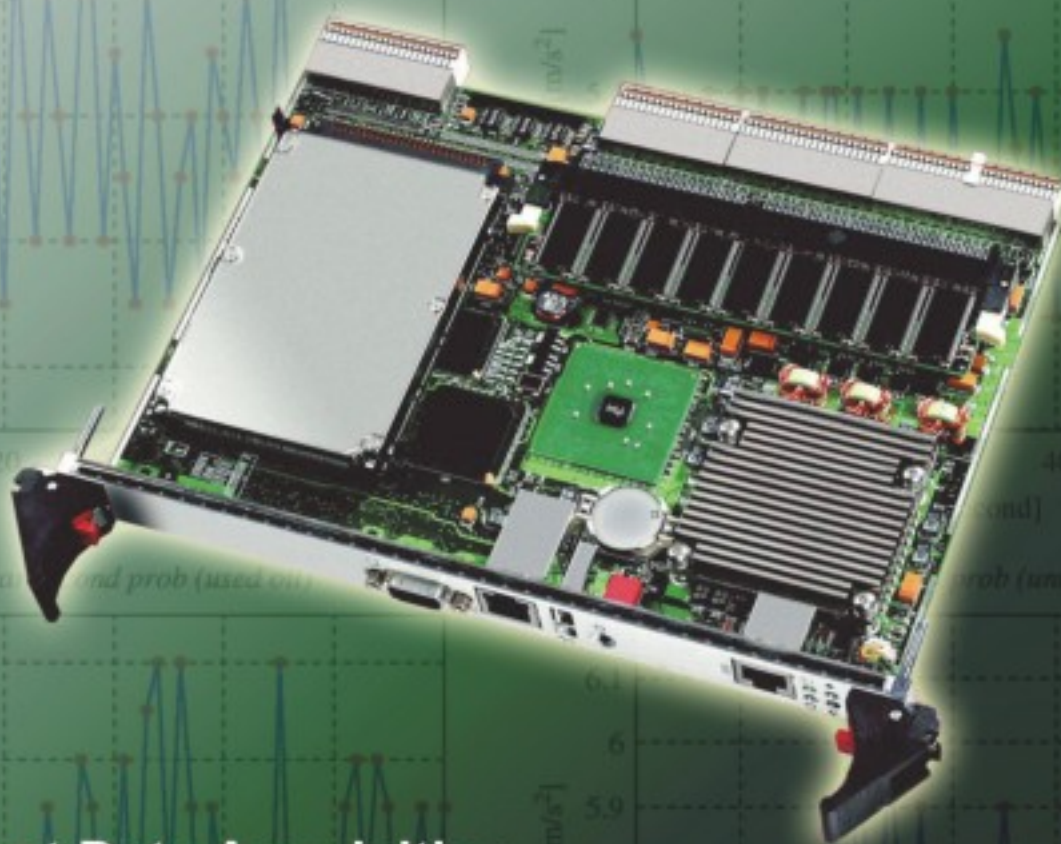


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**Intelligent Data Acquisition
and Information Process Technologies
and Their Applications. Part II**

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Contents

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
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Research Articles

Study on VSI Switching Frequency Optimization of PMSM Based Servo System <i>Shi-xiong Zhang</i>	1
Application of an Improved Genetic Algorithm in Network Information Filtering <i>Min Ren, Baoya Song, Jirong Jiang</i>	7
Compression of Power Quality Data Based on Improved DCT Transform <i>Hua Ouyang, Hui Li, Mei Qian</i>	13
Mechanical Optimization Design Based on Genetic Algorithm <i>Ying Sun, Yuesheng Gu and Hegen Xiong</i>	19
Camera Pose Estimation in Dynamic Scenes with Background Tracking <i>Dong Zhang and Ping Li</i>	25
Application of Step Design Method to Realize the Synchronization of Genesio Chaotic System <i>Yu ZhiPeng</i>	34
Short-term Probabilistic Load Forecasting with the Consideration of Human Body Amenity <i>Ning Lu</i>	39
Analysis on Rural Land Circulation Subject Interests <i>Shi Dong-mei, Xu Yue-ming, Wang Jian, Tong Lei</i>	45
A High Precision Multi-function Electronic Scale Based on PSoC3 <i>Lv Dian-ji, Peng Jian-sheng, Zhou Guo-juan, Xu Yong</i>	51
Studies on Equalization Strategy of Battery Management System for Electric Vehicle <i>Nan Jinrui, Guo Meng</i>	57
Design and Optimal Control of Parallel Robot <i>Ying Sun, Yuesheng Gu and Hegen Xiong</i>	64
Pure Surface Texture Mapping Technology and it's Application for Mirror Image <i>Wei Feng Wang, Hui Feng Yan, QinMao, Ming Liang Zhou</i>	68
Forming Flaws Analysis of Lead Screw Cold Roll-Beating Based on Stress-Strain Evolution <i>He Wangyun, Li Yan, Yang Mingshun, Wang Ming</i>	74
A Reflective Grating Microcantilever Biosensor <i>Feng Wen, Yuejin Zhao, Xiaomei Yu, Cheng Gong, Jiancheng Yang</i>	83

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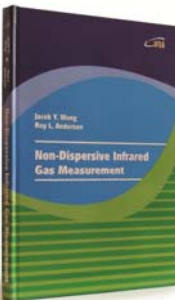
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Short-term Probabilistic Load Forecasting with the Consideration of Human Body Amenity

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Abstract: Load forecasting is the basis of power system planning and design. It is important for the economic operation and reliability assurance of power system. However, the results of load forecasting given by most existing methods are deterministic. This study aims at probabilistic load forecasting. First, the support vector machine regression is used to acquire the deterministic results of load forecasting with the consideration of human body amenity. Then the probabilistic load forecasting at a certain confidence level is given after the analysis of error distribution law corresponding to certain heat index interval. The final simulation shows that this probabilistic forecasting method is easy to implement and can provide more information than the deterministic forecasting results, and thus is helpful for decision-makers to make reasonable decisions. *Copyright © 2013 IFSA.*

Keywords: Human body amenity, Support vector machine, Short-term load forecasting, Confidence level, Probabilistic forecasting.

1. Introduction

Power load forecasting is the basis for the planning and design of power system; it is also an assurance for the economy and reliability of power system operation. Short-term load forecasting is one of the typical load forecasting topics. An accurate short-term load forecasting is very useful for reducing cost and maintaining security and stability of power grid. During the last few years, many scholars have developed different kinds of load forecasting techniques to increase the forecasting accuracy, including the traditional time series method, trend extrapolation method and the modern artificial intelligence method, et al [1-3].

Analysis of these methods shows that the predicted results given by most of them are deterministic. But in

practical applications, the power system is often influenced by certain degree of uncertainty, nonlinearity and randomness. The probabilistic method is proven to be more effective in dealing with these problems with random characteristics. The procedure of this method is summarized simply as follows. Firstly, by analyzing the distribution probability of historical forecasting error, and then obtaining the probabilistic forecasting results and the interval estimation of future load, power system decision-makers can better recognize the uncertainties that may exist in future load. It is helpful to make reasonable decisions in time during production planning and system security analysis. As is well known, weather is one of the major influential factors for load forecasting. The influence of different meteorological conditions is not the same for different

regions, which requires further analysis of the coupling effect caused by various meteorological conditions, as well as their influence on the power load. In this paper, human body amenity is adopted to describe the meteorological conditions.

This study aims at probabilistic load forecasting with the consideration of human body amenity. Firstly, support vector machine (SVM) regression method is used to get deterministic load forecasting results, then probabilistic load forecasting at a certain confidence level is acquired through the historical error law analysis of the N-days with similar human body amenity.

The rest of this paper is organized as follows: In section 2, the concept of human body amenity is introduced. In section 3 the point load forecasting considering weather factors is presented. Historical error characteristics analysis is carried out and the probabilistic forecasting corresponding to certain heat index interval is discussed in detail in section 4. Section 5 presents the case study, and further comparison and discussion are also conducted. Section 6 concludes the paper.

2. Description of Human Body Amenity

Weather is a key factor that affecting the load but the detailed relationships between them are not so easy to elucidate. The traditional methods use meteorological factors such as temperature, humidity and wind speed together with the historical load as the neural network input to predict the future load, which need to determine the membership degree of weather, humidity, temperature by fuzzy algorithm. In this study, human body amenity is used to express the comprehensive information. Human body amenity index is a biometeorology indicator that is often used to evaluate amenity under different climate conditions from the meteorological point of view. According to the heat exchange between human body and the atmospheric environment, meteorology is believed to be the major influential factor on human body amenity [4-5].

The correlation of major meteorological elements like temperature, relative humidity, wind power and daily load of a city in Central China is studied in current research. Summer load in this region is greatly affected by meteorological factors than industrial ones. Therefore, this study mainly focuses on the correlation between the summer load and the climate characteristics.

Heat index proposed by Tom is used to express human body amenity in summer and it is adopted to indicate the relationship among human thermal degree

and temperature, humidity [6]. It is expressed as follows:

$$E_t = T_d - 0.55(1 - R)(T_d - 58), \quad (1)$$

where E_t is the heat index, T_d is the dry bulb temperature ($^{\circ}\text{C}$), R is the relative humidity, and

$$T_d (^{\circ}\text{F}) = T_d (^{\circ}\text{C}) \times 9/5 + 32, \quad (2)$$

For the data of load, daily maximum temperature, daily minimum temperature, daily average temperature, daily average humidity and wind speed of one Central China power grid from June 1st, 2011 to July 30th, 2011, directly comparing the load data and climate data is infeasible as they have different magnitude, therefore take their normalized value:

$$X^* = X / X_{\max}, \quad (3)$$

where X represents historical data, X_{\max} represents historical maximum data. SPSS (statistical product and service solution) software is utilized to carry out the correlation analysis of daily load, the maximum temperature, minimum temperature, average temperature, average humidity, wind speed and heat index, as shown in Table 1 below.

It can be seen from Table 1. that the correlation between the daily load and the heat index is maximal, indicating that the heat index can be used to effectively describe the influence of climate in summer of this region on the load.

The size of the training network, the input unit and the output unit directly influence the speed and complexity of forecasting model. Adoption of human body amenity index to replace various meteorological indicators can reduce the complexity of input unit, effectively represent the impact of meteorology on load and speed up network training.

3. Point Load Forecasting with the Considering of Meteorological Factors

SVM model is used to realize load forecasting and to obtain deterministic forecasting results (points forecasting results). Compared to the empirical risk minimization based traditional neural network, SVM has better learning efficiency and learning promotion ability. Its learning outcomes are usually better than other regression forecasting methods [7-8]. Thus it is widely used in short-term load forecasting.

Table 1. Correlation analysis of daily load and meteorological factors.

Meteorological Factors	Maximum Temperature	Minimum Temperature	Average Temperature	Average Humidity	Wind Speed	Heat Index
Correlation	0.817	0.630	0.827	0.344	0.273	0.834

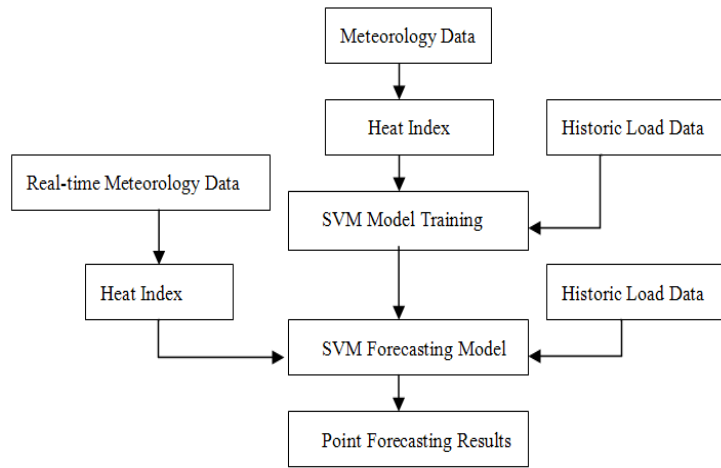


Fig. 1. The Flowchart of SVM model for giving points forecasting results.

The forecasting procedure is as follows. First, heat index is used to describe meteorological information and it is input into SVM model with the historic load, then the method in [9] is adopted to optimize the relevant parameters of SVM forecasting model, and further we can carry out forecasting. Finally, the point forecasting results of load are obtained. The procedure is also shown in Fig. 1. The region's load forecasting in summer is the focus of this paper, therefore the heat index is used here.

4. Historical Error Characteristics Analysis and the Probabilistic Load Forecasting

The distribution probability law of the load forecasting error is analyzed to further get the probabilistic load forecasting results, namely, the interval estimation of load forecasting results corresponding to certain confidence level should be obtained. It helps to better understand the variation of the future load, which is the basis for reasonable decision-making and risk analysis. The procedure of probabilistic forecasting is listed in the following subsection.

4.1. Steps of Probabilistic Forecasting

(1) Load forecasting is carried out and the deterministic results based on historical load and meteorology data are acquired.

(2) The data of heat index are partitioned to some intervals, and the recent N days which having heat index in the same range are searched. Then corresponding history prediction error data are analyzed and error distribution law corresponding to certain heat index interval is obtained.

(3) The interval forecasting results at a certain confidence level are obtained according to the error distribution law. Forecasting process is shown in Fig. 2.

4.2. Error Characteristics Analysis

Error of load forecasting $e(t)$ is obtained by comparing the predictive value of the load $\hat{x}(t)$ and its corresponding actual value $x(t)$:

$$e(t) = x(t) - \hat{x}(t), \quad (4)$$

where $e(t)$ represents the deviation degree of forecasting value and actual value. Statistical analysis on load forecasting error can reveal its property, and this property is different for different regions and different time.

Historical data with 10 minutes intervals, namely daily data of 144 points is used as samples and a large number of load error samples can be obtained within N days. The daily 144 data is divided into 24 intervals, representing load characteristics during different periods.

According to the Central Limit Theorem, if the population does not follow normal distribution, then after large volumes of sample data (usually greater than 50, even greater than 100) are used, it can be processed as normal distribution [10-11]. Because of the above collection methods, the available historical forecasting error samples are large enough to be processed as normal distribution.

According to the principle "Everything looks small in the distance and big on the contrary", the heat index is partitioned and the load forecasting error samples of N days having similar heat index recently (heat index is in the same interval) are analyzed, and then the corresponding variance for different periods are calculated.

$$\sigma^2 = \sum_{i=1}^n \left[x(t) - \hat{x}(t) \right]^2 / n, \quad (5)$$

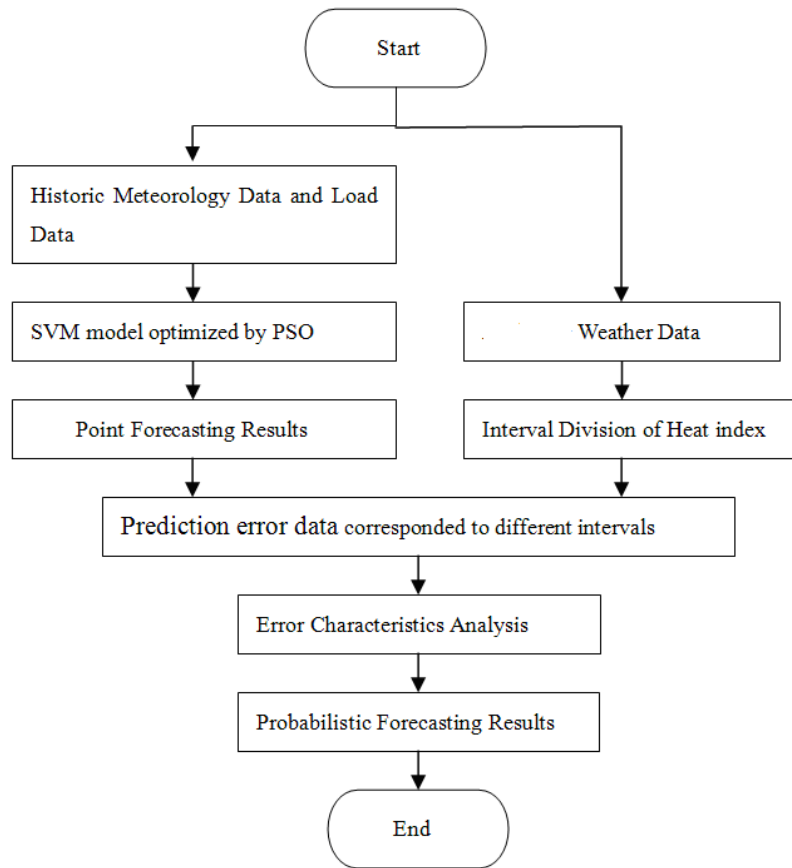


Fig. 2. The process of probabilistic forecasting.

The point forecasting result $\hat{x}(t)$ is adopted as the mean value. The interval with the confidence level $1-\alpha$ can be constructed with the corresponding variance σ^2 as follow:

$$\left[\hat{x}(t) - \sigma z_{\alpha/2} / \sqrt{n}, \hat{x}(t) + \sigma z_{\alpha/2} / \sqrt{n} \right], \quad (6)$$

where $z_{\alpha/2}$ is the sub-median value and n is the number of samples.

5. Case Study

The historical load data and meteorology data are taken from a power grid in Central China from June 1st to June 30th, 2011. More detailed, the sample load data from those 10 minutes intervals, namely 144 points per day (including the training and testing samples). 24 hours loads on June 30 are forecasted and finally get the results of interval estimation.

On June 30, the heat index is 71.55, belonging to the interval [69, 72], the number of days within the scope of this heat index interval recently is $N = 10$ (the specific dates and the corresponding heat index are shown in Table 2.). The number of samples in each time period is $144/24 \times 10 = 60$, which meets the requirements of Central Limit Theorem.

According to equation (5), the curve of variance of every period (24 hours) corresponding to the heat index interval (69-72) is shown in Fig. 3, and it reflects the error characteristics of different period.

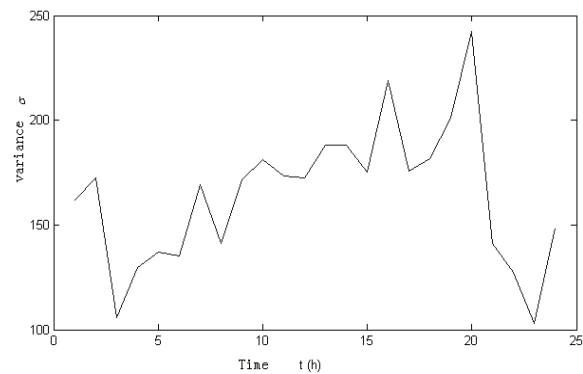
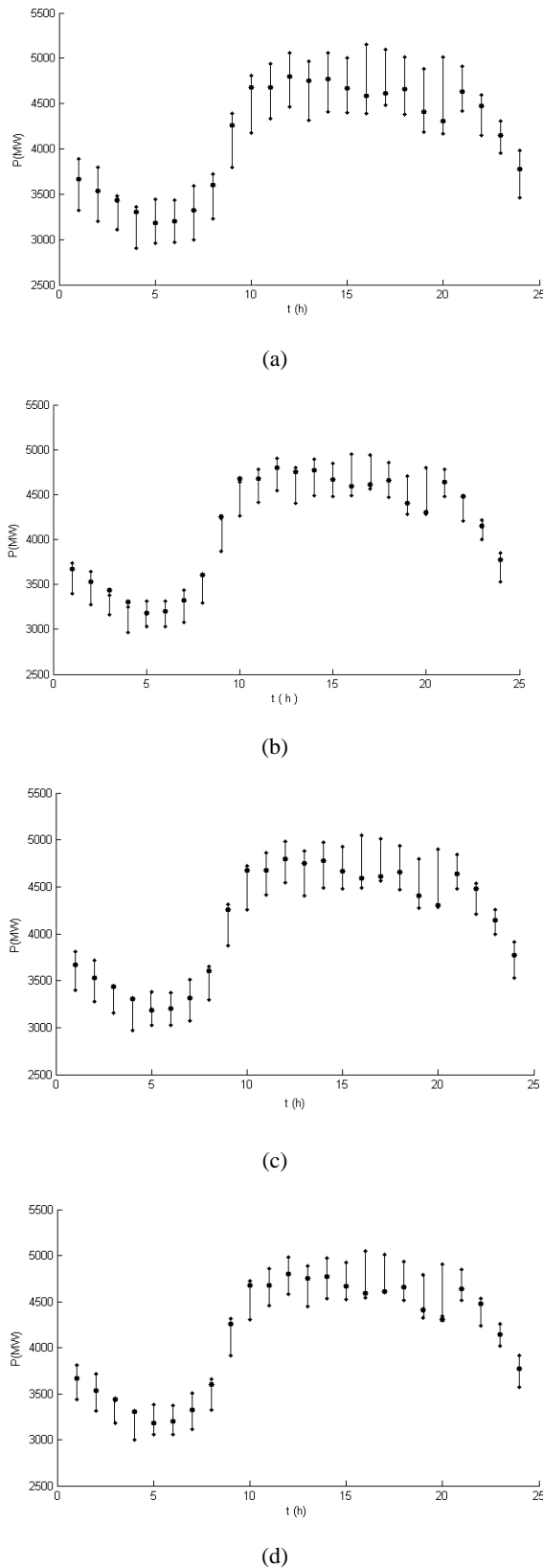


Fig. 3. Variance curve with time.

Interval forecasting results with different confidence levels can be acquired according to equation (6). The results with confidence level of 95 %, 90 %, 85 % and 80 % are shown in Fig. 4. (a), (b), (c), (d), respectively. In Fig. 4, each of the lines represents forecasting interval, and the points on the line are the actual values of load.

Table 2. The similar heat index and its date.

Date	June 1st	June 7th	June 12th	June 16th	June 19th	June 21st	June 25th	June 26th	June 27th	June 29th
Heat Index	69.90	69.10	69.91	69.91	69.91	71.56	69.09	70.71	71.53	71.56

**Fig. 4.** The result of probabilistic forecasting.

It can be seen from probabilistic forecasting results in Fig. 4, that under different confidence level, the interval sizes of the load forecasting results are different. If the confidence level is high, then the forecasting interval is large and the actual values are generally remain in the range. If the confidence level declines, then the forecasting interval becomes smaller and the possibility that the actual value falling out of the range gets larger. In practical applications, the appropriate confidence level should be selected as needed. The forecasting interval can include all the actual values if it is too large, which does not make any sense. On the other hand, too many values will fall out of the interval if it is too small. For example, as shown in Fig. 4 (d), the actual values of load in many periods fall out of the range, such as the actual value of period 3, 4, 10. It means the interval is too small. Inversely, it can be seen that the interval in Fig. 4 (a) is too large. The interval forecasting result with 85 % confidence level is found to be the most appropriate.

6. Conclusions

Regional human body amenity is utilized for load forecasting, in more detail, the probabilistic forecasting on short-term load. The deterministic forecasting results are given by the SVM model optimized by particle swarm optimization, then sub-period error characteristics corresponding to certain heat index interval are analyzed, and finally probabilistic forecasting results under certain confidence level are obtained. This probabilistic forecasting method is easy to realize and also it can provide more information than the deterministic forecasting results. So it is suitable of data supporting for risk analysis of power systems, which is helpful for decision-makers to make reasonable decisions.

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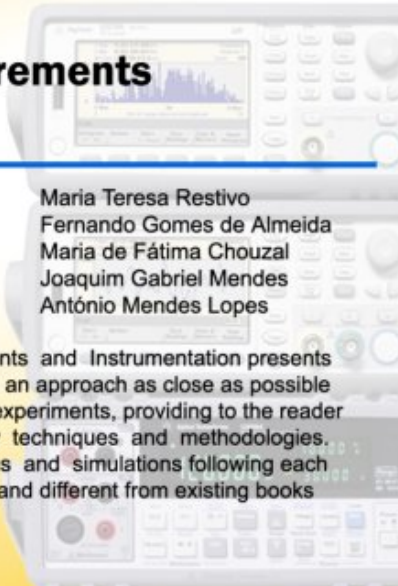
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Handbook of Laboratory Measurements and Instrumentation

Maria Teresa Restivo
 Fernando Gomes de Almeida
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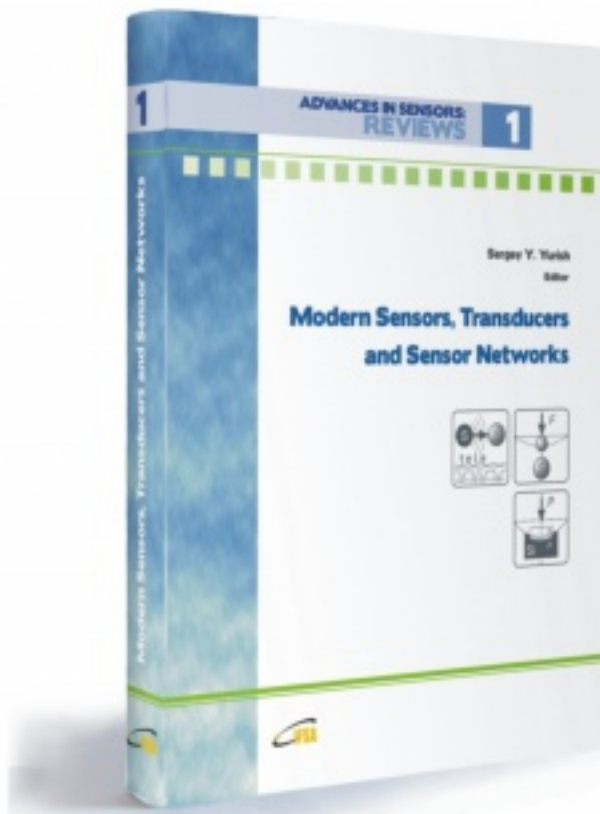
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