

Ladislav Karrach
Elena Pivarčiová

**LOCATION AND RECOGNITION OF
DATA MATRIX AND QR CODES IN IMAGES**

2022

Authors:

Ladislav KARRACH, Ing. PhD.

Elena PIVARČIOVÁ, Prof. PhD.

Department of Manufacturing and Automation Technology

Faculty of Technology

Technical University in Zvolen

Zvolen, Slovakia

Reviewers:

Pavol BOŽEK, Dr.h.c. Prof. Ing. CSc.

Institute of Production Technologies

Faculty of Materials Science and Technology

Slovak University of Technology

Bratislava, Slovakia

Ivan KURIC, prof. Dr. Ing.

Department of Automation and Production Systems

Faculty of Mechanical Engineering

University of Žilina

Žilina, Slovakia

Dagmar JANÁČOVÁ, Prof. Ing. CSc.

Department of Process Control

Faculty of Applied Informatics

Tomas Bata University in Zlin

Zlin, Czech Republic

ISBN 978-3-96595-022-1

LOCATION AND RECOGNITION OF DATA MATRIX AND QR CODES IN IMAGES

Authors:

Ladislav KARRACH, Ing. PhD.

Elena PIVARČIOVÁ, Prof. PhD.

Reviewers:

Pavol BOŽEK, Dr.h.c. Prof. Ing. CSc.

Ivan KURIC, prof. Dr. Ing.

Dagmar JANÁČOVÁ, Prof. Ing. CSc.

Edition: 1st
Published by: RAM-Verlag
Year: 2022
Number of pages: 106
Number of copies: 100

© Copyright 2022 by RAM-Verlag

Publisher: RAM-Verlag

Stüttinghauser Ringstr. 44

D-58515 Lüdenscheid

Germany

RAM-Verlag@t-online.de

<https://ram-verlag.eu>



The publisher cannot be held responsible for any linguistic errors in the book:

Such responsibility is only up to the authors.

ISBN 978-3-96595-022-1

EAN 9783965950221

Location and Recognition of Data Matrix and QR Codes in Images

Ladislav Karrach¹ (0000-0002-5982-6806), Elena Pivarčiová^{1*} (0000-0002-6676-8245)

¹ Department of Manufacturing and Automation Technology, Faculty of Technology, Technical University in Zvolen, Masarykova 24, 960 01 Zvolen, Slovakia

* Corresponding author's email: pivarciova@tuzvo.sk

Abstract

Data Matrix and QR codes are two of the most popular types of two-dimensional (2D) matrix bar codes, which are the descendants of well-known 1D bar codes. However, compared to 1D bar codes, they offer many benefits. They enable us to store much more information in the same area, omnidirectional readability, readability even with partial code corruption, error correction, etc.

2D codes began to be used in the automotive industry but quickly spread to other areas. They are used by many industry organizations as an appropriate industry standard, are often used in production, distribution, storage, and sales processes in product labeling, and are also used in monitoring and analysis of production processes in car production.

The monograph deals with the recognition of Data Matrix and QR codes in images. It presents the current state of knowledge in the field and presents the principles of image processing that can be used to address the topic. The work summarizes the results of the scientific and research work of the authors and proposes their own original algorithms for the recognition of 2D codes in real-scene images. Our goal was to design an affordable solution that enables the processing of scanned 2D codes in real-time. Emphasis is placed on the possibilities of use in industrial practice.

We have proposed algorithms which localize single or multiple Data Matrix and QR Codes in an image and decode information, which is stored in them. Image processing techniques like edge detection, adaptive thresholding, connected component labeling, image moments, and local features under sliding window are utilized to identify objects of interest or areas in an image, which can be 2D codes or their parts. We also deal with partially damaged and perspective distorted 2D codes. The recognition rate of the presented algorithms was tested on publicly available test data sets of images with Data Matrix and QR codes. Test data sets are freely available online, so other authors can compare their results with ours. Algorithms are

computationally efficient, work well for low-resolution images, and are also suited to real-time processing.

The monograph is intended mainly for programmers and developers of business applications, researchers, teachers, doctoral students and students at technical universities, as well as for the scientific community and professionals with an interest in the topic.

This monograph was developed within the project KEGA 006STU-4/2021: "Progressive form of interdisciplinary education and support for the development of vocational subjects in the university environment".

Keywords: 2D matrix code, Data Matrix Code, QR Code, Finder Pattern, Timing Pattern.

Contents

1	Introduction.....	1
1.1	Introduction to two-dimensional matrix codes.....	4
1.2	Data Matrix Codes	6
1.3	QR Codes	9
1.4	Comparison of Data Matrix and QR Codes	12
1.5	Aztec codes	13
2	Analysis of existing methods	15
2.1	Detailed analysis of some selected methods	22
3	Methodology	26
3.1	Data Matrix Codes – Finder Pattern based localization methods	27
3.1.1	Edge Detection Methods (Method Group 1)	28
3.1.1.1	Connecting of Edge Points into Continuous Regions (Alternative 1)	29
3.1.1.2	Connecting of Edge Points into Continuous Regions (Alternative 2)	31
3.1.1.3	Evaluation of Finder Pattern Candidates	31
3.1.1.4	Validating of Finder Pattern Candidates and Aligning to Finder Pattern	32
3.1.2	Adaptive Thresholding Methods (Method Group 2)	33
3.1.2.1	Binarization Using Adaptive Thresholding	33
3.1.2.2	Connecting Foreground Points into Continuous Regions.....	34
3.1.2.3	Evaluation of Finder Pattern Candidates	35
3.1.2.4	Validating Finder Pattern Candidates and Aligning to Finder Pattern	37
3.1.3	Identification of Perspective Distortion and Setting-Up Perspective Transformation.....	39
3.1.3.1	Evaluation Distance to Timing Pattern.....	39
3.1.3.2	Setting-Up Perspective Transformation.....	40
3.1.4	Validating Data Matrix Code Area.....	41
3.1.5	Checking Timing Pattern of a Data Matrix Candidate	42
3.1.5.1	Checking Local Extremes along Expected Timing Patterns.....	42
3.1.5.2	Checking Horizontal and Vertical Edge Projections	43
3.1.6	Decoding the Data Matrix Code	44
3.2	QR Codes –Finder Pattern based localization methods	45
3.2.1	Finder Pattern Localization Based on 1:1:3:1:1 Search.....	47
3.2.2	Verification of Finder Patterns	49
3.2.3	Finder Pattern Localization Based on the Overlap of the Centroids of Continuous Regions	51

3.2.4	Grouping of Finder Patterns	53
3.2.4.1	Grouping Triplets of Finder Patterns	53
3.2.4.2	Grouping Pairs of Finder Patterns.....	54
3.2.5	Verification of Quiet Zone and Timing Patterns	55
3.2.6	QR Code Bounding Box	56
3.2.7	Perspective Distortion.....	57
3.2.7.1	Alternative A—Evaluation the Overlap of the Boundary Line	58
3.2.7.2	Alternative B—Evaluation of the Edge Projections	59
3.2.8	Perspective Transformation	64
3.2.9	Decoding the QR Code	65
3.2.9.1	Determination of the position of the module middle points at variable module size	67
3.3	QR Codes –Region based localization method	68
3.3.1	Identification of image regions that may contain a QR code.....	70
3.3.2	Refinement of QR code bounding box	73
3.3.3	Initial estimate of the rotation angle of the QR code	74
3.3.4	Refinement of the rotation angle and determination of dimensions of the QR code.....	74
4	Results.....	77
4.1	Data Matrix code data set.....	77
4.2	QR code data set	81
4.3	Discussion	83
5	Conclusion	87
Appendix A: Image processing techniques utilized in 2D code recognition		96
A.1	Color conversion.....	96
A.2	Intensity transforms.....	96
A.3	Geometry transforms.....	97
A.4	Image filtering.....	99
A.5	Thresholding	100
A.6	Edge detection.....	101
A.7	Connected component labeling	102
A.8	Feature detection.....	103
Appendix B.1: Data Matrix test data set.....		105
Appendix B.2: QR code test data set.....		106