Honeywell

Redefining the Patient Wristband

Executive Summary

Reduction of errors in the hospital starts with accurate patient identification. Bar codes are becoming a standard feature on the patient wristband. Mobile computers and bar code readers allow bedside reading of the patient ID code. Unfortunately, the current bar code designs make reading exceedingly difficult. This leads to wasted time and frustration among the nursing staff.

This paper describes a system using matrix bar codes and mobile imaging readers that solves all five of the existing patient ID reading challenges:

- Finding the bar code when it wraps around the patient's wrist
- Positioning the reader so that it is aligned within the "scan zone"
- The bar code becomes unreadable due to smudging and smearing that naturally occurs during the patient's stay
- Data accuracy is often compromised in an attempt to solve the first three challenges
- Today's wristbands are up to 1.25 inch wide in order to accommodate current bar code designs; this makes them more expensive, less comfortable for the patient, and too big for children

Introduction

Bar codes are commonly prescribed for improving accuracy and efficiency of data entry. In the hospital setting bar codes are increasingly being used as part of a system to reduce errors in medical treatment. Mobile computers can be used to read bar codes on patient wristbands to accurately identify the patient. Subsequent checks can be performed to ensure that the patient receives the correct treatment.

Unfortunately the people who have to read the bar codes complain that it's a difficult task. The problem? Traditional bar codes are just not suited for the wristband application. Their shape tends to be a long rectangle that becomes wider as one adds more data characters. No matter how hard one tries, these "linear" bar codes cannot be positioned, or rotated, or shrunk in a way that addresses all the reading challenges.

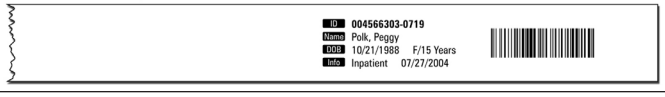
These challenges have motivated people to seek other solutions. No other proposal, including Radio Frequency Identification (RFID), has been successful in removing all of the frustration. The purpose of this paper

is to present a solution that makes use of modern two-dimensional bar codes. Together with area image readers, all of the reading challenges are solved.

Original Design

The hospital wishes to encode at least 9 characters in a bar code to be used for patient identification. Often a linear bar code is selected, such as Interleaved 2 of 5 or Code 128. Choosing a large X-dimension (10 to 20 mils) is good practice with bar codes because that generally translates into greater reading distances and better ease-of-use. The design so far calls for a fairly wide bar code, and the only way to fit that on a wristband is to align the longest dimension with the length of the wristband as shown in Figure 1.

Figure 1 Original wristband design.

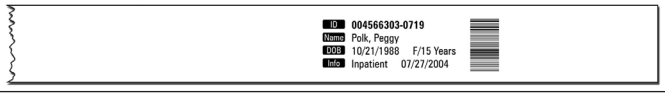


The trouble begins when the bar code curls around the patient's wrist. Bar code readers need to see the entire width of the code. Such a design forces the nurse to turn the wristband so the bar code is visible, and to pull it flat so that the reader can see the entire width of the code. Let's hope the patient isn't trying to sleep while the nurse is tugging at her wrist!

Current Design

The designers recognized one way to prevent the bar code from curling around the patient's wrist: turn it 90 degrees. This constrains the bar code to fit in the narrow width of the wristband as shown in Figure 2.

Figure 2 A better linear bar code design.



Often times to reduce the length of the bar code the designer will choose a small X-dimension (5 mils). That generally translates into smaller reading distances, which makes it difficult for the nurse to position the reader within the scan zone. To make matters worse the smaller bar and space dimensions are more susceptible to damage caused by smearing and smudging.

The bar code won't curl around the patient's wrist so the nurse won't have to pull the symbol flat. He will still have to turn the wristband so that the code is visible – an inconvenience to both the nurse and the patient.

Enter Two-Dimensional Bar Codes

In order to tackle the wristband reading challenges we must make a fundamental change to the bar code. Two-dimensional bar codes are more space-efficient than linear codes. For a given amount of marking space, one can choose a larger X-dimension, which results in greater reading distances.

Two-dimensional codes employ powerful Reed-Solomon error detection and correction. This is the same technology that has been used for reliable communication to and from satellites in deep space. You are more likely to win the Powerball lottery than you are to experience a misread of these codes. Enhanced data security is important for accurate patient identification.

Get the Right Tool for the Job

If you are using a traditional laser scanner, you may be limited to reading traditional linear bar codes. Fortunately, a number of newer scanning technologies have been developed to take full advantage of these two-dimensional bar codes.

Today there are four classes of mobile readers that can decode two-dimensional symbols: linear imagers, area imagers, linear lasers, and raster lasers. Some linear scanners can read stacked two-dimensional codes, such as MicroPDF417 and PDF417. A trained operator manually swipes the scan line over the rows of the code.

Area imagers can read stacked and matrix codes. They operate in a point-and-shoot fashion, which makes them easy to use. Area imagers take a digital picture of the bar code and use software algorithms to find and decode bar codes in the image. The software can read codes at any angle in the digital image, so the nurse doesn't have to twist her/his wrist in order to align a scan line with the bar code.

Area image engines, such as the IT4100 from Honeywell do a good job of reading problem bar codes, and since they see more than a slice of the bar code they can offer data security that's not possible with laser technology. Area imagers work exceptionally well in wristband reading applications.

New Wristband Designs

When you combine the best of the available two-dimensional bar codes with the capabilities of area imaging we derive three distinctly new wristband designs. Each design will be discussed in more detail, but first we summarize one aspect of performance: reading distance.

The new designs use MicroPDF417, PDF417, and Aztec Code. These achieve significantly greater reading distances than the 5-mil Code 128 symbol that is representative of the current crop of wristbands.

Refer to Table 1 and Table 2 for typical reading distances using the IT4100SF and IT4100SR area imagers. The "SF" engine is designed to read high to medium density bar codes. The "SR" engine is designed for maximum reading distance on medium to low density bar codes, where the X-dimension is 6.7 mils or larger.

Note: These are typical reading distances, found by experimentation using one device and one print sample.

Table 1 Comparative bar code reading distances using IT4100 "SF" optics.

Code 128 [5.0-mil]	3.0 to 5.0 in. (2.0 in.)
MicroPDF417 [11.7-mil]	1.5 to 7.5 in. (6.0 in.)
PDF417 [11.7-mil]	1.75 to 9.0 in. (7.25 in.)
Aztec Code [25.0-mil]	1.0 to 9.0 in. (8.0 in.)

Table 2 Comparative bar code reading distances using IT4100 "SR" optics.

Code 128 [5.0-mil]	N.A.
MicroPDF417 [11.7-mil]	2.5 to 10.0 in. (7.5 in.)
PDF417 [11.7-mil]	2.25 to 10.5 in. (8.25 in.)
Aztec Code [25.0-mil]	1.0 to 10.25 in. (9.25 in.)

MicroPDF417 Design

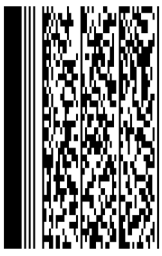
MicroPDF417 is the most space-efficient of the stacked two-dimensional codes. The goal is to use the largest possible X-dimension and encode a 13-character patient ID into the same overall area as a Code 128 symbol. It works out to be 11.7 mils, with a row height equal to 3X (normally MicroPDF417 is printed with a 2X row height but in this case 3X fits into the desired space and will enhance reading performance for all types of reading technologies). The message fits into MicroPDF417's 2 columns by 8 rows format, for an overall dimension of 0.642 by 0.280 inch.

11.7-mil MicroPDF417

With each of these designs we recommend repeating the same symbol multiple times over the length of the wristband. This ensures that at least one code remains readable no matter how the wristband curls around the patient's wrist. MicroPDF417 has a quiet zone requirement of 1X clear area all around the symbol, so the codes cannot touch each other. See Figure 3 for an illustration of the MicroPDF417 wristband concept.

PDF417 Design

PDF417 is the most popular of the stacked two-dimensional codes, and it offers some flexibility in choosing the error correction level (ECL). This design makes use of the ability to set a higher ECL, which makes it just a bit more robust in its ability to sustain damage.



11.7-mil Truncated PDF417

At an X-dimension of 11.7-mils and a row height of 3X the printed symbol appears large, but only six rows of the symbol need to be in the reader's view, or about 0.805 by 0.210 inch. This is a Truncated PDF417 symbol, designed to fit on a 1-inch wide wristband. Error correction level 5 was chosen for this example, but level 4 or 6 would also be appropriate. PDF417 has a quiet zone requirement of 2X

clear area all around the symbol, so the codes cannot touch each other. See Figure 4 for an illustration of the PDF417 wristband concept.

Aztec Code Design

Aztec Code is the best choice of the matrix codes, and is by far the most space-efficient of the two-dimensional symbols that are recommended. Choose an X-dimension of 25 mils for a good balance of code size and reading distance. The resulting symbol size is just 0.375 by 0.375 inch.

25-mil Aztec Code

See Figure 5 for an illustration of the Aztec Code wristband concept. We recommend repeating the same symbol multiple times over the length of the wristband. Of course only one of those symbols needs to be decoded in order to capture the patient ID. This provides protection from damage and it ensures that at least one code remains readable no matter how the wristband curls around the patient's wrist.

Aztec Code is unique in that it does not require any quiet zones, thus the symbols can touch each other. This saves additional label space.

Note that the codes only take up half the width of the wristband. This allows for some creativity. By formatting the text to fit in half the wristband width, the other half can be dedicated to Aztec Codes. Thus there is no break in machine-readable codes anywhere around the wristband, ensuring that the nurse will never have to turn the wristband to reveal a code.

By staggering the Aztec Codes we reduce the center-to-center distance between codes, for the most thorough coverage.

Data Matrix can be used as an alternative to Aztec Code, with a few limitations. First, Data Matrix has a quiet zone requirement of 1X clear area all around the symbol. Second, Data Matrix is sensitive to damage on all four of its outside edges. In any on-demand printing application it is common to see errors in registration between the print head and the wristband label stock. If an entire string of Data Matrix symbols is printed at the edge of the label in such a way that one edge is cut off, then the entire string of symbols becomes unreadable! In contrast, Aztec Code has been designed to sustain edge damage. In that same scenario the string of Aztec Codes remains readable even if an entire edge is cut off.

Figure 5 is the highest performing of these wristband concepts.

Backward Compatibility

There may be some organizations who elect to migrate toward the Aztec Code solution, but who wish to keep their installed base of linear scanners in service during the transition. For this we recommend the design as depicted in Figure 6. The idea is to keep the existing linear bar code in its place, but to fill the remaining area on the wristband with Aztec Codes. During the transition all the legacy readers can read the Code 128 just as before. Anywhere a new image reader is installed the nurse can take full advantage of the benefits described in this paper.

There may also be a need for the new readers to work with the older wristband design. The IT4100SF image engine is able to read 5-mil Code 128 symbols as those are phased out, and it can read Aztec Code as the new design is phased in.

Table 3 Comparative advantages of proposed wristband designs.

	MicroPDF417	PDF417	Aztec Code
Solves Wrap-Around Problem	✓	✓	✓
Reading Distance	Good	Good	Best
Tolerates Smudges & Smearing	✓	✓	✓
Data Accuracy	✓	✓	✓
Tolerates Registration Errors			✓
Pediatric Size			✓

Pediatric Wristbands

All of the wristband examples so far have been printed at 1.0 inch in width. That may be acceptable for adults, but not for children. Fortunately, the Aztec Code solution works even if you cut the wristband in half, as shown in Figure 7. One strip of 25-mil Aztec Codes still provides plenty of redundancy and is readable over the same distance.

We don't recommend trying this with any linear or stacked bar code. Reducing the wristband width requires reducing the X-dimension, which reduces the range that the reader can pick up the code. This leads to increased frustration for the nursing staff.

The Health Industry Bar Code (HIBC) Provider Applications Standard

The Provider Applications Standard was created to facilitate interoperability in a networked hospital environment. It describes the preferred method for formatting bar codes and, more importantly, how to structure the data that is encoded into the bar code. Two flags are used indicate "what" the data is and "where" it was captured from.

Consider the commencement of a surgical procedure. Would you be comfortable knowing that the surgical team captured your Patient ID number from your chart? No, because there is a distinct possibility that the chart does not match the person. You would want to know that the surgical team captured your Patient ID from a wristband that is semi-permanently affixed to your body. The Provider Application Standard recommends a method to ensure that this mistake does not occur.

Experts will recognize that the bar codes in this paper do not conform to the Provider Applications Standard. At first glance the data structures are correct, but the mandatory check character is missing! I had taken the data directly from wristband samples that are in use in a well-respected hospital. I suspect that the check character was dropped because it made the Code 128 bar code too long to fit on the wristband.

By using any one of these two-dimensional bar code solutions one could comply with the Provider Application Standard. In fact, there is a revision to the standard underway that seeks to add additional data to the patient wristband. It will recommend that a second field be added in order to identify the Health Industry Number (HIN). This will identify the health care location where the wristband was affixed. This is a benefit when patients are transferred from location to location, such as a remote clinic or an ambulatory surgical site. How do they propose to fit the resulting bar code on a wristband? They will recommend the use of a two-dimensional bar code.

Conclusion

With a few simple changes to the wristband design, all five of the reading challenges are solved. Instead of becoming frustrated over scanning bar codes, the nurses can concentrate on more important details, making them more efficient and less prone to errors.

Two-dimensional bar codes make better use of space, so they can be printed with larger X-dimensions, which means they can be read over a greater distance. A 25-mil Aztec Code offers an ideal balance of size and readability.

Area imagers make reading even easier because they scan bar codes omnidirectionally. The nurse simply aims at a bar code; no more twisting her/his wrist to align a laser beam with a bar code.

Multiple symbols can be tiled over the wristband so that at least one is visible no matter how the wristband curls around the patient's wrist. The nurse can scan any one of the symbols to successfully capture the patient ID.

When multiple codes appear on the wristband we can be less concerned about symbol damage. After an extended stay in the hospital it is likely that at least one code will be smeared or smudged as a result of natural body oils, antiseptics, or other fluids.

Two-dimensional bar codes offer unprecedented data accuracy thanks to built-in Reed-Solomon error detection and correction. Linear bar codes simply cannot match them with their optional modulo-10 or modulo-103 checksums. Data security is important if the person is to be identified without error.

Finally, people desire a thinner, more comfortable wristband. In the pediatric wing it is virtually a necessity. All of the aforementioned benefits can be achieved with a wristband that is overall smaller in dimensions.

Figure 3

MicroPDF417 can be scanned by most modern bar code readers. This solution offers moderate reading performance but cannot be scaled to fit the pediatric wristband.

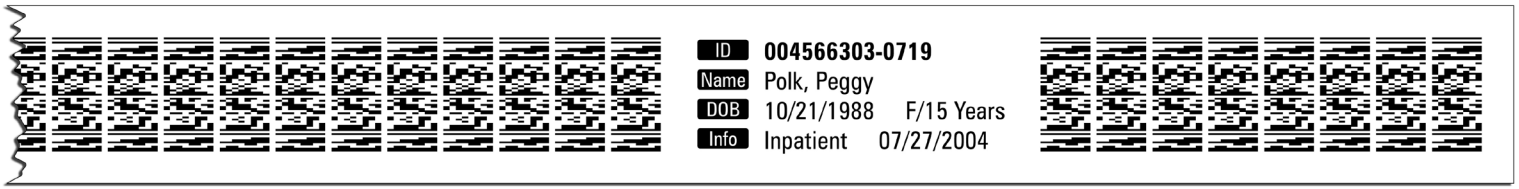


Figure 4

PDF417 can be scanned by the majority of modern bar code readers. This solution offers moderate reading performance but cannot be scaled to fit the pediatric wristband.

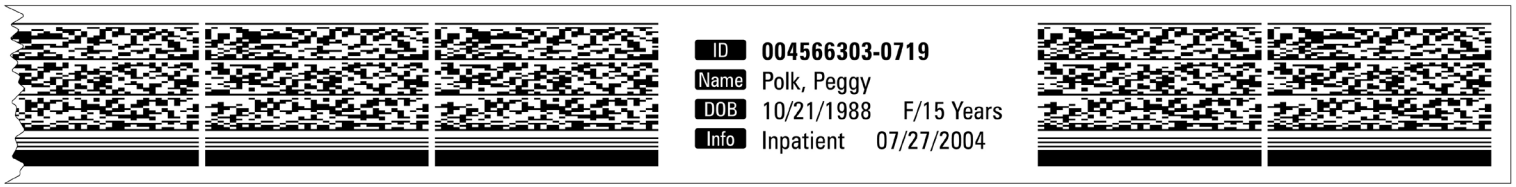


Figure 5

Aztec Code can be read by the majority of image readers on the market. This example offers the best reading distance, and since codes traverse the entire length of the wristband, at least one is always visible.

Figure 6

For a client who wishes to transition from laser scanners to area imagers over a period of time, one can include a single Code 128 symbol on the wristband for backward compatibility.

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Figure 7

A narrower wristband is more suitable for pediatric patients and is more comfortable for adults. This design offers great reading performance in half the width.

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