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Statistical Modelling and Validation of Performance Evaluation of Weather Monitoring System Using Global System for Mobile (GSM) Communication Technology

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***Abstract* - The study which uses the technology communication of Global System for Mobile (GSM) for fabricated weather monitoring system evaluated the reliability, accuracy and efficiency of the system through performance measure of the experimental collected parameters for temperature and humidity and statistically analyzed the data using regression technique with the aid of statistical package for social sciences (SPSS), version 17.0. The experimental data were collected for 126 times which comprises of morning, afternoon and evening period sub-divided to 42 observations respectively. The findings revealed that although the formulated models displayed a high level of significant effect but it accuracy in prediction is low for both parameters except for morning and afternoon period where only temperature is accurately validated in predicting the experimental data based on the considered location of the fabricated weather monitoring system. The study therefore concludes that the mechanism accuracy of the fabricated weather monitoring system can be improved upon.**
***Keywords*: Global System for Mobile (GSM), weather monitoring system, fabricated, temperature, humidity**

I. INTRODUCTION

Adoption of real life models such as mathematical and statistical models to solve some natural climatic issues cannot be overemphasizing. It is highly necessary for every weather monitoring system design to be evaluated based on the tested design so as to come up with some data which will be used to formulate models that can guide a particular climatic environment as an alternative to weather detection in case the required monitoring device is not readily available.

The formulated models which will come up in form of a predicted data against the experimental generated data are expected to show high degree of similarity. Various parameters can easily be considered to formulate a model for weather monitoring system irrespective of the climatic environment but for the purpose of this study, it is streamline to temperature and relative humidity only.

II. LITERATURE REVIEW

Proposing a weather prediction model based on neural network and fuzzy inference system (NFIS-WPM), [1] applied it to predict daily fuzzy precipitation given meteorological premises for testing. The reason for the study was because an accurate weather prediction is apparent when considering the benefits. The findings assessment showed that the adaption of the novel model to a precipitation prediction problem revealed that the predicted outcomes of precipitation is more accurate and the prediction methods simpler than by using the complex numerical forecasting model that would occupy large computation resources, be time-consuming and which has a low predictive accuracy rate.

In describing a simple model for weather forecasting, [2] used simple mathematical equation using multiple linear regression (MLR) equations that can be easily understood by a medium educated farmer. The study recorded weather data at a particular station which is a time series data for maximum temperature, minimum temperature and relative humidity for prediction using calculated features depending upon the correlation values in the weather data series over different periods from the weather parameter time series itself. The personal computer and simple data processing software like MS Excel used in the study can be used to make and validate the model by the user itself. The results of the findings obtained showed that MLR model can estimate the weather conditions satisfactorily.

In China, [3] presented a feasible model for the daily average temperature on the area of Zhengzhou and apply it to weather derivatives pricing. The study started by exploring the background of weather derivatives market and then used 62 years of daily historical data for the application of the mean-reverting Ornstein-Uhlenbeck process so as to describe the evolution of the temperature. Monte Carlo simulations are used in the study to price heating degree day (HDD) call option and the slow convergence of the price of the HDD call can be found through 100, 000 simulations.

The methods adopted in the study provide a framework for modelling temperature and pricing weather derivatives in other similar places in China.

Ref [4] used adaptive neuro-fuzzy inference system (ANFIS) and multiple linear regression models to analyze metrological data sets obtained from the metrological station. The study data covers a five year period (2008-2012) and which are monthly mean of minimum and maximum temperature, wind speed, relative humidity and mean sea level pressure (MSLP). The results of the findings showed that both models could be applied to weather prediction problem but however, ANFIS model yielded better results than multiple linear regression model with a lower prediction error.

Ref [5] examined the applicability of artificial neural network (ANN) approach by developing effective and reliable nonlinear predictive models for weather analysis and also compared and evaluated the performance of the developed models using different transfer functions, hidden layers and neurons to forecast maximum temperature for 365 days of the year. The study concluded that it can be best used to develop supportive statistical plots and concentrated trend of weather over a long period of time in a particular area.

In South Africa, [6] developed a climate-based ordinary-differential-equation model to analyse how temperature and the availability of water affect mosquito population size. The formulated model is used to examine the impact of climatic factors on the gonotrophic cycle and the dynamics of mosquito population over the study region in Kwazulu-Natal province. The results of the study fairly accurately quantify the seasonality of the population of *An.arabiensis* over the region and demonstrated the influence of climatic factors on the vector population dynamics. The model framework in the study is built to accommodate human population dynamics with the ability to predict malaria incidence in future.

Ref [7] presented a new approach using an artificial neural network technique to develop a model to improve rainfall forecast performance using a real world case study set up in Bangkok for 4years of hourly data from 75 rain gauge stations in the area. The developed ANN model is being applied for real time rainfall forecasting and flood management. The study results showed that ANN forecasts have superiority over the one obtained by the persistent model.

III. METHODOLOGY

The data used in this research paper are experimental collected data from a design of wireless weather monitoring system for measuring temperature and humidity in a climatic environment in Owo and Akure location [8]. The design device is powered from 12V batteries deployed within the purposed location and powered on for continuous measurement and transmission of the acquired temperature and humidity through a GSM module that is been activated and send messages to the user's mobile number as in Figure 1. The data were collected for 126 times which comprises of morning, afternoon and evening respectively, each period of occurrence has 42 observations as shown on Table 1, Table 2 and Table 3.

Fig.1(a) Working model of wireless weather monitoring system

Fig.1 (b) Coordinated design when powered

TABLE 1 MORNING DATA COLLECTED

S.No.	TEMP (^{0}C)	HUM (%)	TIME (Secs)
1	30	49	10
2	30	45	20
3	30	45	30
4	30	44	40
5	30	44	50
6	29	54	60
7	29	56	70
8	29	57	80
9	28	66	90
10	29	63	100
11	29	62	110
12	26	56	120
13	26	56	130
14	27	56	140
15	28	64	150
16	28	62	160
17	28	62	170
18	28	62	180
19	27	64	190
20	28	63	200
21	28	63	210
22	28	63	220
23	28	63	230
24	28	62	240
25	28	62	250
26	28	60	260
27	28	60	270
28	29	59	280
29	29	59	290
30	29	57	300
31	29	57	310
32	30	56	320
33	30	56	330
34	31	50	340
35	30	29	350
36	29	41	360
37	29	42	370
38	29	42	380
39	29	42	390
40	29	43	400
41	28	55	410
42	28	54	420

Source: Data from the weathering monitoring system (2017)

TABLE II AFTERNOON DATA COLLECTED

S.No.	TEMP (^{0}C)	HUM (%)	TIME (Secs)
43	28	54	430
44	28	54	440
45	28	55	450
46	28	54	460
47	28	56	470
48	28	56	480
49	28	55	490
50	28	58	500
51	28	58	510
52	27	66	520
53	26	65	530
54	27	62	540
55	27	60	550
56	27	55	560
57	28	40	570
58	29	40	580
59	29	40	590
60	29	40	600
61	28	42	610
62	28	44	620
63	28	46	630
64	28	52	640
65	28	47	650
66	28	47	670
67	28	49	680
68	27	49	690
69	28	46	700
70	28	46	710
71	28	46	720
72	28	46	730
73	28	46	740
74	28	46	750
75	28	48	760
76	28	51	770
77	28	51	780
78	28	52	790
79	28	53	800
80	28	53	810
81	28	53	820
82	27	61	830
83	29	444	840
84	29	44	850

Source: Data from the weathering monitoring system (2017)

TABLE III EVENING DATA COLLECTED

S.No.	TEMP (^{0}C)	HUM (%)	TIME (Secs)
85	28	50	860
86	28	51	870
87	29	49	880
88	29	48	890
89	28	51	900
90	29	51	910
91	28	55	920
92	26	63	930
93	26	62	940
94	26	63	950
95	26	63	960
96	25	59	970
97	25	59	980
98	25	59	990
99	26	57	1000
100	30	41	1010
101	30	40	1020
102	31	36	1030
103	28	44	1040
104	28	44	1050
105	28	45	1060
106	28	45	1070
107	28	45	1080
108	28	45	1090
109	28	55	1100
110	28	58	1110
111	28	57	1120
112	28	57	1130
113	28	58	1140
114	28	59	1150
115	28	59	1160
116	28	58	1170
117	28	57	1180
118	28	56	1190
119	28	55	1200
120	28	55	1210
121	28	55	1220
122	28	55	1230
123	28	55	1240
124	27	55	1250
125	26	60	980
126	25	58	1020

Source: Data from the weathering monitoring system (2017)

A. Model Specification

The research paper formulated some models within the constraints of the experimental investigation based on the weather monitoring system design for morning, afternoon and evening period which was tested based on the system performance. The formulated models are explicitly expressed as below:

1.Morning Period

$$logTempTM = \alpha_1 + \beta_1 logTime \quad (1)$$
$$logHumTM = \alpha_2 + \beta_2 logTime \quad (2)$$

2.Afternoon Period

$$logTempTA = \alpha_3 + \beta_3 logTime \quad (3)$$
$$logHumTA = \alpha_4 + \beta_4 logTime \quad (4)$$

3.Evening Period

$$logTempTE = \alpha_5 + \beta_5 logTime \quad (5)$$
$$logHumTE = \alpha_6 + \beta_6 logTime \quad (6)$$

Where:

TempTM = Ratio of Temperature to Time in the Morning Period

HumTM = Ratio of Humidity to Time in the Morning Period

TempTA = Ratio of Temperature to Time in the Afternoon Period

HumTA = Ratio of Humidity to Time in the Afternoon Period

TempTE = Ratio of Temperature to Time in the Evening Period

HumTE = Ratio of Humidity to Time in the Evening Period

$\alpha_1, \alpha_2, \alpha_3, \alpha_4, \alpha_5 \& \alpha_6$ are constant terms of the respective models and $\beta_1, \beta_2, \beta_3, \beta_4, \beta_5 \& \beta_6$ are coefficient parameters for logTime in the formulated models.

IV. RESULTS AND DISCUSSION

TABLE IV REGRESSION MODELS FOR THE INVESTIGATED DURATION

Duration	Model(s)	Degree of Freedom (df)	R^2	Adj.R^2	F-statistic	P-value
Morning	$logTempTM = 3.398 - 1.009 logTime$ (7) $logHumTM = 3.958 - 0.994 logTime$ (8)	41	99.8 96.1	99.8 96.0	22653.478 992.830	0.000 0.000
Afternoon	$logTempTA = 3.200 - 0.980 logTime$ (9) $logHumTA = 2.948 - 0.841 logTime$ (10)	41	98.9 18.6	98.9 16.5	3327.304 9.124	0.000 0.004
Evening	$logTempTE = 2.829 - 0.930 logTime$ (11) $logHumTE = 3.071 - 0.871 logTime$ (12)	41	81.2 33.5	80.7 31.8	172.710 20.126	0.000 0.000

Source: Author Computation from SPSS 17.0
N.B: The p-values are significant at 5% significance level

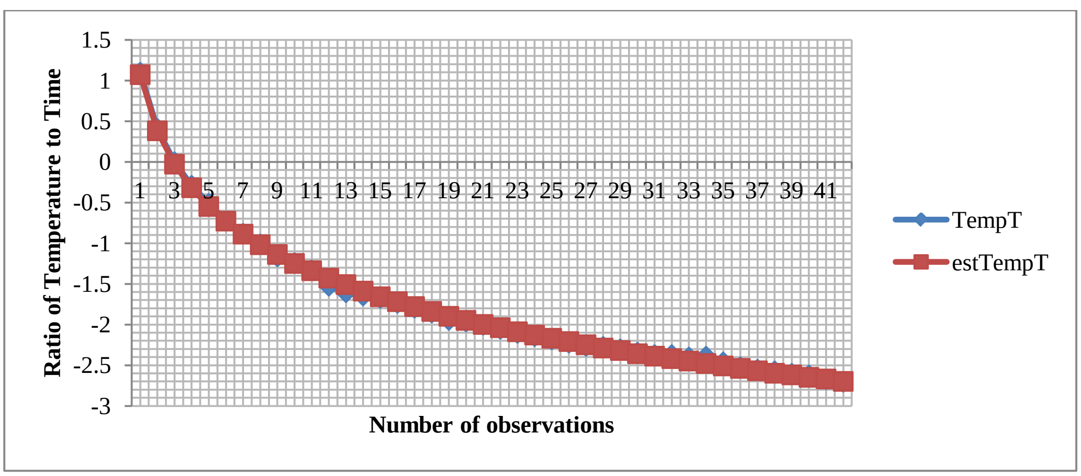

Fig.2 Relationship between Experimental and Estimated Value of the Temperature to Time Ratio

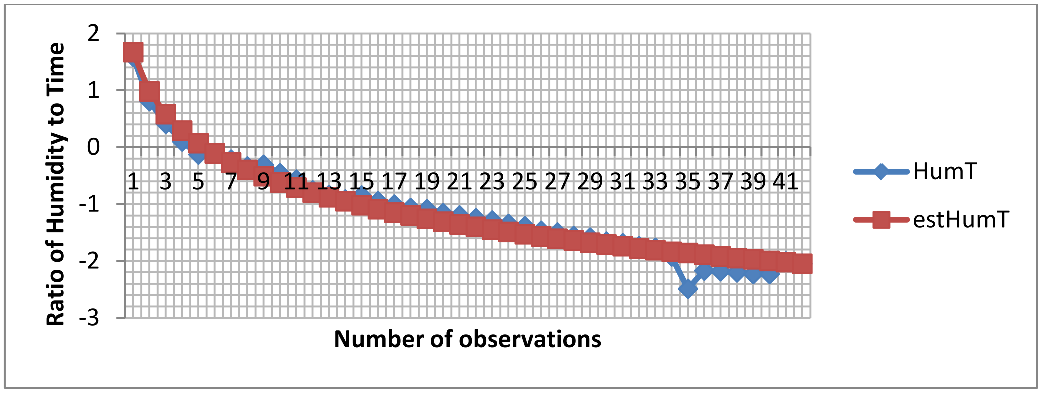

Fig.3 Relationship between Experimental and Estimated Value of the Humidity to Time Ratio

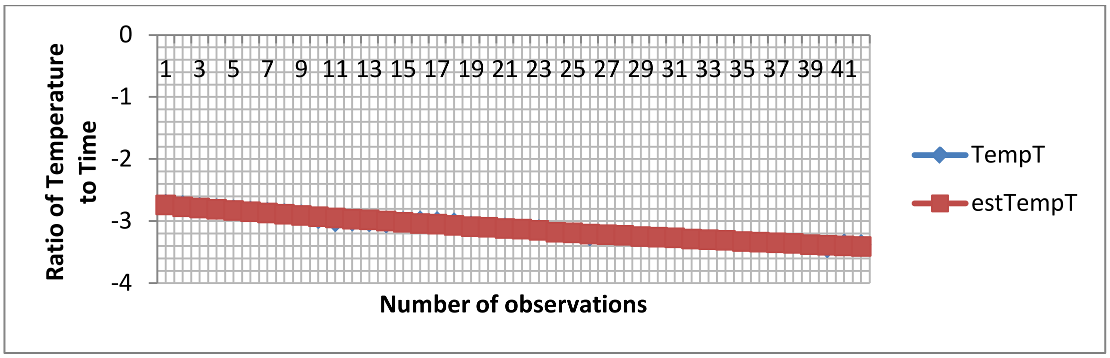

Fig.4 Relationship between Experimental and Estimated Value of the Temperature to Time Ratio

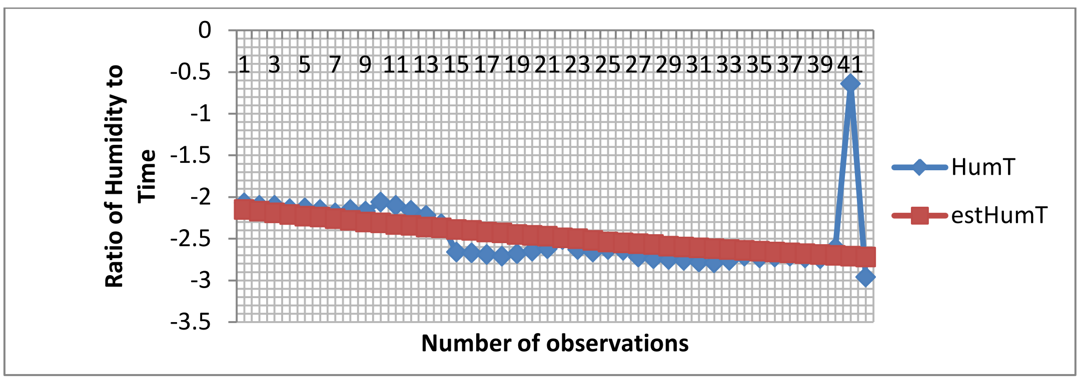

Fig.5 Relationship between Experimental and Estimated Value of the Humidity to Time Ratio

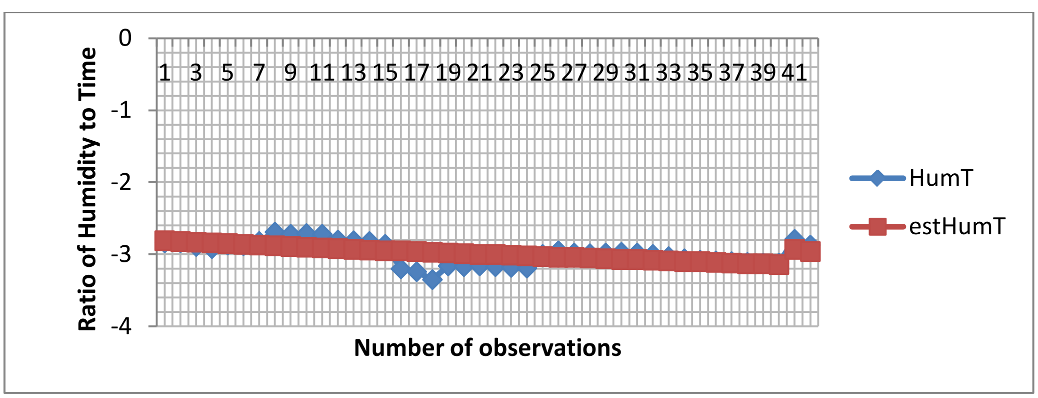

Fig.6 Relationship between Experimental and Estimated Value of the Temperature to Time Ratio

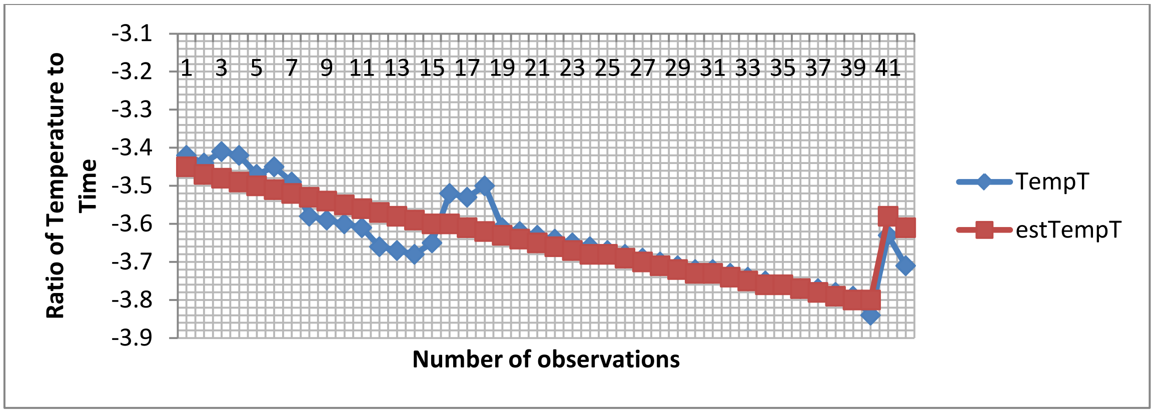

Fig.7 Relationship between Experimental and Estimated Value of the Humidity to Time Ratio

1. Morning Period

The ratio of the temperature and humidity to time models for the morning period displayed a high significant value of coefficient of determination (R^2) of 99.8% and 96.1%, and which is also best explained through the adjusted R^2 value of 99.8% and 96.0% respectively as in Table 1. This values implies that about 99.8% and 96.1% is been explained by time based on the weather monitoring system design of the model while 0.2% and 3.9% remain unexplained in the models. The calculated F-statistic values (22653.478 & 992.830) of the P-values (0.000 & 0.000) of the ratio of the temperature and humidity to time models are lesser than the test of significance at 5%; this also explained the significant effect of the models. However, the models displayed a good fit. The validation of the models as shown on Figure 2 and Figure 3, revealed that the model can predict accurately the temperature which will be in agreement with the experimental investigation from the weather monitoring system design while that of humidity prediction tends to deviate a little away from the experimental data even if it shows a kind of agreement at the beginning.

2. Afternoon Period

The formulated models for the ratio of temperature, humidity to time has coefficient of determination (R^2) values of 98.9% and 18.6% against it adjusted R^2 values of 98.9% and 16.5% respectively as in Table 1. Both models are significant having a p-value (0.000 & 0.004) against it calculated F-statistic values (3327.304 & 9.124) which are lesser than the test of significance at 5%. However, the high and low R^2 implies that about 98.9% and 18.6% is been explained by time based on the weather monitoring system design for the temperature and humidity while about 1.1% and 81.4% is unexplained in the model due to some disturbance error. The low value R^2 effect of the humidity might be due to some precision lapses of the design during point of monitoring of the parameter as shown on Figure 5. The experimental data of the temperature readings shows good agreement with the estimated results as in predicting the parameter as shown on Figure 4.

3. Evening Period

The values of the R^2 for the ratio of temperature, humidity to time displayed a higher and lower effect respectively, against it adjusted R^2 values of 80.7% and 31.8% which also is in agreement as in Table 1. The higher and lower value effect implies that about 81.2% and 33.5% is been explained by the time based on the design of the weather monitoring system while about 18.8% and 66.5% remain unexplained due to some precision error as shown on Table 1. Despite the significant effect of both models, that is, having a p-value which is lesser than the test of significant at 5%, it is revealed that they failed to properly validate the experimental data which fails to showed good agreement with the estimated results for both considered parameters as shown on Figure 6 and Figure 7 respectively.

V.CONCLUSION

The study which investigated on statistical modelling and validation of the performance of the fabricated weather monitoring system showed that the fabricated system displayed a high significant measures for the duration considered in predicting the considered parameters (Temperature & Humidity) but the accuracy is still relatively too low compared to the experimental data in the investigation. It is however showed that better performance of the fabricated system is revealed for the morning and afternoon period only as in accurate temperature monitoring as compared to the estimated prediction data. The experimental humidity data shows poor agreement with the estimated data despite the significant effect of the models with respect to the considered duration. This is in agreement with the study of [9] that accuracy predicted by weather stations is not too high to predict the actual weather condition for a particular area. This research paper formulates the mechanism to improve the accuracy precision of the fabricated design.

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