors*, 17(1), 135. <https://doi.org/10.3390/s17010135>
- Xue, D. J. E. J. o. W. C., & Networking. (2019). Research of localization algorithm for wireless sensor network based on DV-Hop. *EURASIP Journal on Wireless Communications and Networking*, 2019(1), 1-8. <https://doi.org/10.1186/s13638-019-1539-5>
- Yang, J., Cai, Y., Tang, D., & Liu, Z. J. S. (2019). A novel centralized range-free static node localization algorithm with memetic algorithm and Lévy flight. *Sensors*, 19(14), 3242. <https://doi.org/10.3390/s19143242>
- Yang, X. S. (2010). A new metaheuristic bat-inspired algorithm. In *Nature inspired cooperative strategies for optimization (NICSO 2010)* (pp. 65-74). Springer, Berlin, Heidelberg. [https://doi.org/10.1007/978-3-642-12538-6\\_6](https://doi.org/10.1007/978-3-642-12538-6_6)
- Yang, X.-S., & Deb, S. (2009). Cuckoo search via Lévy flights. In *2009 World congress on nature & biologically inspired computing (NaBIC)* (pp. 210-214). Ieee. <https://doi.org/10.1109/NABIC.2009.5393690>
- Yang, X., Zhang, W. J. C., & Technologies, I. (2016). An improved DV-Hop localization algorithm based on bat algorithm. *Cybernetics and Information Technologies*, 16(1), 89-98. <https://doi.org/10.1515/cait-2016-0007>
- Yick, J., Mukherjee, B., & Ghosal, D. (2008). Wireless sensor network survey: *Computer networks*, 52(12), 2292-2330. <https://doi.org/10.1016/j.comnet.2008.04.002>
- Yin, S., Wu, J., Yu, G. J. P.-t.-P. N., & Applications. (2021). Low energy consumption routing algorithm based on message importance in opportunistic social networks. *Peer-to-Peer Networking and Applications*, 14(2), 948-961. <https://doi.org/10.1007/s12083-021-01072-y>
- Yoon, H., Shiftehfar, R., Cho, S., Spencer Jr, B. F., Nelson, M. E., & Agha, G. J. J. o. C. i. C. E. (2016). Victim localization and assessment system for emergency responders. *Journal of Computing in Civil Engineering*, 30(2), 04015011. [https://doi.org/10.1061/\(ASCE\)CP.1943-5487.0000483](https://doi.org/10.1061/(ASCE)CP.1943-5487.0000483)
- Yu, X., & Hu, M. J. W. P. C. (2019). Hop-count quantization ranging and hybrid cuckoo search optimized for DV-HOP in WSNs. *Wireless Personal Communications*, 108(4), 2031-2046. <https://doi.org/10.1007/s11277-019-06507-7>

- Zazali, A. A., Subramaniam, S. K., & Zukarnain, Z. A. J. I. A. (2020). Flood control distance vector-hop (FCDV-Hop) localization in wireless sensor networks. *IEEE Access*, 8, 206592-206613. <https://doi.org/10.1109/ACCESS.2020.3038047>
- Zhang, D.-G., Chen, L., Zhang, J., Chen, J., Zhang, T., Tang, Y.-M., & Qiu, J.-N. J. I. A. (2020). A multi-path routing protocol based on link lifetime and energy consumption prediction for mobile edge computing. *IEEE Access*, 8, 69058-69071. <https://doi.org/10.1109/ACCESS.2020.2986078>
- Zhang, D.-g., Niu, H.-l., Liu, S., & Ming, X.-c. J. W. p. c. (2017). Novel positioning service computing method for WSN. *Wireless personal communications*, 92(4), 1747-1769. <https://doi.org/10.1007/s11277-016-3632-y>
- Zhang, H., Wang, Z., Gulliver, T. A. J. J. o. A. I., & Computing, H. (2018). Two-stage weighted centroid localization for large-scale wireless sensor networks in ambient intelligence environment. *Journal of Ambient Intelligence and Humanized Computing*, 9(3), 617-627. <https://doi.org/10.1007/s12652-017-0458-8>
- Zhang, K., Zhang, G., Yu, X., & Hu, S. (2021). Boundary-Based Anchor Selection Method for WSNs Node Localization. *Arabian Journal for Science and Engineering*, 46(4), 3779-3792. <https://doi.org/10.1007/s13369-020-05286-9>
- Zhang, S., Liu, X., Wang, J., Cao, J., & Min, G. J. A. T. o. S. N. (2015). Accurate range-free localization for anisotropic wireless sensor networks. *ACM Transactions on Sensor Networks (TOSN)*, 11(3), 1-28. <https://doi.org/10.1145/2746343>
- Zhou, C., Yang, Y., Wang, Y. J. M. T., & Applications. (2019). DV-Hop localization algorithm based on bacterial foraging optimization for wireless multimedia sensor networks. *Multimedia Tools and Applications*, 78(4), 4299-4309. <https://doi.org/10.1007/s11042-018-5674-5>
- Zhou, G., He, T., Krishnamurthy, S., & Stankovic, J. A. J. A. T. o. S. N. (2006). Models and solutions for radio irregularity in wireless sensor networks. *ACM Transactions on Sensor Networks (TOSN)*, 2(2), 221-262. <https://doi.org/10.1145/1149283.1149287>
- Zhou, Y., Charles, M., Wang, T., & Song, M. J. I. J. o. S. N. (2020). Improved localisation algorithm based on Markov chain Monte Carlo-Metropolis Hastings for wireless sensor networks. *International Journal of Sensor Networks*, 33(3), 159-167. <https://doi.org/10.1504/IJSNET.2020.108561>