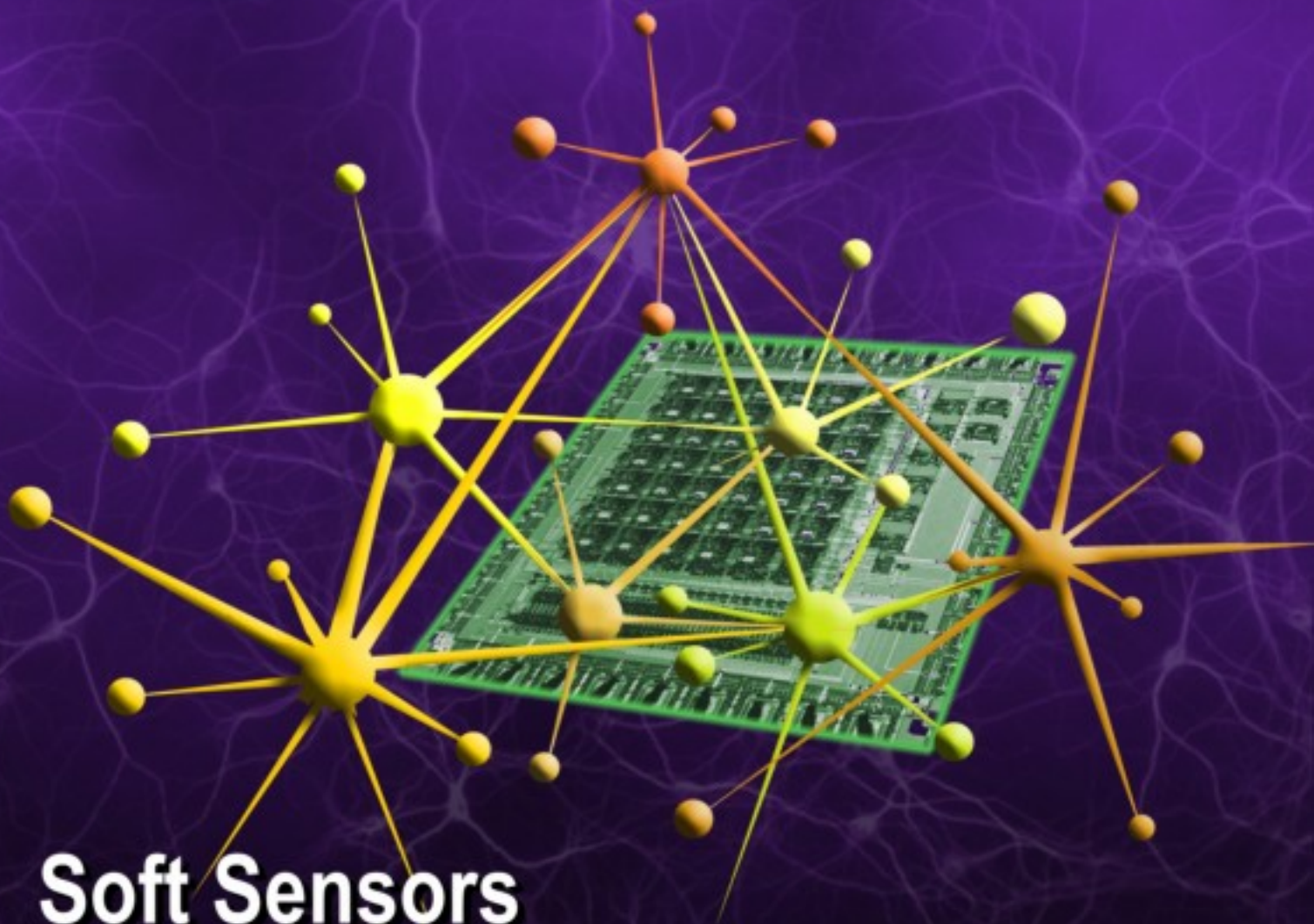


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Uncertainty Analysis of Temperature Measurement System Using Interval Arithmetic

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Abstract: An uncertainty in temperature measurement system is analyzed by deriving the transfer function model using interval arithmetic. The measurement system uses Resistance Temperature Detector (RTD) as a sensor and the uncertainty assumed is structured one. *Copyright* © 2007 IFSA.

Keywords: Uncertainty analysis, RTD, Interval arithmetic

1. Introduction

All measurements have some amount of uncertainty associated with them [1]. Uncertainty arises at every stage in the measurement system. Understanding the uncertainty within our predictions and decisions is at the heart of understanding the problem. Uncertainty analysis using Interval Arithmetic is more reliable, it does not use statistical methods, and it can handle simultaneously the uncertainty in more than one parameter [2, 3, 5]. Appropriate simulation techniques must be used in the case of uncertainty analysis. The prediction of the behavior of systems with incomplete knowledge is one of the hardest tasks of the system supervision because each one of those precise models has a different behavior. The way to deal with uncertainty depends on the available information (numeric, qualitative, etc.) and the future use of the results. There are many methods: qualitative, statistics, Monte Carlo, interval, error treatment, etc [4]. One way to represent structured uncertainty is by means of interval models. The behavior of the interval model can be represented by trees of behaviors or by envelopes [7].

2. Experimental Setup

Temperature measurement system using Pt-1000 as a sensor and its block diagram is shown in Fig. 1. The overall transfer function of the measurement system is derived as follows: Sensor transfer function is

$$\left(\frac{\Delta R_2(s)}{\Delta T_s(s)} \right) = \left(\frac{\alpha R_0}{1 + \tau s} \right),$$

where τ is the time constant of the system, $\alpha = 6.89655 \times 10^{-4} / ^\circ\text{C}$ is temperature coefficient of the sensor, R_0 is the resistance at 0°C , $\Delta T_s(s)$ is the change in temperature of the sensor and $\Delta R_2(s)$ is the change in the sensor resistance. Transfer function of Wheatstone bridge is

$$\left(\frac{\Delta V_w(s)}{\Delta R_2(s)} \right) = \left(\frac{V_{in} R_4}{(R_4 + R_2)^2} \right),$$

where V_{in} the excitation voltage and R_4 is the general purpose resistor. Transfer function of amplifier is

$$\left(\frac{V_o(s)}{V_w(s)} \right) = - \frac{R_6}{R_5},$$

where R_5, R_6 are general purpose resistors and $V_o(s)$ is the output of amplifier. From these transfer functions the overall transfer function of the temperature measurement system derived as

$$\left(\frac{V_o(s)}{\Delta T(s)} \right) = \left(\frac{k}{(1 + \tau s)} \right),$$

where $k = - \frac{\alpha R_0 V_{in} R_4 R_6}{R_5 (R_4 + R_2)^2}$, $\Delta T(s)$ is the change in the process temperature.

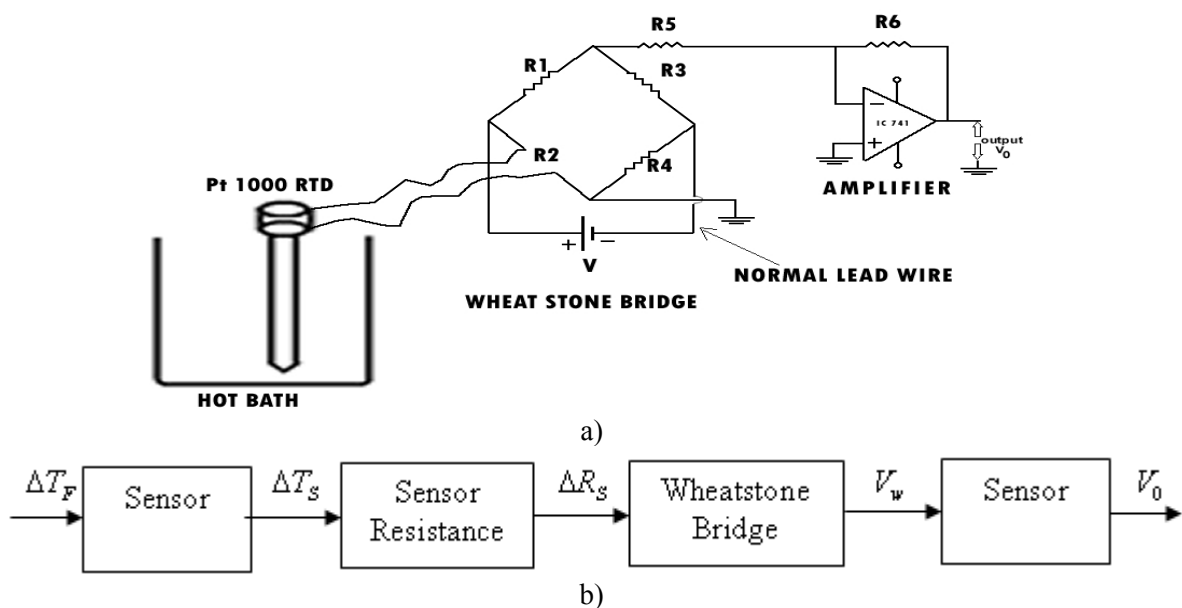


Fig. 1. Temperature measurement system using Pt-1000: experimental setup (a) and block diagram (b).

3. Uncertainty Analysis

The tolerance level for the components used are, general-purpose resistors $\pm 1\%$, voltage source $\pm 0.251\%$, temperature coefficient of the sensor $\pm 1\%$ and time constant $\pm 1\%$ [6]. With this tolerances general purpose resistors, excitation source, temperature coefficient of the sensor and the time constant are represented in interval form as $[990 \ 1010] \ \Omega$, $[4.9925 \ 5.0025] \ \text{V}$, $[0.000689 \ 0.000690] \ \text{per}^\circ\text{C}$ and $[7.9 \ 8.1]$ respectively. The overall transfer function in interval form is [5]

$$\left(\frac{V_0(s)}{\Delta T_F(s)} \right) = \frac{[0.05240 \ 0.09002]}{1 + [7.9 \ 8.1]s} \quad (1)$$

Scalar system method proposed in [7] is the quantitative simulation technique based on interval arithmetic, which considers only systems with structured uncertainties. The family of systems for (1) is generated with extreme values. The transfer function of the extreme systems is

$$T1(s) = \frac{0.0524}{(7.9s + 1)}, T2(s) = \frac{0.0524}{(8.1s + 1)}, T3(s) = \frac{0.09002}{(7.9s + 1)}, T4(s) = \frac{0.09002}{(8.1s + 1)}$$

and the extreme points are shown in Fig. 2.

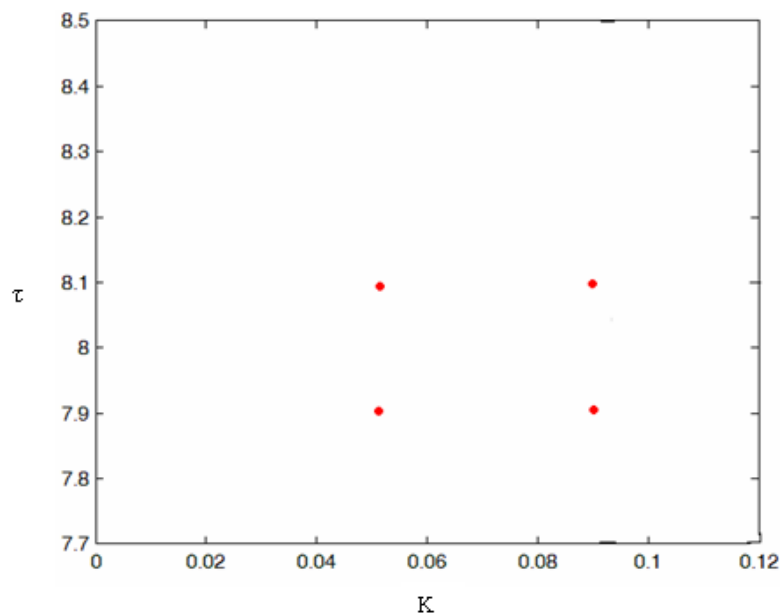


Fig. 2. Extreme systems represented in the parameter space.

The dynamics of the extreme and nominal systems are simulated using MATLAB by applying a step input with the amplitude of 90°C for the duration of 50 seconds. The simulation results are given in Fig. 3.

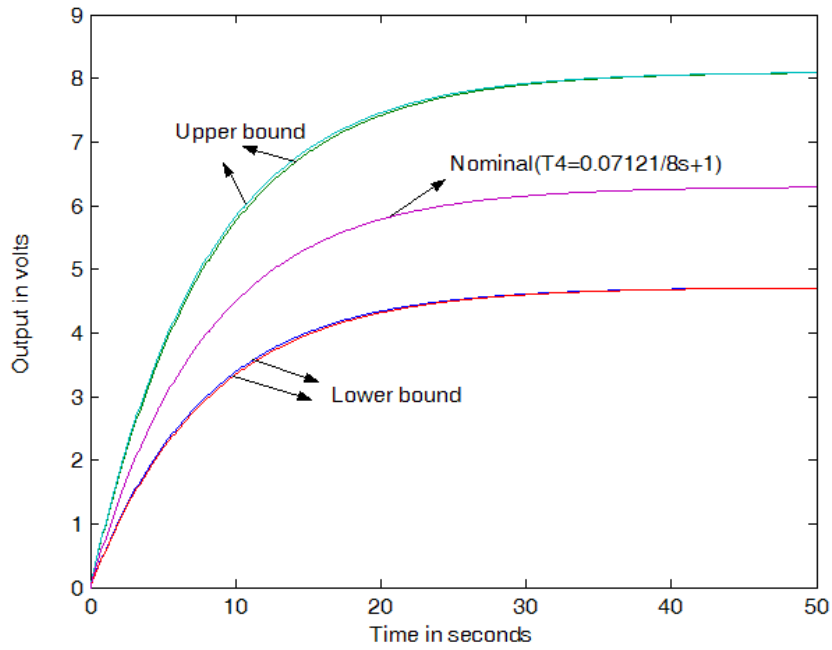


Fig. 3. Simulation of extreme bounds and a nominal system.

Therefore, the envelope obtained by simulating only the extreme systems is bounded and complete. Further to see the over bound and under bound systems belonging to the family, additional systems are chosen systematically by making a grid in parameter space as shown in Fig. 4 and randomly as shown in Fig. 5.

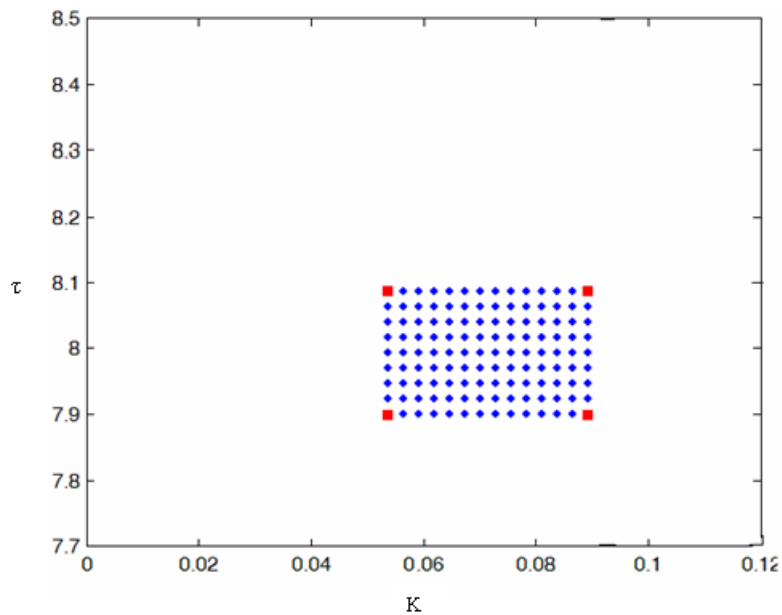


Fig. 4. The scalar system chosen systematically.

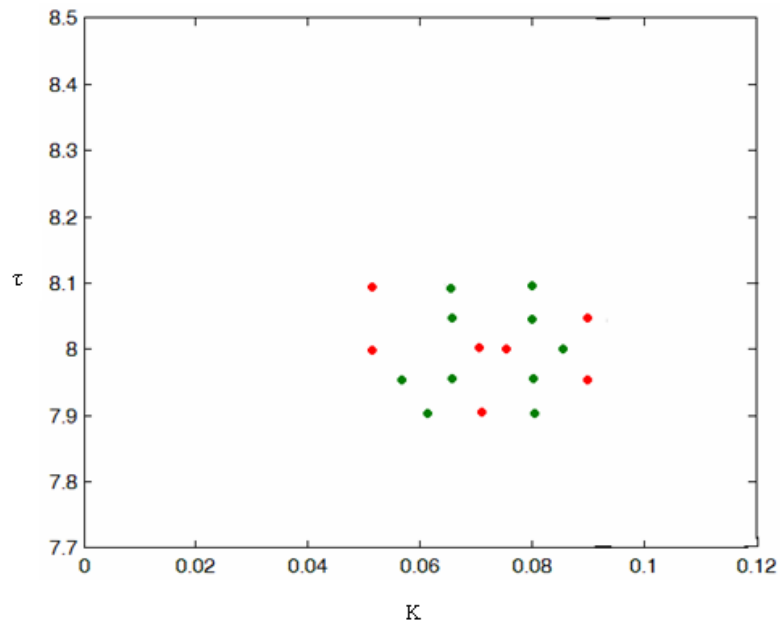


Fig. 5. Scalar system chosen randomly.

The simulations are carried out by selecting any scalar systems from the systematically generated space and randomly generated space. The responses are shown in Fig. 6 and 7.

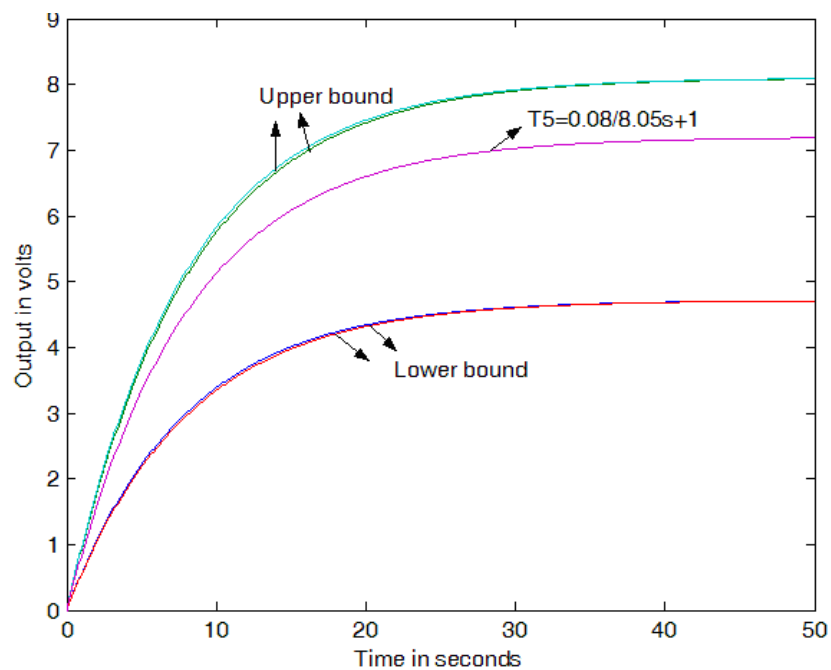


Fig. 6. The simulation of extreme systems with systematically selected systems.

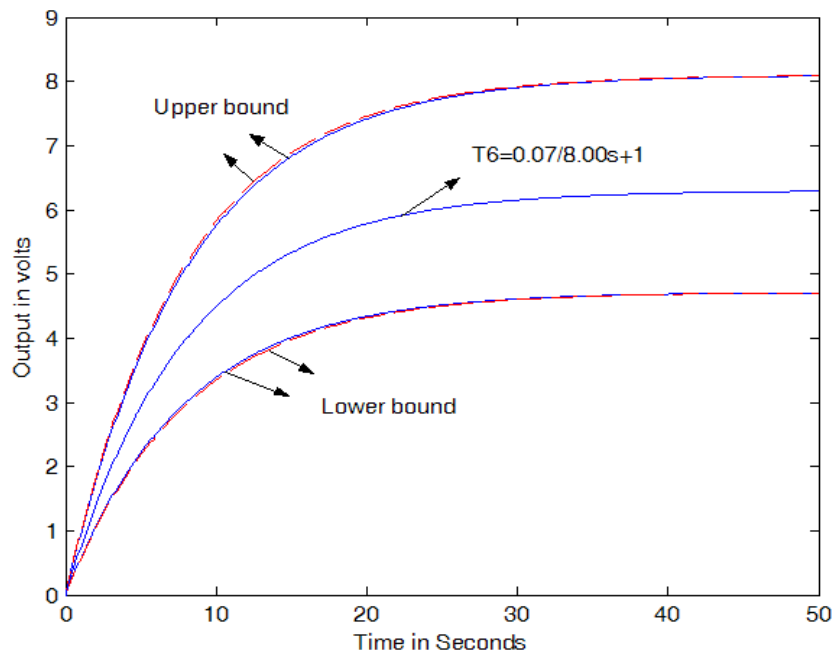


Fig. 7. The simulation of extreme systems with randomly selected systems.

4. Conclusion

The use of interval method for uncertainty analysis in temperature measurement system gives an envelope that definitely includes all possibilities resulting from the full range of input uncertainty. This feature further provides a basis for considering coarsely specified parameters in design problems and for deriving decision margins that are completely verified. Also, an indication of sensitivities and robustness may be gained by evaluating the width of input and result intervals with respect to one another.

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Guide for Contributors

Aims and Scope

Sensors & Transducers Journal (ISSN 1726- 5479) provides an advanced forum for the science and technology of physical, chemical sensors and biosensors. It publishes state-of-the-art reviews, regular research and application specific papers, short notes, letters to Editor and sensors related books reviews as well as academic, practical and commercial information of interest to its readership. Because it is an open access, peer review international journal, papers rapidly published in *Sensors & Transducers Journal* will receive a very high publicity. The journal is published monthly as twelve issues per annual by International Frequency Association (IFSA). In addition, some special sponsored and conference issues published annually.

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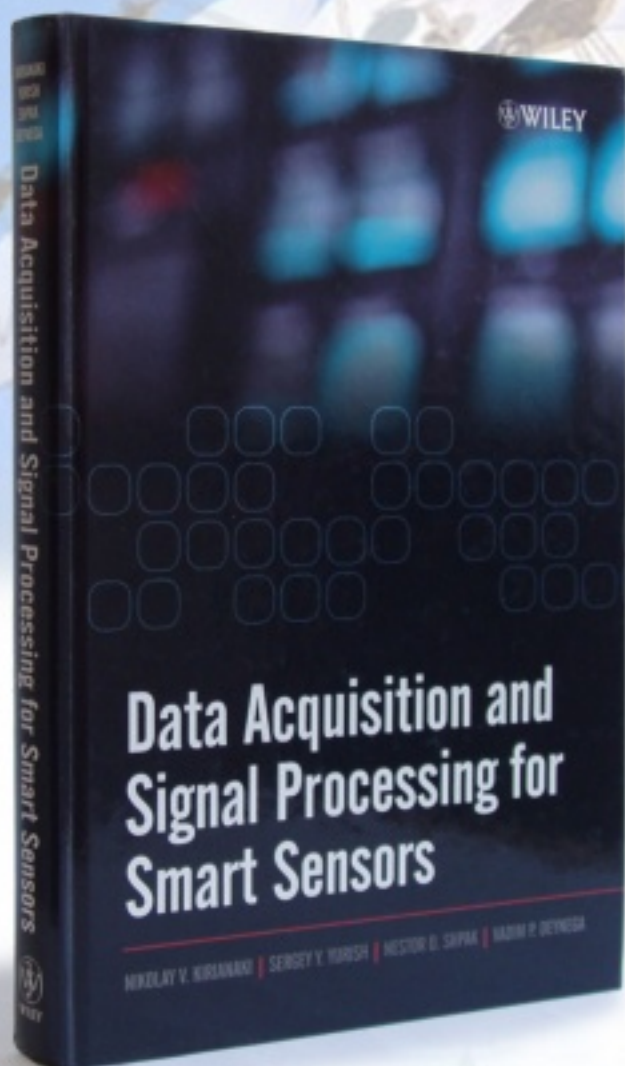
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