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PSEUDORANDOM BINARY ARRAYS FOR POSITION DETERMINATION USING VIRTUAL INSTRUMENTATION

Ivana Stojković
University of Niš,
Faculty of Electronic Engineering, Serbia

Goran Miljković
University of Niš,
Faculty of Electronic Engineering, Serbia

Dragan Denić
University of Niš,
Faculty of Electronic Engineering, Serbia

Dragan Živanović
University of Niš,
Faculty of Electronic Engineering, Serbia

Abstract

Designing of pseudorandom binary arrays for two-dimensional position determination using virtual instrumentation is proposed in this paper. Based on existing pseudorandom binary sequence, examples of generating pseudorandom binary array, which are constructed by folding method, are given in the paper. The determination of the two-dimensional position based on the contents of the "window" was implemented using a look-up table.

Keywords: pseudorandom binary array, virtual instrumentation, folding method, LabVIEW, two-dimensional position determination.

INTRODUCTION

Two-dimensional position measurement is needed in various industrial applications where there is a motion in two dimensions. Different optical sensors are used for accurate two-dimensional position measurement [1]. Also, in practice, there are different coding schemes and scanning techniques of applied two-dimensional arrays. Pseudorandom binary sequences (PRBS) can be generated using Fibonacci or Galois generator, where each of them contains n-stage shift register with a corresponding feedback. Feedbacks for particular pseudorandom sequence of maximum length $N = 2^n - 1$ can be found in table of primitive polynomial [2, 3]. Generated pseudorandom binary sequences are series of 1's and 0's which have the following properties: 1) the signal is bipolar, series of 1's and 0's; 2) sequence is deterministic and repeatable; 3) the number of "1" in sequence is equal to 2^{n-1} and the number of "0" is equal to $2^{n-1} - 1$; 4) according to the "window property" of PRBS of length $N = 2^n - 1$, any n-bit code word obtained by a window of width n is unique, [4].

A pseudorandom binary array (PRBA) can be constructed from PRBS of maximum length using different methods [2, 5]. The dimensions of the pseudorandom binary array depend on the length of the pseudorandom binary sequence used. For each pseudorandom binary array a specific window is defined and it is unique in its position in the array. Applications of pseudorandom binary arrays are numerous and one for two-dimensional position sensing is presented in the papers [5, 6]. Another interesting example where robotic tactile sensing system is used for recognition of three-dimensional objects [7]. Here, geometric symbols of a pseudorandom array are embossed on object surfaces. In the paper [8] is presented an algorithm which provides analysis of PRBA-based images for surface characterization. The applications of pseudorandom sequences and arrays can be found in many other fields, including angular and linear position determination [9], communications [10], navigation, radar technology, remote control, measurements and industrial automation.

Virtual instrumentation is used as a concept in many industrial applications, so in this paper it has been applied for pseudorandom binary array formation and two-dimensional positioning. As is commonly known, the virtual instrument is a computer based instrument with a dominant software component that gives it the flexibility, modularity and hierarchical features. The major advantages of virtual instruments compared to traditional are their flexibility, price and maintenance, [11].

In the first part of the paper, different methods of constructing a pseudorandom binary array are presented and several examples of arrays are constructed using the folding method. Then in order to automate, a virtual instrument was used to generate PRBS of maximum length and construct a corresponding array from it, and then to determine a two-dimensional position based on the read data.

FOLDING METHOD FOR CONSTRUCTION PSEUDORANDOM BINARY ARRAY

Pseudorandom coding has been a very efficient technique for absolute position recovery applications [4, 5]. To obtain correct position information for two-dimensional position sensing, a pseudorandom binary array is using. Pseudorandom arrays can be constructed by diagonal folding of pseudorandom binary sequences [7], where pseudorandom sequence is mapped into an array of n_1 rows and n_2 columns, Figure 1.

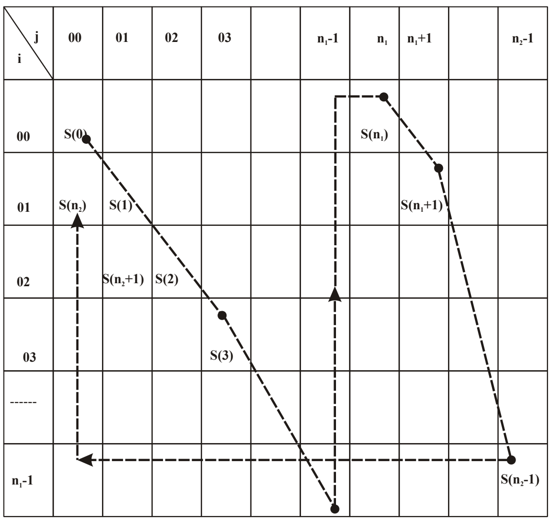


Fig. 1. *The folding method for generated pseudorandom binary array*

According to "folding method" [7], pseudorandom binary array is filled by writing pseudorandom sequences down the main diagonal and continuing from opposite side whenever an edge is reached. Pseudorandom binary array has many properties. The number of "1" in array is equal to 2^{n-1} and the number of "0" is equal to $2^{n-1}-1$, same as PRBS. Generated pseudorandom binary array have feature that columns are symmetric about column of zeros. The other property is that, apart from one column which is all zeros, the columns of the array are all shifted copies of a pseudorandom sequence of length $n_1 = 2^{k_1}-1$. Alike as pseudorandom binary sequences, pseudorandom binary array also has "window property" of PRBA which means that each possible pseudorandom binary subarray of a certain size except the all zero one occurs exactly once in the array. Using this properties of PRBA, any sensor array $(k_1 \times k_2)$ is unique and is seen only once. These window contents are identified to the current row-column coordinates (i, j) in the pseudorandom binary array, [7]. The dimensions $n_1 \times n_2$ of the resulting PRBA are:

$$n_1 = 2^{k_1}-1,\ n_2 = \frac{2^n-1}{n_1} \qquad (1)$$

where $k_1 k_2 = n$.

Depending on different *n*, some available pseudorandom binary arrays are given in the Table 1.

Table 1. *Examples for constructing a pseudorandom binary array for different N*

n	Length $N=2^n-1$	Pseudondom binary array $(n_1 \times n_2)$	Sensor array $(k_1 \times k_2)$
4	15	(3×5)	(2×2)
6	63	(7×9)	(3×2)
8	255	(3×85) (15×17)	(2×4) (4×2)
9	511	(7×73)	(3×3)
10	1023	(3×341) (31×33)	(2×5) (5×2)
....	....	……………….	....

Start point is to select a suitable sized pseudorandom array for desire resolution n. For the example presented here, with a shift register feedback configuration according to primitive polynomial $h(x)=x^8+x^6+x^5+x+1$, pseudorandom sequence for $n=8$ is generated, Figure 2.

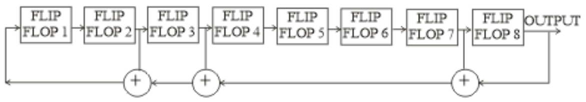
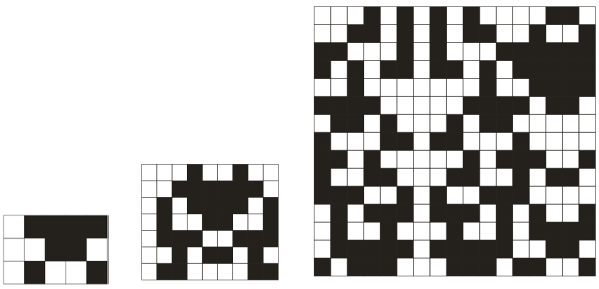
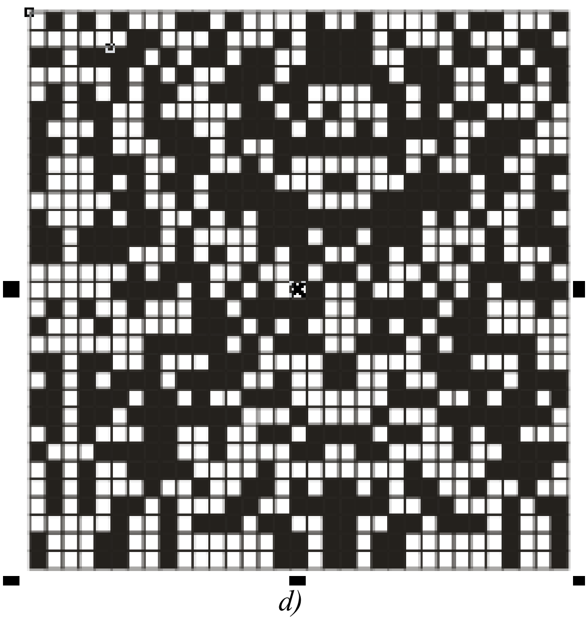


Fig. 2 *Generating pseudorandom sequence with shift register*

Using generated PRBS and folding method, pseudorandom binary array can be constructed. Figure 3 shows some examples of PRBA and in practice to achieve floor pattern for 2D positioning of some mobile robot, binary 1 and binary 0 are replaced by a mosaic of white and black rectangular covering areas.



a) b) c)



d)

Fig. 3 *Examples of pseudorandom binary array a) 3 by 5; b) 7 by 9; c) 15 by 17 and d) 31 by 33*

ARRAY CONSTRUCTION AND TWO-DIMENSIONAL POSITIONING USING VIRTUAL INSTRUMENTATION

Firstly, a virtual instrument was realized that generates maximum length PRBS sequence of 8-bit resolution, with feedback as in Fig. 2, and then this sequence is used for construction of adequate PRBA according to the folding method presented in Fig. 1. According to this method the array is filled by writing the sequence down the main diagonal and continuing from the opposite side whenever and edge is reached, Figure 3. The generated PRBS made of 255 bits filled the PRBA of dimensions 15-by-17.

Formed PRBA can be used for two-dimensional positioning using adequate 'window' which is unique for every of 255 positions. The window is dimensions 4-by-2 in presented example and it is unique if all bits are accurately recognized. The recovery process may be impossible if any bit in the window is incorrectly read. One more disadvantage may be non-square window 4-by-2 dimensions.

The front panel of the realized virtual instrument using a LabVIEW 8.0 software environment, [11] is shown in Figure 4. On the front panel of the virtual instrument, the resolution of the PRBS, the pseudorandom window size can be changed, and the filled PRBA is presented. The pseudorandom to natural code conversion of read window is implemented using memory store table. In the front panel of the virtual instrument can be defined resolution of PRBS, dimensions of 'window', and also can be viewed dimensions of array, content of the array, content of the read 'window' and obtained two-dimensional position.

The read 'window' for position A1 is marked with a red rectangle in the PRBA. Each 4-by-2 'window' placed over a PRBA is unique. The 'window' can not be filled with all the zeros and allows recovery of the row and column coordinates. Two-dimensional position is obtained using look-up table and one disadvantage may be that with larger PRBA a larger look-up table will be needed. Symbols representing PRBA code elements can be coded on different ways depend on concrete application and applied code reading method, for example, tactile, visual, magnetic, etc. Constructed PRBA can be used, for example, in the mobile robot positioning using computer vision techniques. The PRBA can be printed on the factory floor and viewed through a camera mounted on a mobile robot. Accuracy depends on the resolution of captured image and retrieving symbols from it.

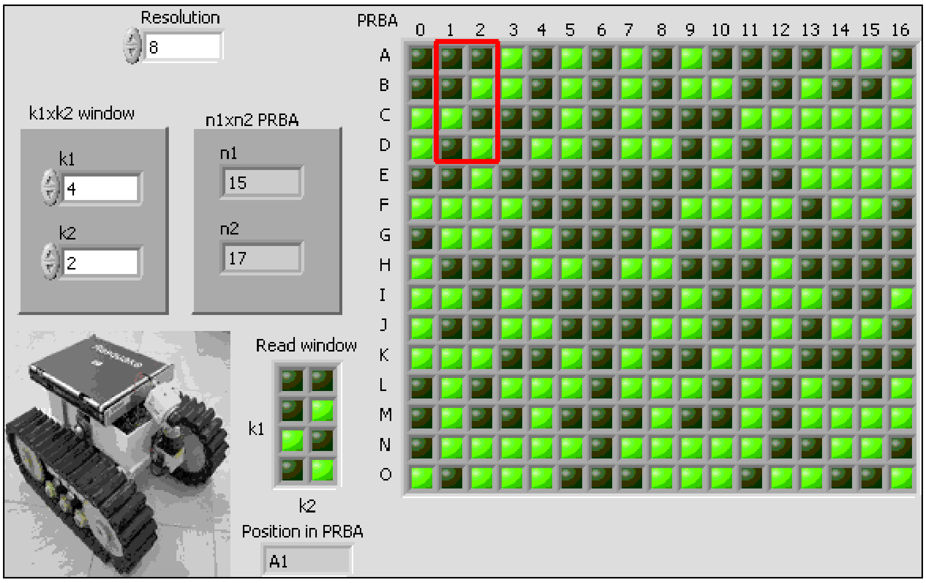


Fig. 4 *Virtual instrument for PRBA construction and two-dimensional positioning*

CONCLUSION

The paper discusses the application of PRBS for PRBA construction and their use in two-dimensional positioning, where some advantages and disadvantages are highlighted. The virtual instrument is realized for PRBS generation and construction of adequate PRBA and also for positioning based on 'window' An example is shown with a 8-bit PRBA that is read with 4-by-2 'window' and where there is 255 unique positions.

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