THE TECHNOLOGY BEHIND BAR CODES Part B

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A Bar Code that cannot be scanned

Why?

Photo courtesy of Paul Bergé of AIDC 100

A Digression on Scanners and Image Analysis

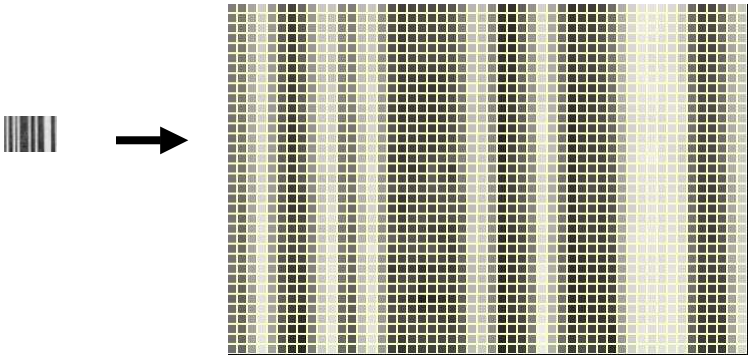
OR

Why it is very hard for machines to read numbers (and letters)

Using Image Capture

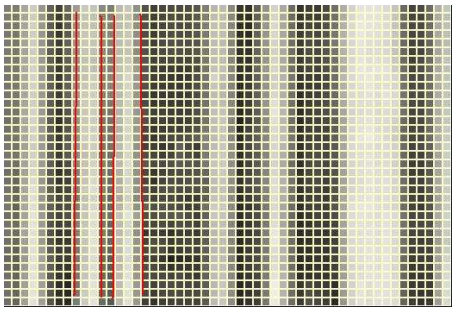
- We can take a picture of a bar code or a page of text with a digital camera.
- We get an array of pixels, each one with three color values (for color shots) or with a brightness value (for B/W shots)
- The results are similar if we use a contact scanner (such as that of a copier)

Pixels of a Bar Code Scan

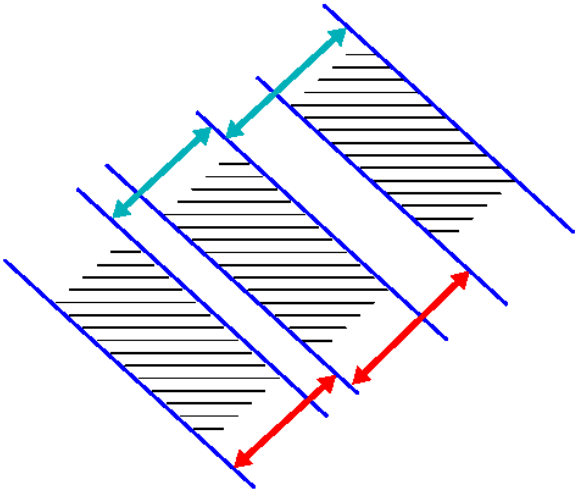


Making Sense of the Pixels in the case of a Bar Code

1. Find edges, D to L or L to D.
2. Fit straight lines on the edges.
3. Compute the distance between lines.

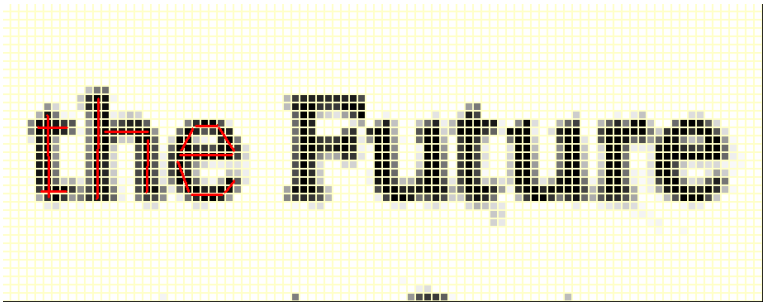


Computing t-distances on a scanned bar code



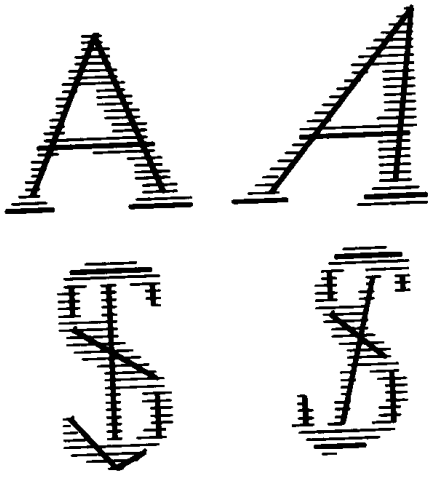
Pixels of a Text Scan

Making Sense of the Pixels in the case of Text



To reach an anthropomorphic description of the image we need to fit lines along groups of dark pixels. (Other representations are also possible.)

Even after we find the lines (vectors) the formal description of a character presents challenges.



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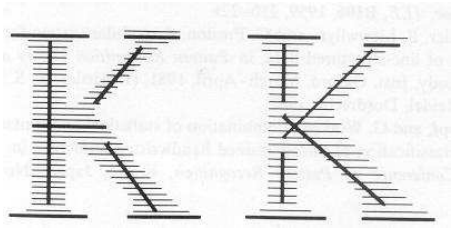


Back to Barcodes

Mostly 2D

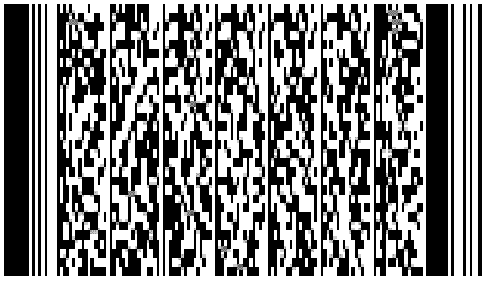
Linear Bar Code Limitations

- Because linear bar codes have low information density (the vertical dimension is "wasted") they can store only indices to a database.
- They are useless unless we have access to the database.

Two-Dimensional Bar Codes

- Two-dimensional bar codes use the vertical dimension and as a result have much higher information density.
- They can store a full record of data without needing access to a database.

PDF417 - 1



A stack of thin bar code strips

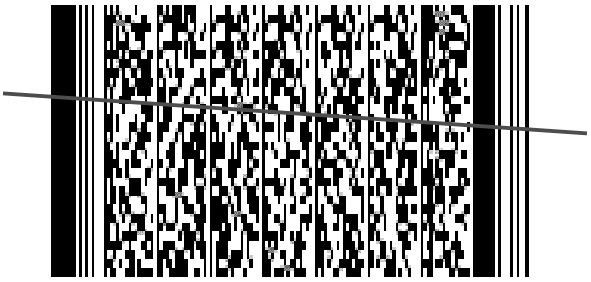
(You will find it in NY State DMV documents such as car registrations, etc)

Example of PDF417 use

PDF417 - 2

- The code encodes all letters and numbers (full ASCII character set) in elements of four bars and four spaces covering 17 modules.
- It came into existence around 1990 as a result of research at Stony Brook University and Symbol Technologies. (Y.P. Wang completed a PhD thesis at SBU while employed by Symbol.)

PDF417 - 3



Scanner beam crosses data rows. How can we find what row we are on?

PDF417 - 4

- Use a different encoding scheme for each row!
- We need only three schemes! (Greek / Roman / Cyrillic alphabets)
- In PDF417 we use a discriminator *f*:

  $f(\underline{W}) = (w[0]-w[2]+w[4]-w[6])\%9$

  where *w[k]* (*k* even) is the width of a bar.

PDF417 - 5

- The discriminator *f* has 9 possible values and it divides the possible code words of PDF417 into 9 **clusters**.
- We use only three clusters with discriminator values 0, 3, and 6.
- This policy provides for *error detection*: If we find a value, say, 1 we know we made an error!

PDF417 - 6

- Each cluster has 929 possible code words, thus each code word can store $log_2(929) = 9.86$ bits. Therefore there is plenty of room for a full ASCII set.
- In addition, PDF417 provides for error correction by storing a few additional code words besides the data code words.

Error Correction - 1

- Error correction in communications is achieved by transmitting an over determined systems of equations, for example:

$$x = 5$$
$$y = 8$$
$$x + y = 13$$
$$x - y = -3$$

We can miss two of the transmissions and still recover the data!

Error Correction - 2

- Error detection and error correction are used widely in electronic communications and electronic storage media.
- There is a considerable mathematical theory behind them.
- In order to use this theory for the 2D barcodes we had only to modify the model for noise: "paper" noise has different characteristics than "electronic" noise.

Other 2D Symbologies

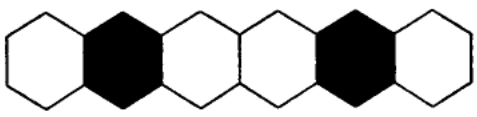
- PDF417 was designed to be scanned by handheld laser scanner.
- If we limit scanning to CCD array cameras, then we can increase the information density of a symbol.
- Datamatrix
- Maxicode (**U**nited **P**arcel **S**ervice)

Datamatrix

- Use each spot as a bit. Result is higher information density, but less robust reading.
- Example of use in prepaid mail.

Maxicode

- Developed for UPS to be used on conveyor belts for package sorting (at speeds of 150m per minute.)
- A codeword consists of six hexagonal cells.



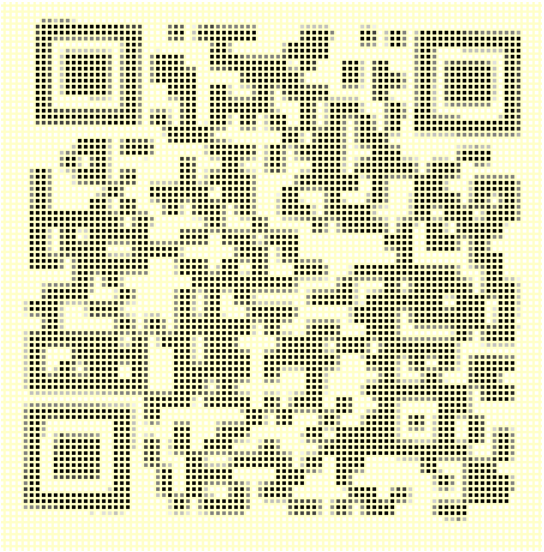
Bar Codes for Cell Phones

- It is a challenge because cell phone cameras have too low resolution.
- Why would we want to do that?
- To read URLs?
- Letter indexing makes typing URLs easy!!!

2D Bar Codes for Cell Phones

By typing only priority in Google Chrome you get the desired page.

Scanning the special 2-D code is not easy!



RFID

- **R**adio **F**requency **Id**entification has been proposed as an alternative to bar codes. (A resonant chip is attached to an item and no contact scanning is needed.)
- Too expensive compared to bar codes so it seems applicable only to high value items.