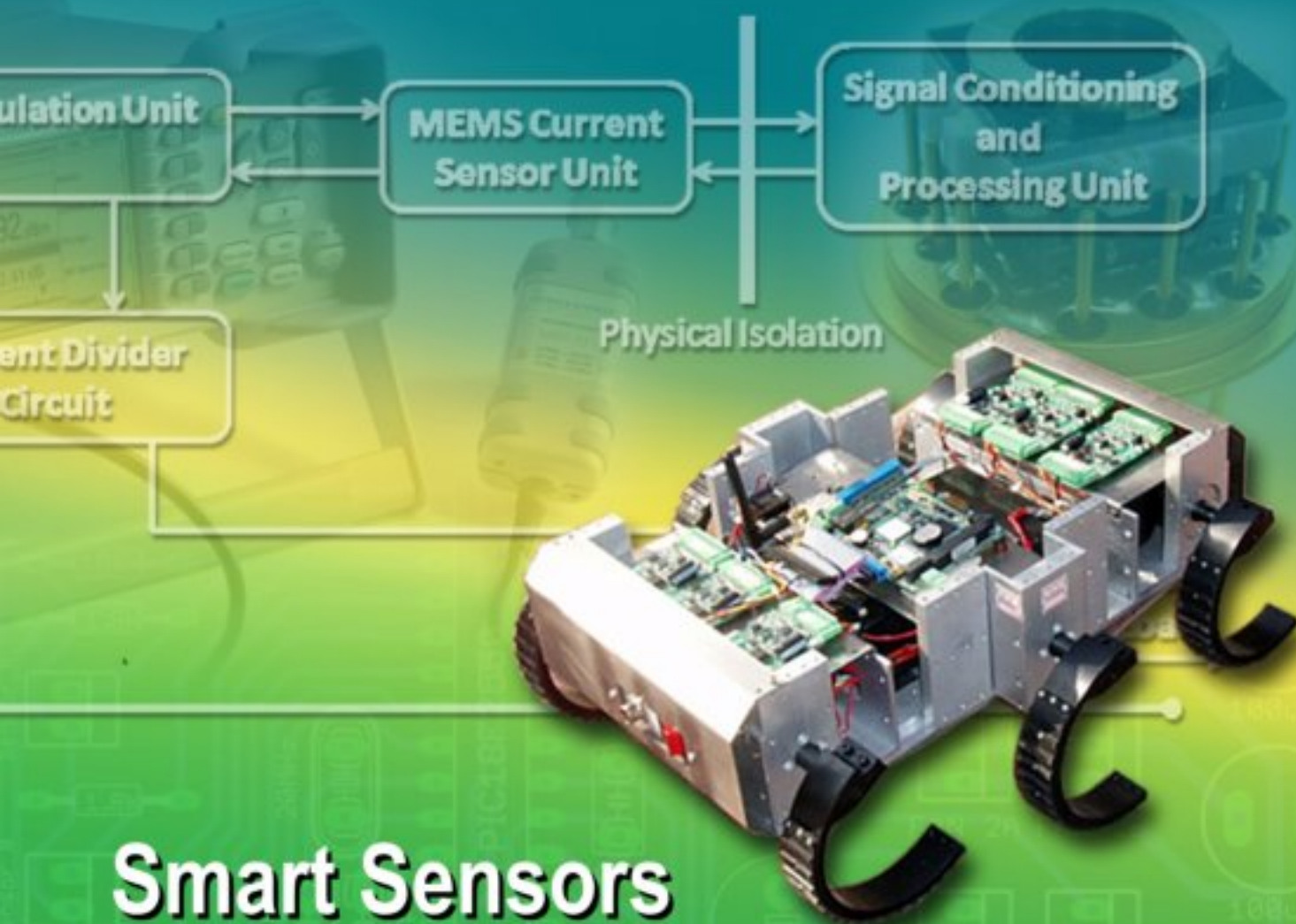


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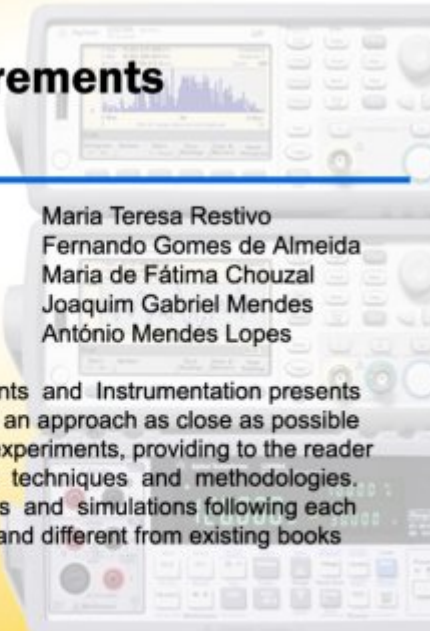





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Applications of Angular Measurement Using Hit or Miss Transform

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Abstract: This paper proposes a fully automated angular measurement method for various applications using hit or miss morphology technique. The morphological transformation is analyzed for the recognition of pattern and the hit-or-miss transform indicates the positions where a certain pattern occurs in the image. The extracted position in the image is mapped into a line graph for angular measurement.

The efficiency of the proposed technique is justified by applying it in various applications such as instrument panel board interfacing, angular speed measurement and angular orientation of a robotic arm. From the results, it is evident that the proposed system provides a better performance and cost effectiveness. *Copyright © 2012 IFSA.*

Keywords: Angular measurement, Hit or miss transform, Image processing.

1. Introduction

Angular measurement is the relationship between two surfaces that are not parallel. Angular measurement uses degrees as the standard of measure. Under this system, a full circle has a measure of 360 degrees, denoted as 360°. A right angle is measured as 90°, and a straight angle (a straight line) is measured as 180°. The measurement of position or rotation angle is very important for control systems in industry. Most engineers select optical tachometers for such measurements [5].

Image processing involves in processing or altering an existing image in a desired manner. The image processing may either take place from any video or the image itself. Image processing is of two types, improving the visual appearance of images and preparing images for measurement of the features and structure present in it. Image processing technique has a wide range of application in noise filtering, content enhancement, medical imaging, remote sensing, astronomy [1], navigation [3] and autonomous machine applications [2].

The image processing technique involves different morphological function in which hit-and-miss transform is a general binary morphological operation that can be used to look for particular patterns of the foreground and background pixels in an image [10]. It is actually the basic operation of binary morphology since almost all the other binary morphological operators can be derived from it. The hit or miss transform, a well-known morphological operator dedicated to template matching, can adequately tackle the problem of object detection in noisy images [1]. The HMT has several benefits compared to other template-matching techniques, including the fact that it is based on rank-order operations which are generally faster than linear correlation techniques and that it is insensitive to DC variations of the template and the image [3].

The proposed system aims at the angular measurement of various applications with minimum hardwares. This is achieved using image processing technique.

2. Methodology

2.1. Hit-or-miss Transform

The Hit-or-Miss transform was originally defined for binary images and signals. The basic idea behind the hit-or-miss transform is that of extracting all pixels within an image that are matched by a given neighborhood configuration, consisting of some arrangement of the foreground pixels and background pixels. The neighborhood configuration is therefore defined by a pair of disjoint sets: one for the foreground pixels and the other for the background pixels. If we represent our foreground and background sets with a pair of structuring elements (A, B), (the “Hit” and “Miss” templates, respectively), then if we apply the HMT to an image X using (A, B), we are looking for all positions where A can be fitted within the foreground X and simultaneously where B can be fitted within the background X^c (where X^c denotes the complement of X). This can be represented mathematically as:

$$X \odot (A,B) = \{x \mid Ax \subseteq X, Bx \subseteq X^c\} \quad (1)$$

Note that Ax (resp. Bx) denotes the translation of set A by x (resp. B by x). We can also describe the HMT in terms of an intersection between two erosions (where \ominus denotes the binary erosion operator):

$$X \odot (A,B) = (X \ominus A) \cap (X^c \ominus B) \quad (2)$$

3. Proposed Algorithm

In the proposed system we have a measurand, a camera for capturing the image and a PC in which the digital image has to be processed. The hit or miss morphological transform recognizes the pattern by matching the image with the foreground and background images. It indicates the position of the pattern, occurring in the image. The binary image with the indicated position is mapped into a line

graph using the mathematical functions. The proposed system is implemented using the following steps:

Step1. Capture image using USB camera.

Step2. Convert from RGB to binary image.

Step3. Get the position of the pattern where it occurs in the image using hit or miss transform.

(x_{hit}, y_{hit}) is the desired position which can also be determined by finding the maximum of sum of rows or columns and finding the midpoint of maximum value of rows or columns which would be the desired position. This is shown in Fig. 1.

$$R_{sum}(j) = \sum_{i=1}^{i_{max}} B(i, j) \quad (3)$$

$$R_{sum}(i) = \sum_{j=1}^{j_{max}} B(i, j) \quad (4)$$

$$x_{hit} = \{(j) \text{ if } \max(R_{sum}(j))\} \quad (5)$$

$$y_{hit} = \{(i) \text{ if } \max(R_{sum}(i))\} \quad (6)$$

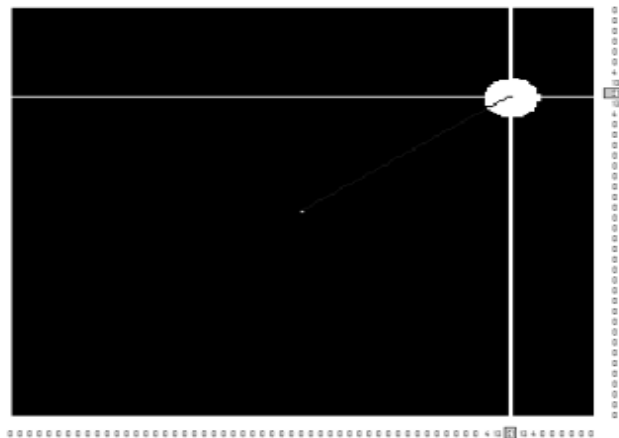


Fig. 1. Extracting of position using max of sum of rows or columns method.

This method is more complex due to large mathematical calculations. This can be overcome by hit or miss transform in which it fixes the position by comparing the pattern with the foreground and background image.

For multiple positions the desired positions can be determined by tracing the points on the circumference of the circle. The circles are drawn with the radius of fixed lengths of the joints in the arm.

But this method requires large processing time which could be effectively overcome by using the hit or miss transform. It compares the foreground and background with the image and returns multiple desired points.

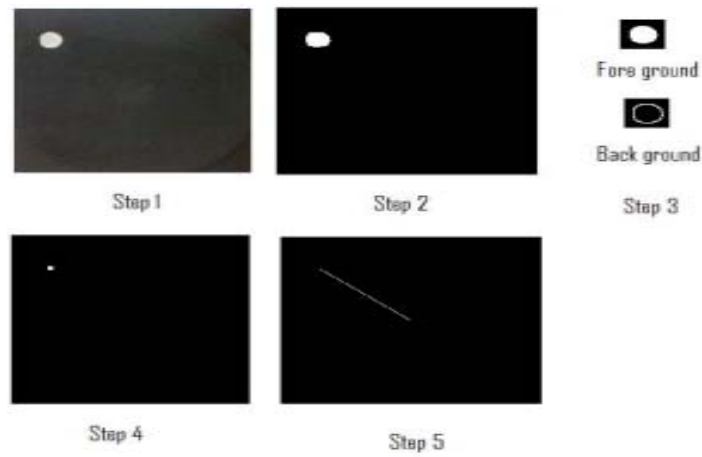


Fig. 2. Extracting of position using hit or miss transform.

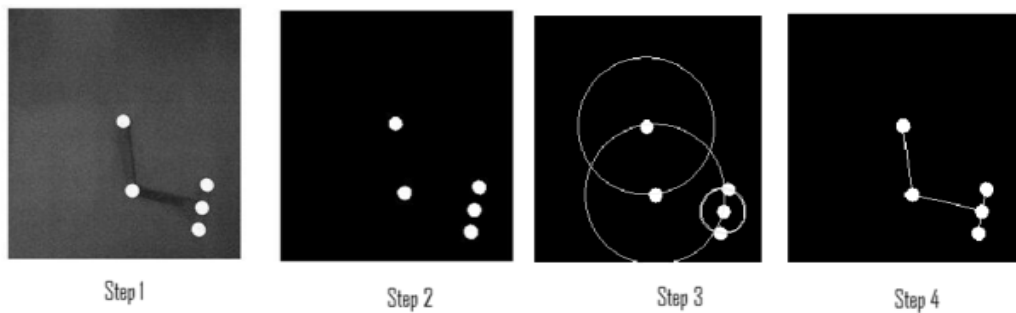


Fig. 3. Extracting of multiple position by tracing the circumferences of the circles.

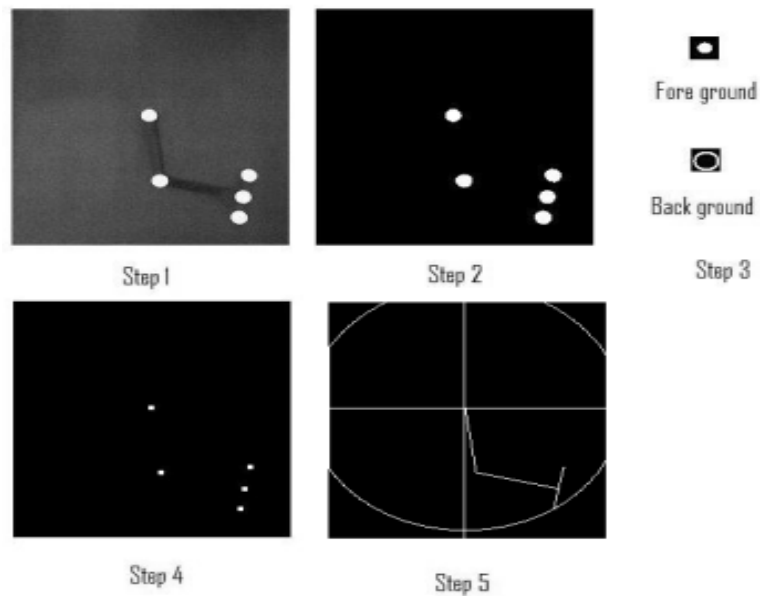


Fig. 4. Extracting of multiple position using hit or miss transform.

Step4. The image is then mapped into a line graph.

Step5. The position is fitted in any one of the 4 quadrants.

Step6. Angle is calculated with respect to the centre point of the image using mathematical formulas.

$$M = \frac{\frac{i_{\max} - y_{hit}}{2}}{x_{hit} - \frac{j_{\max}}{2}}, \quad (7)$$

where i and j are the number of rows and columns in the image.

$$x_{quad} = \text{sign}\left(x_{hit} - \frac{j_{\max}}{2}\right) \quad (8)$$

$$y_{quad} = \text{sign}\left(\frac{i_{\max}}{2} - y_{hit}\right) \quad (9)$$

$$\text{angle} = \begin{cases} \tan^{-1}(M) \text{ if } (x_{quad} = 1 \ \& \ y_{quad} = 1) \\ 180^\circ + \tan^{-1}(M) \text{ if } (x_{quad} = -1 \ \& \ y_{quad} = 1) \\ 180^\circ + \tan^{-1}(M) \text{ if } (x_{quad} = -1 \ \& \ y_{quad} = -1) \\ 360^\circ + \tan^{-1}(M) \text{ if } (x_{quad} = 1 \ \& \ y_{quad} = -1) \end{cases} \quad (10)$$

4. Applications

The proposed system using hit or miss transform is found to be cost effective and have minimal hardware requirement. It is applied for various applications such as panel board interfacing, angular speed measurement and angular orientation of multi joint arm.

4.1. Panel Board Interfacing

The conventional panel board interfacing system has various intermediate stages and a variety of hardware components such as transducer, bridge circuit, analog to digital converter and etc., Whereas the proposed system has a panel board, a camera for capturing the image and a PC only. The proposed system has a patterned structure at the back side of the panel board which has to be captured as an image for further processing. The processed image using hit or miss transform gives the position of the pattern in the image and using that, the angle it makes with the reference line can be determined. The position of the panel board is determined from the angle obtained. Thus the angular measurement of the panel board gives the current position of the control panel.

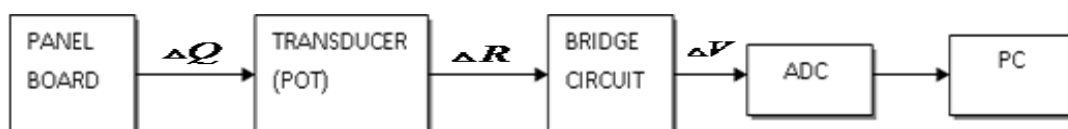


Fig. 5. Conventional control panel interfacing.

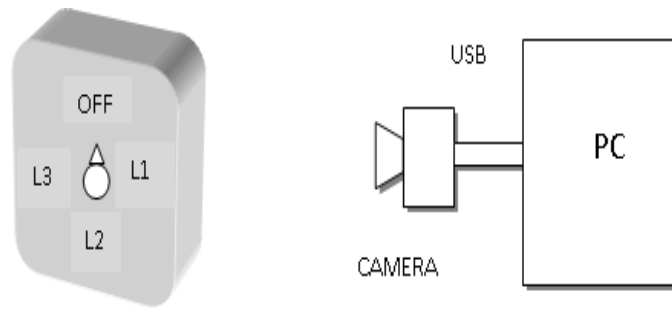


Fig. 6. Proposed panel board interfacing.

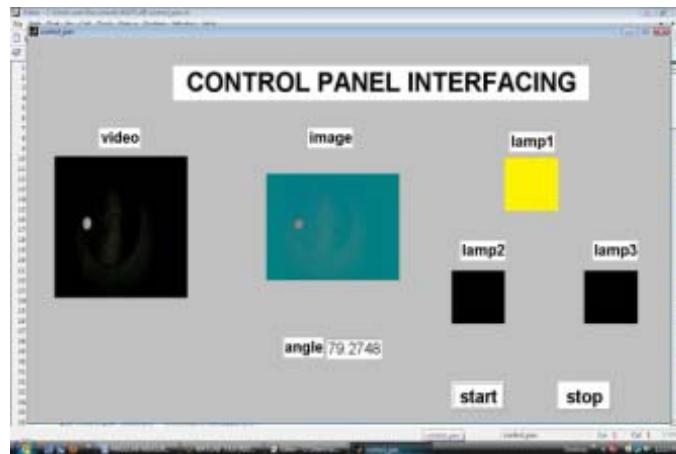


Fig. 7. GUI for panel board interfacing.



Fig. 8. Experimental setup for panel board interfacing.

4.2. Angular Speed Measurement

The speed of the rotating object can be determined using image processing technique without any physical contact with the system. The position of the pattern in the image is determined using hit or miss morphological function and the angular measurements are done with respect to the reference line. Angular displacement can be determined by calculating the difference between the angles of two images taken at time t_1 and time t_2 with which the speed of the micro motor can be determined. Using this method a speed measurement of higher RPM is reliable.

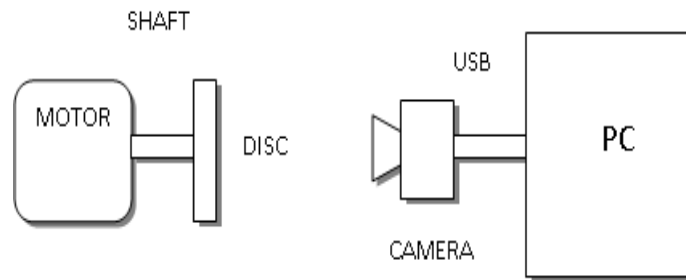


Fig. 9. Proposed angular speed measurement.

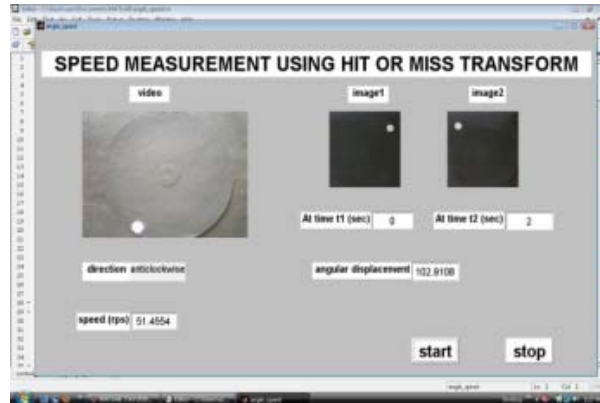


Fig. 10. GUI for angular speed measurement.



Fig. 11. Experimental setup for angular speed measurement.

4.3. Angular Orientation of a Multi Joint Robotic Arm

Robotic arms are widely used in many industrial applications such as pick and place operation, inspection and assembly. This method was proposed to control the motion of a robotic arm using visual feedback system. The position of the robotic arm can be determined using centroid method but it is a time consuming process and not reliable. Whereas hit or miss morphological function fixes the exact position of the arm from which the angular orientation of robotic arm can be calculated.

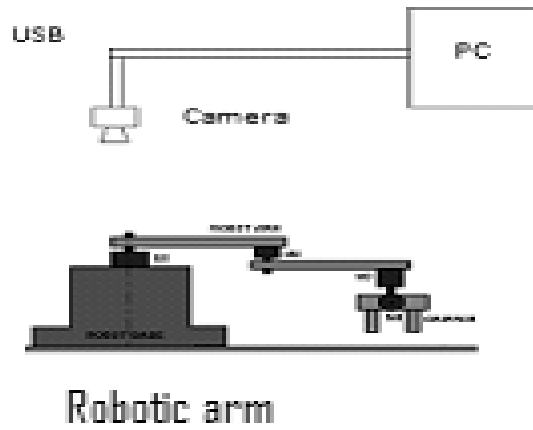


Fig. 12. Proposed angular orientation of robotic arm.

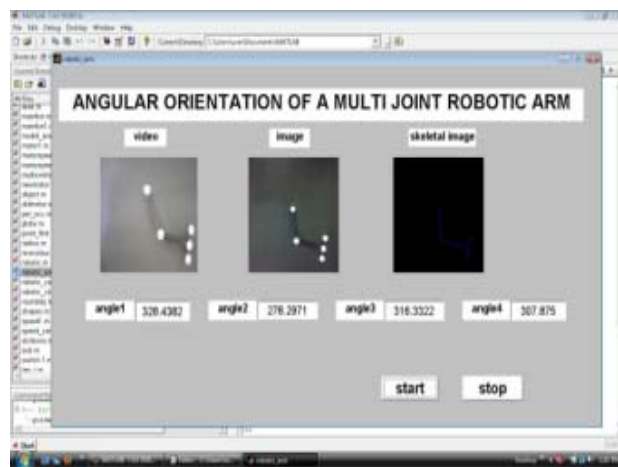


Fig. 13. GUI for angular orientation measurement of robotic arm.



Fig. 14. Experimental setup for angular orientation measurement of robotic arm.

5. Result and Discussion

The proposed system takes a processing time less than 500 milliseconds. This has a better performance than the conventional angular measurement systems. The CPU load is less for the execution of the

program. The proposed system has minimal hardware requirement such that the data transmission could be effectively done and free from data loss problems. The resultant is free from hardware noises and other signal interferences since there is no physical contact between the measurand and the system and thus a reliable output can be obtained.

6. Conclusion

A method for measuring the angle of various systems is developed using digital image processing technique and hit or miss transform. With this better performance, acceptable accuracy and reliability, the proposed system would have faster response and would be cost effective for substitution. This work could be further used for speed measurement in MEMS (Micro Electro Mechanical System) technology and simultaneous multiple operation speed measurement.

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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 of it is a peer reviewed international journal, papers rapidly published in *Sensors & Transducers Journal* will receive a very high publicity. The journal is published monthly as twelve issues per year by International Frequency Sensor Association (IFSA). In addition, some special sponsored and conference issues published annually. *Sensors & Transducers Journal* is indexed and abstracted very quickly by Chemical Abstracts, IndexCopernicus Journals Master List, Open J-Gate, Google Scholar, etc. Since 2011 the journal is covered and indexed (including a Scopus, Embase, Engineering Village and Reaxys) in Elsevier products.

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Contributions are invited on all aspects of research, development and application of the science and technology of sensors, transducers and sensor instrumentations. Topics include, but are not restricted to:

- Physical, chemical and biosensors;
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- Theory, principles, effects, design, standardization and modeling;
- Smart sensors and systems;
- Sensor instrumentation;
- Virtual instruments;
- Sensors interfaces, buses and networks;
- Signal processing;
- Frequency (period, duty-cycle)-to-digital converters, ADC;
- Technologies and materials;
- Nanosensors;
- Microsystems;
- Applications.

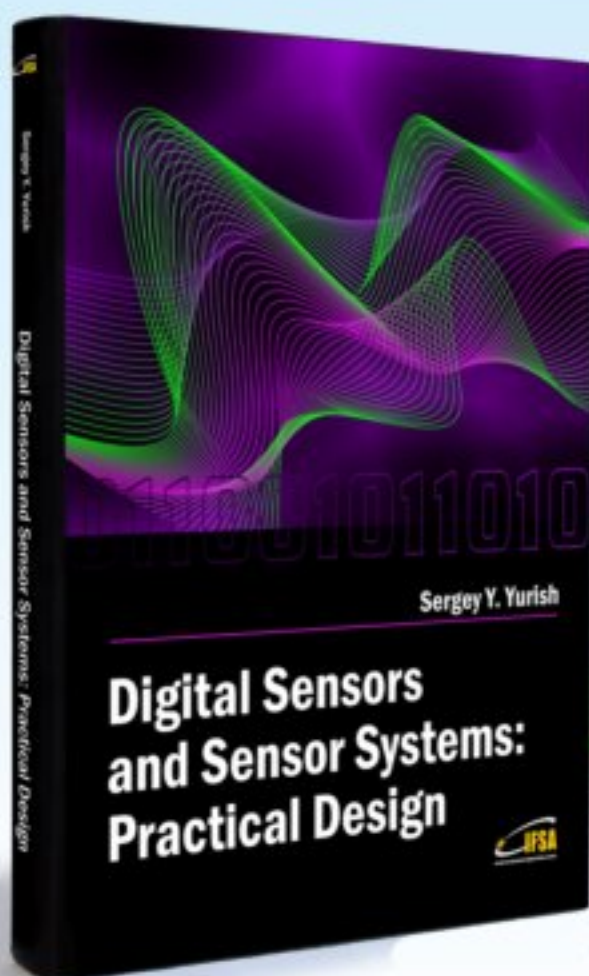
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