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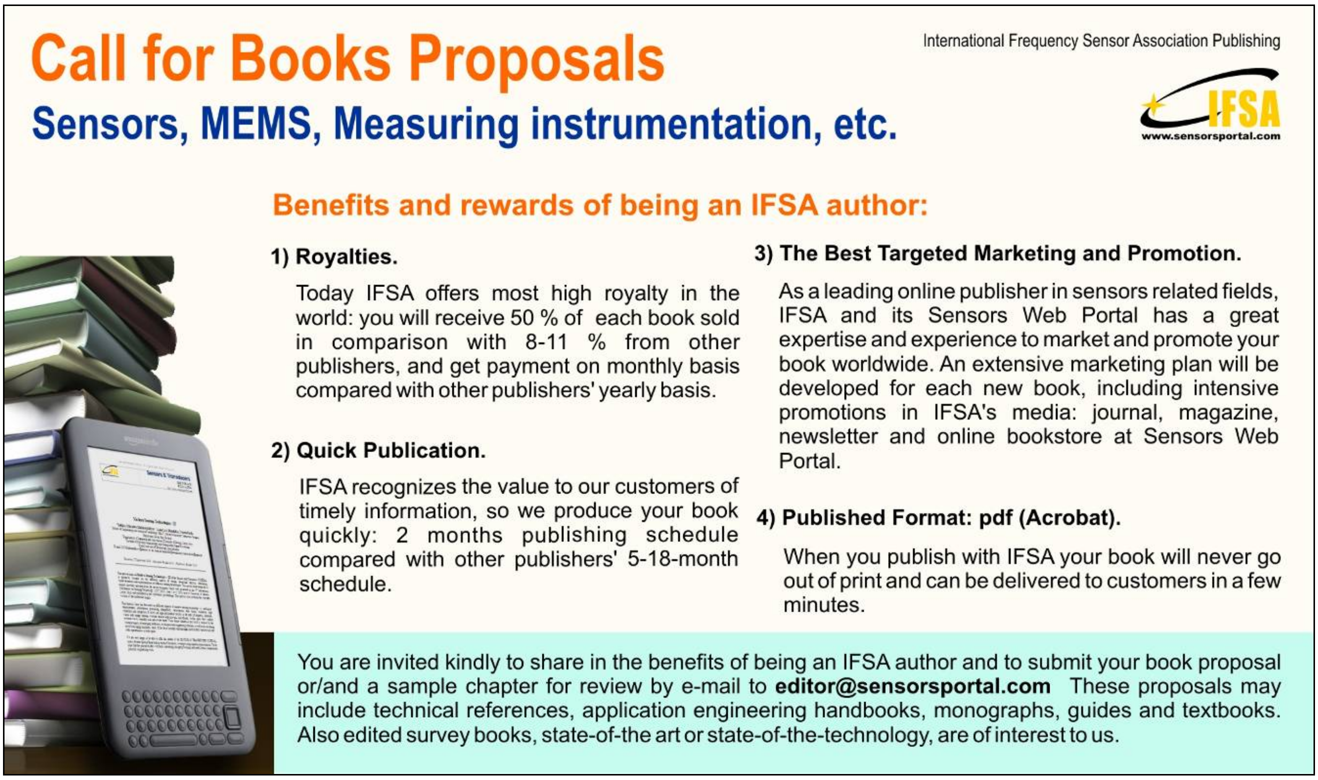
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Applying Time Series Analysis Model to Temperature Data in Greenhouses

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Abstract: The objective of the research is to find an appropriate Seasonal Auto-Regressive Integrated Moving Average (SARIMA) Model for fitting the inside air temperature (Tin) of a naturally ventilated greenhouse under Mediterranean conditions by considering the minimum of Akaike Information Criterion (AIC). The results of fitting were as follows: the best SARIMA Model for fitting air temperature of greenhouse is SARIMA (1,0,0) (1,0,2)24. *Copyright © 2011 IFSA.*

Keywords: Greenhouse, Time series, SARIMA, Box-jenkins.

1. Introduction

Since the 1970's, improvements in computing facilities together with theoretical and experimental studies have increased our understanding on the physical and physiological processes involved in the Biophysics greenhouse system. Mathematical simulation models for predicting inside climate control have primarily focused on the determination of heating requirement; however other climate control systems have been largely ignored although they play an important role, particularly under Mediterranean conditions where the greenhouse production area has tremendously increased over the last ten years. These climate control systems include natural ventilation, evaporative cooling and shading and irrigation control [1-3].

In econometrics, the Box-Jenkins methodology, named after the statisticians George Box and Gwilym Jenkins, applies autoregressive moving average ARMA or ARIMA models to find the best fit of a time series to past values of this time series, in order to make forecasting. The Box-Jenkins methodology consists of a four-step iterative procedure: tentative identification, estimation, diagnostic checking and forecasting [4].

Section 2 defines a Multiplicative Seasonal ARIMA Models. In the following section we discuses a case study. Finally conclusions are drawn.

2. Multiplicative Seasonal ARIMA Models

Often, the dependence on the past tends to occur most strongly at multiples of some underlying seasonal lags. Natural phenomena such as temperature also have strong components corresponding to seasons. Because of this, it is appropriate to introduce autoregressive and moving average polynomials that identify with the seasonal lags.

The resulting pure seasonal autoregressive moving average model, say, ARMA (p, q), then takes the form

$$\Phi_p\left(B^s\right)x_t = \Theta_Q\left(B^s\right)\omega_t\,, \tag{1}$$

with the following definition.

The operators

$$\Phi_p\left(B^S\right)x_t = 1 - \Phi_1 B^S - \Phi_2 B^{2S} - \cdots - \Phi_P B^{PS}\,, \tag{2}$$

and

$$\Theta_Q\left(B^S\right) = 1 + \Theta_1 B^S + \Theta_2 B^{2S} + \cdots + \Theta_Q B^{QS}\,, \tag{3}$$

Are the seasonal autoregressive operator and the seasonal moving average operator of orders P and Q, respectively, with seasonal period S.

The multiplicative seasonal autoregressive integrated moving average model, or SARIMA model, of Box JenKins is given by

$$\Phi_p\left(B^S\right)\phi(B)\nabla_S^D\nabla^d x_t = \alpha + \Theta_Q\left(B^S\right)\theta(B)\omega_t\,, \tag{4}$$

where ω_t is the usual Gaussian white noise process. The general model is noted as ARIMA(p,d,q)× (P,D,Q)S. the non-seasonal difference components are $\nabla^d = (1-B)^d$ and the seasonal are $\nabla_S^D = \left(1-B^S\right)^D$ [5, 6].

Table 1. Behavior of the ACF and the PACF for pure Seasonal ARMA Models [4].

	$AR(P)_S$	$MA(Q)_S$	$ARMA\ (P,Q)_S$
ACF	Tails off at lags ks, k=1,2,…..	Cuts off after lag Qs	Tails off at lag ks
PACF	Cuts off after lag Ps	Tails off at lags ks k=1,2…	Tails off at lag ks

3. Building ARIMA Model

In this study, we used the temperature data for Greenhouse between 07 and 18 April, in a 416 m2 double roof plastic house occupied by a tomato-crop and situated near Avignon in the South of France. The plot of the hour's temperature series is given in Fig. 1 as below.

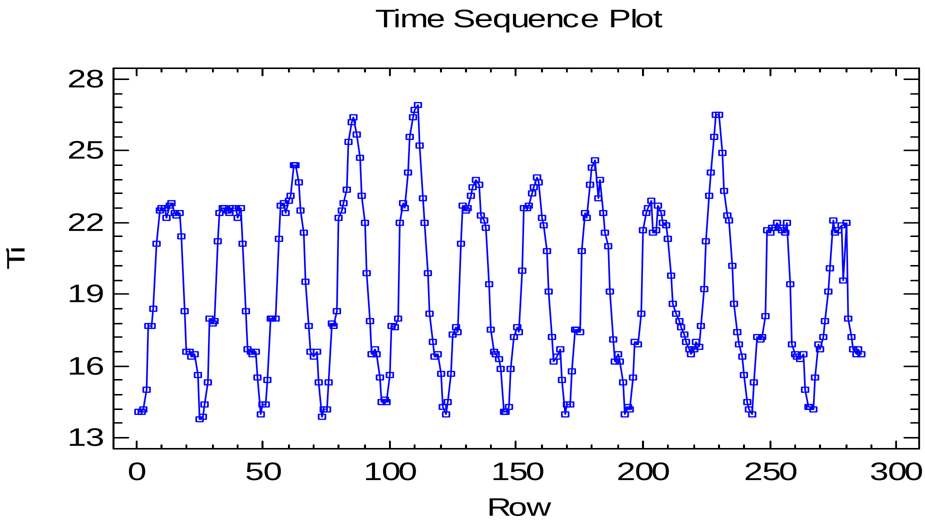

Fig. 1. The hour's temperature of Greenhouse between 07 and 18 April we can see that the patterns of the whole series became the same.

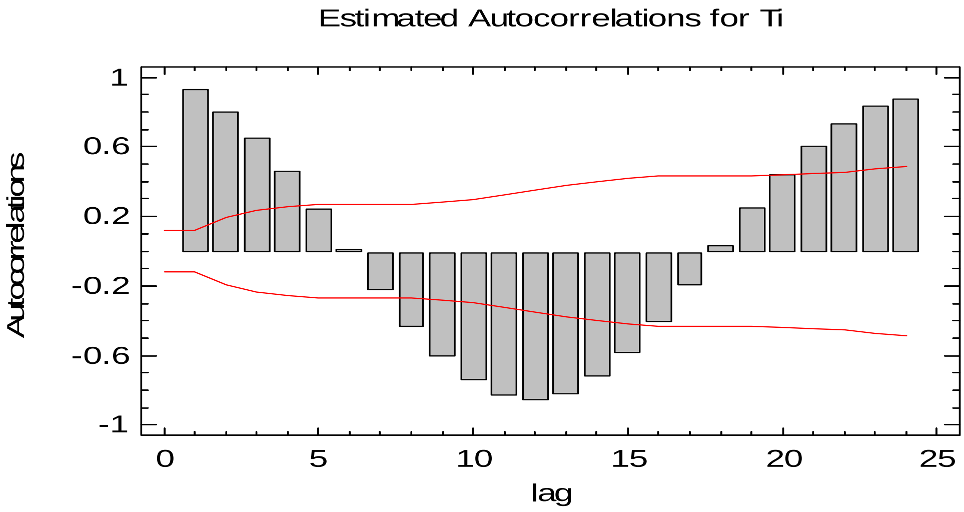

Fig. 2. The PACF for the hour's temperature of Greenhouse between 07 and 18 April.

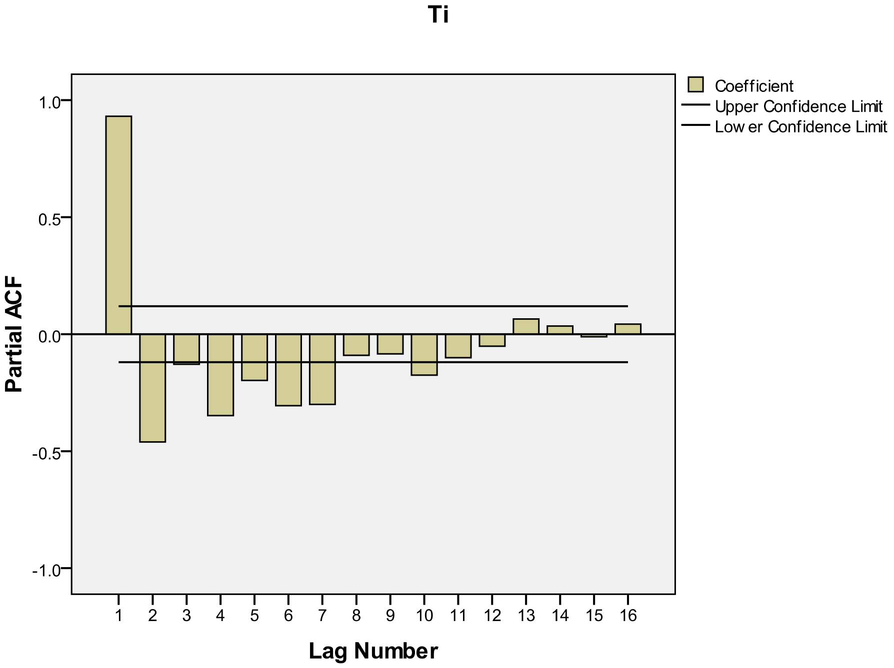

Fig. 3. The ACF for the hour's temperature of Greenhouse between 07 and 18 April.

3.1. Estimated Autocorrelations

The estimated Autocorrelations for the data temperature are given in the Table 2.

Table 2. Represent the estimated autocorrelations between values of data at various lags.

			Lower 95.0 %	**Upper 95.0 %**
Lag	**Autocorrelation**	**Stnd. Error**	**Prob. Limit**	**Prob. Limit**
1	0.931013	0.0597614	-0.11713	0.11713
2	0.805438	0.0988067	-0.193658	0.193658
3	0.652952	0.119986	-0.235168	0.235168
4	0.463475	0.132068	-0.258848	0.258848
5	0.249664	0.137754	-0.269994	0.269994
6	0.0184481	0.139361	-0.273143	0.273143
7	-0.221387	0.13937	-0.27316	0.27316
8	-0.436147	0.14062	-0.275611	0.275611
9	-0.610178	0.145371	-0.284922	0.284922
10	-0.749003	0.154247	-0.302319	0.302319
11	-0.840672	0.166731	-0.326788	0.326788
12	-0.873257	0.181238	-0.355222	0.355222
13	-0.840123	0.195689	-0.383545	0.383545
14	-0.74584	0.208173	-0.408012	0.408012
15	-0.606477	0.217507	-0.426307	0.426307
16	-0.431155	0.223465	-0.437984	0.437984
17	-0.218086	0.226416	-0.443769	0.443769
18	0.0118656	0.227165	-0.445237	0.445237
19	0.229686	0.227167	-0.445241	0.445241
20	0.42847	0.227995	-0.446864	0.446864
21	0.59553	0.230853	-0.452465	0.452465
22	0.726805	0.236276	-0.463094	0.463094
23	0.832122	0.24413	-0.478488	0.478488
24	0.876419	0.254058	-0.497946	0.497946

This table shows the estimated autocorrelations between values of Tin at various lags. The lag k autocorrelation coefficient measures the correlation between values of data at time t and time t-k. Also shown are 95.0 % probability limits around 0. If the probability limits at a particular lag do not contain the estimated coefficient, there is a statistically significant correlation at that lag at the 95.0 % confidence level.

3.1. Fitting ARIMA Models

Choosing the best model will involve obtaining some important values in fitting like the root mean squared error (RMSE), the mean absolute error (MAE), the mean absolute percentage error (MAPE), the mean error (ME), the mean percentage error (MPE) and Akaike Information Criterion (AIC), which will be compared to their corresponding values when applying the seasonal ARIMA models ((A)ARIMA(1,0,0)x(1,0,2)24 with constant, (B) ARIMA(1,0,0)x(2,0,1)24 with constant, (C) ARIMA(1,0,0)x(1,0,1)24 with constant, (D) ARIMA(1,0,1)x(1,0,1)24 with constant, (E) ARIMA(1,0,1)x(1,0,2)24 with constant).

Table 3. Represent a comparison fitting models.

Model	RMSE	MAE	MAPE	ME	MPE	AIC
(A)	0.616645	0.421642	2.12024	-0.0169097	-0.174842	-0.931208
(B)	0.616918	0.421649	2.11963	-0.0127488	-0.151926	-0.930324
(C)	0.619362	0.427146	2.14854	-0.0117434	-0.152547	-0.929561
(D)	0.617797	0.426719	2.15047	-0.0106783	-0.148279	-0.927477
(E)	0.615666	0.421524	2.1225	-0.0130905	-0.154165	-0.927243

This table compares the results of fitting different models to the data. The model with the lowest value of the Akaike Information Criterion (AIC) is model A, which has been used to generate the fitting. The table also summarizes the performance of the currently selected model in fitting the historical data. The best model selected is ARIMA(1,0,0)x(1,0,2)24 with constant with parameters estimators represent as below:

Table 4. Represent parameters estimators of ARIMA(1,0,0)x(1,0,2)24 with constant.

Parameter	Estimate	Stnd. Error	T	P-value
ϕ_1	0.808119	0.0355943	22.7036	0.000000
Φ_1	0.988904	0.0111143	88.9757	0.000000
Θ_1	0.600318	0.0680488	8.82187	0.000000
Θ_2	-0.0267058	0.0683009	-0.391003	0.696098
Mean	19.3476	2.96788	6.519	0.000000
Constant	0.0411944			

Where the ARIMA(1,0,0)x(1,0,2)24 with constant equation given as below:

$$(1-\phi_1\beta)(1-\Phi_1\beta^{24})Tin_t = (1+\Theta_1\beta^{24}+\Theta_2\beta^{48})e_t + const\,, \tag{4}$$

Then

$$Tin_t = const + \phi_1 Tin_{t-1} + \Phi_1 Tin_{t-24} - \phi_1 \Phi_1 Tin_{t-25} + \Theta_1 e_{t-24} + \Theta_2 e_{t-48} + e_t , \tag{5}$$

$$\hat{T}in_t = 0.04119 + 0.808 Tin_{t-1} + 0.9889 Tin_{t-24} - 0{,}799 Tin_{t-25} + 0.60032 e_{t-24} - 0.026706 e_{t-48} , \tag{6}$$

4. Conclusions

This paper presents a deferent time series analysis models for fitting the internal temperature inside the greenhouse. The inside air temperature simulation models were identified using the described approaches for a greenhouse between 07 and 18 April located near Avignon in south-east France. The greenhouse had a tomato-crop area of 416 m^2, in a double roof plastic house. Several actuators and sensors were installed and connected to an acquisition and control system based on a personal computer and a data acquisition and control card using a sampling interval of 1 hour. It was found that the best Seasonal ARIMA model is SARIMA (1,0,0)(1,0,2)24.

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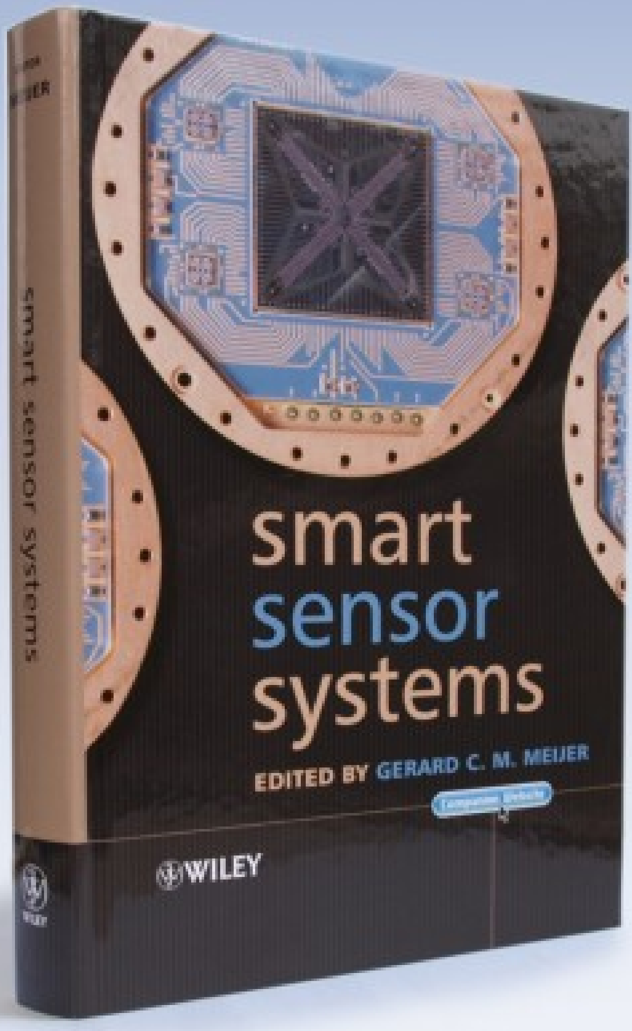

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