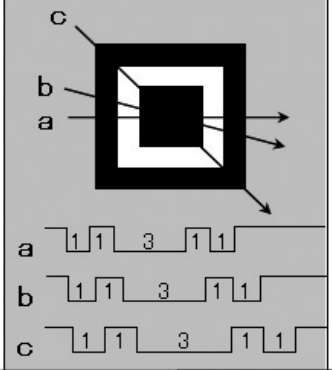
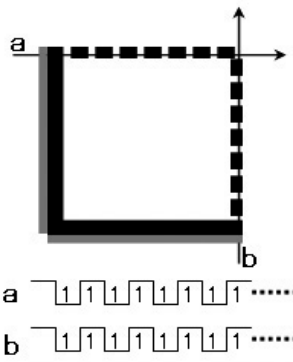
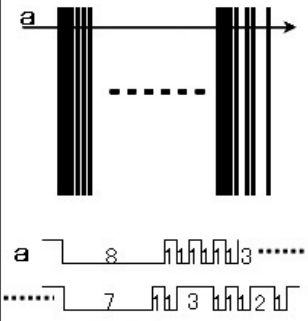
Comparing QR Code with Various Symbols

1. Finder Pattern

The role of the finder pattern is to promptly identify the position of the symbol from among the image that has been reflected upon the sensor of a reader. If the symbol area is taking up a large percentage of the image, there is not much possibility to improve the recognition speed. However, if the symbol area is taking up only a small percentage among the image, and if there are various figures and characters in the image, it would take much longer to have the position of the symbol recognized. To shorten the time for recognizing the symbol position, the finder pattern for the QR code is characteristic in its shape when compared with other 2-dimentional symbols. The QR code finder pattern had been determined based on a research result that the sequential pattern of 1, 1, 3, 1, 1, would rarely appear when patterns including figures and characters are scanned.

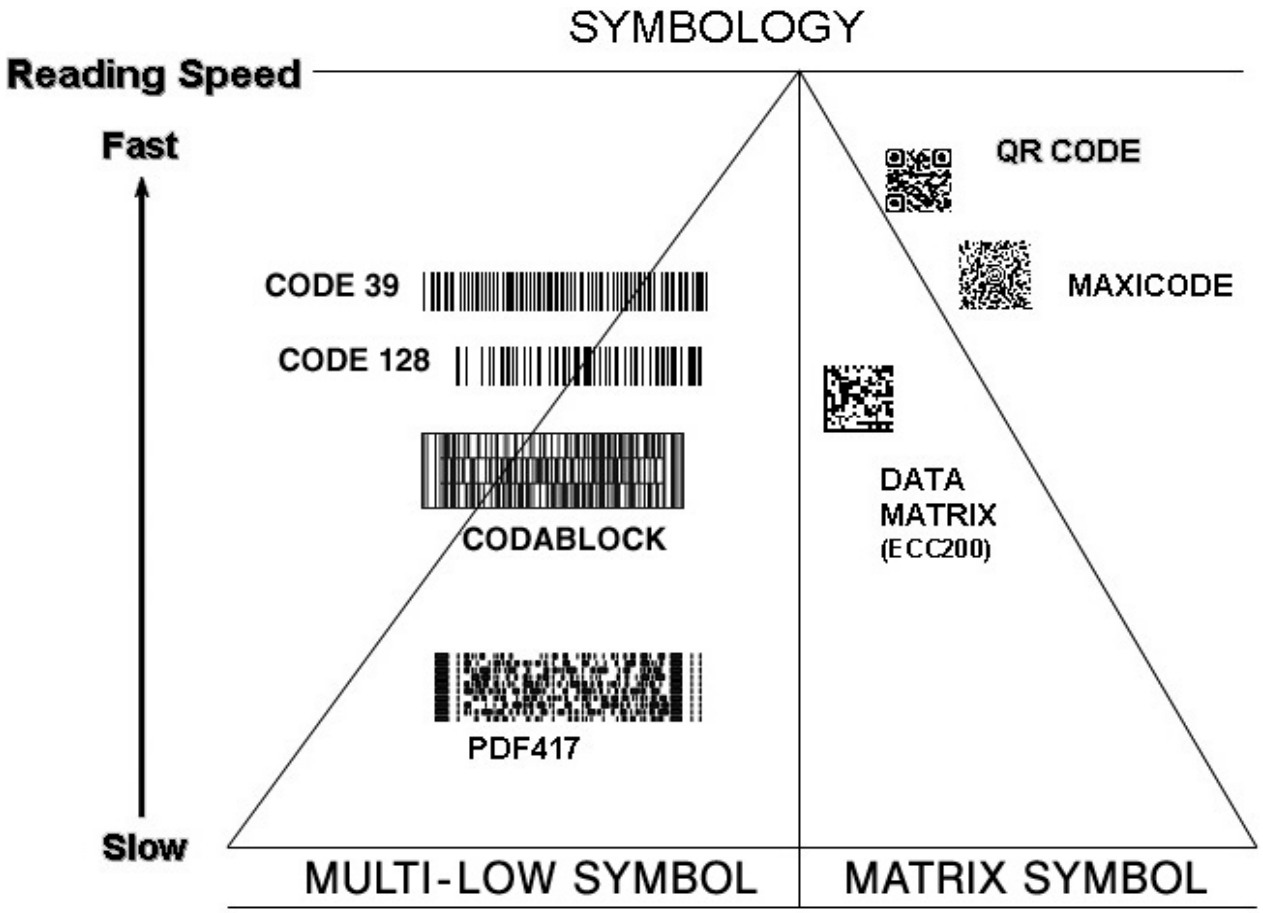
The finder pattern for data matrix is L-shaped. When pattern including figures and characters are scanned, in many cases there are relatively many L-shaped patterns included, and therefore it is difficult to recognize the L-shaped finder pattern for that data matrix. Printed books or labels contain many patterns with crossed straight lines. The 1, 1, 1……pattern which is the timing pattern for data matrix also exists quite often in images, too. For example, if a dotted line is included in the image, that will turn out to be the same pattern. Since the start/stop patterns for PDF417 are consisted of straight lines, the image has more straight lines included than when compared with the L-shaped pattern for data matrix. There will be no problem as long as the image is scanned by a human opeator looking at the label using a lazor-type reader. However, if the symbol is read by a fixed CCD-type reader, the symbol usually rotates from the original image, and therefore it takes longer time to recognize the position of the symbol. Maxi codes have a characterisitc finder pattern. However, since the number of digits for a maxi code is fixed and it has been developed for a specific purpose,
we will not make any description about it in this document.

	QR CODE	DATA MATRIX	PDF417
			
recognition algorithm			
quiet zone	4 modules	1 module	1 module
recognition speed	fast	medium	slow

2. Reading Speed

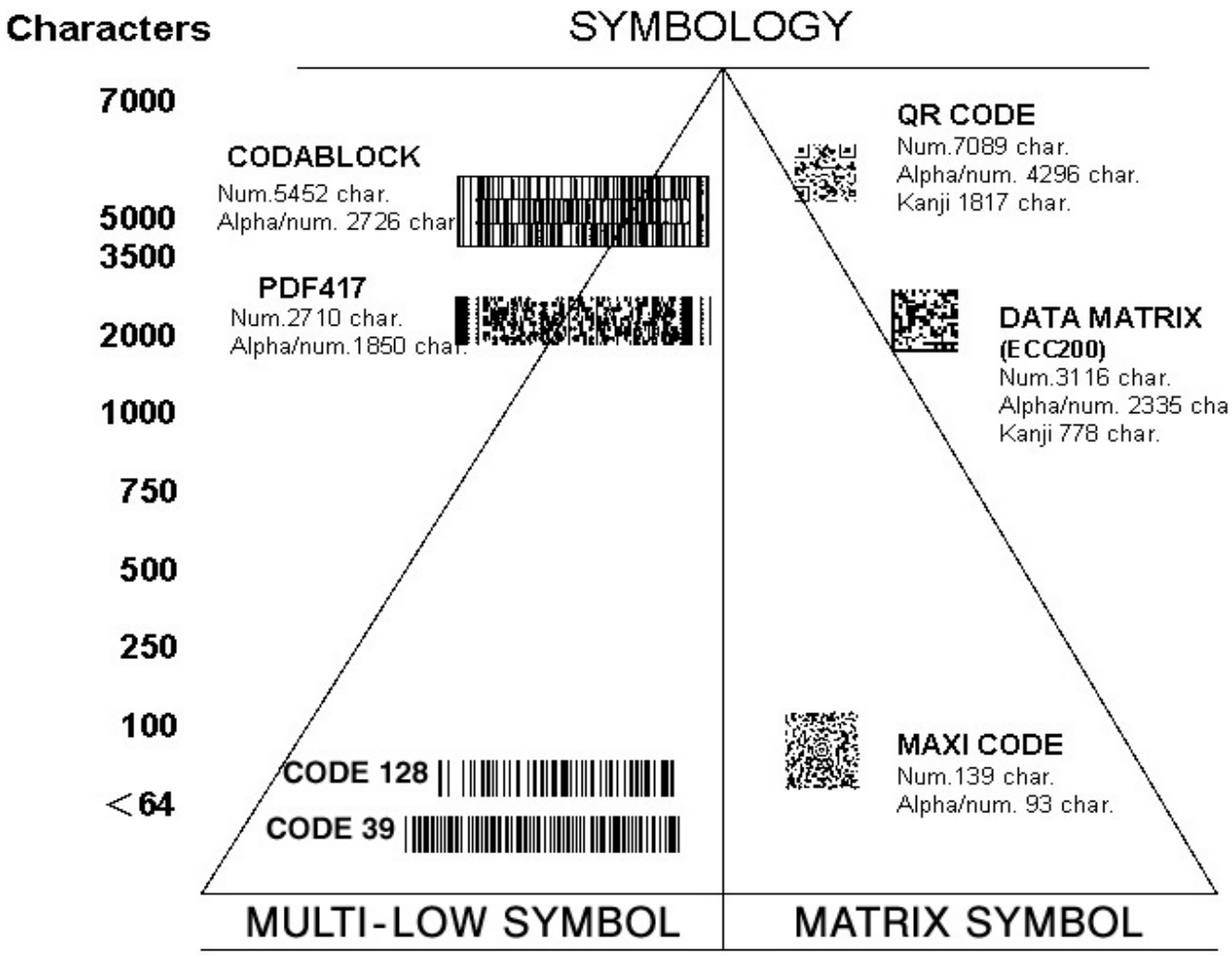
Matrix symbols are more suitable for high-speed reading than multi-row symbols (stacked symbols). The symbols included in the images obtained via a CCD type reader are normally rotating. It takes time to recognize data string (linear bit stream) of the multi-row symbol, to calculate the width of the bar and space, and then to convert that data. The multi-row type 2-dimensional symbols are not suitable for high-speed reading. Since matrix symbols have their intersection point of its orthogonal coordinate axes binarized in black or white, it is easier to binalize against the rotating image. From among the matrix symbols, QR codes has a special finder pattern to enable high-speed reading. QR codes, which have approx. 80 characters encoded, can have 30 symbols read in a single second. Although maxi codes, which has been developed for the purpose of high-speed reading, have their number of digits fixed (approx. 100 digits), it still can have more than 20 symbols read in a single second. Linear symbols can have approx. 15 symbols read in a single second as long as they are consisted of approx. 20 digits, but in that case, they would need to have the height of the symbols (the length of the longer bar) higher. Linear symbols are often read by single-beam lazors or linear CCD sensors; it is necessary to accurately align the scan line at the right angle with the bar direction of the linear symbol. The information stored in the symbol are as shown in the following comparison chart.

Samples for a message of 80 characters:
1234567890-123456720-123456-30-234567-40
ABCDEFGH50IJKLMNOP60QRSTUVWX70YZABCDEF80



3. Maximum Number of Characters that can be stored

QR codes can store 7089 numerical characters, 4296 alphanumerical characters, and 1817 Kanji characters at maximum. Codablocks can store 5452 numerical characters and 2726 alphanumerical characters at maximum. Codablock has much larger storage capacity than PDF417. Maxi code is the only 2-dimensional symbol whose number of characters is fixed. Maxi code can store 139 numerical characters and 93 alphanumerical characters at maximum. Even if it contains less data (stored characters), the size of the maxi code is fixed. Linear symbols are assumed to contain approx. 30 characters at maximum considering their reading operationability, but in some cases, as much as approx. 50 characters are being stored depending on the application. However, it is assumed that the maximum allowable amount of characters would be approx. 30 characters considering the reading operationability.



4. Number of Bits Required for Storing a Single Character

The number of bits (modules) required for storing a single character is different according to the symbol type. Basically, the number of bits required for storing a single character determines the information density for that symbol. The target is Model 2 for QR codes and ECC200 for data matrix. QR codes can have a single numerical character stored in 3,3 bits, and a single alphanumerical character in 5,5 bits. Data matrix can have a single numerical character stored in 4,0 bits and a single alphanumerical character in 5,3 bits. PDF417 can have a single numercial character stored in 5,8 bits and a single alphanumerical character in 8,5 bits. QR codes can have 3 numerical characters stored in 10 bits, which means that a single numerical character can be stored in 3,3 bits, and it can also have 2 alphanumerical characters stored in 11 bits, which means that a single alphanumerical character can be stored in 5,5 bits. The types of alphanumerical characters that can be stored in 5,5 bits are the same with those for Code 39, which are consisted of the 45 types of; number 0-9, alphabet A-Z, space, $, %, *, +, - , ., /, and ;. Data matrix can have 2 numerical characters stored in 8 bits, which means that a single numerical character can be stored in 4,0 cits, and it can also have 3 alphanumerical characters stored in 16 bits, which means that a single alphanumerical character can be stored in 5,3 bits. The types of alphanumerical characters that can be stored in with 5,3 bits are consisted of the 37 types of; number 0-9, alphabet A-Z, and space. Data matrix can have alphanumerical characters stored in less number of bits when compared with QR codes, but we must note that only space is available for special symbols. PDF417 can have a single code word stored in 17 bits. PDF417 can store 44 digits of numerical characters in 15 code words (255 bits), which means that a single numerical character can be stored in 5,8 bits, and it can also store 2 alphanumerical characters in a single code word (17 bits), which means that a single alphanumerical character cah be stored in 8,5 bits. In binary mode (byte mode), 6 digits can be stord in 5 code words (85 bits) which means that a single digit can be stored in 14,2 bits.

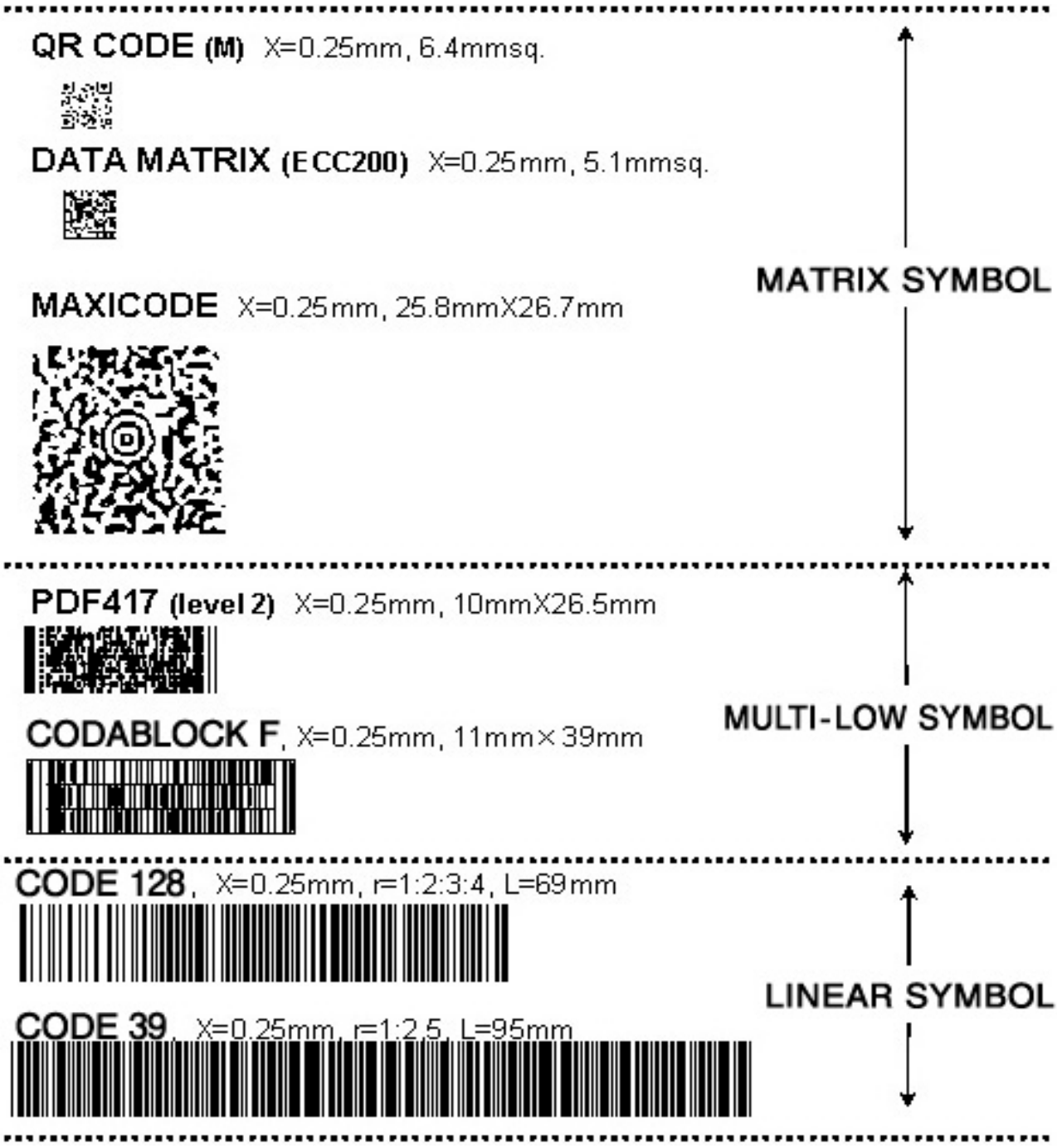
Encoding mode	QR CODE 	DATA MATRIX 	PDF417 
numeric	3.3bits	4bits	5.8bits (modules)
alphanumeric	5.5bits	5.3bits	8.5bits (modules)
binary (kanji)	8bits (16bits)	8bits (16bits)	14.2bits (modules) (28.4bits)(modules)
Kanji	13bits	to be encoded in binary mode	to be encoded in binary mode
mode indicator	4bits	8bits	17bits (modules)

5. Information Density

5-1 27 Alphanumerical Characters

We will assume that the module size is consolidated into 0,25mm. We will also assume that the QR code error correction level to be level M (error correction level equivalent with the data matrix error correction level), and that the PDF417 error correction level to be level 2 (error correction code equivalent with the data matrix error correction level). The error correction level for data matrix errors will be determined automatically. Based on that assumption, when 27 alphanumerical characters are encoded, the QR code will be sized 6,4 square mm, the data matrix sized 5,1 square mm, and PDF417 sized 10mm x 26,5mm. The information stored in the symbol are as shown in the comparison chart below.

Samples for a message of 27 characters: +HIBC12345678901/9901510234



5-2. 80 Alphanumerical Characters

Here we will compare the sizes for a QR code, data matrix, and PDF417 when the module sizes are in 3 types of 0,25mm, 0,35mm, and 0,5mm. We will assume that the QR code error correction level to be level M (error correction level equivalent with the data matrix error correction level), and that the PDF417 error correction level to be level 3 (error correction code equivalent with the data matrix error correction level). The error correction level for data matrix errors will be determined automatically. The information stored into the symbol is consisted of 80 alphanumerical characters. With the conditions listed above, the QR code and the data matrix will have approximately the same size, but PDF417 will be approx. 4 times larger than the QR code. The information stored in the symbol are as shown in the comparison chart below.

Samples for a message of 80 characters:
1234567890-123456720-123456-30-234567-40
ABCDEFGH50IJKLMNOP60QRSTUVWX70YZABCDEF80

QR CODE (M)

X=0.25mm 8.2mm sq.

X=0.35mm 11.5mm sq.

X=0.5mm 16.5mm sq.

DATA MATRIX

X=0.25mm 8.0mm sq.

X=0.35mm 11.2mm sq.

X=0.5mm 16.0mm sq.

PDF417 (level 3)

X=0.25mm 34.2mm×15mm

X=0.35mm 47.9mm×21mm

X=0.5mm 68.5mm×30mm

5-3. 120 Japanese Kanji Characters

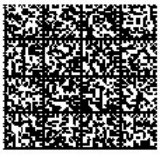
Here we will compare the sizes for a QR code, data matrix, and PDF417 when the module size is 0,3mm. We will assume that the QR code error correction level to be level L (error correction level equivalent with the data matrix error correction level), and that the PDF417 error correction level to be level 4 (error correction code equivalent with the data matrix error correction level). The error correction level for data matrix errors will be determined automatically. The information stored into the symbol is consisted of 96 Japanese Kanji characters, 12 space characters, and 2 " mark characters, totalling to 120 characters. With the conditions listed above, the QR code will be sized 15,9 square mm, the data matrix will be sized 19,2 square mm, and the PDF417 will be sized 27x61,5mm. Since QR codes can store Japanese Kanji characters in 13 bits, its storage efficiency is improved by 20% when compared with data matrix. The information stored in the symbol are as shown in the comparison chart below.

Samples for a message of 120 characters:

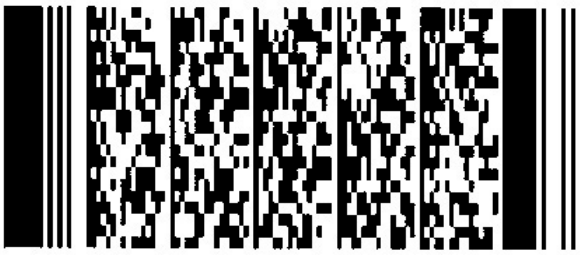
"日本自動車工業会 日本自動車部品工業会 日本自動車工業会 日本自動車部品工業会 日本自動車工業会 日本自動車部品工業会 日本自動車工業会 日本自動車部品工業会 日本自動車工業会 日本自動車部品工業会"

QR CODE (L)
X=0.3mm
15.9mm sq.

DATA MATRIX
X=0.3mm
19.2mm sq.



PDF417 (level 4)
X=0.3mm
27mm × 61.5mm



5-4. 200 Japanese Kanji Characters and Alphanumerical Characters

Here we will compare the sizes for a QR code, data matrix, and PDF417 when the module size is 0,3mm. We will assume that the QR code error correction level to be level L (error correction level equivalent with the data matrix error correction level), and that the PDF417 error correction level to be level 4 (error correction code equivalent with the data matrix error correction level). The error correction level for data matrix errors will be determined automatically. The information stored into the symbol is consisted of 60 numerical characters, 20 alphabetical characters, 96 Japanese Kanji characters, 12 space characters, and 2 " mark characters, totalling to 200 characters. With the conditions listed above, the QR code will be sized 17,1 square mm, the data matrix will be sized 21,6 square mm, and the PDF417 will be sized 30,6mmx61,5mm. The storage efficiency of the QR code is improved by 25% when compared with data matrix. The information stored in the symbol are as shown in the comparison chart below.

Samples for a message of 200 characters:

12345678901234567890123456789012345678901234567890123456789012345678901234567890ABCDEFGHIJKLMNOPQRST"日本自動車工業会 日本自動車部品工業会 日本自動車工業会 日本自動車部品工業会 日本自動車工業会 日本自動車部品工業会 日本自動車工業会 日本自動車部品工業会 日本自動車工業会 日本自動車部品工業会 日本自動車工業会 日本自動車部品工業会"

QR CODE(L)
X=0.3mm
17.1mm sq.

DATA MATRIX
X=0.3mm
21.6mm sq.

PDF417 (level 4)
X=0.3mm
30.6mm × 61.5mm

5-5. 1365 Alphanumerical Characters

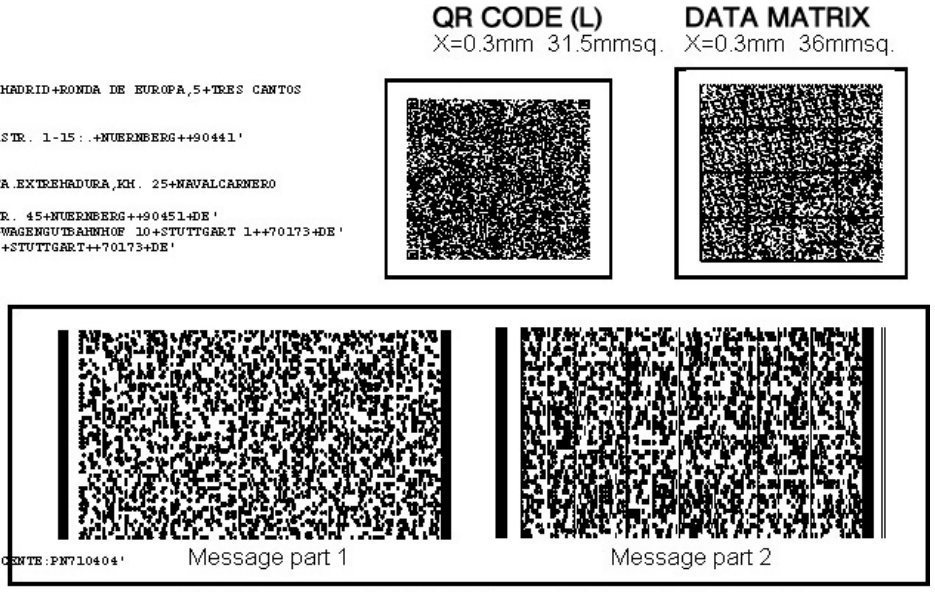
Here we will compare the sizes for a QR code, data matrix, and PDF417 when the module size is 0,3mm. We will assume that the QR code error correction level to be level L (error correction level equivalent with the data matrix error correction level), and that the PDF417 error correction level to be level 6 (error correction code equivalent with the data matrix error correction level). The error correction level for data matrix errors will be determined automatically. The information stored into the symbol is consisted of 1365 characters for an EDI message using ISO/IEC646 character set. With the conditions listed above, the QR code will be sized 31,5 square mm, the data matrix will be sized 36 square mm, and the PDF417 will have to have the information stored by being devided into 2 symbols. The total size of the 2 symbols is 42,7mmx172mm. The information stored into the symbol are the EDI messages shown on the left side of the comparison chart below.

PART1

```
[)>-06 -
UNH+3104  01506430+DESADV:D:95A:UN++: '
BGM+351+PN710404AA+9'
DTM+124:970630:101'
RFF+IV:PN710404AA'
DTM+3:970627:101'
RFF+AEE:***AKH***'
DTM+171:970627:101'
RFF+AFC:00625'
DTM+137:970630:101'
NAD+BY+01100::91++S234567, S.A.::SUCURSAL MADRID+RONDA DE EUROPA,5+TRES CANTOS
(MADRID)++28760+ES'
RFF+ADE:01100VPN14CY8151'
NAD+SU+::92++S234567 AG:ASI:.+VOGELWEIHERSTR. 1-15:.+NUERNBERG++90441'
RFF+JB:PP950-0000710404'
NAD+CS+EVNA5::91'
NAD+UC+::92++PAPELERA DEL CENTRO,S.A.+CRTA.EXTREMADURA,KM. 25+NAVALCARNERO
(MADRID)++28600S+ES'
NAD+FW+GES04::91++HANS GEIS+DUISBURGER STR. 45+NUERNBERG++90451+DE'
NAD+*F3+SEC05::91++SCHENKER EUROCARGO AG+WAGENGUTBAHNHOF 10+STUTTGART 1++70173+DE'
NAD+*F4+::91++SCHENKER+WAGENGUTBAHNHOF,10+STUTTGART++70173+DE'
NAD+UD+0163740::92+++++++ES'
RFF+UC:04.04.97 REF.JG/BE'
TOD+6++*H'
LOC+1++:16+DE:162:5'
TDT+13++*H'
CPS+1++4'
FTX+AAK++*N'
PAC+3++*EF:ESS:91+S::SA'
```

PART2

```
MEA+WT+AAD+KGM:3286.32'
MEA+WT+AAC+KGM:3180'
MEA+PL+LN+CMT:160'
MEA+PL+WD+CMT:76'
MEA+PL+HT+CMT:110'
MEA+WT+D+KGM'
PCI+*6+PN710404AA:PN710404AA:PN710404AA'
RFF+CW:001'
PCI+3+40/MASI/V/CY8151:GIL SUARES JOSE VICENTE:PN710404'
LIN+1++LLA63164AA60-E:SA'
PIA+1+85015392:CV'
PIA+1+H53'
IMD+B+8+:::BAUF?:B 3   / LEIST?: 160'
MEA+WT+AAL+KGM:1060'
QTY+21:3:PCE'
FTX+CCI++J+024:028:039:046:052'
FTX+CCI++J+053:054:055:060:061'
FTX+CCI++J+063:064:066:068:091'
FTX+CCI++J+600:624'
RFF+*AG:N'
RFF+*EC:N'
SGP+PN710404AA001+1'
UNT+49+3104  01506430'
UNS+30+(BAV)97060229'
J
```



PDF417 (level 6) X=0.3 42.7mm x 172.0mm (86.0mm x 2)

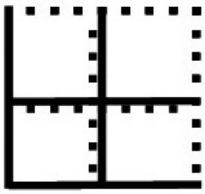
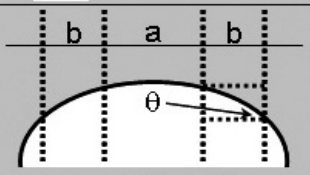
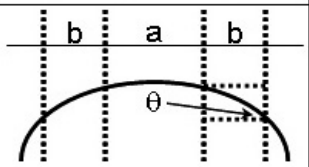
6. Defective Finder Patterns

2-dimensinal symbols can have their data restored by utilizing the error correction functionality even when they are defective due to having their data area smeared or torn. However, defective finder patterns cannot be restored. Since QR codes have 3 characteristic finder patterns, they have high readability even when their finder patterns are defective. Specifically talking, the QR code can be read even if 2 out of 3 finder patterns turn out to be defective. The finder pattern for data matrix is in L-shape; if the intersection part of the horizontal line and the vertical line is defective, the base point of the entire symbol would become unclear, and therefore it would be difficult to read that data matrix. It will be difficult to read PDF417 when its start or stop pattern on both ends are defective.

	QR CODE	DATA MATRIX	PDF417
			
15% clipping of corner damaged			
15% side missing			
reading	good	difficult	possible

7. Curved Symbols

Linear symbols are created based on the premise that they will be used by being printed upon labels etc. and attached on a flat surface. However, actual application cases often have the printed symbols or the labels curved. Many linear symbols (GS1 codes, JAN codes) attached onto products sold at convenience stores or super markets are curved. To be able to read curved linear symbols, it is required to make the threshold of the bar width variable, and reader manufacturers are making various efforts to do so. Bar widths are often varied by 20% or more in printing, and if the bar width is varied by 30% or more by being curved, it would be extremely difficult to read that symbol. Multi-row type 2-dimensional symbols are structured in a way as if linear symbols are stacked, and therefore it is necessary to consider curvature in both horizontal and vertical direction, which makes it almost impossible to read them. Matrix-typed 2-dimensional symbols are using the intersection information where the horizontal axis and the vertical axis are orthogonal, and therefore it is easy to correct the coordinates. QR codes and data matrix have correction patterns (alignment patterns) that are developed based on a similar principle arranged within the symbols to support curved symbols. The length between the alignment patterns will be measured to correct the horizontal axis and the vertical axis based on the variance of these lengths (the variance will be 0 if the symbol is not curved) to enable correcting the coordinate of the intersection. These alignment patterns enable superior readability even for curved symbols.

	QR CODE	DATA MATRIX	PDF417
			
alignment pattern			not applicable
compensation	 a=normal length b=a x cosθ	 a=normal length b=a x cosθ	not applicable
reading	possible	possible	difficult

8. Dividing the Symbols (Structured append)

When the area for printing the symbol or attaching the symbol label is small, various efforts need to be made for printing the symbol. There are cases where we need to make direct markings upon small products for a symbol with limited amount of information, or where we need to symbolize information with large volume such as those for a contract document and then print it onto a document page. In such cases, a single symbol within the reader view angle may not be enough to have all the information contained. QR codes are equipped with a functionality for being devided and printed (structured append), so we can simply divide the data and store the divided data into each of the divided QR code. The QR codes will contain the division information, so we can make sure whether we have read all of the QR codes.

Listed below is a specific example. Let's assume here that we are having QR codes attached onto various products to have them automatically read within a production process or a sorting process within a logistics warehouse. In this case, the size of the QR codes (module size) may vary, and the position where the QR codes are attached may be flactuated. Therefore, we would be using a lense with superior depth of field to ensure readability. However, there are some cases where the QR code may not be contained into the optical view angle due to the optical limitations. For such cases, the data will be divded (the example has the data divided into 3) and then encoded into QR codes, so that the symbol size would be smaller and enabled to be read.