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Correlated T-test analysis of Internet of Things-based heartbeat measuring device

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***Abstract*— In this paper, correlated t-test analysis of Internet of Things-based heartbeat measurement device (IOT-MHBMD) is presented. The IOT-MHBMD device was designed to enable individuals to measure their heartbeat and send the measured data via the internet connection to a cloud database server. Specifically, this paper is focused on the evaluation of the measurement accuracy of the IOT-MHBMD based on empirical data measurements. Notably, the measurement accuracy of the IOT-MHBMD is compared with respect to the measured heartbeat data using pulse oximeter CE012 IPx2, manufactured by Human Accurate Biomedical Technology Co.Ltd. Official permission was obtained to conduct correlated-test heartbeat data collection from patients in a health facility in Uyo, Akwa Ibom State Nigeria. A total of 84 patient's data were captured and used for the correlated t-test analysis. t-test is conducted in order to determine is the measured data $\mathrm{RMHB_k}$ captured using the IOT-MHBMD device is accurate with respect to the measured data $\mathrm{HMHB_k}$ captured using the hospital pulse oximeter CE012 IPx2 device. The correlated t-test is conducted at 0.05 significant level with respect to the 84 pair of data $\mathrm{RMHB_k}$ and $\mathrm{HMHB_k}$, where k = 1,2,3,…N and N = 84. The results show that at 95 % confidence level, the sample mean $(\bar{D})$of 0.16905 is within the lower point and upper point of -0.25355 and 0.25355 respectively. This means that the mean of $\mathrm{RMHB_k}$ and $\mathrm{HMHB_k}$ are equal or put another way the there is no significant difference between the mean of $\mathrm{RMHB_k}$ and $\mathrm{HMHB_k}$. Essentially, the result show that the measurement done using the microcontroller-based heartbeat measuring device (IOT-MHBMD) is as good as that measured with the hospital pulse oximeter CE012 IPx2 device. After modelling from the training data, then the predicted value $(HMHBP_k)$ is compared with the actual value $HMHB_k$, and it was observed that the error has been minimized; notably the sample mean $(\bar{D})$ of the difference is now -0.00476 whereas it was 0.16905 without the optimization model. In all, the use of the optimization model effectively improve the measurement accuracy of the microcontroller-based heartbeat measuring device (IOT-MHBMD) evaluated in this paper.**

Keywords*— *Heartbeat Measuring Device, Calibration, Microcontroller-Based System, Correlated t-test, Pulse Oximeter CE012 IPx2

1. Introduction

Today, every industry has been significantly impacted by the advancements in the electronic, software and networking technologies. Beyond the wired and fiber optic networks, wireless network technologies have evolved and given rise to satellite communications and various wireless sensor network and Internet of Things solutions [1,2,3,4,5, 6,7,8,9,10, 11,12,13,14, 15,16,17,18, 19,20, 21,22, 23,24,25,26,27]. Particularly, the Internet and the associated Internet of Things, the smarts systems and sensor networks are just parts of the numerous outcomes of the advancements and synergy of the electronic, software and networking technologies [28,29, 30,31, 32,33, 34,35, 36,37, 38,39, 40,41, 42,43, 44,45, 46,47, 48,49, 505,51, 52,53, 54,55, 56,57, 58, 59, 60]. With these technological solution options, many industries are therefore seeking for the cost effective solution option or combinations that are optimal in terms of cost and performance.

Accordingly, in the health sector, there is growing need for affordable devices for capturing the vital health signs of which the heartbeat or pulse rate is included [61,62,63,64]. The vital health signs devices are also expected to be ready for smart applications [65,66,67]. In that case, Internet connectivity and ability to exchange data and other relevant information with online databases, as well as with requisite web and mobile applications are essential.

Accordingly, across the globe researchers are developing different kinds of devices targeted at different kinds of vital health signs [68,79,70,71]. When such a device is developed, it is important to ascertain its measurement accuracy and also to calibrate the device to ensure that the readings are accurate enough for application in health care management [72,73,74,75]. As such, this paper is focused on presenting an approach for verifying the measurement accuracy of a locally designed Internet of Things and microcontroller-based heartbeat measuring device (IOT-MHBMD). Specifically, the IOT-MHBMD is subject to a correlated t-test statistical analysis which is used to confirm whether the mean of a set of two different paired measurements are the same. If so, can be concluded that the two measurements are equivalent.

In view of the correlated t-test statistical analysis, a field measurement was conducted on a number of patients in a hospital, one measurement was done on the patient using the IOT-MHBMD device and another measurement was also done on the same patient using the heartbeat measuring equipment in the hospital. The two datasets were subjected to correlated t-test statistical analysis. The details of the analysis are presented.

Furthermore, analytical model is also developed base on the field measured datasets for improving the measurement accuracy of the IOT-MHBMD relative to the heartbeat measuring equipment in the hospital. The enhanced IOT-MHBMD measurement data output was also subjected to correlated t-test statistical analysis. The essence of the study is to provide research and end users some ideas on how to determine the accuracy of the various vital health signs measuring devices.

2. Methodology

2.1. Field data capturing for Heartbeat

This paper aims at analyzing the measurement accuracy of Internet of Things and microcontroller-based heartbeat measuring device (IOT-MHBMD) designed and implemented by the authors of this paper. The device is designed to enable individuals to measure their heartbeat and send the measured data via the internet connection to a cloud database server. Specifically, this paper is focused on the evaluation of the measurement accuracy of the IOT-MHBMD based on empirical data measurements.

Notably, the measurement accuracy of the IOT-MHBMD is compared with respect to the measured heartbeat data using pulse oximeter CE012 IPx2, manufactured by Human Accurate Biomedical Technology Co.Ltd. Official permission was obtained to conduct correlated-test heartbeat data collection from patients in a health facility in Uyo, Akwa Ibom State Nigeria.

The heartbeat data were captured in beat per minute (bpm) using both the IOT-MHBMD device and the hospital pulse oximeter CE012 IPx2 device. A total of 84 patient's data were captured as shown in Table 1. The data in Table 1 shows the data measured using the IOT-MHBMD device as RM Heartbeat or RMHB and the hospital pulse oximeter CE012 IPx2 device measured data as HM Heartbeat or HMHB (Bpm).

Table 1: The field measured showing the data measured using the IOT-MHBMD device (as RM Heartbeat) and the hospital pulse oximeter CE012 IPx2 device measured data (as HM Heartbeat)

S/N	RM Heartbeat or RMHB (Bpm)	HM Heartbeat or HMHB (Bpm)	S/N	RM Heartbeat or RMHB (Bpm)	HM Heartbeat or HMHB (Bpm)	S/N	RM Heartbeat or RMHB (Bpm)	HM Heartbeat or HMHB (Bpm)
1	55.6	55.6	**29**	78.7	82	**57**	90	90.6
2	60	61.3	**30**	78.8	79	**58**	90.8	91.4
3	62.4	62	**31**	79.7	79	**59**	91	91.8
4	63.7	63.6	**32**	79.7	77	**60**	91.4	92
5	64.3	65	**33**	79.9	81.9	**61**	91.5	92
6	64.7	64	**34**	79.9	78	**62**	91.9	92
7	64.8	65.29	**35**	80.6	80	**63**	92	92
8	66.1	67.5	**36**	80.9	82	**64**	92.5	91.8
9	67.4	68	**37**	81	81.1	**65**	93	92.5
10	67.5	68.5	**38**	82.2	82	**66**	93.1	92
11	68.1	68.8	**39**	82.7	82	**67**	93.3	91
12	68.5	70	**40**	83.5	82.9	**68**	93.9	90
13	69.4	68.5	**41**	83.6	83.7	**69**	94	94
14	69.9	70	**42**	84	84.9	**70**	94.7	95
15	71.4	72	**43**	84.1	86	**71**	94.7	96
16	71.6	73	**44**	84.4	84.8	**72**	94.9	95
17	72.3	73.3	**45**	84.6	86.5	**73**	95.3	96

18	72.9	71	**46**	85.1	85	**74**	95.5	97.8
19	73.4	73.2	**47**	85.5	86	**75**	96	98
20	74.3	74	**48**	85.7	86	**76**	96.4	97
21	74.4	74.5	**49**	86.9	87	**77**	96.9	95
22	74.7	76	**50**	87.4	87	**78**	97.2	95
23	75.2	75	**51**	88.9	89	**79**	97.7	99
24	76.6	78	**52**	89	89.2	**80**	98.6	99
25	76.9	76	**53**	89.4	89.9	**81**	98.8	97
26	77.1	76	**54**	89.6	90	**82**	99.2	101
27	77.9	78.3	**55**	89.7	90.8	**83**	99.5	100
28	78.6	79	**56**	89.9	90.7	**84**	99.6	98

2.2 The correlated t-test analysis of the field measured heartbeat datasets

A correlated t-test is conducted in order to determine if the measured data $RMHB_k$ captured using the IOT-MHBMD device is accurate with respect to the measured data $HMHB_k$ captured using the hospital pulse oximeter CE012 IPx2 device. The correlated t-test is conducted with respect to the 84 pair of data $RMHB_k$ and $HMHB_k$, where k = 1,2,3,…N and N = 84. The difference D_k between $RMHB_k$ and $HMHB_k$ is given as;

$$D_k = RMHB_k - HMHB_k \text{ for } k = 1,2,3,\ldots N \quad (1)$$

The difference (D_k) has a mean $(\bar{D})$where;

$$\bar{D} = \frac{[\sum_{k=1}^{N}(D_k)]}{N} \quad (2)$$

The standard deviation (S_D) is;

$$S_D = \sqrt[2]{\left(\frac{[\sum_{k=1}^{N}(D_k-\bar{D})^2]}{(N-1)}\right)^2} \quad (3)$$

The standard error (SE_D) is;

$$SE_D = \left(\frac{S_D}{\sqrt{N}}\right) \quad (4)$$

The t-statistic (t_D) is ;

$$t_D = \frac{\bar{D}}{SE_D} \quad (5)$$

The (df) degree of freedom, is

$$df = N - 1 \quad (6)$$

If significance value is α, then , the critical t value $(t_{Dcritical})$ is;

$$t_{Dcritical} = t_{(\alpha/2)} \text{ at df} \quad (7)$$

The confidence interval $(CI_{D\alpha})$ is expressed as;

$$CI_{D\alpha} = \left[\left(\bar{D} - \left((t_{(\alpha/2)})(SE_D)\right)\right), \left(\bar{D} + \left((t_{(\alpha/2)})(SE)\right)\right)\right] \quad (8)$$

If no significant difference exist the mean of $RMHB_k$ and $HMHB_k$ then following condition must be satisfied;

$$\left(\bar{D} - \left((t_{(\alpha/2)})(SE_D)\right)\right) \leq \bar{D} \leq \left(\bar{D} + \left((t_{(\alpha/2)})(SE)\right)\right) \quad (9)$$

3. Results and Discussion

3.1 The results of the correlated t-test based on the pair of heartbeat field datasets

The results of the correlated t-test at 0.05 significant level or confidence level of 95% is shown in Figure 1. The results show that at 95 % confidence level, the sample mean $(\bar{D})$of 0.16905 is within the lower point and upper point of -0.25355 and 0.25355 respectively. This means that the mean of $RMHB_k$ and $HMHB_k$ are equal or put another way the there is no significant difference between the mean of $RMHB_k$ and $HMHB_k$. Essentially, the result show that the measurement done using the microcontroller-based heartbeat measuring device (IOT-MHBMD) is as good as that measured with the hospital pulse oximeter CE012 IPx2 device.

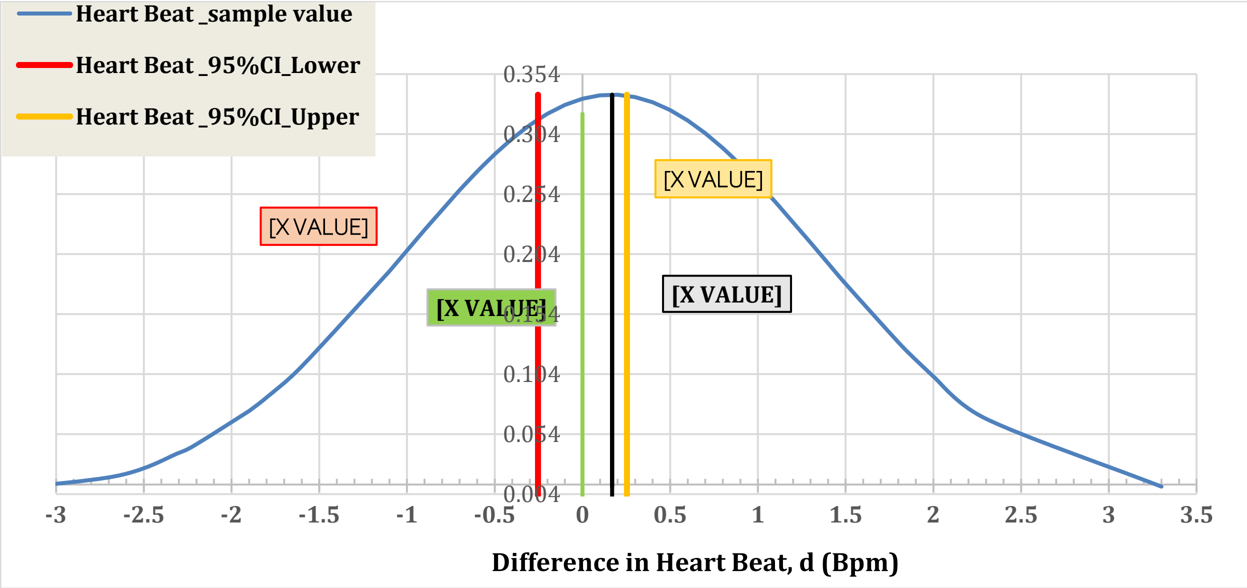

Figure 1: The graph of the correlated t-test of heartbeat field datasets

3.2 Development of analytical model for improved measurement accuracy of the microcontroller-based heartbeat measuring device (IOT-MHBMD)

An analytical model for improved measurement accuracy of the microcontroller-based heartbeat measuring device (IOT-MHBMD) is developed by using the Microsoft Excel Solver plug-in tool to fit analytical model that minimizes the root mean square error (RMSE) of the paired field measured dataset. First, the data was divided into two, namely 75 % training data model and 25% cross validation. About 75% of the measured dataset were used for training data and this is about 63 patient's data while 25% were used for cross validation, which represent 21 patient's data (as shown in Table .2 and 3 respectively).

Table 2: The training dataset for heartbeat model development

S/N	RM Heartbeat or RMHB (Bpm)	HM Heartbeat or HMHB (Bpm)	S/N	RM Heartbeat or RMHB (Bpm)	HM Heartbeat or HMHB (Bpm)	S/N	RM Heartbeat or RMHB (Bpm)	HM Heartbeat or HMHB (Bpm)
1	55.6	55.6	22	78.7	82	43	90	90.6
2	60	61.3	23	78.8	79	44	90.8	91.4
3	62.4	62	24	79.7	79	45	91	91.8
4	64.3	65	25	79.9	81.9	46	91.5	92
5	64.7	64	26	79.9	78	47	91.9	92
6	64.8	65.29	27	80.6	80	48	92	92
7	67.4	68	28	81	81.1	49	93	92.5
8	67.5	68.5	29	82.2	82	50	93.1	92
9	68.1	68.8	30	82.7	82	51	93.3	91
10	69.4	68.5	31	83.6	83.7	52	94	94
11	69.9	70	32	84	84.9	53	94.7	95
12	71.4	72	33	84.1	86	54	94.7	96
13	72.3	73.3	34	84.6	86.5	55	95.3	96
14	72.9	71	35	85.1	85	56	95.5	97.8
15	73.4	73.2	36	85.5	86	57	96	98
16	74.4	74.5	37	86.9	87	58	96.9	95
17	74.7	76	38	87.4	87	59	97.2	95
18	75.2	75	39	88.9	89	60	97.7	99
19	76.9	76	40	89.4	89.9	61	98.8	97
20	77.1	76	41	89.6	90	62	99.2	101
21	77.9	78.3	42	89.7	90.8	63	99.5	100

Table 3: The validation dataset for cross validation of heartbeat measurement accuracy optimization model

S/N	RM Heartbeat or RMHB (Bpm)	HM Heartbeat or HMHB (Bpm)	S/N	RM Heartbeat or RMHB (Bpm)	HM Heartbeat or HMHB (Bpm)	S/N	RM Heartbeat or RMHB (Bpm)	HM Heartbeat or HMHB (Bpm)
1	63.7	63.6	8	79.7	77	15	91.4	92
2	66.1	67.5	9	80.9	82	16	92.5	91.8
3	68.5	70	10	83.5	82.9	17	93.9	90
4	71.6	73	11	84.4	84.8	18	94.9	95
5	74.3	74	12	85.7	86	19	96.4	97
6	76.6	78	13	89	89.2	20	98.6	99
7	78.6	79	14	89.9	90.7	21	99.6	98

From the training data, the model was developed in order to minimize the RMSE. The model was generated using Microsoft excel with the trend line equation (Figure 4.6). The model was further modifying with the used of MS excel Solver tool in order to have better predicted values closer to that of the hospital measurement device. The model generated the predicted hospital equipment measured value, $HMHBP_k$ from the given $RMHB_k$ where;

$$HMHBP_k = 1.0652\,(RMHB_k)^{0.9862} \qquad (1)$$

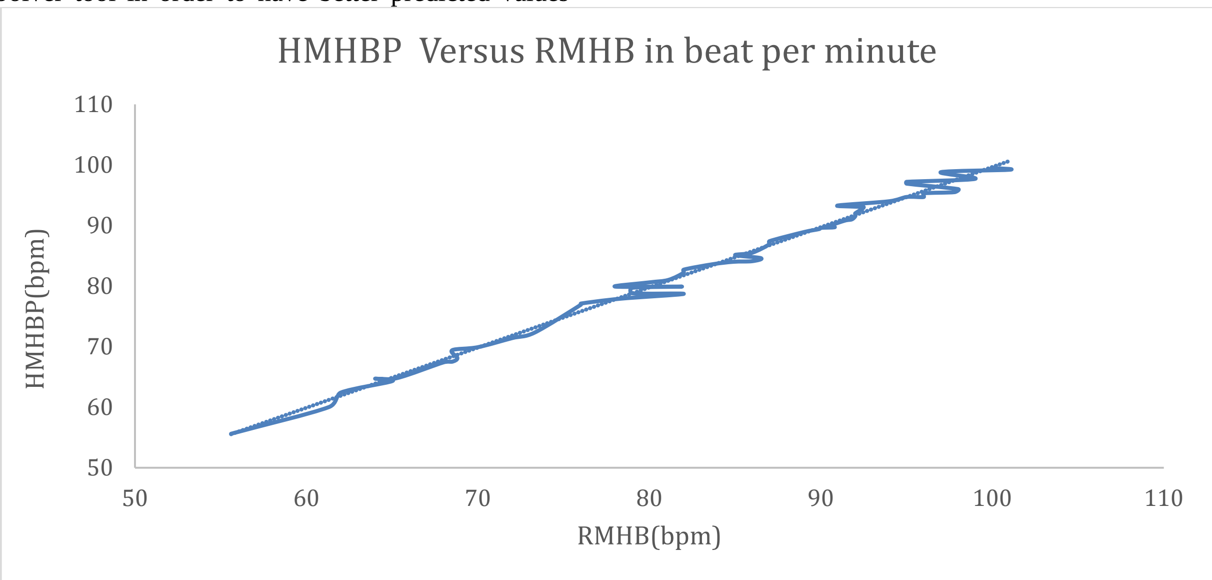

Figure 2: The graph of $HMHBP_k$ against $RMHB_k$ in beat per minute

After modelling from the training data, then the predicted value ($HMHBP_k$) is compared with the actual value $HMHB_k$, and it was observed that the error has been minimize (Figure 3 and Figure 4) where the sample mean ($\bar{D}$) of the difference is now -0.00476 whereas it was 0.16905 without the optimization model. In all, the use of the optimization model effectively improve the measurement accuracy of the microcontroller-based heartbeat measuring device (IOT-MHBMD) evaluated in this paper.

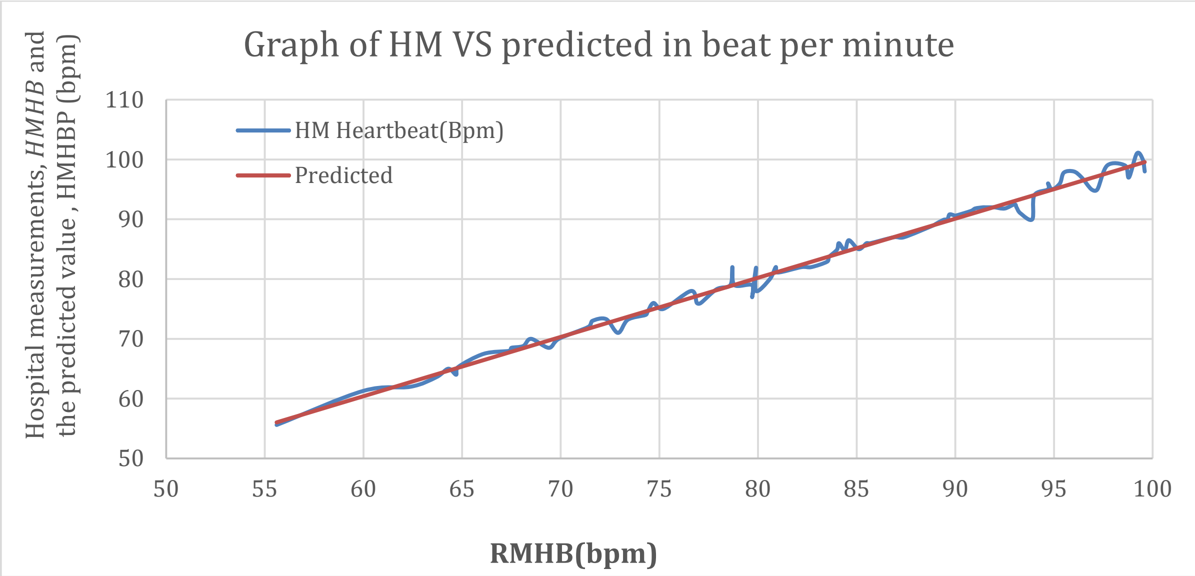

Figure 3: Comparison of the actual hospital measured value and predicted value generated using the optimization model

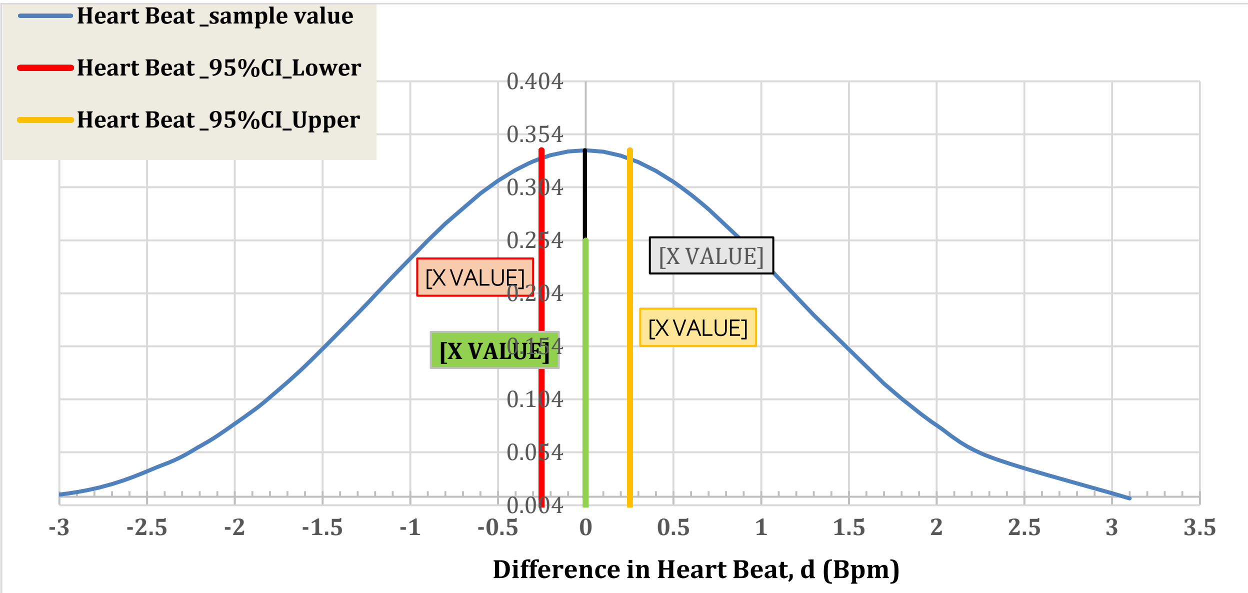

Figure 4: The graph shows the Correlated t-test of heart beat for predicted value

3. Conclusion

An approach for analyzing the measurement accuracy of a microcontroller-based heartbeat measuring device (IOT-MHBMD) with respect to the equivalent device used in a hospital is presented. The approach utilized correlated t-test statistics to determine how significance is the difference between the heartbeat measurements captured using the IOT-MHBMD and the one captured using the equivalent device used in a hospital. The analysis was based on pair of field datasets collected from 84 patients in the hospital.

In addition, analytical model was developed to improve on the measurement accuracy of the IOT-MHBMD with respect to the equivalent device used in a hospital. The model was further evaluated using the correlated t-test statistics and the results show that the model significantly reduced the mean error of the measured datasets.

References

1. Ozuomba Simeon and Chukwudebe G. A.(2003) *An improved algorithm for channel capacity allocation in timer controlled token passing protocols, The Journal of Computer Science and its Applications (An international Journal of the Nigerian Computer Society (NCS)) Vol. 9, No. 1 , June 2003 , PP 116 124*
2. Idio, Uduak, Constance Kalu, Akaninyene Obot, and Simeon Ozuomba. (2013) "An improved scheme for minimizing handoff failure due to poor signal quality." In *2013 IEEE International Conference on Emerging & Sustainable Technologies for Power & ICT in a Developing Society (NIGERCON)*, pp. 38-43. IEEE, 2013.
3. Kalu, S. Ozuomba, G. N. Onoh (2011) ANALYSIS OF TIMELY-TOKEN PROTOCOL WITH NON-UNIFORM HEAVY LOAD OF ASYNCHRONOUS

TRAFFIC. Electroscope Journal Vol. 5 No. 5 (2011)

4. Atakpo, F. K., Simeon, O., & Utibe-Abasi, S. B. (2021) A COMPARATIVE ANALYSIS OF SELFORGANIZING MAP AND K-MEANS MODELS FOR SELECTION OF CLUSTER HEADS IN OUT-OF-BAND DEVICE-TO-DEVICE COMMUNICATION. *Journal of Multidisciplinary Engineering Science Studies (JMESS).*
5. Ozuomba Simeon , Chukwudebe G. A. and Akaninyene B. Obot (2011); *"Static-Threshold-Limited On-Demand Guaranteed Service For Asynchronous Traffic In Timely-Token Protocol " Nigerian Journal of Technology (NIJOTECH)* Vol. 30, No. 2 , June 2011 , PP 124 – 142
6. Samuel, W., Ozuomba, Simeon, & Constance, K. (2019). SELF-ORGANIZING MAP (SOM) CLUSTERING OF 868 MHZ WIRELESS SENSOR NETWORK NODES BASED ON EGLI PATHLOSS MODEL COMPUTED RECEIVED SIGNAL STRENGTH. *Journal of Multidisciplinary Engineering Science and Technology (JMEST) Vol. 6 Issue 12, December - 2019*
7. Kalu C. , Ozuomba Simeon, Onoh G.N. (2013) Dynamic Threshold limited timed token (DTLTT) Protocol *Nigerian Journal of Technology (NIJOTECH)* Vol. 32. No. 1. March 2013, pp. 266-272.
8. Johnson, Enyenihi Henry, Simeon Ozuomba, and Ifiok Okon Asuquo. (2019). Determination of Wireless Communication Links Optimal Transmission Range Using Improved Bisection Algorithm. *Universal Journal of Communications and Network, 7(1), 9-20.*
9. Kalu, C., Ozuomba, Simeon., & Anthony, U. M. (2015). STATIC-THRESHOLD-LIMITED BuST PROTOCOL. *European Journal of Mathematics and Computer Science Vol, 2(2).*
10. Ozuomba, Simeon, Amaefule, C. O., & Afolayan, J. J. (2013). Optimal Guaranteed Services Timed Token (OGSTT) Media Access Control (Mac) Protocol For Networks That Support Hard Real-Time And Non Real-Time Traffic. *Nigerian Journal of Technology (NIJOTECH) 32*(3), 470-477
11. Anietie Bassey, Simeon Ozuomba & Kufre Udofia (2015). An Effective Adaptive Media Play-out Algorithm For Real-time Video Streaming Over Packet Networks. European. *Journal of Basic and Applied Sciences Vol, 2(4).*
12. Constance Kalu, Simeon Ozuomba and Umoren Mfonobong Anthony (2015) Performance Analysis of Fiber Distribution Data Interface Network Media Access Control Protocol Under-Uniform Heavy load of Asynchronous Traffic. European Journal of Basic and Applied Sciences. Vol 2 No. 4
13. Ozuomba Simeon and Chukwudebe G. A. (2004) *A new priority scheme for the asynchronous traffic in timer-controlled token passing protocols, The Journal of Computer Science and its Applications (An international Journal of the Nigerian Computer Society (NCS)) Vol. 10, No. 2 , December 2004 , PP 17 -25*
14. Constance Kalu, Simeon Ozuomba and Umoren Mfonobong Anthony (2015) Static-Threshold-Limited Bust Protocol, European Journal of Mathematics and Computer Science, Vol. 2 N0. 2
15. Uduak Idio Akpan, Constance Kalu, Simeon Ozuomba, Akaninyene Obot (2013). Development of improved scheme for minimising handoff failure due to poor signal quality. *International Journal of Engineering Research & Technology (IJERT), 2(10), 2764-2771*
16. Kalu, C., Ozuomba, Simeon. & Udofia, K. (2015). Web-based map mashup application for participatory wireless network signal strength mapping and customer support services. *European Journal of Engineering and Technology, 3 (8)*, 30-43.
17. Ozuomba Simeon and Chukwudebe G. A.(2011) ; *"Performance Analysis Of Timely-Token Protocol With Variable Load Of Synchronous Traffic" NSE Technical Transactions , A Technical Journal of The Nigerian Society Of Engineers,* Vol. 46, No. 1 Jan – March 2011, PP 34 – 46.
18. Samuel, Wali, Simeon Ozuomba, and Philip M. Asuquo (2019). EVALUATION OF WIRELESS SENSOR NETWORK CLUSTER HEAD SELECTION FOR DIFFERENT PROPAGATION ENVIRONMENTS BASED ON LEE PATH LOSS MODEL AND K-MEANS ALGORITHM. EVALUATION, 3(11). *Science and Technology Publishing (SCI & TECH) Vol. 3 Issue 11, November - 2019*
19. Njoku, Felix A., Ozuomba Simeon, and Fina Otosi Faithpraise (2019). Development Of Fuzzy Inference System (FIS) For Detection Of Outliers In Data Streams Of Wireless Sensor Networks. *International Multilingual Journal of Science and Technology (IMJST) Vol. 4 Issue 10, October - 2019*
20. Simeon, Ozuomba. (2020). "APPLICATION OF KMEANS CLUSTERING ALGORITHM FOR SELECTION OF RELAY NODES IN WIRELESS SENSOR NETWORK." *International Multilingual Journal of Science and Technology (IMJST) Vol. 5 Issue 6, June - 2020*
21. Akpan, Itoro J., Ozuomba Simeon, and Kalu Constance (2020). "Development Of A Guard Channel-Based Prioritized Handoff Scheme With Channel Borrowing Mechanism For Cellular Networks." *Journal of Multidisciplinary Engineering Science and Technology (JMEST) Vol. 7 Issue 2, February - 2020*
22. Simeon, Ozuomba. (2020). "Analysis Of Effective Transmission Range Based On Hata Model For Wireless Sensor Networks In The C-Band And Ku-Band." *Journal of Multidisciplinary Engineering Science and Technology (JMEST) Vol. 7 Issue 12, December - 2020*

23. Ogbonna Chima Otumdi , Ozuomba Simeon, Kalu Constance (2020). Clustering Of 2100 Mhz Cellular Network Devices With Som Algorithm Using Device Hardware Capacity And Rssi Parameters *Science and Technology Publishing (SCI & TECH) Vol. 4 Issue 2, February – 2020*

24. Simeon, Ozuomba. (2016). Evaluation Of Bit Error Rate Performance Of Multi-Level Differential Phase Shift Keying. Evaluation, 1(8). *International Multilingual Journal of Science and Technology (IMJST) Vol. 1 Issue 8, August – 2016*

25. Ogbonna Chima Otumdi , Ozuomba Simeon, Philip M. Asuquo (2020) Device Hardware Capacity And Rssi-Based Self Organizing Map Clustering Of 928 Mhz Lorawan Nodes Located In Flat Terrain With Light Tree Densities *Science and Technology Publishing (SCI & TECH) Vol. 4 Issue 9, September - 2020*

26. Kalu C., Ozuomba S., and Mbocha C.C. (2013) Performance Analysis of Static- Threshold-Limited On-Demand Guaranteed Services Timed Token Media Access Control Protocol Under Non Uniform Heavy Load of Asynchronous Traffic. *NSE Technical Transactions, A Technical Journal of the Nigerian Society of Engineers,* Vol. 47, No. 3 July – Sept 2013,

27. Sharma, S. R., & Rana, S. (2017). Comprehensive study of radio over fiber with different modulation techniques–a review. *International Journal of Computer Applications*, *170*(4), 22-25.

28. Gordon, O., Ozuomba, Simeon. & Ogbajie, I. (2015). Development of educate: a social network web application for e-learning in the tertiary institution. *European Journal of Basic and Applied Sciences, 2 (4)*, 33-54.

29. Ozuomba, Simeon, and Etinamabasiyaka Edet Ekott. (2020). "Design And Implementation Of Microcontroller And Internet Of Things-Based Device Circuit And Programs For Revenue Collection From Commercial Tricycle Operators." *Science and Technology Publishing* (SCI & TECH) Vol. 4 Issue 8, August – 2020

30. Sylvester Michael Ekpo, Kingsley M. Udofia, Ozuomba Simeon (2019) Modelling and Simulation of Robust Biometric Fingerprint Recognition Algorithm. *Universal Journal of Applied Science 6(2): 29-38, 2019*

31. Ozuomba, Simeon, Ekaette Ifiok Archibong, and Etinamabasiyaka Edet Ekott (2020). Development Of Microcontroller-Based Tricycle Tracking Using Gps And Gsm Modules. *Journal of Multidisciplinary Engineering Science and Technology (JMEST) Vol. 7 Issue 1, January - 2020*

32. Zion, Idongesit, Simeon Ozuomba, and Philip Asuquo. (2020) "An Overview of Neural Network Architectures for Healthcare." *2020 International Conference in Mathematics, Computer Engineering and Computer Science (ICMCECS).* IEEE, 2020

33. Akpan, Nsikak-Abasi Peter, Kufre Udofia, and Simeon Ozuomba (2018). Development and Comparative Study of Least Mean Square-Based Adaptive Filter Algorithms. Development, 3(12). *International Multilingual Journal of Science and Technology (IMJST) Vol. 3 Issue 12, December - 2018*

34. Simeon, Ozuomba. (2018) "Sliding Mode Control Synthesis For Autonomous Underwater Vehicles" *Science and Technology Publishing (SCI & TECH*

35. Chikezie, Aneke, Ezenkwu Chinedu Pascal, and Ozuomba Simeon. (2014). "Design and Implementation Of A Microcontroller-Based Keycard." *International Journal of Computational Engineering Research (IJCER) Vol, 04 Issue, 5 May – 2014*

36. Otumdi, Ogbonna Chima, Kalu Constance, and Ozuomba Simeon (2018). "Design of the Microcontroller Based Fish Dryer." *Journal of Multidisciplinary Engineering Science Studies (JMESS) Vol. 4 Issue 11, November - 201*

37. Maduka, N. C., Simeon Ozuomba, and E. E. Ekott. . (2020) "Internet of Things-Based Revenue Collection System for Tricycle Vehicle Operators." *2020 International Conference in Mathematics, Computer Engineering and Computer Science (ICMCECS)*. IEEE, 2020.

38. Thompson, E., Simeon, O., & Olusakin, A. (2020). A survey of electronic heartbeat electronics body temperature and blood pressure monitoring system. Journal of Multidisciplinary Engineering Science Studies (JMESS) Vol. 6 Issue 8, August – 2020

39. Ozuomba Simeon, Chukwedebe G. A. , Opara F. K., Ndinechi M. (2013) Preliminary Context Analysis Of Community Informatics Social Network Web Application. *Nigerian Journal of Technology (NIJOTECH)* Vol. 32. No. 2. July 2013, pp. 266-272

40. Ezenkwu C. P , Ozuomba Simeon, Kalu C. (2013) Community informatics social network for facilitated community policing: A case study of Nigeria . *Software Engineering* 2013; Vol.1(No.3): PP 22-30 . Published online November 20, 2013

41. Ozuomba, Simeon. (2013). Triple-win user innovation network and facilitated all-inclusive collective enterprise (TWUINFAICE): A postdoctoral research agenda for turning the youth bulge in Africa into blessing. *Science Innovation1*(3), 18-33.

42. Ekanem, Mark Sunday, and Simeon Ozuomba. (2018). ONTOLOGY DEVELOPMENT FOR PEDAGOGIC CONTENT INFORMATICS. *European Journal of Engineering and Technology Vol, 6(4).*

43. Bassey, M. U., Ozuomba, Simeon, & Stephen, B. U. A. (2019). DEVELOPMENT OF A FACILITATED CROWD-DRIVEN ONLINE PROFIT-MAKING SYSTEM. *European Journal of Engineering and Technology Vol, 7(5).*

44. Ezenkwu C. P , Ozuomba Simeon, Amaefule O. C. (2013) The Pure-Emic User Interface Design Methodology for an Online Community Policing Hub. *Computer Engineering and Intelligent Systems* Vol.4, No.11, 2013. ISSN 2222-1719 (Paper) ISSN 2222-2863 (Online)
45. Nicholas Aigbobhiose Esene, Simeon Ozuomba, obinwa Christian Amaefule (2013) Strategies for Improving Software Development and Acquisition Practices in Developing Countries. International Journal of Computer (ISSN 2307-4531) Vol. 8 No 1 (2013)
46. Chinedu Pascal Ezenkwu , Simeon Ozuomba , Constance Kalu (2015) , *Application of k-Means Algorithm for efficient Customer Segmentation: A strategy for targeted customer services. (IJARAI) International Journal of Advanced Research in Artificial Intelligence, Vol. 4, No.10, 2015*
47. Ezeonwumelu, P., Ozuomba, Simeon. & Kalu, C. (2015). Development of swim lane workflow process map for enterprise workflow management information system (WFMIS): a case study of comsystem computer and telecommunication ltd (CCTL) EKET. *European Journal of Engineering and Technology, 3 (9)*, 1-13.
48. Ozuomba, Simeon, Kalu, C., & Anthony, U. M. (2015). Map Mashup Application And Facilitated Volunteered Web-Based Information System For Business Directory In Akwa Ibom State. *European Journal of Engineering and Technology Vol*, *3*(9).
49. Akpasam Joseph Ekanem, Simeon Ozuomba, Afolayan J. Jimoh (2017) Development of Students Result Management System: A case study of University of Uyo. *Mathematical and Software Engineering*, Vol. 3, No. 1 (2017), 26-42.
50. Ezenkwu, Chinedu Pascal, Simeon Ozuomba, and Constance Kalu. (2013). "Strategies for improving community policing in Nigeria through Community Informatics Social Network." *2013 IEEE International Conference on Emerging & Sustainable Technologies for Power & ICT in a Developing Society (NIGERCON)*. IEEE, 2013.
51. Simeon Ozuomba , Gloria A. Chukwudebe , Felix K. Opara and Michael Ndinechi (2014)Chapter 8: Social Networking Technology: A Frontier Of Communication For Development In The Developing Countries Of Africa . *In Green Technology Applications for Enterprise and Academic Innovation (Chapter 8).* IGI Global, Hershey, PA 17033-1240, USA
52. Eyibo, I. E., Ozuomba, Simeon, & Stephen, B. U. A. (2018). DEVELOPMENT OF TRUST MODEL FOR PROXY MARKETERS ENGAGED IN E-COMMERCE PLATFORMS. *European Journal of Engineering and Technology Vol, 6(4).*
53. Nicholas A. E., Simeon O., Constance K. (2013) Community informatics social e-learning network: a case study of Nigeria *Software Engineering 2013; 1(3): 13-21*
54. Mathew-Emmanuel, Eze Chinenye, Simeon Ozuomba, and Constance Kalu. (2017) "Preliminary Context Analysis of Social Network Web Application for Combating HIV/AIDS Stigmatization." *Mathematical and Software Engineering* 3.1 (2017): 99-107
55. Stephen, B. U., Ozuomba, Simeon, & Eyibo, I. E. (2018). Development of Reward Mechanism for Proxy Marketers Engaged in E-Commerce Platforms. *European Journal of Engineering and Technology Research, 3(10), 45-52.*
56. Inyang, Imeobong Frank, Simeon Ozuomba, and Chinedu Pascal Ezenkwu.(2017) "Comparative analysis of Mechanisms for Categorization and Moderation of User Generated Text Contents on a Social E-Governance Forum." *Mathematical and Software Engineering* 3.1 (2017): 78-86.
57. Ozuomba, Simeon, Constant Kalu, and Akpasam Joseph. (2018). Development of Facilitated Participatory Spatial Information System for Selected Urban Management Services. *Review of Computer Engineering Research, 5(2), 31-48.*
58. Kalu, Constance, Simeon Ozuomba, and Sylvester Isreal Umana. (2018). Development of Mechanism for Handling Conflicts and Constraints in University Timetable Management System. *Communications on Applied Electronics (CAE) 7(24).*
59. Ibanga, Jude, and Ozuomba Simeon, Obot, Akaniyene. B. (2020) "Development of Web-Based Learning Object Management System." Development 7, no. 3 (2020). *Journal of Multidisciplinary Engineering Science and Technology (JMEST) Vol. 7 Issue 3, March – 2020*
60. Maramba, I., Chatterjee, A., & Newman, C. (2019). Methods of usability testing in the development of eHealth applications: a scoping review. *International journal of medical informatics*, *126*, 95-104.
61. Khan, Y., Ostfeld, A. E., Lochner, C. M., Pierre, A., & Arias, A. C. (2016). Monitoring of vital signs with flexible and wearable medical devices. *Advanced materials*, *28*(22), 4373-4395.
62. Chan, M., Estève, D., Fourniols, J. Y., Escriba, C., & Campo, E. (2012). Smart wearable systems: Current status and future challenges. *Artificial intelligence in medicine*, *56*(3), 137-156.
63. Dias, D., & Paulo Silva Cunha, J. (2018). Wearable health devices—vital sign monitoring, systems and technologies. *Sensors*, *18*(8), 2414.
64. Adib, F., Mao, H., Kabelac, Z., Katabi, D., & Miller, R. C. (2015, April). Smart homes that monitor breathing and heart rate. In *Proceedings of the 33rd annual ACM conference on human factors in computing systems* (pp. 837-846).
65. Haghi, M., Thurow, K., & Stoll, R. (2017). Wearable devices in medical internet of things: scientific research and commercially available devices. *Healthcare informatics research*, *23*(1), 4-15.

66. West, D. M. (2016). How 5G technology enables the health internet of things. *Brookings Center for Technology Innovation*, *3*(1), 20.
67. West, D. M. (2016). How 5G technology enables the health internet of things. *Brookings Center for Technology Innovation*, *3*(1), 20.
68. Ajana, B. (2017). Digital health and the biopolitics of the Quantified Self. *Digital health*, *3*, 2055207616689509.
69. Malasinghe, L. P., Ramzan, N., & Dahal, K. (2019). Remote patient monitoring: a comprehensive study. *Journal of Ambient Intelligence and Humanized Computing*, *10*(1), 57-76.
70. Chen, M., Gonzalez, S., Vasilakos, A., Cao, H., & Leung, V. (2011). Body area networks: A survey. *Mobile networks and applications*, *16*(2), 171-193.
71. Dhanvijay, M. M., & Patil, S. C. (2019). Internet of Things: A survey of enabling technologies in healthcare and its applications. *Computer Networks*, *153*, 113-131
72. Ra, H. K., Ahn, J., Yoon, H. J., Yoon, D., Son, S. H., & Ko, J. (2017, February). I am a" smart" watch, smart enough to know the accuracy of my own heart rate sensor. In *Proceedings of the 18th International Workshop on Mobile Computing Systems and Applications* (pp. 49-54).
73. Pretto, J. J., Roebuck, T., Beckert, L., & Hamilton, G. (2014). Clinical use of pulse oximetry: official guidelines from the T horacic S ociety of A ustralia and N ew Z ealand. *Respirology*, *19*(1), 38-46.
74. Banerjee, T., Peterson, M., Oliver, Q., Froehle, A., & Lawhorne, L. (2018). Validating a commercial device for continuous activity measurement in the older adult population for dementia management. *Smart Health*, *5*, 51-62.
75. Muntner, P., Shimbo, D., Carey, R. M., Charleston, J. B., Gaillard, T., Misra, S., ... & Wright Jr, J. T. (2019). Measurement of blood pressure in humans: a scientific statement from the American Heart Association. *Hypertension*, *73*(5), e35-e66.