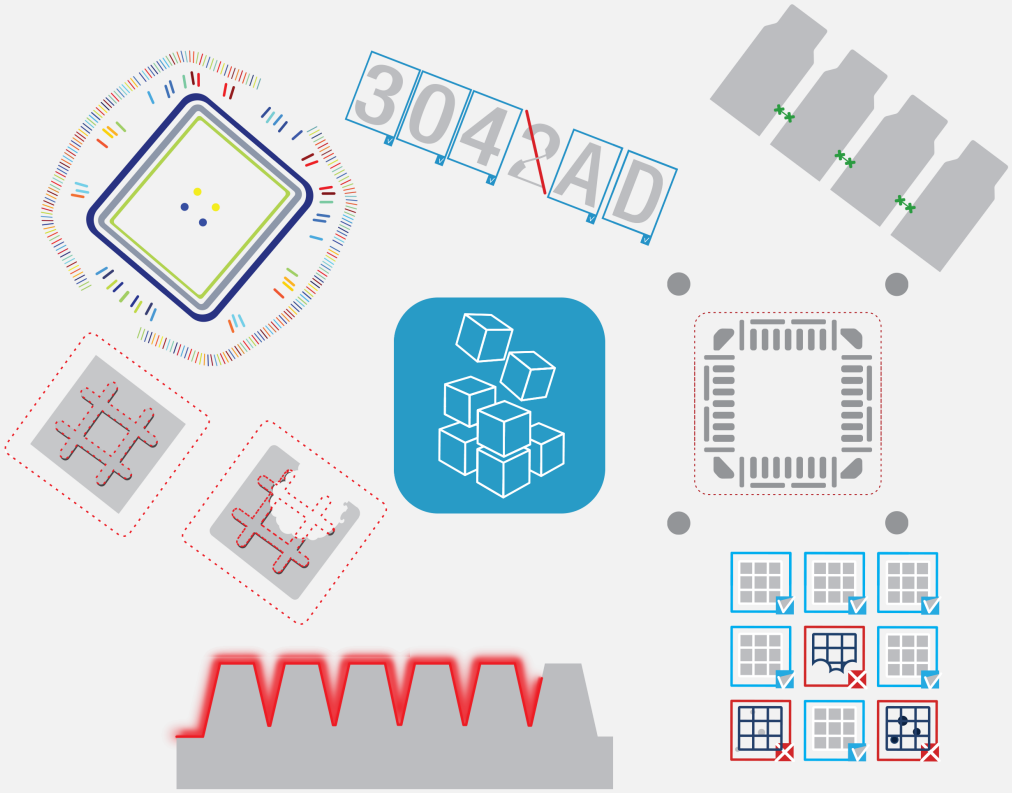
euresys
Empowering Computer Vision

USER GUIDE

Open eVision

Code Grading Guide



This documentation is provided with **Open eVision 24.02.0** (doc build **1198**).
www.euresys.com

Contents

1. What Is Grading?

The "code grading", or "code quality verification", is a process that assesses the quality of a printed or engraved code.

- Different grading standards exist, each pertaining to one or more code types, that specify several grading parameters and how to compute them. In addition to these parameters, a global grade is often computed to summarize the overall quality of the code.
- When a code receives a failing grade, identifying which grade(s) caused the failure can help to locate the physical problem.
- The grades are generally returned:
  - As letters, from A (best) to F (worst).
  - As numbers: from 4.0 (best) to 0.0 (worst).
- While grading is meant to assess the print quality of a code, it also requires specific capture conditions to give accurate results. However, if these conditions are not met, the grading results might give insight on how you can improve your acquisition setup for better results.
- The grading standards currently implemented within **Open eVision** are:
  - **ISO/IEC 15416** for 1D bar codes
  - **ISO/IEC 15415** for data matrix codes and QR codes
  - **ISO/IEC 29158** for data matrix codes and QR codes
  - **SEMI T10-0701** for data matrix codes

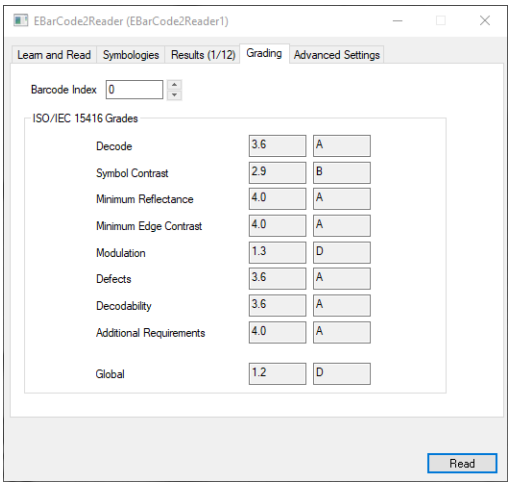
2. How to Compute the Grading with Open eVision

Read the grades in Open eVision Studio

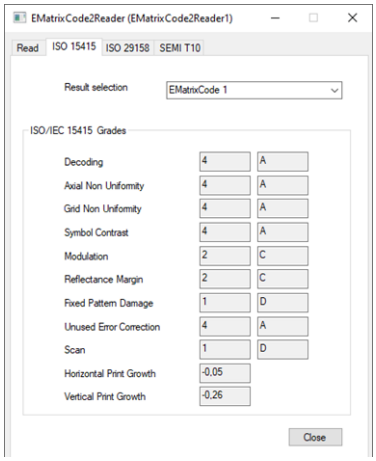
In **Open eVision Studio**:

1. Open an image.
2. Check `Compute Grading` in the first tab of the tool.
3. Read a bar code, a matrix code or a QR code.
4. Open the tab(s) named `Grading` or after the standard name.

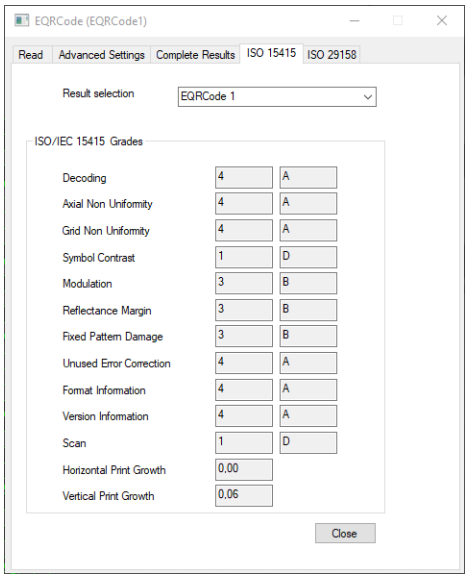
► The tables list the grades (both as numbers and as letters) and the measurement values.



The ISO 15416 grades in EasyBarCode2



The ISO 15415 grades and values in EasyMatrixCode2



The ISO 15415 grades and values in EasyQRCode

Compute the grades in the API

In **Open eVision**, each type of code is handled by a specific reader class:

- 1D Barcode: EasyBarCode2::EBarCodeReader
- QR Codes: EQRCodeReader
- Data Matrix Codes: EasyMatrixCode2::EMatrixCodeReader

While the reader classes are different, the way to compute and retrieve the grading results is the same:

1. Instantiate the relevant reader class.
2. Use `SetComputeGrading(true)` to enable the grading computation.
3. For **ISO 29158** only, use `SetIso29158CalibrationParameters` to set up the calibration parameters (see "ISO/IEC 29158 for Data Matrix and QR Codes" on page 17).
4. Use `Read` on an image containing a code to read and grade the code.

5. Use the corresponding accessor(s) to retrieve the calibration results for the relevant grade(s):
   - For **ISO 15415**: `GetIso15415GradingParameters`
   - For **ISO 15416**: `GetIso15415GradingParameters`
   - For **ISO 29158**: `GetIso29158GradingParameters`
   - For **SEMI T10-0701**: `GetSemiT10GradingParameters`

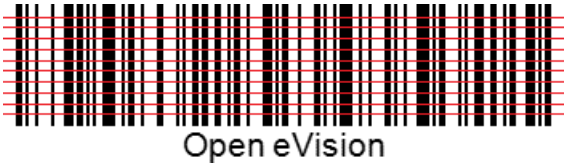
3. ISO/IEC 15416 for 1D Bar Codes

ISO 15416 is a standard that establishes the guidelines on how to assess the print quality of linear (1D) bar code symbols.

It provides a set of quality indicators that give insight on specific areas of the bar code quality. You can use these indicators to compute an overall grade for the inspected bar code.

NOTE
In **Open eVision** 23.12, **ISO 15416** grading is only available for the **Ean13**, **Code128** and **Gs1-128** symbologies.
You can find more information on these symbologies on the ISO website (must be purchased) and on the GS1 website (for free).

The scan lines



Each grade is computed on 10 horizontal scan lines:

1. A margin of 10% is removed at the top and at the bottom of the bar code.
2. The 10 scan lines are distributed evenly on the remaining bar code.
3. A grade between 4.0 and 0.0 is computed for each line.
4. The global grade is the average of the grades for each line.

The decoding

For each scan line, a global threshold is computed:

1. All pixels above the threshold belong to a space and all pixels below to a bar.
2. **Open eVision** computes the exact bar / space widths with sub-pixel interpolation.
3. **Open eVision** decodes the scan line with the reference decoding algorithm of the symbology.

NOTE
This decoding process is imposed by **ISO 15416**.
Open eVision uses a different and more robust algorithm (based on gradients instead of thresholds) to locate the bars and the spaces of a bar code. Thus, **Open eVision** can recognize and read bar codes that are otherwise not decoded by this simpler **ISO 15416** process (for example when the illumination is not uniform along the bar code).

The grade values

Each grade is represented by a number from 4.0 to 0.0 with 0.1 steps or by letters from A to F.

- In this document, we use the numbers notation.
- **Open eVision** returns integers from 40 to 0 instead of float values from 4.0 to 0.0 to avoid any rounding issue.

Numeric grade	Alphabetic grade
4.0 to 3.5	A
3.4 to 2.5	B
2.4 to 1.5	C
1.4 to 0.5	D
0.4 to 0.0	F

The ISO 15416 quality indicators

The decode grade

- For each scan line, the *decode grade* is set to 4.0 if the decoding succeeds and 0.0 otherwise.

Symbol Contrast grade

- The *symbol contrast grade* indicates the fraction of the total image contrast used by the bar code for each scan line.

► If the printing contrast is too weak, if the lighting is not bright enough or if the camera exposure time or gain is too small, the grade is low.

The bars and the spaces are too close on the gray scale

The minimum reflectance grade

- For each scan line, the *minimum reflectance grade* is set to 4.0 if the lowest gray value is less than half of the highest gray value and 0.0 otherwise.

► If the printed barcode or lighting is too bright or if the camera exposure or gain is too high, the grade is low.

The minimum edge contrast grade

- The *minimum edge contrast grade* indicates the smallest contrast between two adjacent bar and space (including the quiet zones). For each scan line, this grade is 4.0 if the minimum edge contrast is at least 15% (38 gray values) and 0.0 otherwise.

▶ A dirty background can result in a low grade.

One space is too dark

The modulation grade

- The *modulation grade* indicates the importance of the minimum edge contrast relative to the symbol contrast.

▶ A dirty background can result in a low grade.

There is a light defect in the bar

The defects grade

- The *defects grade* indicates the importance of the irregularities found within the elements and the quiet zones.
  - Damaged or dirty bars or spaces can result in a low grade.

The decodability grade

- The *decodability grade* indicates the importance of the differences between the distances measured and expected.

► If the distances measured are far from those expected, the grade is low.

- Bad measured distances can have several causes:
  - The code is badly printed.
  - The image acquired by the camera is blurry / noisy.
  - The image acquired by the camera has a resolution that is too small.

The bar is 1 px too large and the space is 1 px too thin

The additional requirements grade

- The *additional requirements grade* indicates a requirement that is specific to a symbology.

► **Code128**, **Gs1_128** and **Ean13** grade the size of the quiet zone of the bar code. If the quiet zone is too small for a line, the associated grade is 0.0.

The global grade

- For each line, the *global grade* is the smallest of all the other grades.

► If two scan lines yield different decoded strings, the *global grade* is set to 0.0, irrespective of the other scan lines.

4. ISO/IEC 15415 for Data Matrix and QR Codes

ISO 15415 is a standard that establishes the guidelines on how to assess the print quality of 2D bar code symbols, either multirow bar codes or two-dimensional matrix symbologies such as data matrix and QR codes.

It provides a set of quality indicators that give insight on specific areas of the bar code quality. You can use these indicators to compute an overall grade for the inspected bar code.

The ISO 15415 as a print quality assessment tool

To be used as a print quality assessment tool as intended, the **ISO 15415** standard requires very specific acquisition conditions.

These conditions might include, but are not limited to:

- A camera perpendicular to the plane of the code to be assessed.
- 4 light sources, placed at the 4 cardinal points around the code and providing specific illumination at a 45° angle.
- An 8-bit gray-scale digitization.
- A 1:1 magnification lens.
- At least 5 pixels per module on the produced image.
- A symbol centered in the image.

For more information about those conditions, please refer to chapter 7 of the standard.

The ISO 15415 as a symbol and/or setup quality assessment tool

Obviously, the conditions above are difficult to meet. However, the **ISO 15415** standard is still useful as an assessment tool of your symbol and/or setup quality even if all those conditions are not met.

In the following paragraphs, we will give you insights on how to use the returned grades to that effect.

NOTE

As **Open eVision** assesses one image at a time, it provides, according to the standard, a scan grade.
To compute an **ISO 15415** overall grade, you need to make a total of 5 acquisitions with different symbol rotations, grade each of these acquisitions using **Open eVision** and then average the results.

The ISO 15415 quality indicators

The decode grade

- The *decode grade* indicates if the symbol is readable (if it can be correctly decoded) by the symbology reference decoding algorithm.

The symbol contrast grade

- The *symbol contrast grade* is a measure of the relative difference of reflectance between the brightest and the darkest module in the symbol.

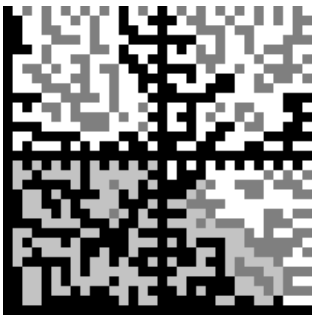
▶ If this grade is low, the detection and the digitization are more difficult as it is difficult to separate the code from the background.

A data matrix with a low contrast

The modulation grade

- The *modulation grade* is a measure of the uniformity of the reflectance of the dark and light modules.

▶ If this grade is low, the digitization is more difficult, as the variations prevent finding an easy way to separate white from black.



A data matrix with a low modulation grade

The reflectance margin grade

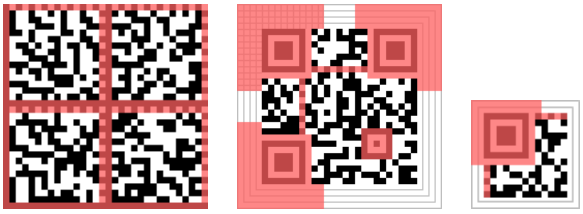
- The *reflectance margin grade* is a measure of how the modules colors are distinguishable relative to the global threshold. This global threhold is the mean reflectance of the brightest and the darkest module.

▶ If this grade is low, the digitization is less reliable. As the cells are too close to the separation limit, the light and dark cells can be confused.

A data matrix with a low modulation grade

The fixed pattern damage grade

- The fixed patterns of the symbols characterize the symbols as such. The *fixed pattern damage grade* indicates the likelihood that the symbol is correctly located and identified in the image.



The areas relevant for this grade

The axial nonuniformity grade

- The *axial nonuniformity grade* is a measure of the isotropy of the principal axis of the symbol relative to its corresponding ideal symbol geometry.

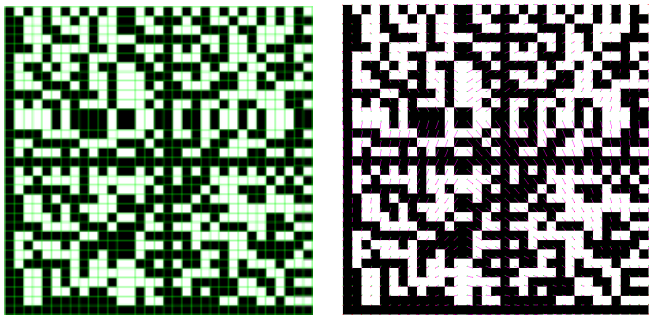
▶ Usually, a low grade here only causes issues if a column or a row becomes too small to be accurately sized during the gridding.

A data matrix stretched along its horizontal axis

The grid nonuniformity grade

- The *nonuniformity grade* is a measure of the maximum relative deviation of the intersection of the lines of the estimated grid from to its corresponding intersection in an ideal grid.

▶ The lower the grade, the less uniform the shapes of the modules of the symbol are. However, this grade relies on a maximum deviation. It is thus quite unstable and its practical usage is limited.

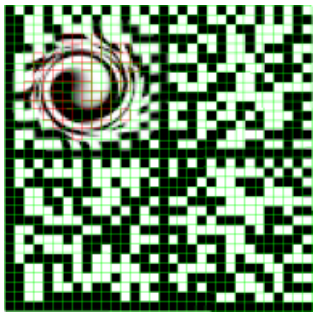


On the left, the grid is computed from a data matrix in which the vertical and horizontal lines comprise one specific module and it had been stretched
On the right, the green dots correspond to the expected positions of the corners of the modules if the grid had been uniform

The unused error correction grade

- The *unused error correction grade* indicates the extent to which the error correction algorithm capacity was used to decode the symbol.

▶ A low grade is a sign that any further degradation of the acquisition conditions will lead to a decoding failure.



A data matrix with damaged modules that requires the use of error correction

The format information grade (QR codes and micro QR codes)

- The *format information grade* indicates the readability of the format information blocks.

► The lower the grade, the more errors must be corrected to recover the error correction level and the masking pattern that are necessary to reliably decode the symbol.

The areas relevant for this grade

The version information grade (QR codes)

- The *version information grad*e indicates the readability of the version information blocks.

► The lower the grade, the more errors must be corrected to recover the version of the symbol.

NOTE: This is relevant only for versions ≥ 7.

The areas relevant for this grade

The scan grade

- The *scan grade* is the lowest grade value of all the grade indicators. It is a measure of the overall quality of the code in the image.

5. ISO/IEC 29158 for Data Matrix and QR Codes

The **ISO 29158** standard is a modification and an extension to the **ISO 15415** standard designed to be more adapted to the grading of DPM (Direct Part Mark) codes.

- It specifies a new acquisition methodology as well as new quality indicators specifically aimed at DPM symbols.
- Compared to **ISO 15415**, the new acquisition methodology simplifies the acquisition setup at the cost of calibrating of this setup and providing the resulting calibration parameters to the grading process.

Calibrating an ISO 29158 setup

To perform the calibration, you must record the image of an "ideal" (perfect) code on the setup.

To have a successful calibration:

1. Set up the Illumination and acquisition parameters (gain, exposure...) so that the *Mean Light* (ML, the mean value of the pixels of the center of the light cells) is in the range considered valid by the standard (70%~86% of the maximum gray level).

   NOTE: To compute the *Mean Light* with **Open eVision**, grade the symbol with the default calibration parameters and retrieve it from the structure returned by `GetIso29158CalibrationParameters`.

2. Record the ML as `MLCal`.

Compute the other calibration parameters:

3. `RCal`, the calibration reflectance, is the maximum reflectance of the calibration symbol, that is the gray level of the lightest cell.
   - This gray level is computed as the mean gray level on the aperture.
   - The aperture is a circle of a radius 50% or 80% of the cell width and centered on the middle of the cell.
4. `SRCal`, the calibration system response, represents the parameters used to set the brightness of the image at the calibration time.
   - It can be the gain, the exposure, the global illumination due to the lighting angle or even a combination of those.
   - Its nature does not matter as long as the same measure is used for `SRCal` and `SRTarget`.

   NOTE: `SRTarget` is the same measure as `SRCal` but taken at the grading time. Since it is part of the calibration parameters, it should be computed at grading time and passed along the other parameters using `SetIso29158CalibrationParameters` just before calling `Read`.

ISO 291528 Quality Indicators

The cell contrast grade

- The *cell contrast grade* is a measure of the relative difference between the mean reflectance of the brightest and of the darkest modules in the symbol.

▶ If the grade is low, the digitization is more difficult as it is difficult to separate the dark from the light cells.

The cell modulation grade

- The *cell modulation grade* is a measure of the variability and the reliability of cell colors. In essence, it is a combination of the *modulation grade* and *reflectance margin grade* of **ISO 15415**. It is thus a composite grade.

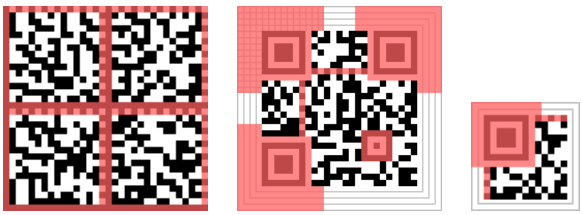
▶ If this grade is low, the digitization is more difficult, as the variations prevent finding an easy way to separate the white from the black. It is also less reliable, as the cells might be too close from the threshold for a clear dark/light classification.

The fixed pattern damage grade

The fixed patterns of the symbols are what characterize the symbols as such.

- The *fixed pattern damage grade* is a measure of the likelihood that the symbol is correctly located and identified in the image.

▶ If this grade is low, the detection and the grid determination are more difficult.
  - □ Finder pattern damages can prevent the recognition of a candidate as a valid code.
  - □ Timing pattern damages can prevent the correct computation of the grid.



The areas relevant for this grade

The minimum reflectance grade

- The *minimum reflectance grade* represents the difference between the calibration conditions and the acquisition conditions.

▶ It is set to 0.0 if the difference is too big for the grading results to be accurate and 4.0 otherwise.

6. SEMI T10-0701 for Data Matrix Codes

SEMI T10-0701 is a grading standard intended to provide quality indicators for DPM (Direct Part Mark) Data Matrix codes. It does not provide guidelines for paper-printed ones.

- **SEMI T10-0701** does not provide grades as defined by the other standards. It does not give ratings (A to F or 4.0 to 0.0) but only numerical values.
- The interpretation of these numerical values is left to the application and can depend on the application context.

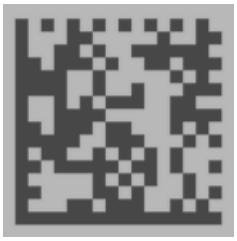
NOTE: **SEMI T10-0701** is pixel-based, in contrast to the other standards. As such, it can be more suited to computer vision purposes, as the specifications are designed with computer processing in mind.

SEMI T10-0701 quality indicators

The symbol contrast

- The *symbol contrast* measures the relative distinctiveness between the light and the dark parts of the code.
- The closer the *symbol contrast* is to 100%, the more the marks and the spaces are color-separated and the code easier to read.
- A mark is defined as a cell of the data matrix that is modified by the marking process (where the substrate is altered, usually resulting in a darker color) while a space, conversely, is left untouched.

► A low contrast score can indicate either a bad printing quality, a bad image contrast or an incorrect code illumination. The detection and the digitization are more difficult as it is difficult to separate the code from the background.



A low contrast data matrix

The symbol contrast SNR

- The *symbol contrast SNR* (Signal to Noise Ratio) measures the relative strength of the noise in the code. You can also see it as the ratio of the useful dynamic (symbol contrast) used to separate white from black.
- The higher this value, the less noise is present in the image of the code.

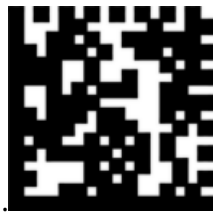
▶ If this grade is low, the digitization is more difficult as it is difficult to separate light from dark.

A noisy data matrix

The mark growth

- The *mark growth* is the measure of the relative size of a mark compared to a space.
  - A value around 50% is ideal, as it means that the marks and the spaces are about the same size.
  - A value over 50% means that the marks cells are bigger than the spaces, hinting at overmarking.
  - A value under 50% hints at undermarking.
- The *mark growth* is computed as 2 separate values: the *horizontal mark growth* and the *vertical mark growth*.

▶ If the *mark growth* deviates from the ideal value (50%), the digitization is more difficult as some cells eat up part of the neighboring cells.



A data matrix showing mark growth

The data matrix mark misplacement

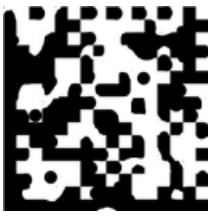
- The *data matrix mark misplacement* is the measure of the relative distance between the ideal position of a mark and its real position in the data matrix. The center of the mark is used as its position.
- The bigger this value, the more the data matrix is potentially deformed.
- The *data matrix mark misplacement* is computed as 2 separate values: The *horizontal data matrix mark misplacement* and the *vertical data matrix mark misplacement*.

- This grade is just an indicator of the cell position errors. Unless extreme, it should not hinder the processing.

Data matrices showing vertical (left) and horizontal (right) mark misplacement

The cell defects

- If the data matrix can be decoded, the correct placement of the marks and the spaces can be determined, and the *cell defects* value can be computed.
- The *cell defects* value is the measure of the ratio of incorrect pixels (pixels that have the wrong color) to the total number of pixels in the data matrix code.
- A high *cell defects* value hints at mark damage, space pollution, difficulties to separate the marks from the spaces or that there is a lot of noise in the image. This can hinder the reading of the code.



A data matrix showing cell defects

The finder pattern defects

- The *finder pattern defects* is the same kind of measure as *cell defects* but computed only on the cells of the finder pattern of the data matrix code.
- A high Finder Pattern Defects value hints at damage to the Finder Pattern, especially if the Cell Defect is otherwise markedly lower. Finder pattern damage might prevent the recognition of a candidate as a valid code.

A data matrix showing finder pattern defects

The unused error correction

- The *unused error correction* is the measure of how much of the error correction capability of the data matrix code was not used.
- The closer this value is to 0, the more error correction was applied to read the code.

▶ A low *unused error correction* can hint at errors in the code itself, difficulties to correctly determine the color of a cell or damage in the marks. It is also a sign that any further degradation of the acquisition conditions will lead to a decoding failure.

The data matrix cell size

- The *data matrix cell size* is the mean size, in pixels, of a cell in the data matrix.
- The *data matrix cell size* is computed as 2 separate values: the *data matrix cell width* (horizontal) and the *data matrix cell height* (vertical).

▶ You can use these values to compute the code anisotropy.

7. Implementation Specifics and Limitations

General limitations of the grading process

- **Open eVision** is an image processing software, and, as such, its inputs are arrays of pixels. Most standards discussed in this document provide guidelines based not on pixels, but on continuous surfaces presenting a continuous reflectance.
- Most standards also impose constraints on lighting and camera placement that **Open eVision** cannot check or enforce.
- All standards also make the hypothesis that the position of the code is perfectly known. That, in practice, is usually not true, especially for 1D bar codes.

▶ So, there is no guarantee that **Open eVision** returns exactly the same grade as other software tools (assuming there is no error in those), as choices made to alleviate or circumvent the previous points can differ.

- If you face important differences in grades for the same image or are unsure why some of your images are graded the way they are, feel free to contact **Euresys**' technical support.

Implementation specifics

- Given the pretty strict scope and requirements of the grading standards, it can be difficult, if not impossible, to grade some codes when the acquisition conditions are not perfect.

▶ Because of this, **Open eVision** sometimes implements some of the grading processes in a manner slightly different than the canonical one to allow a little more leeway in these conditions.

- These adaptations, however, are made in such a way that if the grading process is made within the requirements of the standard, it yields the required grades as values, as verified by the usage of tools such as conformance calibration test cards.

8. References

- **ISO/IEC 15415** - Bar code symbol print quality test specification – Two dimensional symbols: https://www.iso.org/standard/54716.html
- **ISO/IEC 15416** - Bar code symbol print quality test specification – Linear symbols: https://www.iso.org/standard/65577.html
- **ISO/IEC 15417** - Code 128 bar code symbology specification: https://www.iso.org/standard/43896.html
- **ISO/IEC 16022** - Data Matrix bar code symbology specification: https://www.iso.org/standard/44230.html
- **ISO/IEC 18004** - QR Code bar code symbology specification: https://www.iso.org/standard/62021.html
- **ISO/IEC 29158** - Direct Part Mark (DPM) Quality Guideline: https://www.iso.org/standard/69411.html
- **SEMI T10-0701** - Test Method for the Assessment of 2D Data Matrix Direct Mark Quality: https://store-us.semi.org/products/t01000-semi-t10-test-method-for-the-assessment-of-2d-data-matrix-direct-mark-quality
- **GS1** General Specifications: https://www.gs1.org/standards/barcodes-epcrfid-id-keys/gs1-general-specifications