MORE ABOUT ARUCO MARKERS

Introduction

An ArUco marker is an NxN grid or Bit size, that is black and white in colour, where N=4 to 7. ArUco markers are based on Hamming code.

Consider for example an ArUco marker of 5x5 grid or Bit size as shown in Figure 1 below.

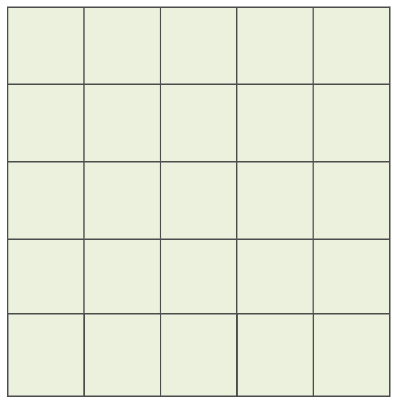


Figure 1. 5x5 grid of an ArUco marker

In this grid, the first, third and fifth columns represent parity bits.
The second and fourth columns represent the data bits.
This is depicted by Red and Blue arrows in alternate columns in Figure 2 below; where Red arrow represents parity bit columns and Blue arrow represents data bit columns.

Thus, from 2 data bit columns, there are a total of 10 data bits.
So the maximum number of markers that can be encoded are 2ˆ10 = 1024.
Thus, a 5x5 ArUco marker can have a maximum of 1000 combinations or IDs.

Note: There are two data bits in each row.

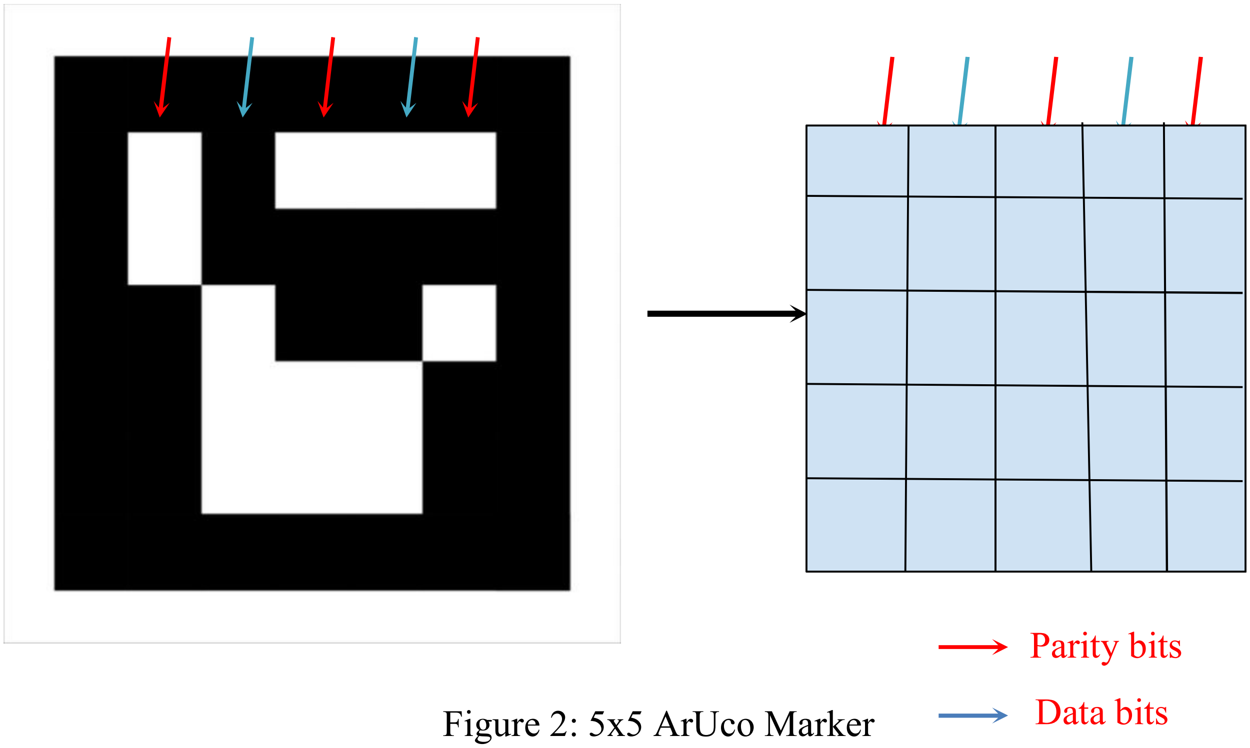


Figure 2: 5x5 ArUco Marker

Encoding

Suppose we choose the example ID of 650
i.e. ArUco ID=650; its binary representation is 1010001010 i.e. 10 Bits.

Each row of the grid is encoded separately using a slightly modified Hamming code for each parity bit i.e.

1. The first parity bit is calculated using even parity
2. The second parity bit is calculated using odd parity
and
3. The third parity Bit is calculated using even parity

The ID 650 is generated according to the above Hamming code and we get the following encoded values, as shown in the Bit table - Table 1 below:

Data bit 2	Parity bit 3	Data Bit 1	Parity bit 2	Parity bit 1
0	0	1	0	1
0	0	1	0	1
0	0	0	1	0
0	0	1	0	1

0	0	1	0	1

Table 1. ArUco ID = 650 Bit table (parity and data bit values).

By rearranging the bits in each row, the following data rows as shown in Figure 3 are obtained:

	1		0	
	1		0	
	0		0	
	1		0	
	1		0	

→ 1010001010

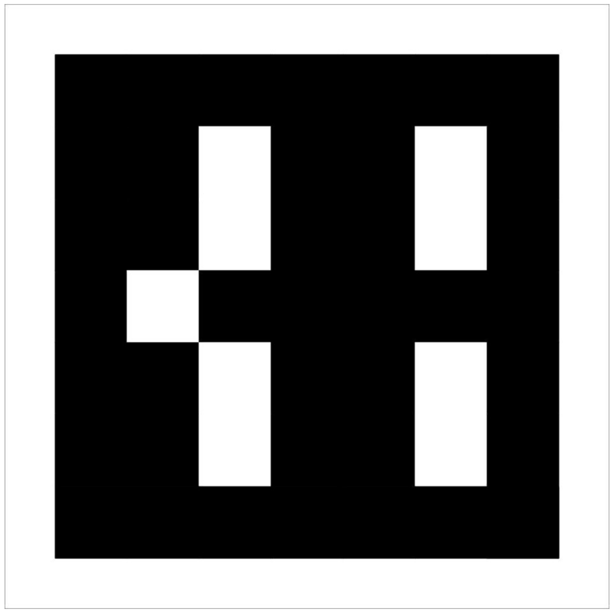
Figure 3: Data rows

Rearranging the parity bits as well, Bits for ArUco ID = 650 looks as shown in Figure 4:

Parity1	Data1	Parity3	Data2	Parity2
0	1	0	0	1
0	1	0	0	1
1	0	0	0	0
0	1	0	0	1
0	1	0	0	1

Figure 4: Bits for ArUco ID = 650 (0b1010001010)

Cells having value 0 are represented by black coloured pixels; while the cells having value 1 are represented by white coloured pixels as shown in Figure 5 below:



igure 5: ArUco marker for ID=650

The encoded ArUco marker image is padded with a single layer of black cells. This layer will be removed during decoding.

Decoding

After understanding the above section, decoding is an extremely simple process. The following steps are to be followed while decoding a perfect, computer-generated image of an ArUco marker.

Step 1: Extract the ArUco from the image.

Step 2: Remove the extra padding.

Step 3: Divide the resulting image into an NxN grid and check the colour in each cell of the alternate columns in a top to bottom manner, starting from the second column.

Step 4: If the colour is white, write 1; else, write it 0.

Step 5: The resulting number will be in binary. Convert it into decimal